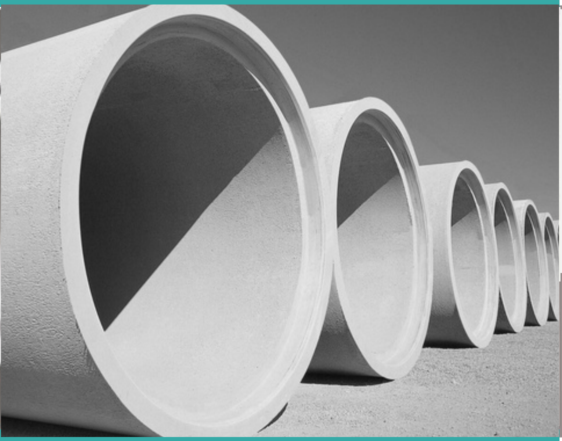


Concrete Products Quality Control

Training Manual

First Edition

American Concrete Pipe Association

Welcome and Introduction

Welcome to the American Concrete Pipe Association Quality School. The ACPA is recognized as the definitive source for technical information regarding precast concrete pipe, box culverts and other precast concrete products. This ACPA Concrete Products Quality Control Training Manual has been provided as a resource to those who attend the Quality School and are seeking to become accredited. The Quality School consists of 18 hours of classroom instruction followed by a 60 question closed book exam. Accreditation through the Quality School will satisfy the QC personnel qualification requirement for the ACPA QCast Plant Certification Program. The QCast Plant Certification Program is an industry-wide quality control program to ensure superior production throughout the country. As QCast continues to grow and gain recognition, our certified plants continue to enjoy the lower costs and higher efficiencies that result from implementing and maintaining the quality practices established by the QCast program.

Purpose of this manual

Who will benefit from the use of this manual?

If you are an employee of a company actively engaged in the manufacture or sale of concrete pipe, box culverts or other precast concrete products, or a specifyer/agency utilizing these products, this manual is for you. Additionally, if you are seeking ACPA Quality Control accreditation as required by ACPA Q-Cast Plant Certification program, this manual will act as an excellent resource during training or individual self-study prior to certification testing.

Why was this manual created?

The primary purpose of this manual is to prepare ACPA Quality School students for Q-Cast certification testing by providing definitions and descriptions of key concepts, processes and procedures for concrete product quality control.

Another purpose of this manual is to introduce ACPA quality requirements to anyone associated with concrete materials and to inform them what controls are in place to assure process consistency and product quality.

How to use this manual

Manual Structure

The manual is divided into five sections beginning with the essentials of concrete you will need to grasp to help ensure concrete product quality. Following the concrete basics are sections that describe the processes and procedures involved in concrete production, concrete products manufacturing, and finished product inspection, repairs and testing. These sections were ordered to illustrate the sequence and overall big picture of what it takes to produce, manufacture and deliver quality concrete products. The manual concludes with an overview of the ACPA Q-Cast Plant Certification manual and the plant certification requirements, as well as appendices covering State specific materials.

The sections are titled:

- ✓ Section 1: Concrete Fundamentals;
- ✓ Section 2: Concrete Production;
- ✓ Section 3: Concrete Products Manufacturing;
- ✓ Section 4: Finished Product Inspection, Repairs and Testing
- ✓ Section 5: ACPA QCast Plant Certification

Each section will begin with an introduction consisting of an overview and a big picture illustration of the concrete concepts and processes contained within the section. Following the introduction are multiple chapters that further describe the concepts, processes and quality control requirements associated with the section. At the end of each section are review questions that will allow you to test your understanding of the material presented. The answers to the review questions are provided at the end of each section.

Chapter Structure

The chapters are ordered according to the sequential nature of the materials or processes within their respective sections. Each will begin with an introduction consisting of a brief overview and the key learnings you will gain by completing the chapter. The body of the chapter will contain written descriptions, graphic illustrations, and any QCast requirements related to a specific concept or process discussed in the chapter.

Quality School Presentations

While attending the ACPA Quality School, various presentations are given on specific subjects. Although every efford has been made to include the same information in both the presentations and this training manual, there are some fundamental differences exspecially in the way in which the presentations and the training manual is organized. This training manual was ordered to illustrate the sequence and overall big picture of what it takes to produce, manufacture and deliver quality concrete products, the presentations covered in the ACPA Quality School are ordered based on the given subject. The following table should help the participant to connect the materials covered in the presentations with the sections and chapters in this training manual.

Presentation	Section/Chapter
Cementitious Materials	S1-C1, -C2, -C3
Aggregates	S1-C4
Admixtures	S1-C5
Self Consolidating Concrete	S1-C1, -C7, S2-C1, -C3
Reinforcement	S1-C1, -C6, S3-C1
Concrete Technology	S1-C8, S2-C3
Mix Design Calculations	S2-C1
Concrete Production – Mixing, Batching & Transport	S2-C2
Pre/Post Pour Inspection	S3-C2, S4-C1
Consolidation	S3-C3
Curing	S3-C4
Product Testing	S4-C3
Repairs and Finishing	S4-C2
QCast Certification	S5-C1, -C2, -C3

Additional blank Notes pages are included at the end of each chapter to allow the students to capture key concepts during the presentations. The presentations are available on the ACPA website (www.concretepipe.org), in the “members only” under “Education – Quality School” Tab. For access to the website, please contact the ACPA at info@concretepipe.org.

Table of Contents

Section 1 – Concrete Fundamentals

Chapter 3: Supplementary Cementitious Materials

Chapter 4: Aggregates

Chapter 5: Admixtures

Chapter 6: Reinforcement

Chapter 7: Self Consolidating Concrete

Chapter 8: Durability

Section 1: Review Questions

Section 2 – Concrete Production

Chapter 1: Designing Concrete Mixes

Chapter 2: Batching, Mixing, Handling and Transporting Concrete

Chapter 3: Testing Concrete

Section 2: Review Questions

Section 3 – Concrete Products Manufacturing

Chapter 1: Reinforcement Fabrication

Chapter 2: Pre-pour Inspection

Chapter 3: Consolidation

Chapter 4: Curing

Section 3: Review Questions

Section 4 – Finished Product Inspection, Repairs and Testing

Chapter 1: Post-pour Inspections

Chapter 2: Repair and Finishing

Chapter 3: Finished Product Testing

Section 4: Review Questions

Section 5 – ACPA QCast Plant Certification

Chapter 1: Introduction to the QCast Certification Program

Chapter 2: QCast Documentation

Chapter 3: The Audit

Section 5: Review Questions

Appendices

Appendix A: References

Appendix B: Images

Appendix C: FDOT QC Level I & II

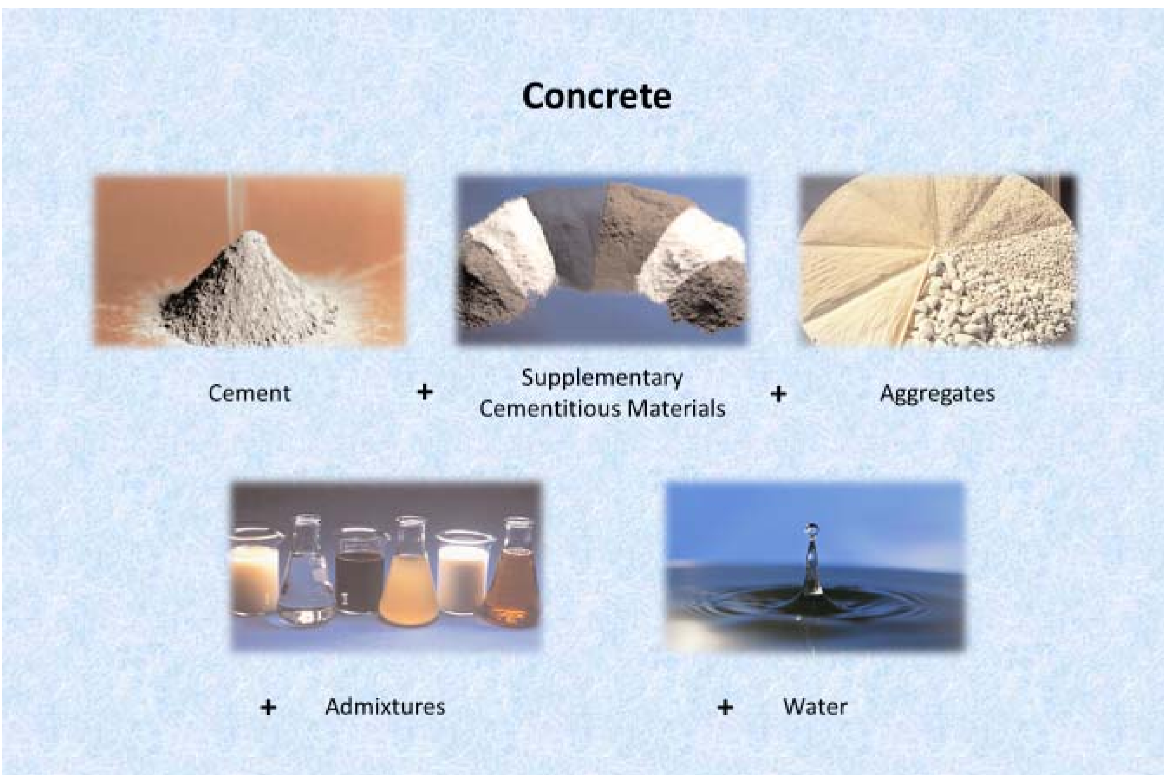
Appendix D: NCDOT Concrete Batching Technician Certification

Page left intentionally blank.

SECTION 1
CONCRETE FUNDAMENTALS

Understanding Precast Concrete Products starts by learning what it takes to make concrete. This section covers the basic information about key materials that go into making concrete including self-consolidating concrete (SCC), an overview of the function and importance of reinforcement in making precast concrete products, and concrete durability. Emphasis will be given to the physical properties of each concrete component material and how each of them affects concrete. Additionally, you will be introduced to the reinforcement used in the precast concrete products we manufacture as well as the various factors that can affect the durability of concrete.

The illustration below shows you the materials that, when combined, make concrete.



Page left intentionally blank.

Chapter 1: Concrete and Concrete Products

Throughout history concrete has been a key material used to build structures that stand the test of time. This is exemplified in such classical builds as the Appian Way, the Coliseum and the dome on the Roman Pantheon, and the more modern structures like the Hoover Dam (Fig. 1-1), the oil platforms in the Gulf of Mexico, or the mega structures that make up the network of interchanges on our interstate highways. The word concrete is defined by the Oxford Advanced Learner Dictionary as, "a heavy, rough building material made from a mixture of broken stone or gravel, sand, cement, and water, that can be spread or poured into molds and that forms a stone like mass on hardening." The origin of the word comes from the Latin word "concretus," which means compact or condensed, which fittingly describes the intended outcome of this mixture. In today's concrete industry, this mixture is composed of some very definitive elements being that of cement, supplementary cementitious materials, aggregates, admixtures and water.[1]

Fig. 1-1. The Hoover Dam, Boulder City, NV, USA.

Objectives

At the end of this chapter, you will be able to:

- ✓ Identify the key components that go into making concrete.
- ✓ Recall the origin of concrete.
- ✓ Recall the origin of Portland Cement.
- ✓ Recognize the difference between non-reinforced and reinforced concrete.
- ✓ Identify how various forces influence concrete behavior.
- ✓ Describe the stress zones in reinforced concrete pipe (RCP), given an illustration.
- ✓ Recall the difference between indirect design and direct design of RCP.
- ✓ Describe the factors related to reinforcement that are important for the structural integrity of reinforced concrete products.
- ✓ Recognize the importance of grade, size, spacing and positioning of steel reinforcement.

- ✓ Identify the three types of concrete used in our industry.
- ✓ Identify the different concrete products typically produced in our industry

What is Concrete?

Concrete is the world's most commonly used building material. In its simplest form, concrete is a mixture of paste and aggregates. The material (paste) used to manufacture concrete pipe is composed principally of Portland cement and water, and is used to coat the surface of the fine and coarse aggregates. The Portland cement is a closely controlled chemical combination of calcium, silicon, aluminum, iron, and small amounts of other compounds, to which gypsum is added in the final grinding process to regulate the setting time of the concrete. Portland cement's chemistry comes to life in the presence of water. Soon after the cement and water are combined, a chemical reaction called hydration occurs and the paste hardens and gains strength to form the rock-like mass known as concrete.

History of Concrete and Cement

It would be difficult to fully understand, appreciate, and explain our products to others without understanding how our industry and our product have continued to develop and improve over the centuries. Reinforced concrete pipe's (RCP's) rich history and continued use is unsurpassed and cannot be matched by any other commonly used storm drain piping product available today. Our history makes us unique in the storm piping business and gives us a perspective that no one else has. The lessons learned and improvements made during the past are continuing to help us improve our industry and our products as we move through the 21st century.

Fig. 1-2. Egyptian Pyramid; Roman Colosseum.

The Early Days

As early as 3000 BC, the Egyptians were using early forms of concrete to build pyramids. They mixed mud and straw to form bricks and used gypsum and lime to make mortars. From 300 BC to 476 AD, the ancient Romans used a material that is remarkably close to modern cement to build many of their architectural marvels, such as the Colosseum, and the Pantheon. The Romans also used animal products in their cement as an early form of admixtures.[2]

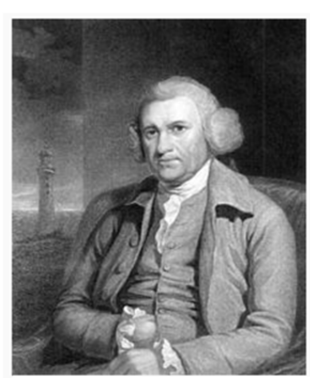


Fig. 1-3. John Smeaton.

John Smeaton (Fig. 1-3), a civil engineer who designed bridges, canals, harbors and lighthouses and was an important figure in the development of what is known today as Portland cement. While working on design of the third Eddystone Lighthouse in (1755-59) commissioned by the Royal Society in London, he developed the technique of dovetailing a block of granite along with a mortar that sets under water called "hydraulic lime." Later when the rock beneath the structure began to erode, the lighthouse could no longer be in use. As a result it was dismantled, moved and partially rebuilt at Plymouth Hoe, where it remains as Smeaton's Tower. Thanks to Smeaton's influence and discovery, the compositional requirements of the hydraulic lime remains an important innovation in the history of modern cement and an impetus to the return of concrete as a modern building material.[3]


Fig. 1-4. Joseph Aspdin.

Joseph Aspdin (Fig. 1-4) was another prominent figure in the history and development of modern cement. As a British stone mason by trade, Aspdin is responsible for the creation of a hydraulic cement that was made using a stone that resembled those quarried on the Isle of Portland, off the British Coast. He created the the cement mixture heating finely ground limestone with clay in his kitchen and then grinding the mixture into the powder known as hydraulic cement. It is called hydraulic cement because it hardens as a result of adding water to the mix. This discovery was foundational to the modern cement industry we have today. It was first used on a large scale during the construction of the tunnel under the Thames River in 1828. The first shipment to the United States was recorded in 1868. Not much later in 1871, a plant located in Coplay, Pennsylvannia became the first to produce Portland cement in the U.S.[4]


Fig. 1-5. Joseph-Louis Lambot concrete boat 1848.

About 30 years prior to the development of the Portland cement industry, the discovery of reinforced concrete began with the invention of ferro-cement by Joseph-Louis Lambot. Lambot began building structures using cement mortar and iron reinforcement such a rod iron and chicken wire. Using his method, he built and tested his first boat (Fig. 1-5), which was later patented in 1855 (as his only patent) and then presented at the World's Fair in Paris. According Robert Courland in *Concrete Planet*, the prototype of his boat sank while Lambo swam back to shore. However the boat was recovered 100 years later and is now preserved on display at the Museum of Brignoles in France.[5]

Man's desire and need to provide a healthy environment, transport goods, and improve agricultural development in the early to mid 1800's created a demand for a way to properly move sewage and accommodate storm water run-off. Concrete pipe used for agricultural drain tile and engineered sewer systems can be traced back to the early 19th century. The oldest recorded concrete pipe sanitary sewer installation was in 1842 in Mohawk, New York. There are also several installations of concrete pipelines that were installed in the late 1800's that are still in service today. These installations prove that our product can provide a reasonable service life of 100 years or more. The concrete pipe industry does not need thousands of pages of research to develop a mathematical equation to **CLAIM** a particular service life; our product has a proven history of its strength, durability and service life.

Technology and Markets…1880 – 1930

From the late 1800’s into the early part of the 20th century the growth of the concrete pipe industry was influenced by related technical and market developments. Engineers began to understand how to predict and quantify storm water runoff amounts and develop methods to size pipelines. Also, during the first three decades of the 20th century, researchers at Iowa State University addressed many key components of pipeline design. They developed methods for estimating loads on buried pipe and determined a methodology to calculate the supporting strength of rigid pipe culverts. As understanding grew, a desire for improved consistency and quality was desired by all stakeholders. The American Society for Testing and Materials (ASTM) became a forum for improved quality and movement of research and study into the market place. In 1904, ASTM Committee C-4 on Clay and Cement-Concrete Sewer Pipe was established. The C-4 Committee was made up of manufacturers and users of both clay and concrete sewer pipe and was the forerunner of the current C-13 Committee on Concrete Pipe. C-13 Committee scope includes RCP specifications, testing procedures, and definitions. C-13 still maintains jurisdiction over the most prominent production and testing specifications used for Reinforced Concrete Pipe, as well as those for reinforced concrete box culverts, manholes, and other related structures.

During the early and mid 20th century, as our countries major cities continued to develop and expand their service areas, the demand for sanitary and storm sewers grew at a rapid pace. During this same period, drainage for agricultural purposes was also experiencing rapid expansion. As the demand for drainage and sanitary sewer pipe grew, better production methods and equipment for pipe manufacturing was developed and introduced.

A rising need for a comprehensive connected roadway system became evident in the early 1900’s as the number of automobiles grew from 50,000 in 1905 to more than 6 million in 1918. Our country and local governments had to organize, construct, and expand our public highway systems. As the demand for surfaced roads grew, so did the demand for RCP to meet the road systems drainage needs. By 1930 all states were using concrete pipe in their roadway construction projects.

Expanded Demand leads to Industry Expansion and Organization

The 20th century brought new technology, new standards, and a new rate of growth for the concrete pipe industry. The need to improve quality and production capabilities was recognized by our industry leaders. On Jan. 23, 1907, the Interstate Cement Tile Manufacturers Association was formed. In 1914, the name of the organization was changed to the American Concrete Pipe Association (ACPA)! The early pioneers in our industry clearly recognized, even in our infancy, that accurate product standards and uniform product quality were of the utmost importance. The most significant development in our product in this early period was the introduction of the use of reinforcement in the concrete pipe wall. After 1916, almost all concrete pipe over 24” in diameter was manufactured with reinforcement. The production of concrete pipe became automated and productivity rates were growing rapidly to meet demand. Tamp machines and the packer head processes were both developed in the early 1900’s. Production grew from one million tons to two million tons from 1925 to 1930.

Advancement of the Industry Post 1930

Following the great depression and World War II, annual production doubled to 4 million tons by 1950. By the early 1970's more than 10 million tons were being produced, and by the middle of the 1970's the annual market value of production exceeded one billion dollars. The advancement of the concrete pipe industry from the 1930's to the 1970's can be attributed to the following major factors:

- Performance surveys verified the durability of RCP
- Increased acceptance of concrete pipe by planners, engineers, and government agencies
- Continued advancement in research and technology led to better understanding of our products and development of improvements
- Improvements of pipe production tools and finished product quality

1980-Present Consolidation, Competition, and Continued Improvements

The face (or at least the company names) of the concrete pipe industry changed due to consolidation in the industry, as large companies purchased many of the one and two plant independent operators throughout the 80's and 90's. Gone are the days when there was a RCP production facility in almost every other community along the highway.

Competitive products began an invasion of the sanitary and storm drain market, Polyvinyl Chloride (PVC) became the favorite choice for small diameter sanitary sewer in the late 70's and in the 80's, High Density Polyethylene (HDPE) pipe began its push into the storm drain market. By the late 70's and early 80's very little small diameter concrete pipe was being specified or used for sanitary sewer or agricultural drainage needs. By the mid 90's HDPE had gained wide acceptance in the private development market and was beginning to make progress in the municipal and DOT market segments.

As competitive pressure grew, our producers once again focused their attention on improving product quality and production techniques. Many of today's modern production facilities are fully automated and computer controlled. These new production facilities look and function more like automotive assembly lines with robots and computers doing much of the work. New production methods, improved joints, and a constant drive to make a better quality finished product have helped us remain competitive and the best storm drain product still available.

Summary of Historical Overview of Concrete Pipe Industry

Without RCP our nation's cities would not function or be able to continue to support their residents with adequate sanitary sewers, storm sewers, and roadway culverts. Concrete pipe provides the backbone of our modern sewer and drainage systems currently in operation today over this country and the world. All of our nations' most important transportation systems are supported by RCP. Our products history speaks for itself. RCP has proven to be strong, durable, and economically proficient to serve our countries needs and will continue to meet any demand identified in the future.

Reinforced Concrete

Reinforced concrete is defined as concrete in which metal (as steel) is embedded so that the two materials act together in resisting forces that can cause structural fractures in concrete.

Non-reinforced concrete pipe does not have steel embedded to help withstand forces, but it is a rigid pipe that has significant inherent structural strength. Non-reinforced concrete pipe has a proven history of successful and extensive use throughout the country. Prior to the mid 1920’s, all concrete pipe installed in the United States was non-reinforced. The oldest concrete sanitary sewer pipeline installed in this country was non-reinforced. This line, installed in Mohawk, New York in 1842, is still in use. Without reinforcement, however, most modern concrete structures would not be possible.

Concrete Behavior Under Stress

Concrete has relatively high compressive strength, but significantly lower tensile strength, and as such is usually reinforced with materials that are strong in tension (often steel). Concrete can withstand compressive stress, however it is weak against tensile stress.

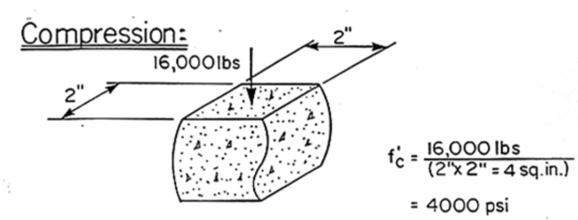


Fig. 1-6. Compression.

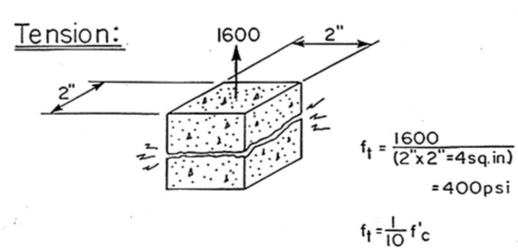
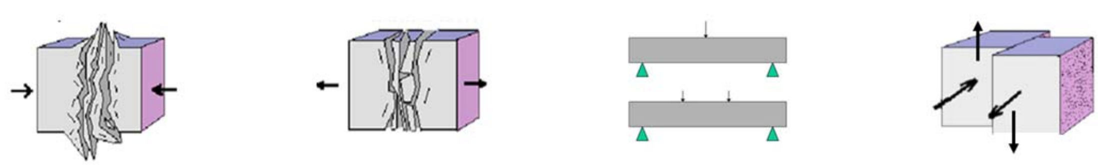


Fig. 1-7. Tension.

For example: 4,000psi, 2” x 2” concrete cube would be able to support a 16,000 lb load (Fig. 1-6), whereas it would only take a 1,600 lb load to pull the same cube apart (Fig. 1-7). Steel reinforcement is placed in the areas where the concrete experiences tensile stress to increase the structural load-bearing capacity of the product.



Compressive Stress
Force that squeezes an object's surfaces together and causes its mass to bulge.

Tensile Stress
Force that pulls a structural beam to the point where it breaks

Flexural stress
Force that causes a structure to bend or buckle when a load is applied

Shear stress
Horizontal or vertical, unaligned forces pushing one part of a body in one direction, and another part of the body in the opposite direction.

Fig. 1-8. Four Types of Stress

There are four types of stress that can impact the behavior of concrete; they are: compressive stress, tensile stress, flexural stress and shear stress as shown in Fig. 1-8.

Stress Zones in RCP

Reinforced concrete pipe (RCP) is a composite structure and specially designed to use the best features of both concrete and reinforcement. As the RCP is subjected to a vertical load (Fig. 1-9), compressive and tensile stresses develop inside the pipe wall as shown. Reinforcement is utilized especially in the tensile stress zones where the concrete by itself is very weak. Concrete pipe is generally designed to carry loads well within the engineered load bearing capacity of a pipeline, and therefore hairline cracks do not typically occur in the field. However, unless the concrete cracks, the reinforcement is not being used to its full design capacity. Hairline cracks are not an indication of danger, distress, or loss of structural integrity. If hairline cracks do occur, they tend to seal themselves through a process known as autogenous healing. Autogenous healing is the ability of concrete to repair itself in the presence of moisture. Reinforced concrete pipe, unlike reinforced concrete beams and slabs, are buried where moisture conditions are present for autogenous healing to take place.

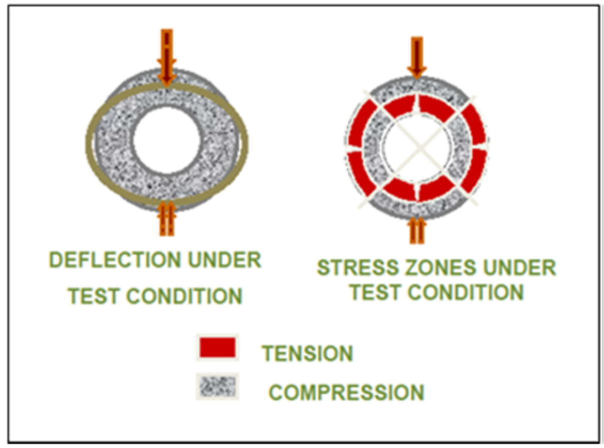


Fig. 1-9. RCP behavior under a Three-Edge-Bearing Test

Reinforcement in RCP

Cage machines and wire rollers are the most common methods used to produce the reinforcing cages. Cage machines (Fig. 1-10) wrap the circumferential wire in a helix around the longitudinal wires while welding the intersecting wires automatically. Wire rollers utilize welded wire reinforcement which is rolled, cut and welded or clipped to form the cage. A number of different reinforcing cage configurations are utilized in RCP production depending on the strength requirements of the installation conditions.

Fig. 1-10. Automatic cage welding machine.

Structural Design Considerations

When designing reinforced concrete pipe, special attention must be given to four very important structural integrity dependencies:

- Grade of steel

- Type and size of reinforcement
- Spacing of the steel
- Positioning of the steel

All of the above influence how well the reinforcement is able to resist the tensile stresses in the concrete. If any of these parameters (Fig. 1-11) do not meet what was originally designed, the reinforced concrete product will have less structural capacity and may fail the performance test

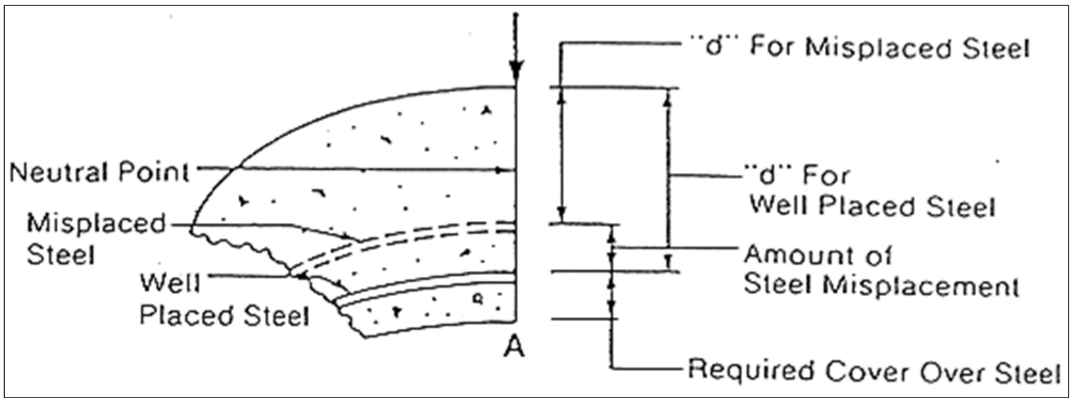


Fig. 1-11. RCP design parameters.

such as a Three-Edge-Bearing test, or even in the field once installed. For example, on a 36" CL3 B-Wall RCP, increasing the steel cover by 1/2" can reduce the D-Load capacity by up to 30%. In order to maintain the same D-Load performance, the steel area would need to be increased up to 45%. Proper grade, type, size, spacing, and positioning of the reinforcement is critical to ensure product performance meets expectations.

RCP Design Considerations

Two design methods are used in designing reinforced concrete pipe. The most common and widely used method is the indirect design method.

Indirect Design is the comparison of the structural strength of the pipe found in the three-edge-bearing test, expressed as a D-Load (lb/ft/ft), to the field supporting strength of a buried pipe. It is the standard method for designing reinforced concrete pipe. It is a simplified method that corresponds to a pipe produced to a performance specification, whereby it is tested at the plant to verify its strength. When a concrete pipe cannot be tested to verify its strength in the plant, then the pipe structure must be designed similar to any other concrete structure using a direct design method that incorporates load factors and process factors into the design.

The **Direct Design** method is the design of the pipe in the installed condition. The magnitude and distribution of the loads are determined, and the physical properties necessary to support those loads are calculated. Since the resulting design yields the steel area and concrete strength to be utilized for the given size of pipe, the three-edge-bearing test is no longer applicable. The acceptability of the RCP is determined based on the concrete compression tests, material tests, conformance to the design parameters and inspection of the product for defects. Small diameter pipe should not be designed using the direct design method due to the fact that the equations for direct design were originally formulated for larger diameters and therefore are overly conservative for the design of small diameter concrete pipe.

Types of Concrete

Three types of concrete are utilized in the production of concrete products—they are Dry Cast, Wet Cast and Self-Consolidating. The type of concrete used depends on the intent of its use.

Fig. 1-12. Dry cast concrete.

Dry Cast

Dry cast concrete has a low water to cement ratio and a zero slump (Fig. 1-12). The inherent strength in the compacted concrete allows for immediate removal of the form(s) therefore enabling a single form to be used multiple times throughout the production day. The formwork used for dry-cast production is typically more rigid due to the heavy vibration and/or packing pressures needed to consolidate the concrete. High durability and strength of the concrete combined with a controlled plant production environment makes dry-cast concrete a good choice for producing concrete pipe, box culverts, manholes and other precast products.

Wet Cast

Wet cast concrete (Fig. 1-13) is a more flowable form of concrete having a given measurable slump, which may be poured from a mixer, bucket or a truck. Wet cast concrete is often used in the precast industry, where it is cast in forms and cured until the concrete has gained enough strength to allow for the removal of the forms. Wet cast is often used for larger pieces that are more complex and need flow-ability in the concrete in order to consolidate around reinforcement and throughout the form.

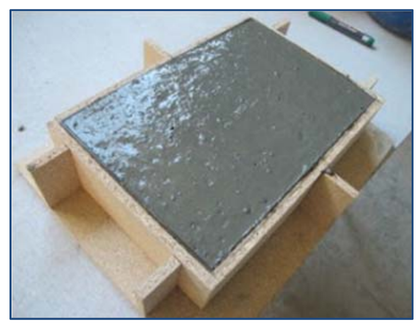


Fig. 1-13. Wet cast concrete.

Fig. 1-14. Self consolidating concrete.

Self Consolidating Concrete

"Self Consolidating Concrete (Fig. 1-14) is a highly flowable, non-segregating concrete that can flow into place, fill the formwork, and encapsulate the reinforcement without any mechanical consolidation." (ACI International, Committee 237 SCC).

SCC is more than flowable concrete, it is a highly engineered fluid with unique Rheological properties. SCC fills the formwork without vibration and with a significant reduction in labor. With conventional concrete mix design it is almost impossible to acheive true SCC (24 inch slump flow), because the viscosity is insufficient to suspend the aggregates in the mix, and segregation will occur. Therefore SCC needs to be properly designed to take advantage of it's properties. SCC is starting to be widely used in the precast industry given the advantages over conventional wet cast concrete.

Concrete Products

The greatest strength of the precast concrete pipe and box culvert industry is its ability to manufacture durable products with a service life of more than 100 years. Each product is briefly discussed below.

Pipe

Circular reinforced concrete pipe (Fig. 1-15) offers an impressive record of strength and performance, making it the most economical and reliable choice for drainage materials available today. It is recommended for installations where low, moderate or severe cover and/or live load conditions exist. Retention of shape to minimize stoppage is necessary. It is available in diameters ranging from 12" through 144." Circular pipe is used for such applications as:

Fig. 1-15. Circular reinforced concrete pipe.

- Sanitary sewers
- Storm drains and Culverts
- Irrigation distribution systems
- Low-pressure sewer force mains
- Low-pressure water supply systems
- Treatment plant piping
- Outfalls
- Utility tunnels
- Groundwater recharge systems
- Jacked, Tunneled or Trenchless installations

Fig. 1-16. Horizontal elliptical (HE) concrete pipe.

Horizontal elliptical (HE) concrete pipe (Fig. 1-16) is installed with the major axis horizontal and is extensively used for minimum cover conditions or where vertical clearance is limited by existing structures. It offers the hydraulic advantage of greater capacity for the same depth of flow than most other structures of equivalent water-way area. Under most embankment conditions, its wide span results in greater earth loadings for the same height of cover than for the equivalent size circular pipe and, at the same time, there is a reduction in effective lateral support due to the smaller vertical dimension of the section. Earth loadings are normally greater than for the equivalent circular pipe in the trench condition, since a greater trench width is usually required for HE pipe. For shallow cover, where live load requirements control the design, loading is almost identical to that for an equivalent size circular pipe with the same invert elevation.

Vertical elliptical (VE) concrete pipe is installed with the major axis vertical and is useful where minimum horizontal clearances are encountered or where unusual strength characteristics are desired. Hydraulically, it provides higher flushing velocities under minimum flow conditions and carries equal flow at a greater depth than equivalent HE or circular pipe. For trench conditions the smaller span requires less excavation than an equivalent size circular pipe and the pipe is subjected to less vertical earth load due to the narrower trench. The structural advantages of VE pipe are particularly applicable in the embankment condition where the greater height of the section increases the effective lateral support while the vertical load is reduced due to the smaller span.

Arch pipe (Fig. 1-17) is useful in minimum cover situations or other conditions where vertical clearance problems are encountered. It offers the hydraulic advantage of greater capacity for the same depth of flow than most other structures of equivalent water-way area. Structural characteristics are similar to those of horizontal elliptical pipe in that under similar cover conditions it is subject to the same field load as a round pipe with the same span. For minimum cover conditions where live load requirements control the design, the loading to which arch pipe is subjected is almost identical to that for an equivalent size circular pipe with the same invert elevation.

Fig. 1-17. Arch pipe.

Box Culvert

Box culverts (Fig. 1-18) are four-sided structures that are useful in minimum cover and width situations or other conditions where clearance problems are encountered, for special waterway requirements, or designer preference. Standard box sizes are 3’ x 2’ to 12’ x 12’ in 1’ span and rise increments and typically come in 6’ and 8’ lengths. Larger sizes are also available from various box culvert producers. Precast concrete box culverts have many uses including water retention, storm drainage, utility conduit, holding tanks, underpasses, service tunnels, outfalls, bridges, and more.

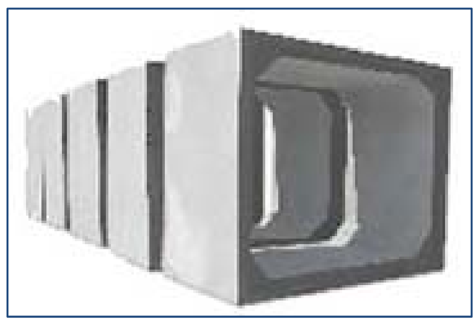


Fig. 1-18. Box culvert.

Inlets/Manholes

Precast concrete manholes/inlets are universally

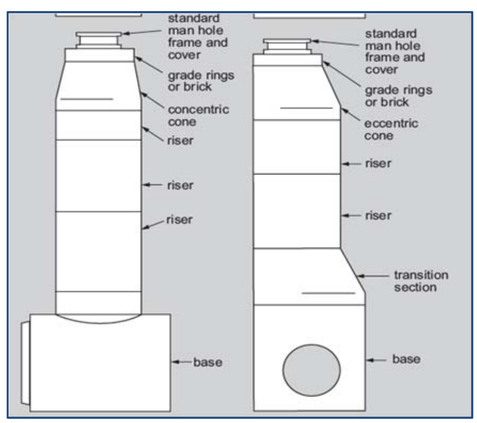


Fig. 1-19. Illustration of precast manhole.

accepted for use in sanitary or storm sewers. The typical precast concrete manhole (Fig. 1-19) consists of riser sections, a top section and grade rings and, in many cases, precast base sections or tee sections. The riser sections are usually 48 inches in diameter, but are available from 36 inches up to 72 inches and larger. The maximum allowable depth of a typical precast concrete manhole with regard to lateral earth pressures is in excess of 300 feet or, for all practical purposes, unlimited. Because of this, the critical or limiting factor for manhole depth is the supporting strength of the base structure or the resistance to crushing of the ends of the riser section.

Three-Sided Structures

Three-sided structures are U-shaped structures (Fig. 1-20) that may or may not have a crown in the center. Standard three-sided structures range from 8' to 48' span lengths. Custom sizes are available and must be designed per project design specifications. These structures are used for short span bridges – flat and arched. [6]

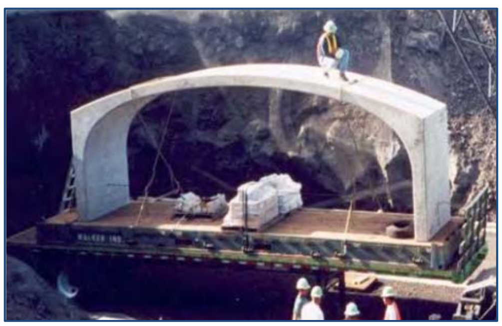


Fig. 1-20. Examples of three-sided / u-shaped concrete structures.

Notes

Notes

Chapter 2: Cement

Builders have been using various materials to bind stones together since early antiquity. The Egyptians used straw and gypsum mixed together to bind the large stones of the pyramids. The Romans mixed lime and sand together to make a mortar which is believed to have been borrowed by the Greeks.[1] In fact, the word "cement" can be traced back to the Romans, who used the term opus caementicium to describe masonry very similar to modern concrete that was made from burnt lime binder and crushed rock. They added volcanic ash and pulverized brick supplements to the burnt lime, to achieve a hydraulic binder, which was later referred to as cementum, cimentum, cäment, and cement.[2] Today, cement is the most widely used construction material worldwide. A variety of construction applications benefit from its desirable properties such as compressive strength (construction material with highest strength per unit cost), durability, and aesthetics.

Figure 2-1. Cemex, Monterrey, Mexico.

Objectives

At the end of this chapter, you will be able to:

- ✓ Define hydraulic cement.
- ✓ Identify the raw materials that go into making cement.
- ✓ Identify the steps involved in the cement production process.
- ✓ Identify the four main compounds that make up cement.
- ✓ Describe how the four main compounds affect concrete properties.
- ✓ Identify the types of cement and what is different about each.
- ✓ Describe how cement hydrates, i.e., how the “glue” is formed.
- ✓ Describe the various test results in a Cement Mill Certification Report and how they affect concrete properties.

Portland Cement

Fig 2-2. Portland cement: a fine powder that when mixed with water becomes the glue that holds aggregates together in concrete.

Merriam Webster defines cement as "a powder of alumina, silica, lime, iron oxide, and magnesium oxide burned together in a kiln and finely pulverized and used as an ingredient of mortar and concrete." Joseph Aspin's early cement was nothing more than hydraulic lime, but his 1824 patent gave him the priority for the use of the term Portland Cement even though his product was not the Portland Cement that we know today. Its mineralogy was completely different, as well as its hydraulic activity.[1] The name "Portland," for which it is known, came from the color of the limestone on the Isle of Portland. Modern Portland Cement is manufactured in a very closely controlled process. The Portland Cement chemistry and the combination of the various oxides is very important to the performance expectations of the concrete that is made. Portland Cement is manufactured in accordance with ASTM C150 and is classified into 5 different types. Portland Cement is the key ingredient that when mixed with water, the resulting paste "glues" the aggregate particles together to form concrete.

Hydraulic and Non-hydraulic Cement

In the context of our industry, cements are characterized as being either **hydraulic** or **non-hydraulic**, depending on the ability of the cement to be used in the presence of water.

Non-hydraulic cement will not set in wet conditions or underwater, rather it sets as it dries and reacts with carbon dioxide in the air.

Hydraulic cement sets and hardens in the presence of water and can be used in underwater applications. These are the cements used throughout our industry.

Portland Cements are composed primarily of hydraulic calcium silicates. It is called a hydraulic cement because its chemistry comes to life in the presence of water. Soon after the cement and water are combined, a chemical reaction called hydration occurs and the paste hardens and gains strength to form the rock-like mass known as concrete. During hydration, a node forms on the surface of each cement particle. The node grows and expands until it links up with nodes from other cement particles or adheres to adjacent aggregates. Within this process lies the key to the remarkable trait of concrete–it's plastic and malleable when newly mixed and strong and durable when hardened (Fig. 2-2).

Blended and Performance Cements

Blended hydraulic cements are blends of portland cements and one or more natural or manufactured pozzolans. Pozzolans are materials that chemically react with the byproduct of cement hydration, calcium hydroxide, to form more calcium silicate hydrate (C-S-H), which is the "glue" that binds the aggregate particles together to form concrete. Pozzolans are discussed in more detail in Chapter 3 – Supplementary Cementitious Materials.

Portland Cement Composition

Portland cement is a closely controlled chemical combination of calcium, silicon, aluminum, iron, and small amounts of other compounds. When these ingredients are heated at high temperatures and cooled rapidly, a hard substance known as clinker is formed, to which gypsum is added in the final grinding process (to regulate the setting time of the concrete) and then it is ground into the fine powder that we commonly know as Portland Cement (Fig. 2-3.)

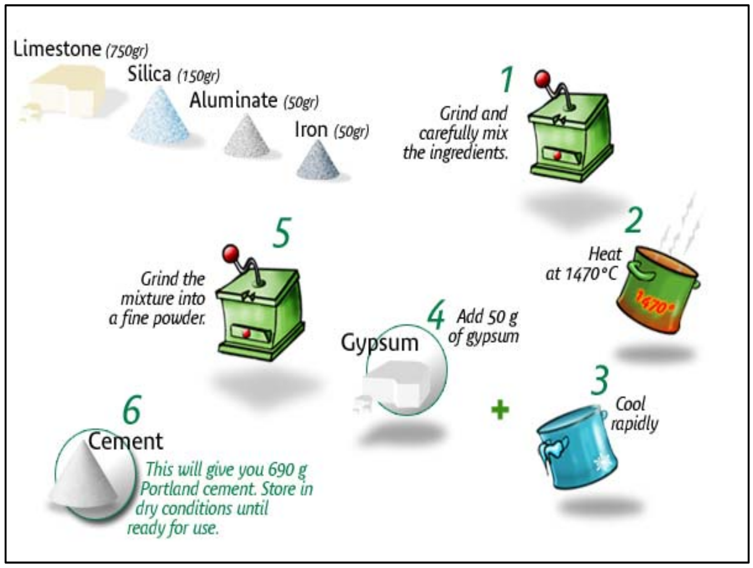


Fig 2-3. The Recipe for Portland Cement.

Raw Materials

There are two major raw material components to Hydraulic Cement: Calcium (calcareous component) and Silica (argillaceous component). Calcareous components include minerals such as limestone, marly limestone, chalk (which is generally easy to grind), coral limestone, marble, lime-sand and shell deposits. When heated these minerals generate Calcium Oxide (CaO), which is one of the key ingredients in cement (Fig. 2-4).

Fig 2-4. Calcium Oxide.

The argillaceous component is found in clay-like materials such as clay, shale, marl, calcerous marl, marly clay, tuff, ash, phyllite, and slate. These minerals provide Silicon Dioxide (Fig. 2-5), known as Silica (SiO2, AI203 and Fe203). Minor components such as alkali (Na_2O, K_20), magnesium (MgO), sulfur (SO_3), Titanium (TiO_2), sodium and potassium are in minor oxides and come from either calcareous or argillaceous raw material.

Fig 2-5. Silicon Oxide.

Materials used in the manufacture of Portland cement must contain appropriate amounts of calcium, silica, alumina and iron oxides (Table 2.1). Out of these components, calcium is the highest percentage component used. Rigorous quality control testing is performed to ensure the proportions of the components are within acceptable specification limits.

Table 2.1 Components used in manufacturing Portland Cement.

Components	%	Name	CCN
Calcium oxide (CaO)	64%	"Lime"	C
Silicon oxide (SiO_2)	22%	"Silica"	S
Aluminum oxide (Al_2O_3)	6%	"Alumina"	A
Iron Oxide (Fe_2O_3)	3%	"Iron"	F

It takes 1.5 to 1.7 tons of raw materials to make 1 ton of cement, which produces 1 ton of $C0_2$ from both raw materials and fuels. The 0.5-0.7 tons is waste made up of moisture and oxides.

Portland Cement Manufacturing

Early in the 19th century Joseph Aspdin first burned powdered limestone and clay in his kitchen to make portland cement. With this crude method, he laid the foundation for an industry that annually processes millions of tons of limestone, clay and other materials into a powder so fine it will pass through a sieve capable of holding water.[1]

The Process

Step 1: Mining, Crushing and Storing Raw Materials. Initially the principal raw materials, limestone, clay, and other materials are mined. After mining, the rock is crushed. Each of the raw materials is transported separately to silos, where it later will be added in specific amounts according to the particular type of cement being produced.

Step 2: Grinding, Proportioning and Blending Raw Materials into Kiln Mix (Fig. 2-6). The materials are ground up by the pressure exerted by the three conical rollers in a vertical steel mill. The rollers roll over a turning milling table. Horizontal mills are also in use at some cement plants, they utilize steel balls to pulverize the material. This step utilizes either a dry or a wet process. The most common way to manufacture portland cement is through a dry process. In a dry process, the crushed rock is combined with other ingredients such as iron ore or fly ash and ground, mixed, and either stored or fed into a cement kiln. The advantages to using a dry process is that the preheating is done outside the kiln, which shortens the time in the kiln and is more efficient. However, disadvantages are higher alkalies, sulphur and chlorides.

If a wet process is used, the grinding and blending operations are done with materials mixed with water in a slurry form. The advantages to using a wet process are that the kiln mix is more uniform and the raw material may already contain moisture. However, this process has a higher energy use which may result in higher cost to produce.

Step 3: Heating Raw Materials in the Kiln (Calcination). Calcination is the core portion of the process where the kiln mix is fed into a huge rotary kiln. Inside, at 1400 degrees C, the raw material is transformed into clinker: small, dark gray nodules 3-4 centimeters in diameter.[3]

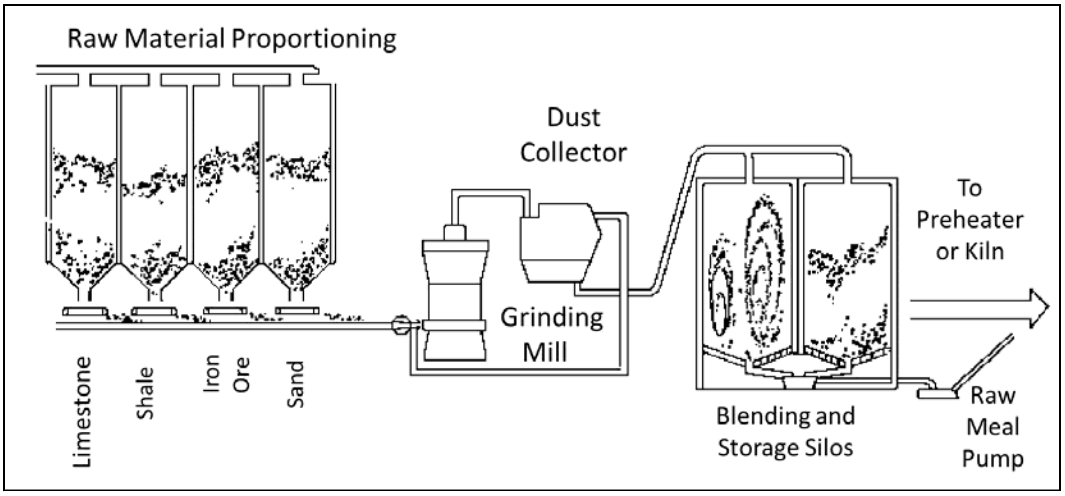


Fig. 2-6. Raw Materials Proportioning and Blending.

There are two types of dry plants, precalciner and dry process. In a precalciner the material is calciened in pre heater towers to breakdown the calcium carbonate into free lime (CaO) and gas (C02). The kiln length of precalciner is about half as long as an old fashion dry process plant. A wet process plant kiln averages 400 to 500 feet. These sizes are dependent upon the capacity of the plant production.

Fig. 2-7. Inside the Kiln: Diameters can range from 12 to 24 ft.

The cement kiln heats all the ingredients to about 2,700 degrees Fahrenheit in huge cylindrical steel rotary kilns lined with special firebrick. Kilns are frequently as much as 12 feet in diameter—large enough to accommodate an automobile and longer in many instances than the height of a 40-story building (Fig. 2-7). The large kilns are mounted with the axis inclined slightly from the horizontal. The finely ground raw material or the slurry is fed into the higher end. At the lower end is a roaring blast of flame, produced by precisely controlled burning of powdered coal, oil, alternative fuels, or gas under forced draft.

Location of flame and distance of the burning zone are important factors in the formation of the clinker crystalline structure.

As the material moves through the kiln, certain elements are driven off in the form of gases. The remaining elements unite to form a new substance called clinker. Clinker comes out of the kiln as grey balls, about the size of marbles (Fig. 2-8).

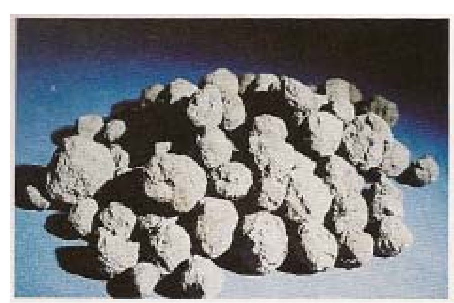


Fig 2-8. Portland cement clinker; about 20 mm in diameter.

Clinker is discharged red-hot from the lower end of the kiln and generally is brought down to handling temperature in various types of coolers. The heated air from the coolers is returned to the kilns, a process that saves fuel and increases burning efficiency.

The oxides from the raw materials form new compounds in the kiln. These four new compounds contribute to the strength and hardening of the cement at varying time periods (fig 2-9).

Dicalcium Silicate (C_2S), or Belite, hardens slowly and contributes largely to increasing strength at ages beyond 7 days.

Tricalcium Silicate (C_3S), or Alite, hardens rapidly and is largely responsible for initial set and early strength. In general, the early strength of portland cement concrete is higher with increased percentages of C_3S.

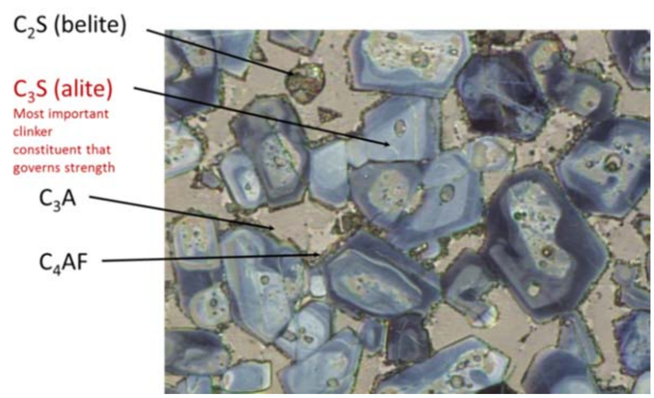


Fig 2.9. Cement properties of clinker materials.

Tricalcium aluminate (C_3A), hydrates and hardens the quickest (between 1-3 days). It liberates a large amount of heat almost immediately and contributes somewhat to early strength. Gypsum is added to portland cement to retard C3A hydration. Without gypsum, C3A hydration would cause portland cement to set almost immediately after adding water.

Tetracalcium Aluminoferrite (C_4AF) has a negligible contribution to strength gain. However, it contributes the grey color in Portland cement.

C_2S and C_3S are the calcium bearing compounds, whereas C_3A and C_4AF are the alumina and iron bearing compounds.

Step 4: Grinding Clinker into Cement (Fig. 2-10). After the clinker is cooled, the clinker is ground by different-size steel balls while it works its way through the mill's two chambers, with gypsum being added to extend cement setting times.

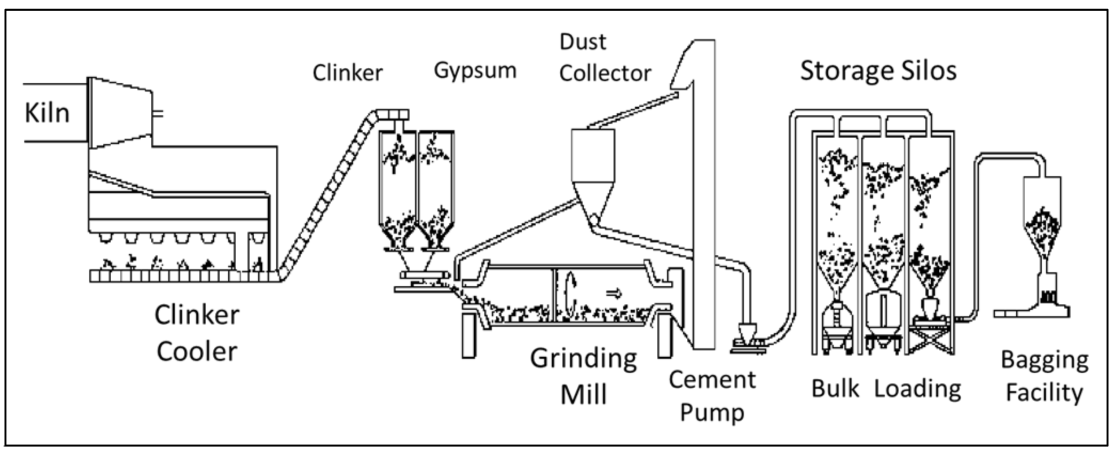


Fig. 2-10. Grinding clinker and gypsum.

Quality Control Frequent chemical and physical tests are performed by the quality control technicians during each step of the Portland Cement manufacturing process. The finished Portland Cement powder also undergoes final testing and analysis to ensure that it complies with all industry specifications.

Types of Portland Cement

Portland Cements are produced to meet ASTM Standard C 150 and classified into five types (Fig. 2-11). This ASTM standard sets limits for chemical composition, fineness of grind, setting time, strength at certain ages, resistance to chemical attack, and rate of development of heat of hydration. Due to the differences in the composition, different types of Portland Cements should never be mixed and stored in the same silo.

Type I Normal Portland Cement is a general purpose cement suitable for many uses. Type I cement can be used in any application not subject to sulfates or where heat of hydration is not critical. Sulfates found in soils, groundwater, or effluent can be highly aggressive to Portland cement concrete by combining chemically with certain constituents of concrete which leads to eventual disruption of the concrete. Sulfate attack caused by alkali soils primarily occur in the western and southwestern areas of the US.

Type II Modified Portland Cement has a lower heat of hydration than Type I, improved resistance to sulfate attack, and is intended for use in structures of considerable size to minimize temperature rise. Some production facilities use Type II cement in the summer months to take advantage of the lower heat of hydration, and use Type I cement in the colder months due to its higher heat of hydration.

Type III High-Early Strength Portland Cement is used where high early strengths are desired. Production facilities might choose to use Type III cement when quick service/shipment of product is required, or during cold weather to protect against low temperatures.

Type IV Low-Heat Portland Cement is no longer manufactured by the cement producers since low-heat concrete can be achieved through other blends. Type IV was used when the amount of heat generated had to be kept to a minimum, but strength development was also reduced to a slower rate. Type IV would not be a good fit in the production of RCP.

Type V High Sulfate Resistant Portland Cement is a special cement intended for use in structures exposed to severe sulfate action. It has a slower rate of strength development than Type I. It provides better sulfate resistance than Type II cement.

Cement Fineness is determined by the Blaine apparatus, it is an expression of the total surface of the cement particles. More surface the cement particles have, i.e. the smaller the size of the cement particles shown by the higher Blaine value are, the faster the cement will react with water potentially resulting in faster set times and earlier strength gain.

Composition & Fineness of Portland Cements

Type	C_3S	C_2S	C_3A	C_4AF	Blaine Fineness m^2/kg
I	57.5 49-62	12.7 9-16	9.3 7-11	7.3 4-11	397.2 375-440
II	59.1 51-68	12.7 7-20	6.4 0-8	10.3 7-13	392.7 305-471
III	58.0 49-66	13.5 7-20	7.3 4-14	9.1 4-12	560.8 365-723
IV	42.2 37-49	31.7 27-36	3.7 3-4	15.1 11-18	339.5 319-362
V	59.2 52-63	14.6 8-22	4.1 2-5	11.7 9-15	401.1 302-551
White	62.7 50.5-72.4	17.8 9.3-25.2	10.4 5.2-12.6	1.0 0.7-1.8	482.4 384-564

Fig. 2-11. Typical % Portland Cement Compounds and Fineness.

Standards

There are chemical limits that must be adhered to by cement-producing plants to ensure production consistency in the industry. These standards and specifications have been established by organizations such as American Society for Testing and Materials (e.g., ASTM C150 Standard Specification for Portland Cement and C559 for blended hydraulic cement), and the American Association of State Highway (), (e.g., AASHTO 85 for portland cement and M240 for blended cements), which is followed by some state agencies. These specifications also provide guidance to ensure that standard test methods are followed in a consistent manner.[3]

The Mill Certification Report (Fig. 2-12) shows that the manufacturer conforms to particular specifications including limits and results. Mill Certificates represent a composite of tests done by the manufacture for a particular prior time period. The ASTM C150 states that: “Upon request of the purchaser in the contract or order, a manufacturer’s report shall be furnished at the time of shipment stating the results of tests made on samples of the material taken during production or transfer and certifying that the cement conforms to applicable requirements of this specification.”

Material Certification Report

Material:	Portland Cement	Test Period:	01-Dec-2012
Type:	I-II	To:	31-Dec-2012

Certification

This cement meets the specifications of ASTM C150 for Type I-II cement, and complies with AASHTO M85 specifications for Type I-II cement.

General Information

Supplier:		Source Location:	
Address:			
Telephone:		Contact:	
Date Issued:	15-Jan-2013		

The following information is based on average test data during the test period.
The data is typical of cement shipped by ; individual shipments may vary.

Tests Data on ASTM Standard Requirements

Chemical			Physical		
Item	**Limit[A]**	**Result**	**Item**	**Limit[A]**	**Result**
SiO_2 (%)	-	19.7	Air Content (%)	12 max	7
Al_2O_3 (%)	6.0 max	4.6	Blaine Fineness (m^2/kg)	260 min	375
Fe_2O_3 (%)	6.0 max	3.2			
CaO (%)	-	63.9			
MgO (%)	6.0 max	2.9	Autoclave Expansion (%) (C151)	0.80 max	0.00
SO_3 (%)	3.0 max[B]	3.4	Compressive Strength MPa (psi):		
Loss on Ignition (%)	3.0 max	2.5			
Insoluble Residue (%)	0.75 max	0.45	3 days	12.0 (1740) min	28.0 (4070)
CO_2 (%)	-	1.2	7 days	19.0 (2760) min	34.9 (5060)
Limestone (%)	5.0 max	3.1			
$CaCO_3$ in Limestone (%)	70 min	89	Initial Vicat (minutes)	45-375	89
Inorganic Processing Addition (%)	5.0 max	0.0			
Potential Phase Compositions[C]:			Mortar Bar Expansion (%) (C1038)	-	0.008
C_3S (%)	-	60			
C_2S (%)	-	8			
C_3A (%)	8 max	7			
C_4AF (%)	-	9			
$C_3S + 4.75C_3A$ (%)	-	91.3			

Tests Data on ASTM Optional Requirements

Chemical			Physical		
Item	**Limit[A]**	**Result**	**Item**	**Limit[A]**	**Result**
Equivalent Alkalies (%)	0.60 max	0.58	False Set (%)	50 min	87

Notes

[A] Dashes in the limit / result columns mean Not Applicable.
[B] It is permissible to exceed the specification limit provided that ASTM C1038 Mortar Bar Expansion does not exceed 0.020 % at 14 days.
[C] Adjusted per Annex A1.6 of ASTM C150 and AASHTO M85.
[D] Test result represents most recent value and is provided for information only. Analysis of Heat of Hydration has been carried out by CTLGroup, Skokie, IL.
Equavalent Alkalies (%) Minimum = 0.56, Maximum = 0.59
This data may have been reported on previous mill certificates.

Additional Data

Inorganic Processing Addition Data		Base Cement Phase Composition	
Item	**Result[A]**	**Item**	**Result**
Type	-	C_3S (%)	62
Amount (%)	-	C_2S (%)	9
SiO_2 (%)	-	C_3A (%)	7
Al_2O_3 (%)	-	C_4AF (%)	10
Fe_2O_3 (%)	-		
CaO (%)	-		
SO_3 (%)	-		

Fig. 2-12. Mill Certification Report.

The mill certification can be very useful when quality issues arise with the concrete, or when the production facility is looking to switch cement suppliers. Understanding how the various cement components (C_2S, C_3S, C_3A, C_4AF) as well as the fineness of the cement particles (Blaine) and the setting characteristics of the cement (Vicat) affect concrete properties, it may be possible to either confirm or eliminate the cement as a cause for the concrete product issue, or determine which cement has more favorable properties and how they will impact the product once the cement switch is made.

Portland Cement Hydration

When cement and water react to produce the C-S-H gel (Fig. 2-13), which “glues” the aggregate particles together to form concrete, this process is called hydration. As the cement hydration continues over time, more bonds are formed between the aggregate particles and the cement hydration products resulting in the strengthening of the concrete.

Primary cement reaction (fast):

C_3S (and C_2S) + **water** = **C-S-H gel & CH + Heat**

Byproduct from hydration = **Calcium Hydroxide (CH)**

Pozzolanic reaction (slow):

Fly Ash + Calcium Hydroxide = **C-S-H gel**

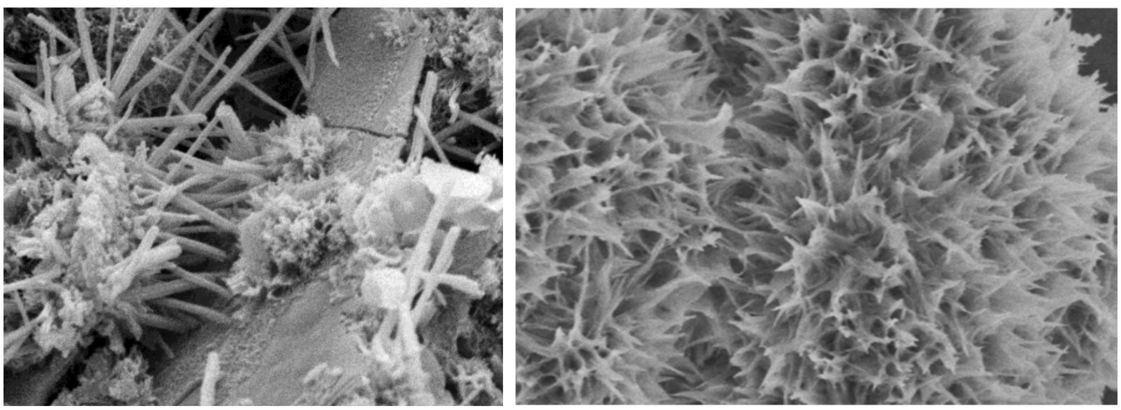


Fig. 2-13. Examples of Calcium Silicate Hydrate (C-S-H) under microscope.

Notes

Notes

Chapter 3: Supplementary Cementitious Materials


Fig. 3-1. Supplementary Cementitious Materials.[1]

As the name implies, Supplementary cementitious materials (SCMs) are used as a substitute for cement in the concrete mix (Fig. 3.1). They are used not only for potential economical benefits, the SCMs enhance the properties of concrete, for example they can improve the resistance to alkali-silicate reactivity or reduce permeability and increase the strength of the concrete. Many of the supplementary cementitious materials are derived from by-products of other industrial processes providing a good use for the material that would otherwise end up in a landfill. These materials, as shown in the illustration from left to right, include fly ash (Class C), metakaolin (calcined clay), silica fume, fly ash (Class F), slag cement, and calcined shale.

Objectives

At the end of this chapter, you will be able to:

- ✓ Recall the difference between a pozzolanic and a hydraulic SCM.
- ✓ Recall where each type of SCMs originate.
- ✓ Identify the key features and benefits of each type of SCM.
- ✓ Recognize the cautions around the usage of each type of SCM.

Pozzolanic vs. Hydraulic Materials

When SCMs are added to cement, they alter the cement's properties through hydraulic or pozzolanic activity or both. A hydraulic material reacts chemically with water to form cementitious compounds. A pozzolan is a siliceous or aluminosiliceous material, like fly ash or silica fume, when in the presence of moisture, chemically react with calcium hydroxide to form compounds possessing cementitious properties**.** ASTM C618 is the standard that covers pozzolans (such as fly ash or silica fume) used in making concrete.

Slag Cement

Slag cement is a ground granulated blast-furnace slag (GGBFS), and is considered a latent hydraulic material[1] (Fig 3-2). The term latent refers to slow process of hydrating when it is mixed solely with water.[2] Using slag cement to replace a portion of portland cement, in the concrete mix, can make the concrete product more consistent and better, including improvements such as:

- Enhanced concrete workability
- Easier finishability
- Higher compressive and flexural strengths
- Lower permeability
- Improved resistance to aggressive chemicals
- More consistent plastic and hardened properties
- Lighter color

Fig. 3-2. Slag Cement.

Production process

When iron ore is heated in a blast furnace to about 2700 – 3000 degrees (Fig. 3-3), limestone and coke are added as a flux material. As the iron melts, the furnace is tapped and the iron is released into a channel. Impurities that were in the iron ore, the limestone, and the coke float on top of the dense iron. The impurities in this molten state are called slag. The slag and iron are separated by mechanical means (usually by a gate that drops over the channel of flowing iron and slag). The separated slag is diverted into its own channel where it flows to the granulator.

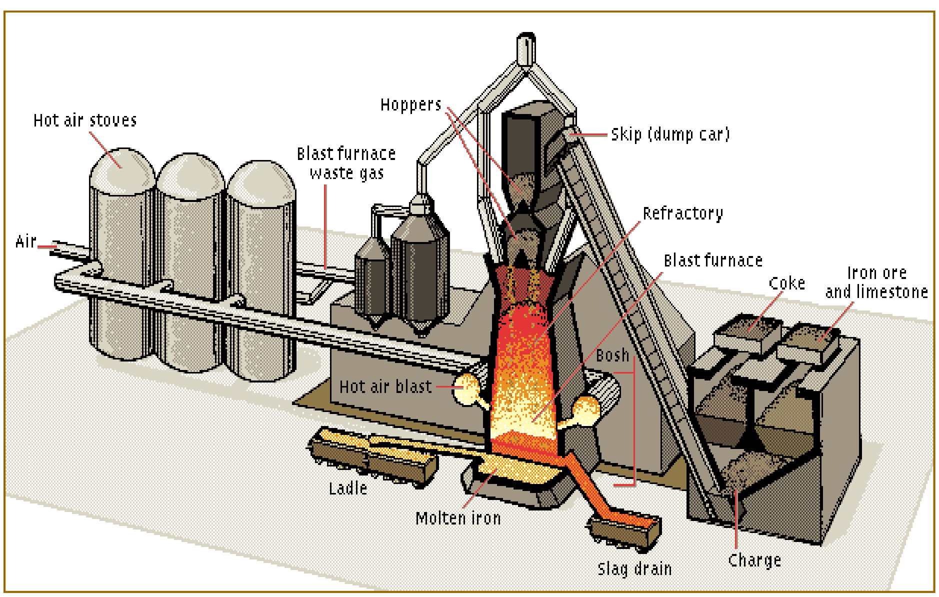


Fig. 3-3. Production of Slag Cement.

Flux. In the process of smelting, inorganic chlorides, fluorides (see fluorite), limestone and other materials are designated as "fluxes" when added to the contents of a smelting furnace or a cupola for the purpose of purging the metal of chemical impurities such as phosphorus, and of rendering slag more liquid at the smelting temperature.

Rapid quenching with water at a ratio of 10:1 changes the hot slag to glassy, non-metallic silicates and aluminosilicates of calcium, known as granulated blast furnace slag. If the slag was air cooled then it would not have cementitious properties and would be more of an aggregate type material. The granulated slag is ground to a suitable fineness, resulting in slag cement.
The benefits of using slag include increased flexural strength, later age strength, increased ability to reflect solar heat, reduced permeability, increased durability, increased resistance to alkali silica reaction (25% to 70%) and increased sulfate resistance (40% to 70%). Conversely, some cautions when using slag cement are (1) as cement replacement rates increase, freeze/thaw durability can be reduced (on flat work); (2) sensitivity to cold weather, below 40^oF(set time and early strength); and (3) as levels of unoxidized sulfide sulfur increase, a temporary greening of the hardened concrete may occur.

Pozzolans

Typical pozzolans include fly ash (Class F), silica fume, metakaolin and calcined shale. They do not react and harden on their own, but they react with calcium hydroxide (by-product of cement hydration) to form compounds possessing cementitious properties. More than 2000 years ago, ancient Romans were the first to combine ground lime stone with volcanic ash to produce a mortar used in binding large stones together , in Pozzuoli, Italy, hence the terms pozzolan and pozzolanic.

Fly Ash

Fly Ash (Fig. 3-4) is the most widely used supplementary cementitious material since the 1930s. Thirty percent of the fly ash in the United States is recycled into making concrete.

Fig. 3-4. Fly Ash.

Fly Ash is a by-product, produced from the coal combustion at coal-fired power plants. Coal is mined from a quarry and transported to power stations where it is stockpiled into different grades. The coal is milled in large mills into a fine powder, where after it is blown through a series of pre-heaters into a furnace where it burns at +- 1400 degrees Celsius (2600 degrees fahrenheit). After the burning process, the leftover coarse material is discarded at the bottom of the furnace known as 'bottoms ash' and stockpiled in waste dumps, while the leftover finer material is drawn through particle filtration equipment (fly ash). This fine material is retained while the flue gasses are released into the atmosphere.

There are two classes of fly ash – Class C and Class F. Class C fly ash originates from subbituminous coal and generally has a calcium oxide content above 20%. Sub-bituminous coal is a type of coal whose properties range from those of lignite to those of bituminous coal and are used primarily as fuel for steam-electric power generation due to its lower sulfur and heating values.

Class F fly ash originates from bituminous coal and generally has a calcium oxide content of less than 10%. Bituminous coal (organic sedimentary rock)is a relatively soft coal containing a tarlike substance called bitumen. This type of coal is known for releasing the largest amounts of firedamp, a dangerous mixture of gases that can cause underground explosions.

The higher calcium oxide content of a C ash gives it a more cementitious nature. Higher early strength but lower later day strengths. The main properties of Class C and Class F Fly Ash are listed below:

Class C Fly Ash	Class F Fly Ash
• Readily reacts with calcium hydroxide, which is produced when portland cement hydrates, to form cementitious compounds but may also exhibit hydraulic (self-cementing) properties.	• Readily reacts with calcium hydroxide, which is produced when portland cement hydrates, to form cementitious compounds.
• Contains higher CaO content (8% to 40%)	• Contains low CaO content (1% – 15%)
• High lime content, light color due to lower carbon and iron contents	• Low lime content, dark color due to presence of unburned carbon
• Has higher early strengths because pozzolanic activity begins earlier	• Usually preferred for durability

There are many benefits that come with the use of fly ash in concrete. It improves concrete mix workability and reduces permeability. In addition to these benefits, Class F fly ash also increases resistance to alkali-silca reactivity and sulfate conditions and reduces heat of hydration. Along with the benefits are a few cautions. Fly ash can affect air entrainment dosages, increase initial set time and lower early age strengths.

Silica Fume

Silica Fume (microsilica) is pure, amorphous silica with particle size of 0.1-0.2 μm (Fig. 3-5), which is collected during the manufacture of silicon and ferrosilicon alloys that is carried from the burning surface area of an electric-arc furnace by exhaust gases. Particle size of silica fume is finer than cigarette smoke (One micron is 1/1000 mm (1/25,000 of an inch)). It is very dangerous to inhale and therefore proper cautions need to be taken when adding silica fume to the concrete mix.

Fig. 3-5. Silica Fume.

The process for Silica Fume is illustrated below (Fig. 3-6). During silicon metal production, raw materials (such as quartz or quartzite) are added to together with wood chips and coal and heated in a smelting furnace at 3630°F/2000°C to remove oxygen from the silica. Silica fume rises as oxidized vapor from the furnace. When it cools it condenses and is collected in bag filters. The condensed silica fume is then processed to remove impurities.

One of the most beneficial uses for silica fume is in concrete. Silica fume is typically used in amounts between 5% and 10% by mass of total cementitious material. When silica fume is added to fresh concrete it chemically reacts with the calcium hydroxide to produce additional calcium silicate hydrate (CSH). Additionally, because silica fume is 100 to 150 times smaller than a cement particle, it can fill the voids created by free water in the matrix, thus creating a much denser pore structure. Silica fume is used in applications where a high degree of impermeability is needed and also in high-strength concrete.

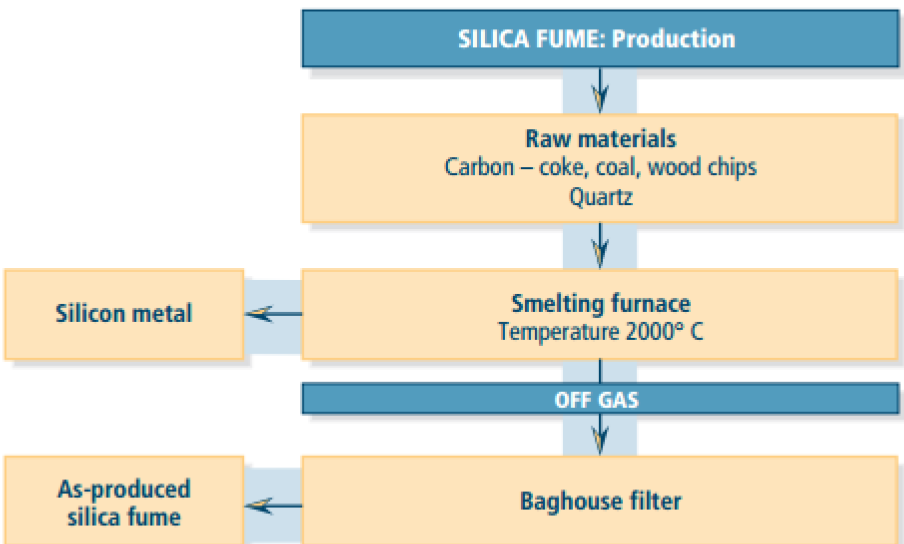


Fig.3-6. Silica Fume Production Schematic.

Metakaolin

Metakaolin is a calcined clay which is produced by low-temperature calcinations of kaolin clay (Fig. 3-7). The clay is purified by water processing prior to very carefully controlled thermal activation at relatively low temperature compared to other clays (650°C to 800°C or 1202°F to 1472°F). Metakaolin is used in applications where very low permeability or very high strength is required. In these applications, metakaolin is used more as an additive to the concrete rather than a replacement of concrete; typical additions are around 10% of the cement mass.[3]

Fig. 3-7. Metakaolin.

Calcined Shale

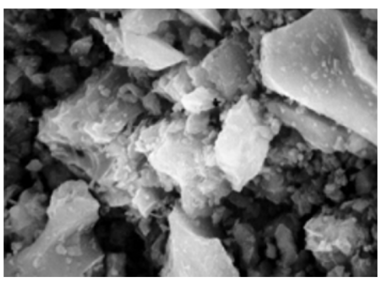


Fig. 3-8. Calcined Shale.

Calcined shale is considered a natural pozzolan (Fig. 3-8). Shales become pozzolanic if they're heat-processed at calcining temperatures between 1,200° and 1,500° F. Cement containing calcined shale and clay reduces concrete's chloride permeability. Concrete made with this blended cement keeps chloride ions out but still finishes like ordinary concrete. The cements used in concretes for both the Golden Gate and San Francisco Bay bridges contained about 25% calcined shale.[4]

Notes

Notes

Chapter 4: Aggregates

Over two billion tons of aggregate are used each year in the United State alone, to construct and repair roads, highways, sidewalks, houses, schools and a variety of other personal and commercial buildings.[1] For example, constructing one mile of interstate highway requires about 85,000 tons of aggregates, whereas a house uses 120 tons of aggregate and 17 tons of concrete. For projects like this and others, this equates to more than 10 tons of sand, gravel and stone being mined yearly for every person in the United States.[2]

Aggregates are key ingredients in the concrete used to manufacture pipe, box culverts, manholes and other underground structures. The type, size, shape and other material properties of aggregates influence strength, density, permeability, ease of consolidation and durability of the concrete. Therefore, it is critical to maintain close scrutiny of the sourcing of aggregates to ensure the products we manufacture meet and exceed the service life expectations of the projects we build.

Objectives

At the end of this chapter, you will be able to:

- ✓ Compare fine and coarse aggregates.
- ✓ Recognize the key properties of aggregates.
- ✓ Recall the ASTM C-33 standard that applies to aggregate durability, size and gradation.
- ✓ Define the Total Moisture (TM) of aggregates.
- ✓ Calculate the total moisture content in aggregate, given the weight of wet sand and dry sand of a particular sample.
- ✓ Recall the testing procedures for moisture determination in aggregates
- ✓ Recall the ASTM standards for aggregate abrasion testing and soundness testing.
- ✓ Explain how concrete properties are affected by aggregates with respect to strength, finishability, water requirement, workability, durability, volume and specific gravity:
- ✓ Recall the standards for collecting aggregate samples and reducing aggregate samples.

- ✓ Recognize the key storage requirements for minimizing segregation and preventing contamination in aggregate.
- ✓ Select the correct method for filling aggregate bins, given an illustration.

Concrete Aggregates

Aggregates are inert granular materials such as sand, gravel, or crushed stone that, along with water and portland cement, are an essential ingredient in concrete. Aggregates provide needed bulk to concrete mixes to enable them to harden into materials capable of withstanding immense weight and virtually all forces of nature. Aggregates account for approximately 60-75% of the volume of precast concrete and dramatically affect the properties of the mix.

Types of Aggregates

Aggregates consist of natural sand, gravel and crushed materials such as granite, limestone and other naturally occurring rock. They are divided into two distinct categories—fine and coarse.

Fine (Fig. 4-1) aggregates consist of natural sand, manufactured sand or crushed stone with most particles passing through a #4 sieve.

Coarse (Fig. 4-2) aggregates are also made of natural or crushed stone with most particles generally ranging between 3/8 and 1 ½ inches in diameter, which would be larger than a #4 sieve.

Additional information about grading is included later in this chapter.

Fig. 4-1. Fine aggregate (sand).

Mineralogy – The Origin of Aggregates

Fig. 4-2. Coarse aggregate; rounded gravel and crushed stone.

Naturally occurring concrete aggregates are a mixture of rocks and minerals. A mineral is a naturally occurring solid substance with an orderly internal structure and a chemical composition that ranges within narrow limits. Rocks, which are classified as igneous, sedimentary, or metamorphic, depending on origin, are generally composed of several minerals.

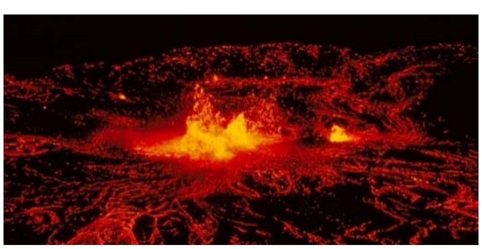


Fig. 4-3. Hawaii Volcanoes Magma.

Igneous comes from the Latin word "ignis" meaning "fire". As one of the three main rock types, igneous rock is formed from volcanic processes and the heating and cooling of magma or lava (Fig 4-3). Igneous rock may form with or without crystallization, either below the surface as intrusive (plutonic) rocks or on the surface as extrusive (volcanic) rocks. Over 700 types of igneous rocks have been described, most of them having formed beneath the surface of Earth's crust. An example of igneous rock is granite, which contains quartz, feldspar, mica, and a few other minerals.

Fig. 4-4. Limestone Rocks.

The second rock type, **sedimentary**, comes from the Latin word sedimentum meaning "settling." Sedimentary rock is formed by the layering of sediments due to the action of wind or water. Particles that form a sedimentary rock by accumulating are called sediment. Before being deposited, sediment was formed by weathering and erosion in a source area, and then transported to the place of deposition by water, wind, ice, mass movement or glaciers. Sedimentary rocks are only a thin veneer over a crust consisting mainly of igneous and metamorphic rocks. Examples of sedimentary rock are sandstone and limestone. Limestone (Fig. 4-4) is produced from the mineral calcite (calcium carbonate) and sediment. Most limestones consist of calcite, dolomite and minor amounts of quartz, feldspar, and clay.

Fig. 4-5. Quartzite, a form of metamorphic rock, from the Museum of Geology at University of Tartu collection.

Lastly, **metamorphic** (meaning "change" in Greek) rock results from long-term high temperature and pressure on igneous and sedimentary rocks. In a process called metamorphism, the original rock is subjected to temperatures greater than 150 to 200 °C and pressure at 1500 bars (one bar is about equal to the atmospheric pressure on Earth at sea level) causing profound physical and/or chemical change. The original rock may be a sedimentary rock, an igneous rock or another older metamorphic rock. Metamorphic rock (Fig. 4-5) may be formed simply by being deep beneath the Earth's surface, subjected to high temperatures and the great pressure of the rock layers above it. They can form tectonic processes such as continental collisions, which cause horizontal pressure, friction and distortion. They are also formed when rock is heated up by the intrusion of hot magma from the Earth's interior.

Aggregate Key Characteristics and Properties

The quality and grading of aggregates strongly influence concrete's freshly mixed and hardened properties, mixture proportions, and economy. Aggregates comprise as much as 60% to 75% of a typical concrete mix, so they must be properly selected to be durable, blended for optimum efficiency, and properly controlled to produce consistent concrete strength, workability, finishability, and durability. Good-quality aggregate is verified by regular aggregate test results in compliance with *ASTM C 33, "Standard Specifications for Concrete Aggregate"*.

Consequently, selection of aggregates is an important process. Although some variation in aggregate properties is expected, characteristics that are considered include:

- Mineral composition
- Particle shape and texture

- Gradation
- Soundness
- Abrasion resistance
- Specific gravity
- Absorption and surface moisture

Aggregate Production

Aggregates have been used in foundation construction for thousands of years. However, it wasn't until the construction of roads and aqueducts in the Roman Empire that the process of using sand and stone was refined leading to the invention of concrete, used in creating the arches necessary for these structures. This led to an increase and ongoing demand for construction aggregates to be produced.[3]

Extracting Aggregates

Fig. 4-6. Limestone processing plant in Tennessee, by M. Garard; 19:27, 21 September 2006.

Aggregates are the most mined materials in the world. Sources for these materials can be divided into three main areas: rock quarries, sand and gravel quarries or marine beds. Natural gravel and sand are usually dug or dredged from a pit, river, lake, or seabed. Crushed aggregate is produced by crushing quarry rock, boulders, cobbles, or large-size gravel.

In order to mine the rock from the ground, the overburden layer of any unusable rock and soil covering the ore body is removed and stockpiled for later use. Depending on how hard or loose the rock to be mined is, it may be removed by either dredging, digging or blasting.

Fig. 4-7. Snabe sand and gravel quarry.

Blasting Hard Rock Quarries. Rock quarries usually operate for long periods of time and are developed in distinct benches or steps. A controlled explosion is normally used to break the rock from the working face. A powerful excavator loads the rock into dump trucks or on conveyors for delivery to the primary crusher, where powerful hammers or metal jaws within the crusher break the rocks down. From the primary crusher the rock goes through a series of crushing and screening stages to produce a range of final sizes to suit customers' needs as it's delivered by road or rail from the quarry (Fig. 4-6).

Digging Sand and Gravel Quarries. Sand and gravel quarries are much shallower than rock quarries and are usually worked and restored continuously (Fig.4-7). This minimizes the area exposed for quarrying at any time, and limits the period the land is out of use for other productive purposes .

Sand and gravel quarries are pumped to allow them to be worked dry or operated as lakes with extraction below water. Once the material is quarried, a conveyor draws raw material into the processing plant, where it is washed to remove unwanted clay and to separate sand. Sand separated during processing is dewatered and stockpiled. Gravel then passes over a series of screens that sift the material into different sizes. Processing separates the gravel into stockpiles in a range of sizes for delivery by truck.

Dredging Marine Beds. A significant proportion of the demand for aggregates is satisfied from river, lake, and sea beds. Vessels trail a pipe along the marine floor at speeds approaching 1.5 knots and use powerful suction pumps to draw sand and gravel into the cargo hold. After extraction, the dredged material is discharged at wharves and other marine facilities, where it is processed, screened, and washed as required

Processing Aggregates

Aggregates are processed after extraction. Large aggregates are crushed, screened and washed at the quarry or plant to obtain proper cleanliness and gradation. Some variation in the type, quality, cleanliness, grading, moisture content and other properties is expected. Approximately half of the course aggregates used in Portland cement concrete in North America are natural gravels with the other half being crushed stones.

Storage and Handling

Fig. 4-8. Conveyor and sand stockpiles.

Aggregates should be stored in a manner to minimize segregation and prevent contamination by deleterious substances. To minimize segregation, aggregates should not be stored in conical piles regardless of the handling and transport method. Stockpiles that stack traditionally can segregate, with coarser material falling to the bottom or outside, and finer material remaining in the center and top**.** It is important that correct loading techniques are used to ensure that a blend is gathered in a way that does not hurt the pile. Degradation can also occur if loaders or dozers drive onto the stockpile, or if material is falling from a great height — potentially splitting or crushing the gradated material. Equipment driving on stockpiles can also cause contamination, as it tracks dirt or loose material onto the stockpile (Fig. 4-8).

To prevent contamination, store aggregates on slabs or planking. In addition, make sure that storage bins are separated by walls that are high enough to ensure that aggregates do not mix (Fig 4-9).

When loading the bin, the material should fall vertically over the outlet into the bin (Fig 4-10). Other possible sources of degradation due to improper loading and storage include:

Fig. 4-9. Stockpile storage bins.

- Allowing adjacent aggregate stockpiles to overlap, causing cross-contamination.
- Aggregate leakage through or around bulkheads in storage bins.
- Allowing leaves and other contaminants to fall into the aggregate stockpile.
- Allowing vegetation to grow in the aggregate stockpile.
- Scooping up underlying soil when using a front-end loader to move aggregate from a stockpile.

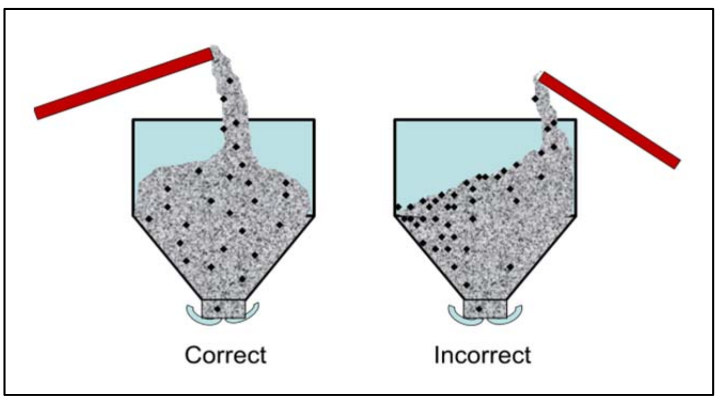


Fig. 4-10. How to fill aggregate bins.

- Dumping the wrong size aggregate in a bin or pile.
- Failure to let the receiving hopper and conveyor belt or elevator run until empty before adding a different size aggregate.

Aggregate Properties and their Impact on Concrete

The importance of using the right type and qualify of aggregates cannot be overemphasized. The fine and coarse aggregates generally occupy 60% to 75% of the concrete volume (70% to 85% by mass) and strongly influence the concrete's freshly mixed and hardened properties, mixture proportions, and economy.

This section takes a look at the aggregate properties critical to quality and type and how they impact concrete and concrete products.

Mineral Composition

Good-quality aggregate must be clean, hard, strong, have durable particles, and be free of absorbed harmful chemicals, coatings of clay, or other contaminates that can affect hydration of cement or reduce the paste-aggregate bond.

Deleterious Materials are harmful substances that may be present in aggregates such as organic impurities, silt, clay, shale, iron oxide, coal, lignite, and certain lightweight and soft particles. Aggregates are potentially harmful if they contain compounds known to react chemically with Portland cement concrete.

According to ASTM C33/C33M, "Fine aggregate shall be free of injurious amounts of organic impurities. Except as herein provided, aggregates subjected to the test for organic impurities and producing a color darker than the standard shall be rejected." Table 4.1 shows the limits for

Table 4.1. Limits for Deleterious Substances in Fine Aggregate.

Item	Mass % of Total Sample
Clay lumps and friable particles	3.0
Material finer than 75 micron (No. 200) sieve:	
Concrete subject to abrasion	3.0*
All other concrete	5.0*
Coal and lignite:	
Where surface appearance of concrete is of importance	0.5
All other concrete	1.0

Deleterious Substances in Fine Aggregates for Concrete in ASTM C33. In the case of manufactured sand, if the material finer than the 75-micron (No. 200) sieve consists of dust or fracture, essentially free of clay or shale, these limits are permitted to be increased to 5 and 7%, respectively.

Lignite is sometimes found in natural sand. The amount varies, depending on the quarry and the particular deposit. When sand containing lignite is used in making concrete, lignite particles near the surface can expand and cause pop outs. Lignite is often referred to as brown coal, it is the lowest rank of coal quality.

Limits of deleterious substances in coarse aggregates are also addressed in ASTM C33. Methods for testing are addressed in Sampling and Testing.

Particle Texture and Shape

The texture and shape of aggregate particles is important in that it will affect the properties of fresh concrete. The rough textured, angular, elongated particles have greater surface area and require more cement paste than smooth rounded particles. Also the angular and poorly graded aggregates are harder to consolidate and finish.

Generally, rounded gravel makes stronger and more finishable lean mixes. Angular crushed stone is better suited for high strength, richer cement paste mixes (Fig. 4-11).

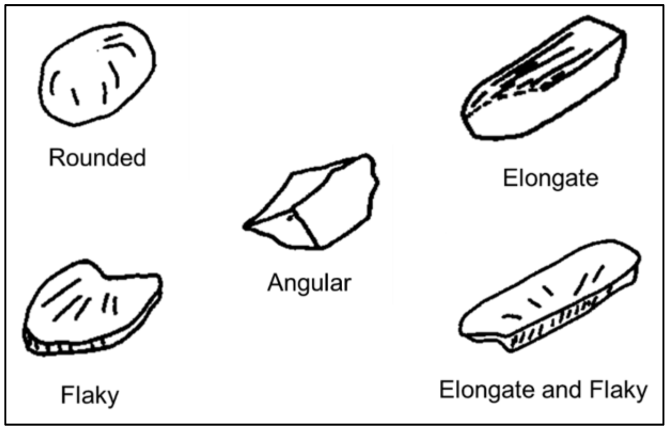


Fig. 4-11. Aggregate particle textures and shapes.

Gradation

Gradation (also known as "sieve analysis") refers to the determination and distribution of aggregate particle sizes (Fig. 4-12). "Well graded" aggregates have particles that are evenly distributed among sieve sizes, which require less cement and water than "poorly graded" aggregates. Careful choice of aggregates provides for optimization of cement, water and admixtures.

Fig. 4-12. Range of particle sizes provided by the Portland Cement Association.

The requirements for grading and quality of fine and coarse aggregate for use in concrete are specified by ASTM C33, the Standard Specification for Concrete Aggregates. The test method for grading aggregates is explained in ASTM C 136, Standard Test Method for Sieve Analysis of Fine and Course Aggregates.

Grading limits and maximum aggregate size are specified because these properties affect the amount of aggregate used as well as cement and water requirements, workability, pump-ability, porosity, shrinkage and durability of concrete. For example, coarse sand or under-sanded mixes tend to be more difficult to pump, hard to consolidate, bleed excessively, tend to segregate and make it hard to get an accurate slump. On the other hand, fine sand (or over-sanded mixes) will increase water demand and create sticky harder to finish surfaces. With finer sand, the resulting concrete has less strength with more blistering, bugholes and scaling. As the maximum size aggregate increases, the amount of paste needed for a given slump decreases. The maximum aggregate size used in a concrete mix is dictated by the size of the structural member and the spacing between reinforcing steel.

Grading Size. Size numbers for coarse aggregates apply to the amounts of aggregate (by mass) in percentage that pass through an assortment of sieves (Fig. 4-13). The grading limits are usually expressed as the percentage of material passing each sieve. The *maximum size* refers to smallest sieve opening through which the entire amount of aggregate is required to pass. The *nominal maximum* size refers to the smallest sieve opening through which the entire amount of aggregate is permitted to pass. For example, ASTM C33 requires that 100% of a # 57 coarse aggregate <u>must</u> pass the 1.5" sieve but 95 to 100% <u>may</u> pass the 1" sieve, therefore # 57 aggregate is considered to have a *maximum size* of 1.5" and a *nominal maximum* size of 1.

Fig. 4-13. Aggregate Screen Shaker.

Fine Aggregate Grading – Fineness Modulus (FM). The dividing line between fine and coarse aggregate is the #4 sieve. The fineness modulus (FM) is a single number system used to express the fineness or coarseness of an aggregate; the higher the value the coarser the grading. The FM is calculated by adding the cumulative percentages by mass retained on each of a specified series of sieves and dividing the sum by 100 (See Table 4.2). Certain sieves are NOT counted (even if used). The FM for fine aggregate should fall within the range of 2.3 to 3.1. Note that ½ inch and the pan are not used in FM calculation.

Table 4.2. ASTM C33 Grading for Fine Aggregate.

Sieve	Percent Passing
3/8 in	100
No. 4	95-100
No. 8	80-100
No. 16	50-85
No. 30	25-60
No. 50	5-30
No. 100	0-10

Percent passing the No. 200 Sieve. Very fine material such as silt, clay, or dust of fracture can increase the water demand in concrete. The limit for fine aggregate is 3% in ASTM C 33 for concrete subject to abrasion. Manufactured sands have limits of 5% and 7%. The limit for coarse aggregate is 1% (1.5% for crushed stone). A low FM is generally sandy in texture and requires more water, resulting potentially in less strength. Aggregate with a high FM requires less water for better strength, but the workability is not as good. In addition, the finer the modulus the more friction you incur when stripping. Note that local specifications may govern these requirements.

The FM should not change more than 0.2, otherwise, mix adjustments may be necessary. Excessively fine materials will have a higher water demand and typically result in a sticky mix. Excessively coarse material will produce harsh mixes that are more difficult to place, consolidate, and finish.

Significance of Grading. Often aggregates are analyzed using combined grading of fine and coarse materials proportioned as anticipated in the proposed concrete mix. This provides an estimate of how the blend will perform in concrete. Every region has its own deficiencies in aggregates, but once a combined aggregate gradation is plotted (percentage retained vs. sieve size), these deficiencies can more easily be identified and remedied. Alternative aggregate sources or additional aggregate blending can then be considered to achieve optimum paste content, the best workability, reduced shrinkage, and economy. The FM can be helpful in calculating blends of two materials. FM of coarse aggregate can also be calculated and can aid in blending coarse and medium size materials.

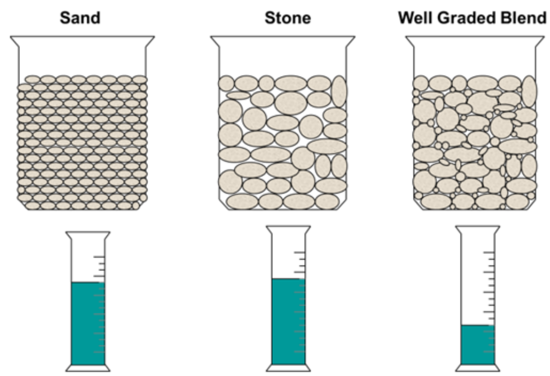


Fig. 4-14. Illustration of how aggregate size affects water demand.

Aggregates Size and Shape Affect Water Demand. As shown in Fig. 4-14. The beaker on the left is filled with small aggregate particles of uniform size and shape; the middle beaker is filled with an equal volume of large aggregate particles of uniform size and shape; and the beaker on the right is filled with particles of both sizes. Below each beaker is a graduate with the amount of water required to fill the voids in that beaker. Note that when the beakers are filled with one particle size of equal volume, the void content is constant, regardless of the particle size. When the two aggregate sizes are combined, the void content is decreased. Hence the water/paste demand is reduced by smaller aggregate particles filling the voids of the larger particles.

Given that aggregates take up the largest amount of volume in concrete, their particle size, distribution, shape, and texture affect the amount of water needed in concrete. Fine aggregates have between 25 and 40 times more surface area than coarse aggregates of same weight and volume. Therefore, more than any other material, aggregates have the greatest effect on the water needed for a given concrete workability (Fig. 4-15) .

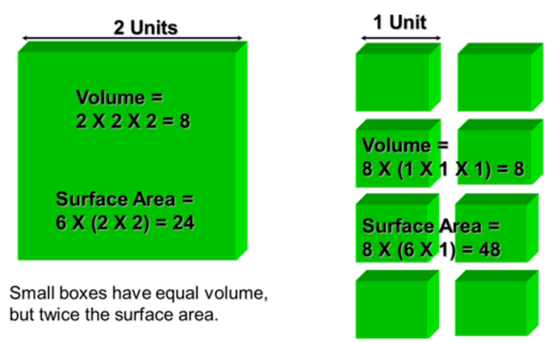


Fig. 4-15. Illustration of Surface Area and Volume.

Use largest nominal max size of coarse aggregate to reduce potential of drying shrinkage. The larger the volume fraction of aggregate, the lower the drying shrinkage of concrete.

Durability of Materials – Soundness

The durability of aggregates depends on how well the aggregate holds up to any weathering action. Aggregates that are durable are less likely to degrade in concrete when the concrete is subjected to weathering, such as freeze-thaw cycles. If the aggregates are not resistant to breakdown and disintegration from weathering, they may break apart and cause premature concrete distress.

Generally, it is coarse rather than fine aggregate particles with higher porosity values and medium-sized pores that are easily saturated and cause concrete deterioration. Larger pores do not usually become saturated or cause concrete distress, and water in very fine pores may not freeze readily.

ASTM C88 specifies the standard Test Method for soundness of aggregates by the use of sodium sulfate or mangnesium sulfate. It is intended to simulate wet or dry and freezing and thawing conditions. See Sampling and Testing for further information on how to test for soundness.

Physical Properties

Specific Gravity. Specific Gravity refers to the relative density of a material compared to water. It is expressed as the ratio of a material's weight to the weight of an equal volume of water (Fig. 4-16). The Bulk specific gravity (SSD) is used to determine the absolute volume of a material going into concrete.

Specific Gravity is not a measure of quality; it ensures proper yield. The Specific Gravity of normal weight aggregates vary from 2.40 to 2.80.

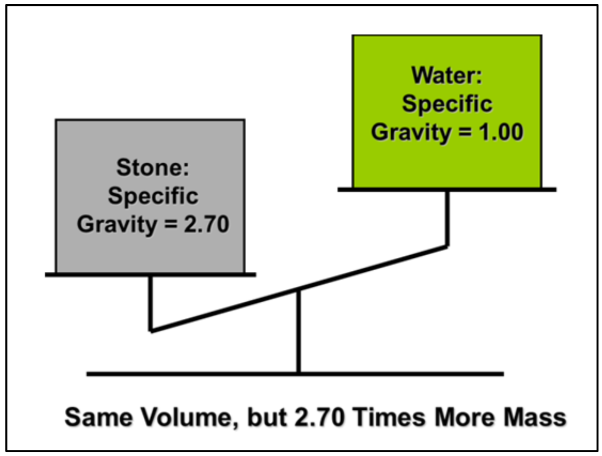


Fig. 4-16. Illustration of volume vs. mass.

When you are dealing with specific gravity you are using it to calculate absolute volumes—do not confuse with Bulk Volumes. For example:

1. Cement bulk volume 94 lbs / cubic foot

2. Cement absolute volume 196.56 lbs / cubic foot (3.15 x 62.4).

Everything in mix designs is absolute. Absolute volume accounts for all void spaces being filled.

Absorption and Moisture Content. The moisture conditions of aggregates are illustrated in Fig. 4-17. Aggregate particles are not solid; they contain pores that absorb water. Concrete mixes are designed based on aggregates being in the saturated surface-dry (SSD) condition. Aggregate in the SSD condition is in a state of equilibrium, i.e., it will neither absorb water from nor give up water to a concrete mix. The amount of water added at the concrete batch plant must be

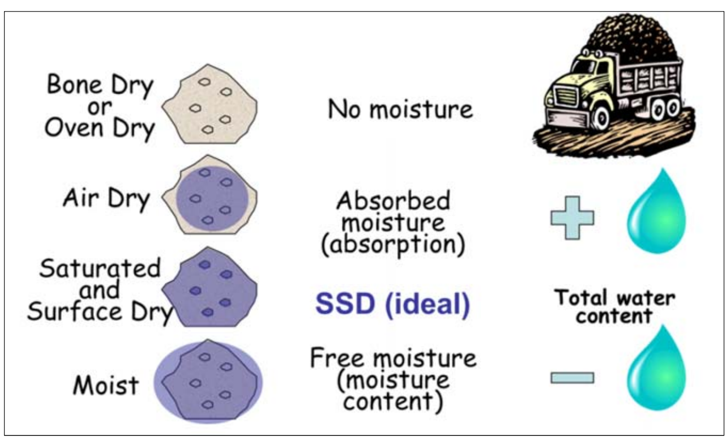


Fig. 4-17. Absorption and moisture content of aggregates.

adjusted for the moisture condition of the aggregates in order to accurately meet the water requirements of the mix design. If the water content of the concrete mixture is not kept constant, the water-cement ratio will vary from batch to batch causing other properties, such as the compressive strength and workability to vary from batch to batch.

Calculating Aggregate Moisture. The amount of moisture in a given aggregate can be calculated using the formula shown in Fig. 4-18. The wet weight is the total weight of the aggregate in the wet condition and the dry weight is the weight of the aggregate in the oven dry condition. The aggregate absorption can be determined from a laboratory test, or one may be obtained from the aggregate producer.

Test Methods for Measuring Moisture in aggregates. There are a number of test methods available to measure aggregate moisture. The most common test method to determine the total moisture in the aggregate is the Cookout Method. The Chapman Flask Method is commonly used to determine the free moisture in the aggregate.

Total Moisture (TM) = Free moisture + Aggregate absorbed moisture

$$\%\,Total\ Moisture\ Content = \frac{(Wet\ Wt - Dry\ Wt)}{Dry\ Wt} \times 100$$

Example: *Wet Wt = 1000g, Dry Wt=980g*

$$\%\,Total\ Moisture\ Content = \frac{(1000 - 980)}{980} \times 100 = 2.0\%$$

Never include the weight of the pan!

% Free Moisture = Total Moisture – Absorbed Moisture

Fig.4-18. Total Moisture Equation with example calculation.

- Cookout Method:

  1. Obtain aggregate sample and record wet weight.
  2. Heat the aggregate in an oven, hot plate, or a microwave until a constant dry weight is achieved, record dry weight.
  3. Calculate the total aggregate moisture (Fig. 4-19); it is important to remember to never include the weight of the pan in the calculation for total moisture.

Aggregate total moisture

MC = Moisture content

$$MC = \frac{(Wet\ Wt - Dry\ Wt)}{Dry\ Wt} \times 100$$

Fig.4-19. Total Aggregate Moisture equation.

- Chapman Flask Method (Fig. 4-20):

  1. Fill Chapman flask to 200 ml mark with water
  2. Add aggregate sample to flask (500.0 gram sample of damp aggregate)
  3. Agitate flask with sample to remove entrapped air
  4. Obtain reading from flask
  5. Using SSD specific gravity of the aggregate look up free moisture on chart (Fig. 4-21).

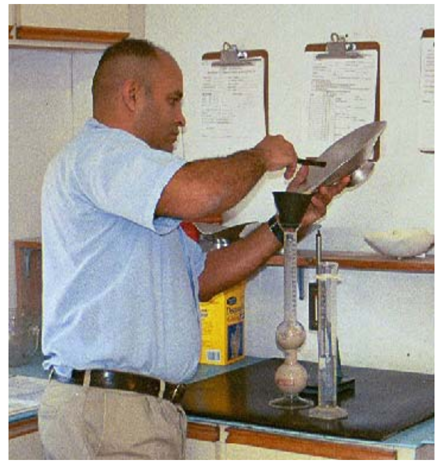


Fig. 4-20. Chapman Flask Method.

CHAPMAN FLASK - MOISTURE DETERMINATION

Total Vol.	Specific gravity of SSD Sand										
	2.50	2.52	2.54	2.56	2.58	2.60	2.62	2.64	2.66	2.68	2.70
385	-	-	-	-	-	-	-	-	-	-	0.0
386	-	-	-	-	-	-	-	-	-	-	0.3
387	-	-	-	-	-	-	-	-	-	0.0	0.6
388	-	-	-	-	-	-	-	-	0.0	0.3	1.0
389	-	-	-	-	-	-	-	0.0	0.3	0.6	1.3
390	-	-	-	-	-	-	-	0.3	0.6	1.0	1.7
391	-	-	-	-	-	-	0.0	0.6	1.0	1.3	2.0
392	-	-	-	-	-	0.0	0.3	1.0	1.3	1.7	2.3
393	-	-	-	-	-	0.3	0.6	1.3	1.7	2.0	2.7
394	-	-	-	-	0.0	0.6	1.0	1.7	2.0	2.3	3.0
395	-	-	-	0.0	0.3	1.0	1.3	2.0	2.3	2.7	3.3
396	-	-	-	0.3	0.6	1.3	1.7	2.3	2.7	3.0	3.7
397	-	-	0.0	0.6	1.0	1.7	2.0	2.7	3.0	3.3	4.0
398	-	0.0	0.3	1.0	1.3	2.0	2.3	3.0	3.3	3.7	4.3
399	-	0.3	0.6	1.3	1.7	2.3	2.7	3.3	3.7	4.0	4.7
400	0.0	0.6	1.0	1.7	2.0	2.7	3.0	3.7	4.0	4.3	5.0
401	0.3	1.0	1.3	2.0	2.3	3.0	3.3	4.0	4.3	4.7	5.3
402	0.6	1.3	1.6	2.3	2.7	3.3	3.7	4.3	4.7	5.0	5.7
403	1.0	1.6	2.0	2.7	3.0	3.7	4.0	4.7	5.0	5.3	6.0
404	1.3	2.0	2.3	3.0	3.3	4.0	4.3	5.0	5.3	5.7	6.5
405	1.6	2.3	2.7	3.3	3.7	4.3	4.7	5.3	5.7	6.0	7.0
406	2.0	2.7	3.0	3.7	4.0	4.7	5.0	5.7	6.0	6.5	7.3
407	2.3	3.0	3.3	4.0	4.3	5.0	5.3	6.0	6.5	7.0	7.7
408	2.7	3.3	3.7	4.3	4.7	5.3	5.7	6.5	7.0	7.3	8.0
409	3.0	3.7	4.0	4.7	5.0	5.7	6.0	7.0	7.3	7.7	8.3

Fig. 4-21. Chapman Flask Moisture Determination Chart.

Concrete mix designs are based on SSD conditions for the aggregates, these conditions seldom exist in reality. For example, a mix design containing 1400 pounds of sand, with free moisture of

5%, will carry 70 pounds of addition water into the batch (Fig. 4-22). This water must be adjusted out of the added batch water. In fact, all aggregates must be adjusted.

(*See Section 2: Concrete Production, Chapter 1: Designing Concrete Mixes for methods of adjusting water for mix designs*).

EXAMPLE

Design Weights
Mix design calls for:

- Sand (ssd) 1400 lb.
- Water 300 lb.

Batch Weights
SAND:

- 1400 lb X 5% (free) = 70.00 pounds of water
- Batch out (1400 +70) = 1470

WATER:

- 300 - 70 = 230 net water

Fig. 4-22. Example of calculating water in mix designs.

Sampling and Testing

According to ASTM C33, sampling and testing the aggregates should be done in accordance with the methods addressed in the specification unless otherwise provided in the specification.

Sampling

Sampling is equally as important as testing, precaution must be exercised to obtain samples that represent the true nature and condition of the material. The sample size obtained during sampling is often larger than desirable for test procedures. Therefore, samples must be reduced in a manner that retains the properties of the original sample. The use of separated sizes from the sieve analysis is acceptable for soundness or abrasion tests, however, additional test specimen preparation is required.

Fig. 4-23. Sample Splitter.

To begin the process, it is critical to any standardized testing of concrete materials that a truly representative sample be collected. Every time aggregate is moved, handled or stored they tend to segregate. As particles tend to segregate (fine vs. coarse) samples obtained may not represent the pile.

- **Sample Splitter Method**. Each sample must be representative of total product (i.e., sampled correctly). The Sample Splitter must have equal width chutes and two receptacles (Fig 4-23). To begin, place the sample in the hopper, distribute it evenly and allow the aggregate to flow freely. This process should be repeated as many times as necessary to reduce the sample to the proper size.

- **Stockpile Quartering Method to Reduce Field Samples**. In using the stockpile method, mix the sample and then place the sample in a single pile. Divide the pile into equal quarters and then collect the opposite quarters, while discarding the rest or setting aside for later use or testing if needed (Fig. 4-24).

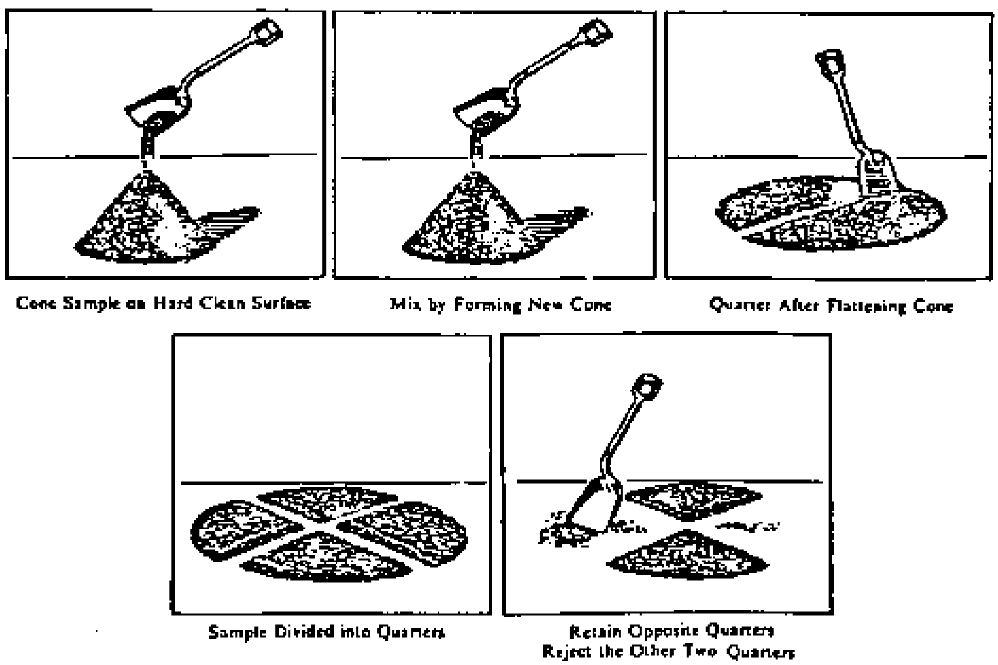


Fig 4-24. Stockpile Quartering Method.

Testing

Testing for Organic Impurities and Deleterious Substances. It is important to determine if the aggregates contain any organic impurities that may delay setting and hardening of the concrete, may reduce strength gain, and in some cases may cause deterioration. In fine aggregate, organic impurities such as peat, humus, and organic loam may not be as detrimental but should be avoided.[4]

Fig. 4-25. Loviband AF347 Test Kit.

Fine aggregates should be tested for organic impurities using the Lovibond AF347 Test Kit (Fig. 4-25), according to ASTM C40. It is a compact, robust and easily portable test kit that can be used on site. There is no need to prepare a standard solution and the testing procedure is simple and straightforward. This test provides dependable measur ement that can be easily interpreted. The results given by the kit are designed to serve as a warning that unacceptable levels of organic impurities are present. This kit meets the standards as specified in ASTM C40 and AASHTO T21.

Testing for Silt or Clay. Larger aggregates should be checked for silt or clay. Although not the official test, a Mason jar test can be used to find out how much fine material is present. ASTM C33 and FDOT Sections 901 and 902 provide the amount and type of allowable fine material.

Testing for LA Abrasion. Abrasion resistance of an aggregate is often used as a general index of its quality. Abrasion resistance is essential to evaluate the aggregate's resistance to degradation during processing, mixing, placing and while in service. In other words, this is a test to ensure that the aggregate is not too soft. The standards test methods are covered in ASTM C131 for aggregates smaller than 1 ½ inches and ASTM C535 for larger aggregates. ASTM C33 specifies a 50% maximum loss calculated by the formula shown in Fig. 4-26.

$$Loss = \frac{W_{initial} - W_{final}}{W_{initial}} \times 100$$

Fig. 4-26. LA Abrasion maximum loss formula.

To test for LA Degradation begin by reducing the sample and sieve to proper gradation. The sample is then washed, dried and weighed. The sample charges are placed into the LA Machine and rotated 500 revolutions at 33 rpm. This process will separate the material courser than 1.70 mm. The material is then washed, if necessary, and re-weighed.

Notes

Notes

Chapter 5: Admixtures

Admixtures are those ingredients in concrete other than hydraulic cement, supplementary cementitious materials, water, aggregates, and fiber reinforcement that are added to the mixture immediately before or during mixing. The major reasons for using chemical admixtures in concrete mixtures are:

- To achieve certain properties in concrete more effectively than by other means;
- To maintain the quality of concrete during the stages of mixing, transporting, placing, finishing, and curing (especially in adverse weather conditions or intricate placements);
- To overcome certain emergencies during concreting operations; and
- Economy.

Fig. 5-1. Liquid admixtures.

Despite these considerations, no admixture of any type or amount is intended as a substitute for good concreting practice. Additionally, the effectiveness of an admixture depends upon factors such as:

- Composition, addition rate, and time of addition;
- Type and amount of cementitious materials;
- Water content;
- Aggregate type, shape, gradation, and proportions:
- Mixing time;
- Slump; and
- Temperature of the concrete.

Objectives

At the end of this chapter, you will be able to:

✓ Identify types of admixtures.

✓ Describe the benefits of each admixture and their effect on concrete

✓ Describe how air entraining admixtures help to mitigate the effects of a Freeze/Thaw threat.

Two Categories of Admixtures

Admixtures vary widely in chemical composition, and many perform more than one function. Two basic categories of admixtures are available: chemical and mineral.

Mineral Admixtures (Pozzolans/Natural Pozzolans)

Mineral admixtures (fly ash, silica fume [SF], and slags) also known as supplementary cementitious materials, are usually added to concrete in larger amounts to enhance the workability of fresh concrete; to improve resistance of concrete to thermal cracking, alkali-aggregate expansion, and sulfate attack. They also enable a reduction in cement content.

Chemical Admixtures

Chemical Admixtures are added to concrete in very small amounts mainly for the entrainment of air, reduction of water or cement content, plasticization of fresh concrete mixtures, or control of setting time.

This chapter will focus on Chemical Admixtures. (In ASTM specifications Chemical Admixtures are referred to only as Admixtures)

History of Chemical Admixtures for Concrete

Like cement, admixtures have had an equally long history. Romans added materials such as milk, blood, lard or even rice to enable greater workability in the cementitious mixtures. But it wasn’t until 1873 that the first patent for calcium chloride was issue in Germany, followed by the introduction of modern admixture technology, such as air-entraining agents, water reducers, retarders and accelerators, in North America in the 1930s. However, use of these products didn’t become widespread until the 1950s, with only 36 states using admixtures by 1962, when ASTM first published the C494 standard for five types admixtures, now called the *Historical Standard: Standard Specification for Chemical Admixtures for Concrete*.[1]

Even though use of admixtures in concrete increased significantly by the 70s, a study in 1982 showed that only 71% of the concrete produced in the US contained water-reducing admixtures, with less than 2% containing high-range water reducers (HRWRs). However, different admixtures continued to be introduced from 1979 to 1996. Some of these admixtures included corrosion inhibited additives for mitigating the affect of chloride salt on steel reinforcment, as well as shrinkage-reducing admixtures to prevent the cracking associated with autogenous drying in high performance concrete.[2]

As HRWRs continued to improve the properties of concrete in North America, the industry experienced a significant shift in understanding how these concrete mixtures could be designed and used. A new concrete technology (and terminology) was developed with the introduction of self-consolidating concrete (SCC). Additives like polycarboxylates-based HRWRs (Fig. 5-2) became a major player in SCC by making it easier to fill a mold quickly without vibration, all while maintaining or even improving the hardening properties of the concrete. This made SCC even more attractive to precast producers.[3]

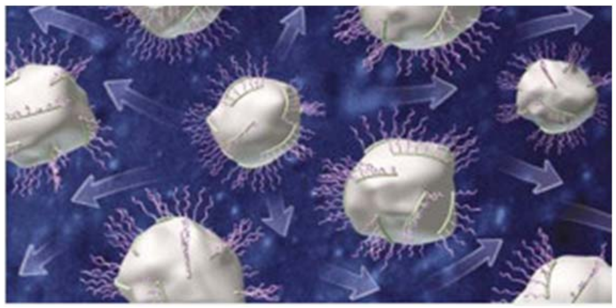


Fig. 5-2. Polycarboxylates are comb shaped and link to the cement grain. Much more of the cement surface is un-covered. These comb-teeth force the cement gain apart by steric repulsion forces (the teeth physically keep the cement grains apart).

Given the benefits of flexbility, workability, and good finishing as those delivered in SCC, HRWR admixtures were readily accepted and became the focus of much experimenting and product development in all areas of concrete and precast productions. This also also prompted the development of another class of admixtures called viscosity-modifying admixtures. These admixtures were used in highly flowable concrete to improve water tolerance and segregation resistance. As a result, VMAs were also included in ASTM C494 standard as Type S.[4]

Chemical Admixtures

There are a variety of chemical admixtures available for use in concrete mixtures to modify fresh and hardened concrete properties. Some of the key chemical admixtures are:

- Water Reducing / Plasticizers
- Retarding
- Accelerators
- Corrosion Inhibitors
- Air-entraining
- Lubricants and Surfactants

Water Reducing Admixtures

By definition (ACI 116), Water Reducer and High Range Water Reducers Admixtures are admixtures that either increase slump of freshly-mixed mortar or concrete without increasing water content **or** maintain slump with a reduced amount of water, the effect being due to factors other than air entrainment.

Water-reducing admixtures usually reduce the required water content for a concrete mixture by about 5 to 10 percent. Consequently, concrete containing a water-reducing admixture needs less water to reach a required slump than untreated concrete. As a result, the treated concrete can have a lower water-cement ratio, thus producing a higher strength concrete without increasing the amount of cement. Recent advancements in admixture technology have led to the development of mid-range water reducers. These admixtures reduce water content by at least 8% and tend to be more stable over a wider range of temperatures. Mid-range water reducers provide more consistent setting times than standard water reducers, mostly due to the advanced chemistry involved.

Superplasticizers, also known as plasticizers or HRWRs, reduce water content by 12 to 30 percent (without the side effect of excessive retardation) and can be added to concrete with a low-to-normal slump and water-cement ratio to make high-slump flowing concrete. Flowing concrete is a highly fluid but workable concrete that can be placed with little or no vibration or compaction. The effect of superplasticizers may typically last from 30 to 90 minutes, depending on the chemistry and dosage rate, and is followed by a loss in workability. Selection of the proper superplasticizer to maintain the proper slump life needed for placement is critical.

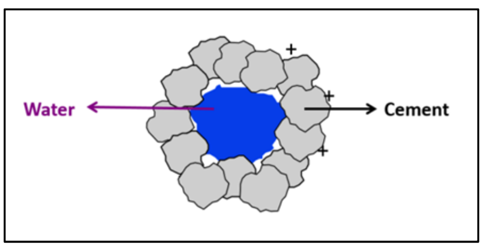


Fig. 5-3. How water-reducing admixtures imparts a negative charge to cement grains.

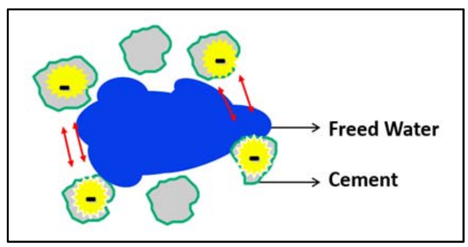


Fig. 5-4. How water reducing admixtures work with cement grains.

How Water Reducing Admixtures Work

Cement grains naturally cluster together to form flocs, which trap water inside them. The water reducing admixture coats the cement grains and imparts a negative charge to cement grains (Fig 5-3). Like charges then repel cement grains away from each other. As the cement flocs are broken up, the water is evenly dispersed (Fig. 5-4).

By dispersing the cement grains and allowing superior hydration to take place, much improved strengths are a result. As the trapped water is released, it becomes available to increase workability and contribute to cement hydration. The result is an increased water cut (lower w/c ratio) which means improved product strength and quality. Additionally the concrete is easier to place and finish, with no sacrifice in quality. Figure 5-5 shows the effect that water-reducing admixtures have on concrete.

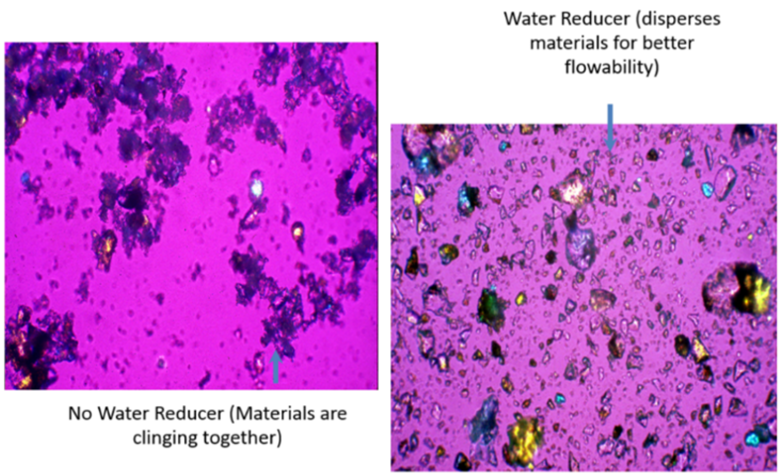


Fig. 5-5. Effect of water-reducing admixtures.

The effects of water reducing admixtures or superplasticizers on fresh concrete include:

- Increased slump
- Improved flow
- Improved placeability, pumpability and finishability
- Improved formed surfaces

The effects of water reducing admixtures or superplasticizers on hardened concrete, due to lower water-cement ratio include:

- Increased compressive strength
- Decreased permeability
- Chloride resistance increases
- Frost resistance improves
- Sulfate resistance increases
- Resistance to abrasion increases

Retarding Admixtures

Retarding admixtures are used to slow or delay the rate of setting of concrete. High temperatures of fresh concrete (30°C/86°F) are often the cause of an increased rate of hardening that makes placing and finishing difficult. One of the most practical methods of counteracting this effect is to reduce the temperature of the concrete by cooling the mixing water and/or the aggregates.

Retarders do not decrease the initial temperature of concrete. The bleeding rate and bleeding capacity of concrete can be increased with retarders.

Retarding admixtures are useful in extending the setting time of concrete, but they are often also used in attempts to decrease slump loss and extend workability, especially prior to placement at elevated temperatures. Retarders are sometimes used to: (1) offset the accelerating effect of hot weather on the setting of concrete; (2) delay the initial set of concrete when difficult or unusual conditions of placement occur, such as placing concrete in large structures or complex formwork, or pumping concrete over considerable distances; or (3) delay the set for special finishing techniques, such as an exposed aggregate surface.

Accelerators

Accelerating admixtures increase the rate of early strength development, reduce the time required for proper curing and protection, and speed up the start of finishing operations. Accelerating admixtures are especially useful for modifying the properties of concrete in cold weather.

There are two types of accelerators: Set Accelerator and Strength Accelerator (Early Age). Calcium chloride ($CaCl_2$) is the chemical most commonly used in accelerating admixtures, especially for non-reinforced concrete. Although calcium chloride is widely used and the most effective accelerator, besides accelerating strength gain, calcium chloride causes an increase in drying shrinkage, potential reinforcement corrosion, discoloration (a darkening of concrete), and an increase in the potential for scaling. Due to the corrosion potential, calcium chloride should <u>never</u> be used in any reinforced concrete products such as pipe, box culverts, manholes and other underground structures.

There are several non-chloride, non-corrosive accelerators available, concrete producers are encouraged to contact their local admixture supplier to match them with the best admixture suitable for their needs.

Corrosion Inhibitors

Fig. 5-6. Illustration of damage to concrete parking structure resulting from chloride-induced corrosion of steel reinforcement.

Corrosion-inhibiting admixtures fall into the specialty admixture category and are used to slow corrosion of reinforcing steel in concrete (Fig. 5-6). Corrosion inhibitors can be used as a defensive strategy for concrete structures, such as marine facilities, highway bridges, and parking garages, that will be exposed to high concentrations of chloride.

Corrosion inhibitors create a passivating layer around the reinforcing steel that enhances the protection of reinforcing steel from corrosion in the concrete. Concrete has natural corrosion protection due to the high pH of the concrete and the use of corrosion inhibitors further enhance the ability to resist corrosion. Potential effects of these inhibitors on concrete include acceleration of the initial set of concrete and improved early age strength of the concrete.

Air-entraining Admixtures

Fig. 5-7. Example of surface damage due to freezing and thawing.

The most potentially destructive weathering factor is freezing and thawing while the concrete is wet, particularly in the presence of de-icing chemicals used for snow and ice removal. Contrary to fresh concrete which can be protected, we can't avoid the exposure of mature concrete to alternating freezing and thawing cycles. Due to freezing and thawing, hardened concrete can suffer both internal as well as surface damage (Fig. 5-7). Internal damage can lead to loss of strength and cracking.

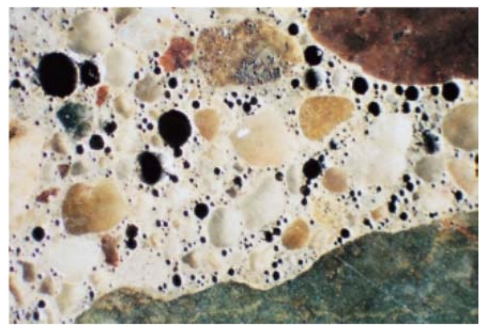


Fig. 5-8. Illustration of a polished section of air-entrained concrete as seen through a microscope.

The frost damage incurred is the result of hydraulic pressure caused by the 9% expansion of water upon freezing. As it freezes, growing ice crystals displace unfrozen water. If a capillary is above critical saturation (91.7% filled with water) hydraulic pressures results as freezing progresses. Conversely, at low absorbed water contents, no hydraulic pressure should exist.

The primary use of air-entraining concrete is for freeze-thaw resistance. Air-entraining admixtures are added to concrete to produce a system of small voids during the mixing process (Fig. 5-8). These voids are stabilized by the air-entraining admixture and remain in the hardened concrete paste.

With the use of air-entraining admixtures, the air voids in the concrete provide pressure relief sites during a freeze event, allowing the water inside the concrete to freeze without inducing large internal stresses. Another related use is for deicer-scaling resistance. The air voids again provide relief sites for the buildup of salt concentrations and the pressures that result due to concentration gradients. The amount of entrained air is usually between four and seven percent of the volume of the concrete, but may be varied as required by special conditions.

The effects of using air-entrained admixtures on concrete include an increased resistance to freeze-thaw damage and improved workability of fresh concrete, as the entrained air bubbles act like tiny ball bearings in the mix. However, every 1% of air content can potentially reduces the concrete strength by up to 5-10%.

Lubricants and Surfactants

Lubricants and surfactants are used to decrease surface friction, therefore, they aid in stripping forms. They also increase reaction to vibration and improve moisture retention.

Lubricants and surfactants have several effects on concrete. They can improve appearance, improve water tolerance and increase surface paste. Rheology modifiers (mix lubricants) can enhance the mechanical consolidation of concrete mixes, speeding production and reducing the stickiness of the mixes. They can also improve the hydration characteristics of low water content mixes and reduce moisture loss due to evaporation. Improved surface finishes and leak proof joints can be a benefit of using these types of products.

Notes

Notes

Chapter 6: Reinforcement

When a load is applied to the concrete pipe in the field or in the three edge bearing test, tensile stresses develop on the inside of the pipe at the crown and invert and on the outside of the pipe at the springline, and compressive stresses develop opposite these tensile stresses (Fig. 6-1). Since concrete is strong in compression but weak in tension, concrete first cracks in the tensile zones. Steel is strong in tension and is therefore needed to transfer the tensile stresses from the concrete to the steel reinforcement and consequently provide structural integrity to the pipe. Without reinforcement, the concrete would fail. The amount of steel reinforcement is specified in ASTM C-76 and other ASTM standards. The type of reinforcement used depends on the production processes and local availability.

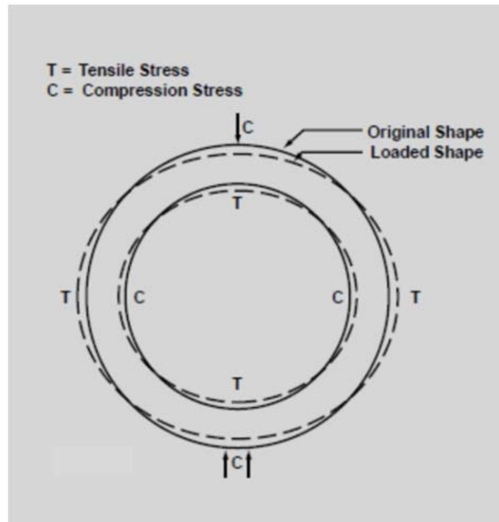


Fig. 6-1. Illustration of pipe subjected to load.

This section will cover the types of reinforcement that are used in concrete pipe, manholes, box culverts and engineering precast products, the ASTM specification requirements for the reinforcement, and the QCast requirements related to these materials.

Objectives

At the end of this chapter, you will be able to:

- ✓ Recognize types of reinforcing materials.
- ✓ Determine corresponding designation for the smooth wire area given the wire diameter.
- ✓ Recall the ASTM standards for concrete reinforcement.

Reinforcing Materials

According to the ACI Education Bulletin E2-00 *Reinforcement for Concrete – Materials and Applications* states that*,* "steel is the most common material used to reinforce concrete, but other materials such as fiber-reinforced polymer (FRP) are also used." According to the bulletin, the reinforcement must be of the right type, of the right amount, and in the right place, in order for the concrete structure to meet its requirements for strength and serviceability. The various types of steel used for concrete reinforcement includes: plain steel bars, deformed steel bars, cold-drawn wire, welded wire fabric, and deformed welded wire fabric. [1]

The reinforcement materials covered in this chapter include:

- Steel reinforcing bars (rebar),
- Reinforcing wire,
- Welded wire reinforcement, and
- Fiber reinforcement.

Steel Reinforcing Bars (Rebar)

As defined by ACI Education Bulletin E2-00 *Reinforcement for Concrete – Materials and Applications, "*reinforcing bar, or **rebar**, is a common steel bar that is hot rolled and is used widely in the construction industry, especially for concrete reinforcement (Fig. 6-2). Deformed bars are round steel bars with lugs, or deformations, rolled into the surface of the bar during manufacturing. These deformations create a mechanical bond between the concrete and steel."[2] This bulletin provides introductory information regarding the materials used to reinforce concrete and their basic properties.

Rebar is classified by strength grade number in metric and U.S. customary grades as restated from the ACI Bulletin E2-00 in the box on the following page (Fig. 6-3).

When it is used. Rebar is typically used to fabricate bar mats that are used to reinforce precast concrete products. Mill certifications are required for each.

Fig. 6-2 Photo of rebar with identification tag.

Steel Reinforcing Wire

The ACI Education Bulletin E2-00 *Reinforcement for Concrete – Materials and Applications* also details size and dimension information regarding wire used in fabricating machine made reinforcement cages or WWR rolls and mats. These products are made from carbon-steel wire produced from hot-rolled rod, where the steel wire is cold-worked, drawn or rolled, plain (non-deformed, as-drawn or galvanized), or deformed.

Grades and Identification Marks. Deformed steel bars are furnished in four metric strength grades of steel: 300, 350, 420, and 520, having minimum yield strengths of 300, 350, 420, and 520 MPa, respectively. The four corresponding U.S. customary grades: Grades 40, 50, 60, and 75, have minimum yield strengths of 40,000, 50,000, 60,000, and 75,000 psi, respectively. They are manufactured from four types of steel: billet steel (ASTM A 615M/A 615), low-alloy steel (ASTM A 706M/A 706), and rail and axle steel (ASTM A 996M/A 996).

Billet-steel bars are available in three metric grades and three equivalent U.S. customary grades. They are available in metric bar sizes No. 10 through No. 19 in Grade 300, in all bar sizes in Grade 420, and in bar sizes No. 19 through No. 57 in Grade 520. Billet-steel bars are available in U.S. customary bar sizes No. 3 through No. 6 in Grade 40, in all bar sizes in Grade 60, and in bar sizes No. 6 through No. 18 in Grade 75.

Low-alloy-steel bars are manufactured in all sizes, but in only one metric grade (420) and one equivalent U.S. customary grade (60). Availability of ASTM standard metric and U.S. customary reinforcing bars is summarized in Table 3.1.1.2(a).

Rail-steel bars are manufactured by rolling used railroad rails, and are available in two metric grades (350 and 420) and two equivalent U.S. customary grades (50 and 60). They are available in metric bar sizes No. 10 through No. 25 and in U.S. customary bar sizes No. 3 through No. 8.

Axle-steel bars are manufactured by rolling used railroad car axles, and are available in two metric grades and two equivalent U.S. customary grades. They are available in metric bar sizes No. 10 through No. 25 in Grades 300 and 420 and in U.S. customary bar sizes No. 3 through No. 8 in Grades 40 and 60.

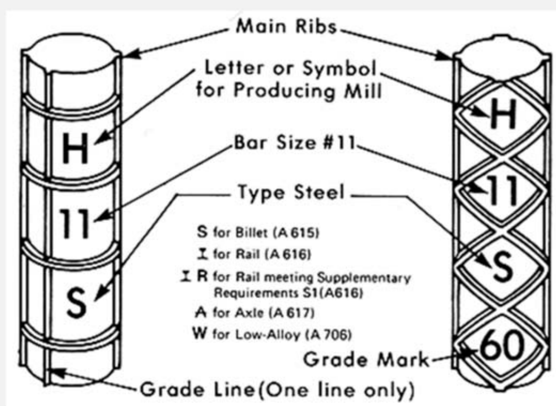


Fig. 6-3. Grade 60 and A706 Rebar Markings.

All deformed steel bars are required to be marked with identifying symbols rolled into one side of each bar (Fig.6-3). The symbols in the markings designate the producer's mill, bar size, type of steel and grade. The marks and can be oriented to read vertically or horizontally.

As an alternate to rolling the grade mark number for Grade 420/Grade 60 or Grade 520/Grade 75, the grade can be designated by rolling an additional longitudinal rib or ribs on the bar.

Fig. 6-3. From: ACI Education Bulletin E2-00 Reinforcement for Concrete – Materials and applications[3]

Wire Sizes and Dimensions. Dimensional requirements for plain and deformed wire are stated in inch-pound units and SI (metric) Units (**ASTM A1064/1064M**). The sizes for the plain wire and deformed wire are designated as follows:

- **Plain wire (inch-pound units):** The size number is the number of one hundredth of a square inch in the nominal area of the wire cross section, prefixed with a "W". For example: Wire size W 5.0 has a nominal area of 0.05 in^2.
- **Plain wire (SI units):** The size number is the number of square millimeters in the nominal area of the wire cross section, prefixed with an "MW". For example: Wire size MW 50 has a nominal area of 50 mm^2.
- **Deformed Wire (inch-pound units):** The size number is the number of one hundredths of a square inch in the nominal area of the deformed wire cross section, prefixed by a "D". For example: Wire size D10 has a cross-sectional area of 0.10 in^2.
- **Deformed Wire (SI units):** The size number is the number of square millimeters in the nominal area of the deformed wire cross section, prefixed with an "MD". For example: Wire size MD 25 has a cross-sectional area of 25 mm^2.

The common wire sizes and dimensions are given in Tables 1-4 of ASTM A1064/A1064M. Actual wire sizes are not restricted to those shown in the tables. These sizes represent the most readily available sizes in the welded wire reinforcement industry.

When it is used. Steel wire is used in the production of machine made reinforcement cages for concrete pipe. It is also used to make welded wire reinforcement. Mill certificates are required for each shipment.

Welded Wire Reinforcement

Welded wire reinforcement (WWR) is a square or rectangular mesh of wires (Fig. 6-4), factory welded at all intersections. It is manufactured with either plain or deformed wire according to ASTM standards A1064/A1064M. WWR is shipped either in rolls or flat sheets depending on the customer requirements and the size of wire used. Wire Spacings and sizes of wires in welded wire reinforcement are identified by "style". An example style designation would be 2x8 – W8xW5, where:

- Spacing of circumferential wires = 2"
- Spacing of longitudinal wires = 8"
- Size of circumferential wires = W8 size (area 0.08 in^2)
- Size of longitudinal wires = W5 size (area 0.05 in^2)

Fig. 6-4. Welded wire reinforcement sheets (courtesy of Wire Reinforcement Institute).

It is important to note the difference in wire nomenclature between the wire producers and our industry, the wires we call "circumferential" are referred to as the longitudinal wires by the wire producers and our "longitudinal" wires are referred to as the transverse wires (Fig. 6-5).

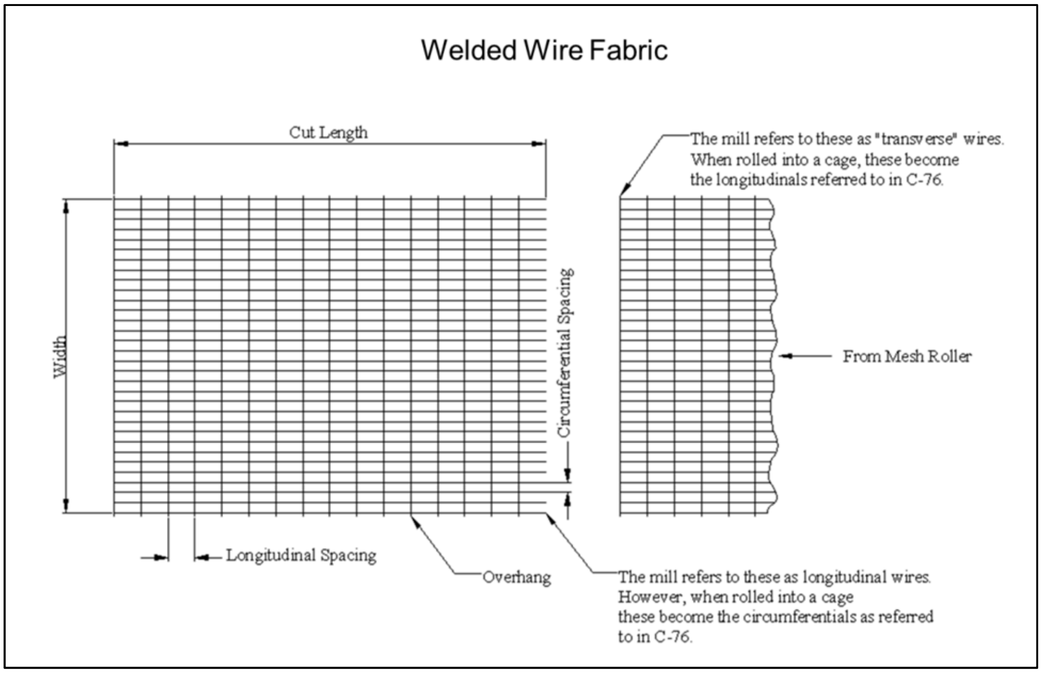


Fig. 6-5. WWR Nomenclature.

When Welded Wire Reinforcement is used. WWR is most commonly used in reinforced concrete pipe and box culverts, as well as in some manhole and precast concrete products. Mill certificates are required for each shipment.

Fiber Reinforcement

Fiber Reinforcement is also covered in the ACI Education Bulletin E2-00 *Reinforcement for Concrete – Materials and Applications.* The bulletin states that: "fiber-reinforced concrete (FRC) is concrete with the addition of reinforcing fibers made of steel, glass, synthetic (nylon, polyester, and polypropylene), and natural fiber materials. At appropriate dosages, the addition of fibers may provide increased resistance to plastic and drying shrinkage cracking, reduced crack widths, and enhanced energy absorption and impact resistance." [3]

Fibers can also be used as a replacement for conventional structural reinforcement. There are two types of fibers used to reinforce concrete; steel fibers and synthetic fibers, they are used in accordance with the following ASTM specifications:

1. C1765 – Steel Fiber Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe (SFRCP) - 2013
    a. 12" – 48"
    b. Class I, II, III, IV, V

c. Dservice and Dtest loads – Dtest is 1.5 times Dservice
d. Proof of Design Test to Dultimate

2. C1818 – Synthetic Fiber Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe (Syn-FRCP) - 2015
    a. 12" – 48"
    b. Class I, II, III, IV, V
    c. Dservice, Dtest and Dreload loads – Dtest is 1.5 times Dservice
    d. Dreload = Dservice/alpha
    e. Alpha is a long-term serviceability factor

Notes

Notes

Chapter 7: Self Consolidating Concrete

One of the greatest advances in the concrete industry over the last 20 years has been the emergence of Self Consolidating Concrete (SCC). With the modern admixtures and some innovative mix design adjustments, it is now possible to produce concrete that flows easily and without segregating (where the coarse aggregate separates from the cement paste). Concrete that segregates loses integrity and results in honeycombed areas next to the formwork. It is the self consolidating nature of SCC that makes it so valuable in construction.

Fig. 7-1. Self consolidating concrete.

SCC can flow into complex forms or forms that have a lot of reinforcing steel (rebar congestion) and completely fill the formwork without vibration. Normal concrete would have to be heavily vibrated in those applications to properly consolidate the concrete and to fill the formwork. The illustration to the left (Fig. 7-1) shows how SCC fills around the reinforcing steel without vibration and with a significant reduction in labor.

With these advantages, one might think that SCC would be used everywhere. The perception is that it's the cost that prevents wider use of SCC, as these mixes need to be specifically designed for the materials available and utilize a specialized group of admixtures. But when the producers compare the advantages of using SCC against the added mix component costs, the decision to use SCC becomes easy.

Objectives

At the end of this chapter, you will be able to:

- ✓ Define self consolidating concrete (SCC).
- ✓ Identify the rheological properties of SCC and their desired targets for SCC mixtures.
- ✓ Explain the key properties of SCC.
- ✓ Identify the factors that impact the key properties of SCC.

History of Self Consolidating Concrete

In 1986, Self consolidating concrete emerged as a solution to durability concerns in Japan due to inadequate consolidation in casting operations. In response to the concern, Professor Hajime Okamura of Kochi University developed the concept of SCC, which was soon ready for real-scale tests by 1988. In 1989, the first paper on SCC was presented at the second East-Asia and Pacific

Conference on Structural Engineering and Construction (EASEC-2), followed by another in 1992 at Energy Diversification Research Laboratories (CANMET)/ American Concrete Institute (ACI) meeting. By 1994, a world-wide movement began for research and development of SCC and with studies being presented at every concrete-related conference since.[1]

The introduction of the SCC technology to the US occurred in 2000. Soon to follow PCI, ASTM, and ACI standards were underway (2002) and the ASTM C1611 slump flow test was approved (2005). The American motivations for using SCC include increased potential for reduced vibration and automation in precast factories, thus increasing worker productivity and limiting vibration health and safety issues.

For further information and guidelines for the use of SCC, please refer to the *Interim Guidelines For The Use of Self Consolating Concrete in Precast/Prestressed Concrete Institute Member Plants* (Fig. 7-2).

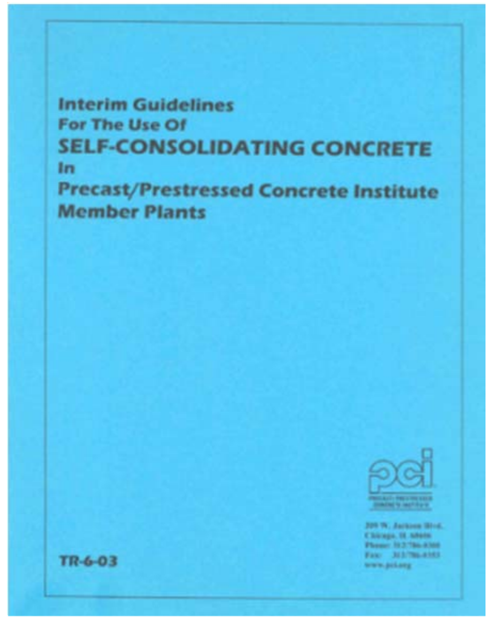


Fig. 7-2. PCI Guide for using Self Consolidating Concrete.

What is Self Consolidating Concrete?

"Self Consolidating Concrete is a highly flowable, non-segregating concrete that can flow into place, fill the formwork, and encapsulate the reinforcement without any mechanical consolidation." [ACI International, Committee 237 SCC] It is very flowable concrete that typically does not need vibration to fill the formwork. The consistency, or filling ability, is measured by what's called a slump flow, where the slump cone is filled and lifted, and the width of the resulting concrete patty is measured. Slump flow for SCC varies from 19 to 30 inches (Fig. 7-3).

Fig. 7-3. SCC slump flow evaluation.

However, self consolidating concrete is NOT simply concrete that flows. If that's all there was to it, we could just use lots of water. The currently accepted definition of what makes good SCC has three parts:

- **High flowability –** it flows easily into the finest details of formwork or molds and around reinforcing under its own weight. This is also called workability or filling ability (meaning it fills a form easily). Flowability is impacted by slump flow, viscosity (T20), aggregate shape and ratio, placing methods, and size and configuration of the forms.

- **Passing ability –** the ability to flow through tight spaces, like congested steel reinforcing bars or narrow spots in the formwork, without "blocking" (Fig. 7-4). Passing ability is impacted by slump flow, viscosity (T20), aggregate shape, ration and size, placing methods, and form or rebar spacing.

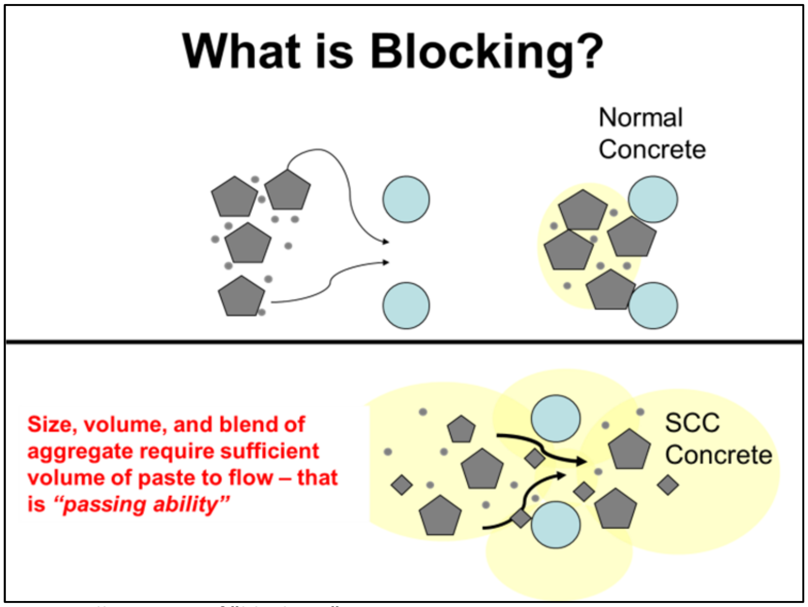


Fig. 7-4. Illustration of "blocking."

- **Stability –** the concrete doesn't segregate and remains homogenous with no separation of the aggregate from the cement paste, even at very high slumps (or slump flows). This is the big difference between SCC and simply wet sloppy concrete. There are actually two kinds of stability: *dynamic stability* (meaning it stays stable while being transported and placed) and *static stability* (meaning it stays stable—the aggregate doesn't settle and it doesn't bleed excessively—while it is in the forms but not yet hardened). Stability is impacted by slump flow, viscosity (T20), aggregate size, ratio and specific gravity, powder content, air content, paste content, mortar content, transportation and placing methods, admixture content and water content.

Another important aspect to consider is the hardened concrete properties, which for SCC are not much different than conventional concrete. Since a lot of fines and superplasticizers (high-range water reducers) are used in SCC to achieve the flowability, the concrete can often be proportioned for very low water-cement ratios and therefore achieve very high strengths and low permeability.

The Advantages of SCC

The advantages of using concrete that flows effortlessly into place are obvious to anyone who works with concrete. In the past, many have tried to produce flowable concrete by adding water to it. Unfortunately, adding water greatly decreases the concrete's strength and leads to segregation. The ultimate desire is being able to set up the forms and then use minimal to no labor to place the concrete. SCC that has been properly proportioned and placed provides many advantages such as:

- Reduced labor since no vibration is needed to fill the forms and little to no screeding is needed for flatwork.
- No need to worry about how good and consistent the vibration is since no vibration is required.
- Faster construction since the concrete places so quickly—SCC can be placed many times faster than conventional concrete.
- Extremely good finished surface quality wherein SCC takes on nearly a mirror-like surface and can produce concrete with very fine detail.
- Easier to detail the reinforcing steel, since it can be fairly congested and still get completely filled with concrete.
- Quieter job sites or precasting shops since there is no vibrator noise. Increased safety, since vibrator operators aren't up on the forms or dragging hoses and cords around the site.

Self Consolidating Concrete Key Properties

In addition to the properties previously mentioned, there are a few others that distinguish it from other concrete starting with its Rheology and Viscosity properties.

Rheology and Viscosity

SCC is a highly engineered fluid with unique Rheological properties.

- **Rheology** is the science dealing with flow of materials, including studies of deformation of hardened concrete, the handling and placing of freshly mixed concrete, and the behavior of slurries and pastes.
- **Viscosity** is the property of a material which resists change in the shape or arrangement of its elements during flow, and the measure thereof.

For the proper flow of an SCC mix to fill the formwork, the Yield Stress of the mix needs to be low enough for the SCC to flow under its own weight. If water were to be used to lower the yield stress, the viscosity of the mix would be so low that the aggregates would separate from the paste and the mix would segregate. In the lab, these characteristics can be measured and evaluated, but in the plant this becomes much more difficult (Fig 7-5).

A rheometer can be used to measure the energy needed to move and place an SCC mix and involves a complex evaluation of the flow characteristics of the mix (Fig. 7-6).

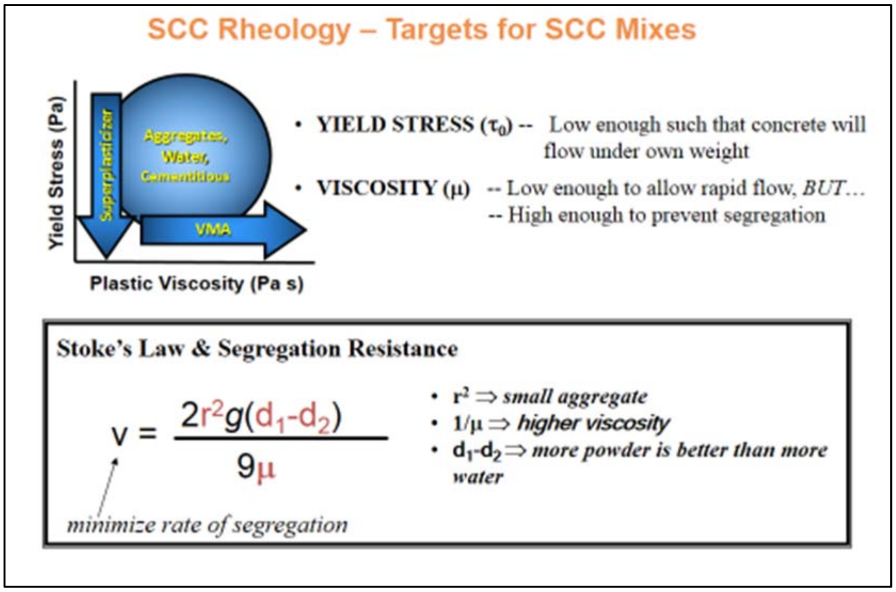


Fig. 7-5. Targets for SCC mixes.

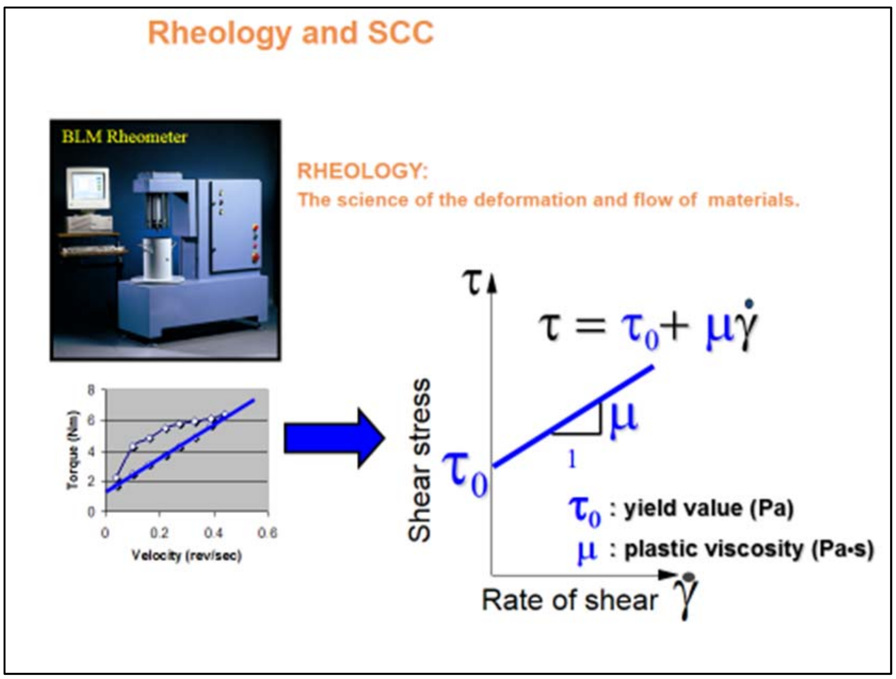


Fig. 7-6. Rheometer used to measure the energy needed to move and place an SCC mix.

In more practical terms, increasing the slump flow from low to high reduces the yield stress while also reducing the viscosity. With conventional concrete mixes, this leads to segregation. While conventional concrete is very forgiving with regard to the ability to change slump and not segregate, this wide range of slump concrete still requires vibration to properly consolidate.

SCC is much different. As the slump increases to slump flow, the proper viscosity must be maintained to prevent segregation. This is referred to as the Workability Space. This is the range of

SCC that does not require vibration to consolidate properly and does not segregate. Much more plant and moisture controls are necessary to consistently produce concrete that is within this Workabilty Space (Fig. 7-7).

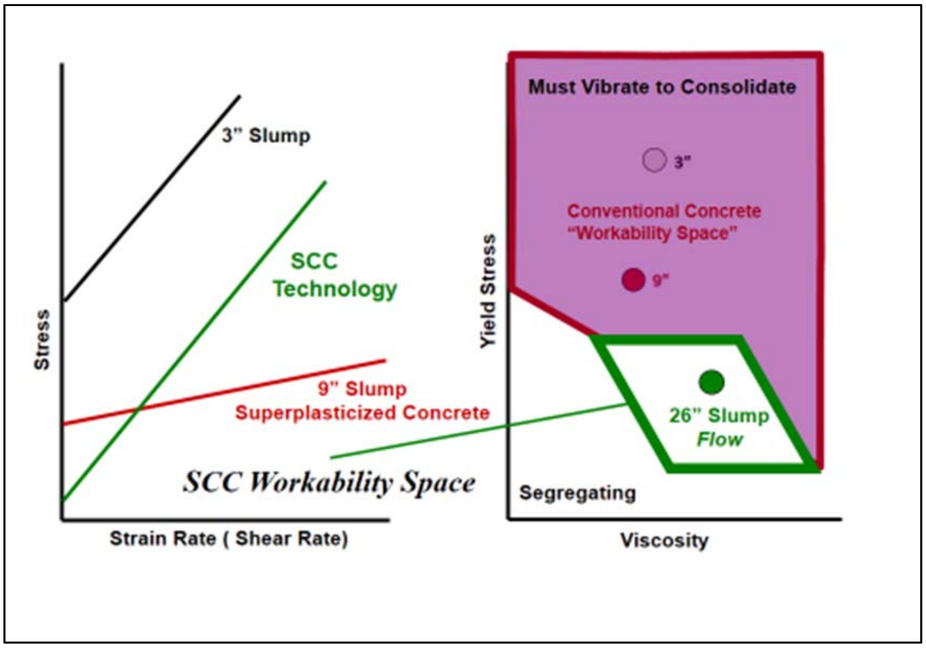


Fig. 7-7. Defining the SCC workability window.

When conducting a visual evaluation of the SCC slump flow patty, look for the following properties when evaluating the relationship to the yield stress and plastic viscosity characteristics:

- Unacceptable has high flow but poor viscosity and exhibits segregation.
- Acceptable exhibits adequate flow and borderline segregation characteristics. This falls into the category of a mix that needs improvement but be usable.
- Superior slump flow patty exhibits good flow characteristics and no signs of segregation or separation (Fig. 7-8, next page).

Thixotrophy vs. Set

Thixotrophy is the tendency of a material to act as a semi-solid (gel) at rest and a fluid while in motion. A material is said to have thixotrophic properties when it exhibits a decrease in viscosity with time when the material is subjected to a constant shearing stress. SCC that is strongly thixotropic—that is, it quickly gels when the material comes to rest—will display a more rapid decay of pressure, and lower overall pressures will be observed during construction. As a general rule, formwork pressure is related to thixotropic characteristics of an SCC.

-

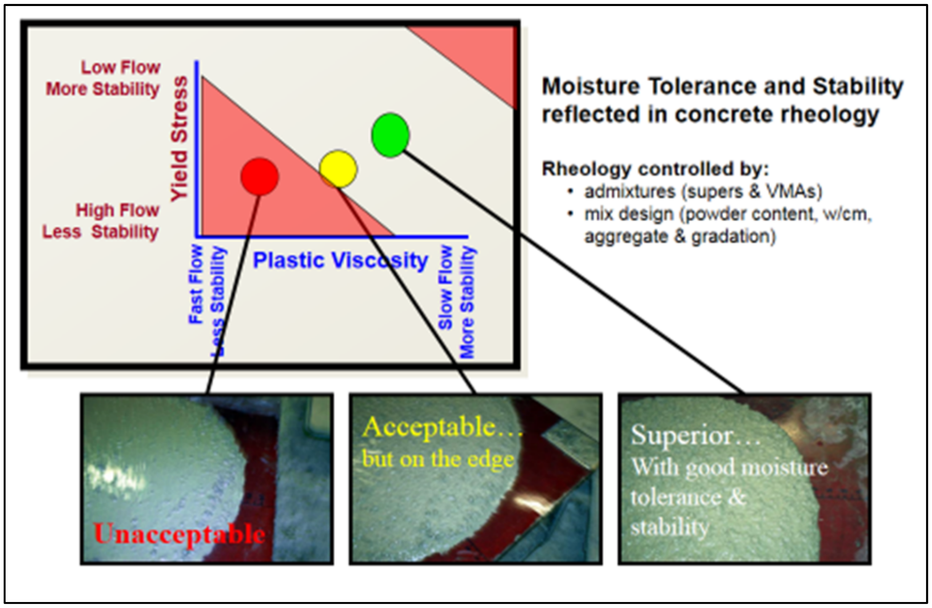


Fig. 7-8. Illustrations of different levels of plastic viscosity when evaluating SCC slump flow.

Resistance to Segregation

During placement and while flowing, the concrete should retain its stability. There should be no separation of aggregate from paste or water from solids and no tendency for coarse aggregate to sink downwards through the fresh concrete mass under gravity. Resistance to segregation is the most difficult to achieve with SCC.

Self Consolidating Concrete Construction

Given the flowing nature of the SCC, there are a few precautions to take when transporting and pouring the mix (Fig. 7-9):

Fig. 7-9. SCC delivered in ready-mix

- Avoid filling ready-mix trucks completely to mitigate the mix from sloshing out or even overturning trucks when the load shifts.
- Given SCCs ability to flow as far as 33 feet or more, allow it to flow under it's own weight from a single location when placing or even pumping up it from the bottom (Fig. 7-10).
- Pumping pressures can be reduced as SCC tends to stay more stable that conventional concrete mix (Fig. 7-11).

- When designing formwork, take into account that 150 pounds of pressure for each foot of height (Fig. 7-12). Since SCC places rapidly, there is potential to develop pressures that could lead to blowouts.

Fig. 7-10. SCC easily flows around obstructions with no vibration. Joe Woolhead for iCrete.

Fig. 7-11. Self leveling slabs require only minimal finishing to get a flat floor. Lafarge Agilia

Fig. 7-12. Elevator shafts poured in a single lift using SCC, despite concern that the forms were not strong or tight enough to handle the pressure.

Cautions When Using SCC in Construction

Although there are many benefits to using SCC, there are some precautions to take when using SCC in construction:

- All SCC is not the same, so have the quality control department design a mix that is right for your application. Specific applications may require more or less filling ability, passing ability, or stability.
- Not only is vibration not necessary but can be damaging to SCC by causing segregation. To blend lifts, vibrators can be used but only for a few seconds.
- Curing is important for SCC since it is so often a low water-cement ratio mix. Low water mixes can develop autogenous shrinkage, where the unhydrated cement consumes all of the water in the concrete matrix. Wet curing is best, but at least apply a curing compound to protect the surface from drying out.

Notes

Notes

Chapter 8: Durability

According to the Portland Cement Association (PCA) durability of concrete is defined as "the ability to last a long time without significant deterioration…The production of replacement component materials depletes natural resources and can produce air and water pollution." [1] Therefore, durable concrete helps the environment by conserving resources and reducing wastes, as well as reducing the environmental impacts of repair and replacement.

Fig. 8.1.concrete pipe installation

"Different concretes require different degrees of durability depending on the exposure environment and the properties desired. Concrete ingredients, their proportioning, interactions between them, placing and curing practices, and the service environment determine the ultimate durability and life of the concrete."[2]

Objectives

At the end of this chapter, you will be able to:

- ✓ Recall conditions that must be present to ensure the durability of concrete
- ✓ Identify the types of threats that can affect the durability of concrete
- ✓ Distinguish between entrapped and entrained air
- ✓ Explain alkali-aggregate reaction
- ✓ Identify different types of chemical attack and their effect on concrete
- ✓ Identify the effects of corrosion

How to Make Concrete Durable

One of the important benefits of concrete is its durability. There are several factors that go together to make concrete durable. They are:

- Low water/cementitious ratio;
- Ample amounts of cementitious;
- Quality aggregates;

- Correct admixtures;
- Proper mixing and placing; and
- Adequate curing.

Water/Cement(itious) Ratio

Abram's water/cement ratio rule states that as the water to cement ratio increases, the strength of a concrete mix decreases. In other words, if everything else is constant and you add more water, you get less strength.

The water/cement(itious) ratio is a calculation (Fig. 8-2) as follows:

w/c_m = lbs of water/lbs of cement(itious)

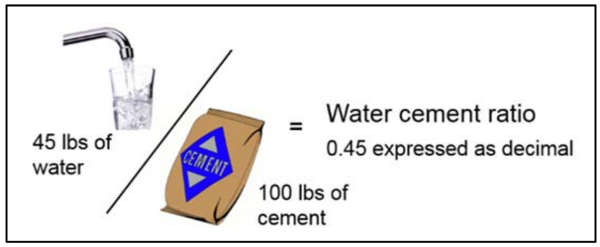


Fig. 8-2. Calculating water to cement ratio.

For example, if you have 45 lbs of water and 100 lbs of cement, the water to cement ratio is 0.45.

Important note: The water needs to be drinkable or meet ASTM 1602.

More information regarding how aggregates, admixtures, mixing/placement and curing impact durability is available in other sections of this manual.

Conditions Influencing Durability

There are a number of conditions that influence the durability of concrete. These conditions include weathering conditions, chemical reactions and corrosion from exposure to moisture or other corrosive materials. Each of these conditions can contribute to the weakening of concrete making it more to vulnerable to cracking and other types of degradation.

Freeze/Thaw Attack

Deterioration of the concrete by freeze/thaw weathering action can be quite destructive over time (Fig. 8-3), especially when the concrete is cyclically saturated with water. The damage is caused by the expansion that happens as water freezes, given that water expands in volume by 9% when frozen. In typical concrete there are no avenues for pressure relief, and, as a result, micro cracks develop inside the concrete. As the freeze/thaw cycles progress, the newly formed micro cracks also fill with water and, as the water

Fig. 8-3. Concrete deterioration due to freeze/thaw.

freezes again, the cracks grow larger. Eventually the deteriorated concrete begins to spall (flake) off. In order to protect the concrete from freeze/thaw deterioration, the pressure from the expanding water/ice needs to be relieved. Entrapped air pockets inside the concrete matrix are too large and too far apart to be able to provide the relief needed. The answer is entrained air—small, microscopic air bubbles spaced closely together to provide the pressure relief reservoirs for the expanding water/ice.

Air Content in Concrete

The air inside the concrete matrix is classified into two categories:

(1) entrapped air

(2) entrained air

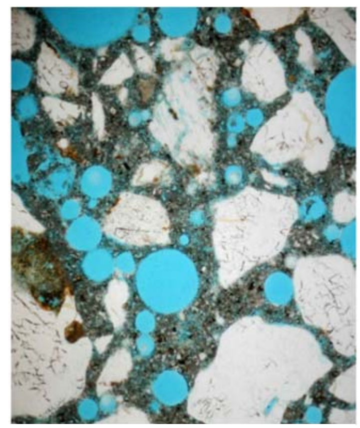


Fig. 8-4. Illustration of entrained air.

Entrapped air is the result of air being trapped during the mixing and placement process. This causes large non-uniform voids which are generally undesirable. It can be reduced through proper vibration and consolidation (See Section 3, Chapter 3). Even after proper consolidation, the concrete will typically have between 2-3% entrapped air.

Entrained air is formed as the result of the air entraining admixture creating a uniform network of small spherical voids/bubbles in the concrete (Fig. 8-4). The negatively charged admixture particles repel water to form the tiny air bubbles (Fig. 8-5). These admixtures do not add air to the concrete— they make the entrained air that is already there stable. These small air voids/bubbles act as relief reservoirs for the pressure created by the freezing of water.

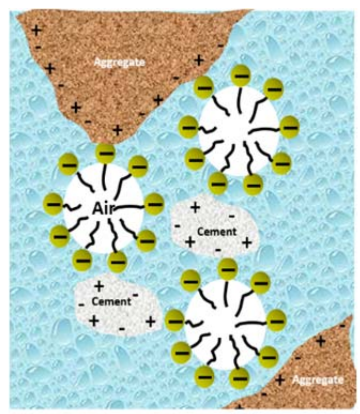


Fig. 8-5. Illustration of how an air-entraining admixture works.

Air-entrainment is commonly required for all products exposed to freeze/thaw conditions. Table 8-1 represents the recommended total target air content for concrete. Aggregates with a total smaller pore size result in a lower resistance to freezing and thawing.

Table 8-1. Recommended total target air content for concrete.

Nominal maximum aggregate size, in. (mm)	Air content, percent*		
	Severe exposure**	Moderate exposure†	Mild exposure††
< 3/8 (< 9.5)	9	7	5
3/8 (9.5)	7-1/2	6	4-1/2
1/2 (12.5)	7	5-1/2	4
3/4 (19.0)	6	5	3-1/2
1 (25.0)	6	4-1/2	3
1-1/2 (37.5)	5-1/2	4-1/2	2-1/2
2 (50)‡	5	4	2
3 (75)‡	4-1/2	3-1/2	1-1/2

Alkali-Aggregate Reaction

There are two forms of alkali-aggregate reaction: alkali-silica reaction (ASR) and alkali-carbonate reaction (ACR). ASR is a reaction between an alkali source and certain forms of reactive silica that can originate from some types of siliceous aggregate. ACR is a reaction between an alkali source and certain calcium magnesium carbonate rocks (dolomites). ASR is more commonly observed than ACR.

Alkali-silica reaction (ASR) is more commonly observed and can be more concerning since the aggregates containing reactive silica materials are more common. When aggregates containing certain forms of silica react with the alkli hydroxide in concrete, it absorbs water (either from the cement paste or the environment) and forms a gel that swells. The swelling from this gel can in turn create enough expansive pressure that the concrete is damaged. However, it is important to note that not all ASR gel reactions produce destructive swelling.

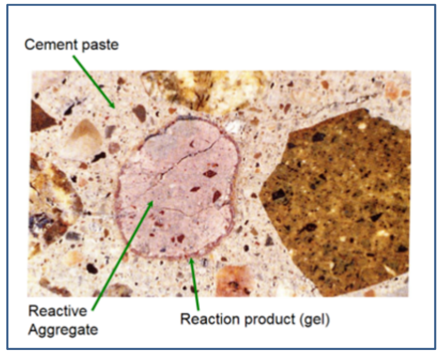


Fig. 8-6. Illustration of how aggregate will crack in ASR.

Indications of ASR can be seen in random cracks, or, if it's advanced, spalling concrete or closed joints. It is common to find cracking in areas that have frequent exposure to moisture, i.e., close to the waterline in piers, near the ground behind retaining walls, near joints and free edges in pavements, or in piers or columns subject to wicking action. If premature failure is suspected, identification and confirmation of ASR can be accomplished through petrographic examination.

The addition of supplementary cementitious materials, such as silica fume, fly ash (class F) and slag cement can be used to significantly reduce or eliminate alkali-silica reactivity and its affect. Lithium compounds, low alkali cement, and non-reactive aggregates can also be used to reduce ASR. However, thanks to the measures taken to control it, ASR distress in concrete is not that common, even though potentially reactive aggregates exist throughout North America.

Alkali-carbonate reaction (ACR) can be found in certain dolomitic rocks. The expansion due to this reaction is called Dedolomitization, which is the breaking down of dolomite and subsequent crystallization of brucite can cause considerable expansion. Although the deterioration caused by ACR (Fig. 8-7) is similar to that caused by ASR; it is somewhat rare because susceptible aggregates are less common and are usually unsuitable for use in concrete. These aggregates susceptible to ACR can be identified through petrography as they tend to have a characteristic texture. Unfortunately the alkali-carbonate reaction cannot be prevented with the use of supplementary cementing materials, therefore it is recommended that ACR susceptible aggregates not be used in concrete.

Fig. 8-7. Cracking within aggregates in reactive carbonate aggregates surrounded by high-alkali cement.

Chemical Attack

Chemical attacks on concrete structures cause deterioration of the structure and affects its durability. The life of the structure is reduced and it can lead to structure failure. The various types of chemical attacks are:

- Sulfate attack from sources external to concrete
- Physical salt attack
- Seawater Exposure
- Acid Attack
- Carbonation

Sulfate Attack

Naturally occurring sulfates of sodium, potassium, calcium, or magnesium, that can attack hardened concrete are found in soils or dissolved in ground water adjacent to the concrete. In sulfate attack, there is a formation of ettringite (calcium aluminate trisulfate hydrate and gypsum, calcium sulfate dehydrate). Ettringite formation can result in increases in solid volume which can lead to expansion and cracking (Fig. 8-8).

Fig. 8-8. Example of sulfate attack in concrete.

In order to protect against sulfate attacks, it is recommended that you use concrete that retards the ingress of the external sulfate. This concrete has a low w/c_m ratio, a low permeability, contains sulfate resistant cement and slag cement or Class F fly ash. The following Table 8-2 lists the requirements to protect against damage to concrete by sulfate attacks.

Table 8-2. Requirements to protect again sulfate attacks.

Severity of potential exposure	Water-soluble soluble sulfate (SO_4)*	Sulfate (SO_4)* in water, ppm	*w/cm* by mass, max.†‡	Cementitious material requirements
Class 0 exposure	0.00 to 0.10	0 to 150	No special requirements for sulfate resistance	No special requirements for sulfate resistance
Class 1 exposure	> 0.10 and < 0.20	> 150 and < 1500	0.50‡	C 150 Type II or equivalent§
Class 2 exposure	0.20 to < 2.0	1500 to < 10,000	0.45‡	C 150 Type V or equivalent§
Class 3 exposure	2.0 or greater	10,000 or greater	0.40‡	C 150 Type V plus pozzolan or slag§
Seawater exposure	—	—	See Section 2.4	See Section 2.4

Physical Salt Attack and Seawater Exposure

During physical salt attack or seawater exposure, deterioration occurs by the physical action of salts from groundwater containing sodium sulfate, sodium carbonate, and sodium chloride. Damage typically occurs at exposed surfaces of moist concrete that is in contact with soils containing salts (Fig. 8-9). The salt crystals grow inside the voids and capillaries in the concrete causing pressure to increase, building enough to cause micro cracks to occur, with cyclic loading of more salts from wetting and drying causing more expansion and scaling. The distress in surface scaling is similar in appearance to freezing-and-thawing damage.

Fig. 8-9. Damage to concrete from soils containing salt.

Acid Attack

Fig. 8-10. Damage to concrete exposed to acidic environments.

Portland cement concrete does not resist acids very well. Acids attack concrete by dissolving both hydrated and un-hydrated cement compounds as well as calcareous aggregate. [3] Concrete deterioration increases as the pH of the acid decreases from 6.5. In fact, no hydraulic cement concrete, regardless of its composition, will hold up for long if exposed to a solution with a pH of 3 or lower. [4] Some weak acids, however, can be tolerated, particularly if the exposure is occasional. According to PCA, there are three ways to improve concrete's resistance to acids, "(1) choosing the right concrete composition to make it as impermeable as possible, (2) isolating it from the environment by using a suitable coating or (3) modifying the environment to make it less aggressive to the concrete." [5]

Carbonation

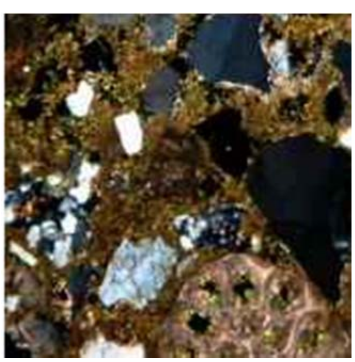


Fig. 8-11. Fully carbonated paste in the concrete surface; appears orange-brown in crossed polarized

"Carbonation is the process by which carbon dioxide from the atmosphere slowly transforms calcium hydroxide into calcium carbonate in concrete." [6] Carbonation may not harm the concrete or its strength, however, corrosion from the carbonation may occur as a result. Carbonated concrete has a pH value of 8.3; passivation of steel starts at a pH value of 9.5. The high pH vlaue in the concrete usually prevents corrosion in the reinforcing steel, through the release of calcium hydroxide during hydration of the cement, which a highly alkaline environment

Time, cover, concrete density, cement content, water-to-cement ratio and the presence of cracks contribute to how quickly carbonation can happen. Carbonation is characterized by a discolored zone in the surface of the concrete, from a light gray to a strong orange (Fig. 8-11) that is more easily recognizable in the field.[7]

Corrosion

The leading cause of concrete deterioration is the corrosion of reinforcing steel. Corrosion is a problem in concrete structures (Fig. 8-12.) due to the expansion created by the hydrated iron oxide (rust) in steel.[8] As the rust continues to expand, internal pressure builds until the concrete fails resulting in spalling.[9] Many studies are being performed to learn how to prevent corrosion from steel and the subsequent failure in concrete.[10]


Fig. 8-12. Corrosion of steel embedded in concrete.

Concrete contains a high pH value, which prevents corrosion under normal conditions, but it is the exposure of the concrete to elements such as sewater or deicers salts that creates a corrosive environment. However, the possible problem of corroding steel embedded in concrete can be mitigated, if proper specifications are used and susceptible reinforcment is quickly identified. Corrosion can also be reduced through the use of concrete mixtures that are specifically designed for use in enviroments that are exposed to these types of elements.

Notes

Section 1: Review Questions

The following questions provide a review of the key concepts introduced in this section. An Answer Key is provided at the end of the questions.

Questions

Chapter 1: Concrete and Concrete Products

1. Name four key components for making concrete:
   a. ____
   b. ____
   c. ____
   d. ____

2. Portland Cement is named after:
   a. Portland, ME
   b. Portland, OR
   c. The Isle of Portland
   d. Joseph Portland

3. Hydraulic Cement is:
   a. Liquid Cement
   b. Cement that hardens when mixed with water
   c. Cement that stays as a liquid paste when mixed with water
   d. None of the above

4. Concrete is good at resisting __________________ stress.
   a. Tensile
   b. Compressive
   c. Emotional
   d. All of the above

5. In a three-edge-bearing test, the tensile stress zones develop in the:
    a. Inside wall at crown and invert
    b. Outside wall at crown and invert
    c. Inside wall at springline
    d. Outside wall at springline
    e. Both a and d
    f. Both b and c
6. Reinforcement is good at resisting ____stress.
    a. Tensile
    b. Compressive
    c. Emotional
    d. All of the above
7. True or False: D-load strength is determined for RCP designed using the Direct Design Method.
    a. True
    b. False
8. If the RCP inside cage steel cover is increased by 1/2 inch, the structural strength of the pipe will:
    a. Increase
    b. Stay the same
    c. Decrease
    d. Doesn’t matter, the contractor will bury it and nobody will know
9. When designing RCP, special attention should be given to the:
    a. Grade of steel
    b. Type and size of reinforcement
    c. Spacing of the steel
    d. Position of the steel
    e. All of the above

10. Dry cast concrete is:
    a. Zero slump
    b. Low w/c ratio
    c. Flowable
    d. Both a and b

11. Box Culverts can be used for:
    a. Water retention
    b. Storm drainage
    c. Utility conduits
    d. Bridges
    e. All of the above

Chapter 2: Cement

1. Name four key raw materials that go into making Portland Cement:
    1. ______________________________
    2. ______________________________
    3. ______________________________
    4. ______________________________

2. What is "Clinker"?
    a. Fine cement powder from the grinding mill.
    b. Small, dark grey nodules formed as raw materials pass through the kiln.
    c. Type of rock mined from the earth that is crushed to 3/4-inch maximum size.
    d. A wedding toast.

3. True or False: Cements of different types (e.g., Type I or Type V) must NOT be combined and stored together in the same silo.
    a. True
    b. False

4. What cement type would be ideal for use in a concrete pipe or box culvert produced for installation in soils with extremely high sulfate content?
    a. Type I
    b. Type II
    c. Type I/II
    d. Type III
    e. Type V

5. What is produced when cement hydrates, i.e. reacts with water?
    a. Calcium Silicate Hydrate (C-S-H), i.e., "Glue"
    b. Calcium Hydroxide (CH)
    c. Heat
    d. All of the above

6. Match the four cement components to their correct properties:

1. Tricalcium Silicate – C_3S	a. Later age strength and less heat production.
2. Dicalcium Silicate – C_2S	b. Some heat generation but contributes little strength. Responsible for grey color.
3. Tricalcium Aluminate – C_3A	c. Lots of heat production and early age strength. Controls initial and final setting.
4. Tetracalcium Aluminoferrite – C_4AF	d. Lots of heat production. Contributes to very early age strength. Controls sulfate attack resistance.

7. True or False: ASTM C 150 Type II Cement provides moderate sulfate resistance.
    a. True
    b. False

Chapter 3: Supplementary Cementitious Materials

1. Fly ash is ____.
    a. Mined from the earth
    b. A byproduct of the burning of pulverized coal for the generation of electricity
    c. An additive that increases permeability
    d. A filler in concrete mix and adds no value in strength

2. Which material(s) can improve concrete durability?
    a. Slag
    b. Fly ash
    c. Chlorine
    d. Both a and b
    e. None of the above

3. True or False, A Pozzolan will immediately harden when mixed with water?
    a. True
    b. False

Chapter 4: Aggregates

1. True or False: Fine aggregates can have up to 40 times more surface area than the same weight and volume of large aggregates.
    a. True
    b. False

2. The amount of water needed in a concrete mix design is affected by which large aggregate characteristic(s)?
    a. Particle size
    b. Particle size distribution (Gradation)
    c. Shape
    d. All of the above
    e. None – aggregates don't impact water usage

3. Calculate the total moisture content in the fine aggregate based on the following information: **Weight of wet sand = 1235g, Weight of dry sand = 1165g**
    a. 5%
    b. 5.7%
    c. 6%
    d. 6.5%

4. When the aggregate is at SSD, ____.
    a. The aggregate does not contain any moisture.
    b. The moisture in the aggregate is not available for cement hydration.
    c. The aggregate absorption is too high.

5. Total moisture (TM) of aggregates is equal to the sum of the aggregate absorption and ____.
    a. Specific gravity
    b. Fineness modulus
    c. Free water
    d. Batch water
6. Specific Gravity is ____:
    a. The relative density of a material compared to water.
    b. Weight of material measured on the moon.
    c. Gravitational constant in the universe.
    d. None of the above.

Chapter 5: Admixtures

1. Water-reducing admixture use has which of the following impacts on fresh concrete?
    a. Gives the concrete a nice sparkle
    b. Improves workability
    c. Improves finishability
    d. Both b and c
    e. None of the above
2. Calcium Chloride is a great concrete set accelerator and should be used in__________________:
    a. Reinforced concrete pipe
    b. Reinforced concrete box culvert
    c. Underground structures
    d. Non–reinforced concrete
    e. All of the above
3. Corrosion inhibitors can be used as a defensive strategy for concrete structures such as ____:
    a. Marine facilities
    b. Highway bridges
    c. Parking garages
    d. All of the above

4. True or False, the primary use of air-entraining concrete is for freeze-thaw resistance
    a. True
    b. False

5. Lubricants and surfactants are typically used for:
    a. Reducing the w/c ratio of the concrete
    b. Aid in stripping of the forms
    c. Protecting the reinforcement from corrosion
    d. Increasing the setting time of the concrete
    e. All of the above

Chapter 6: Reinforcement

1. In the wire mesh designation **3x6 W6.0xW3.0** what do the first two numbers “3x6” indicate?
    a. Area of the reinforcement (0.3x0.6 = 0.18 in^2/ft)
    b. Longitudinal (3”) and circumferential (6”) wire spacing
    c. Circumferential (3”) and longitudinal (6”) wire spacing
    d. Length and width of the mesh, 3’ x 6’

2. In the wire mesh designation **3x6 W6.0xW3.0** what do the second two numbers “W6.0xW3.0” indicate?
    a. Area of the reinforcement (0.6x0.3 = 0.18 in2/ft)
    b. Circumferential (W6.0) and longitudinal (W3.0) wire designation
    c. Longitudinal (W6.0) and circumferential (W3.0) wire designation
    d. Length and width of the mesh, 6’ x 3’

3. In the wire mesh designation **3x6 W6.0xW3.0** what does the letter “W” indicate?
    a. Welded wire
    b. Convoluted wire
    c. Deformed wire
    d. Smooth wire

4. What do the wire producers call the wire referred to as "circumferential" wire by the concrete pipe industry?
    a. Circumferential wire
    b. Longitudinal wire
    c. Transverse wire
    d. Convoluted wire

5. What are the common markings found on rebar?
    a. Producer's mill designation
    b. Bar size
    c. Type of steel
    d. Grade of steel
    e. All of the above
    f. none of the above

Chapter 7: Self-Consolidating Concrete

1. True or False: SCC can flow into forms that have a lot of reinforcing steel and completely fill the formwork without vibration.
    a. True
    b. False

2. Some of the advantages of using SCC are ____.
    a. Faster pour time
    b. Labor saving from not having to vibrate the concrete
    c. Increased safety
    d. Better concrete surface finish
    e. All of the above

3. Define the following terms as they relate to SCC:

   Flowability ____

   ____

Passing Ability ____

____

Stability ____

____

4. True or False: It is necessary to vibrate SCC, especially when a smooth concrete finish is required.
   a. True
   b. False

5. Typical slump flow of SCC is ____.
   a. 2” – 10”
   b. 11” – 18”
   c. 19” – 30”
   d. > 30”

Chapter 8: Durability

1. Entrapped air is: ____.
   a. Purposefully added to the mix
   b. Large, non-uniform air voids trapped in concrete during mixing process
   c. The presence of small, well spaced air bubbles
   d. Only present if concrete is poured very slowly
   e. None of the above

2. Entrained air is: ____.
   a. Usually completely expelled by the time curing is complete
   b. Included only in the aggregates
   c. Small air bubbles made by adding an air-entraining admixture to the concrete mix
   d. Best for dry cast concrete
   e. None of the above

3. Which of the following results in durable concrete?
    a. Low w/c ratio
    b. Quality aggregates
    c. Proper mixing and placing
    d. Adequate curing
    e. All of the above
    f. None of the above
4. Sulfate attack is caused by ____.
    a. Hydrogen sulfide in sanitary sewers
    b. Acidic soils
    c. Sulfates found in soils or dissolved in ground water
    d. Seawater
5. True or False: Under normal conditions, the high pH value of the concrete prevents corrosion of the reinforcing bars by keeping them in a highly alkaline environment.
    a. True
    b. False

Answer Key

Chapter 1: Concrete and Concrete Products

1. a. cement, b. SCMs, c. aggregates, d. admixtures, d.+ water
2. c
3. b
4. b
5. e
6. a
7. b
8. c
9. e
10. d
11. e

Chapter 2: Cement

1. 1. Limestone, 2. Silicate, 3. Aluminate, 4. Iron
2. b
3. a
4. e
5. d
6. 1-c, 2-a, 3-d, 4-b
7. a

Chapter 3: Supplementary Cementitious Materials

1. b
2. d
3. b

Chapter 4: Aggregates

1. a
2. d
3. c
4. b
5. c
6. a

Chapter 5: Admixtures

1. d
2. d
3. d
4. a
5. b

Chapter 6: Reinforcement

1. c
2. b
3. d
4. b
5. e

Chapter 7: Self-Consolidating Concrete

1. a
2. e
3. Flowability - flows easily into the finest details of formwork or molds and around reinforcing under its own weight. Passing Ability - the ability to flow through tight spaces, like congested steel reinforcing bars or narrow spots in the formwork, without “blocking”. Stability - even at very high slump flows the concrete doesn't segregate
4. b
5. c

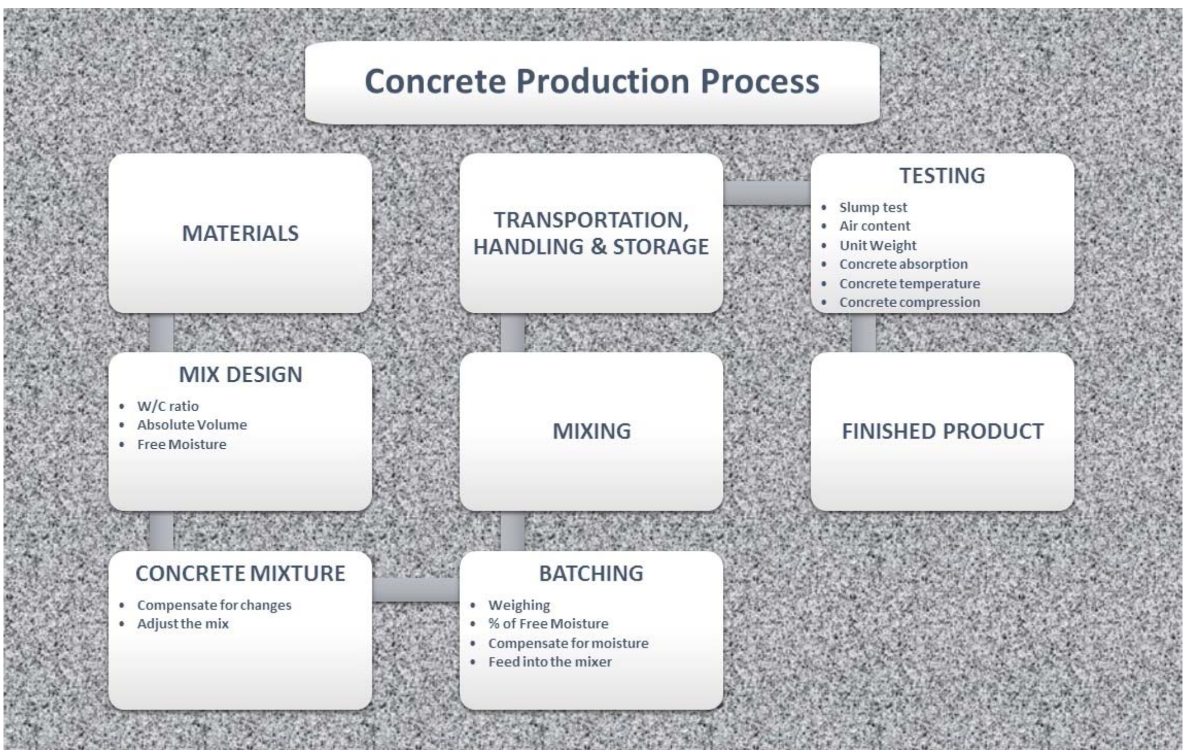
Chapter 8: Durability

1. b
2. c
3. e
4. c
5. a

SECTION 2
CONCRETE PRODUCTION

Now that you have a fundamental understanding of what constitutes desirable concrete, this section will guide you through the process of how concrete is produced. The key steps in the production process include designing the concrete mix, batching the concrete, mixing the concrete, transporting/handling the concrete, and testing. The initial step in the concrete production process is critical because an improperly designed concrete mix can have very adverse effects on the end product. Batching, mixing and transporting concrete also have key requirements that must be followed. Testing of the concrete is required to ensure that the design parameters were met during production and that the product meets the applicable specifications.

The illustration below highlights the key steps in concrete production.



Page left intentionally blank.

Chapter 1: Designing Concrete Mixes

Mix design is the process of determining required and specifiable characteristics of a concrete mixture. The characteristics can be based on fresh and/or hardened concrete properties, and inclusion, exclusion or limits of specific ingredients. Mix design requirements are based on intended use, environment, etc.

Mix proportioning is the process of determining the quantities of concrete ingredients (Fig. 1-1) that meet the mix design criteria. The primary considerations include:

- Meeting or exceeding specifications
- Availability of raw materials
- Acceptable workability of the mix
- Durability, strength and uniform appearance of the finished concrete
- Economy

Fig 1-1. Components of concrete mix design.

Objectives

At the end of this chapter, you will be able to:

✓ Define mix design vs mix proportioning.

✓ Define Absolute Volume and how it affects concrete mix design.

✓ Define w/cm ratio (w/c ratio).

- ✓ Calculate water/cementitious ratio, given specific mix design ingredients.
- ✓ Calculate the absolute volume of cement, fly ash, water, air, rock and sand, given their weight and specific gravity.
- ✓ Identify how to compensate for moisture given the free moisture percentage of coarse and fine aggregates in a given mix.
- ✓ Identify how to compensate for changes in cementitious material quantities.
- ✓ Identify the problems that can occur when too much water is added to the mix.
- ✓ Identify problems that will occur when the mix does not yield properly.
- ✓ Identify the mixture proportioning process steps of self consolidating concrete.
- ✓ Identify how to adjust the mix based on fluidity, viscosity, passing ability and stability of SCC properties.

Key Concepts for Mix Design Calculations

Following are a few "Rules of Thumb" to remember when performing mix design calculations:

- As the water to cement ratio increases, the strength of a concrete mix decreases.
- Arbitrarily adding one gallon of water to the mix design can reduce strength by 5%.
- As the surface area of the aggregate increases the more water will be needed to maintain a given slump. Coarser Surface Texture, Particle Shape, and Particle Size Distribution all affect water demand.
- As the air content increases, the strength of the concrete decreases. A 1% increase in air can reduce strength by 5%.

The **water-cementitious material ratio (w/cm) (Fig. 1-2)** or water-cement ratio of concrete is usually a good indicator of the quality of concrete. Low w/c concrete generally has high compressive strengths, lower permeability, and better long-term durability.

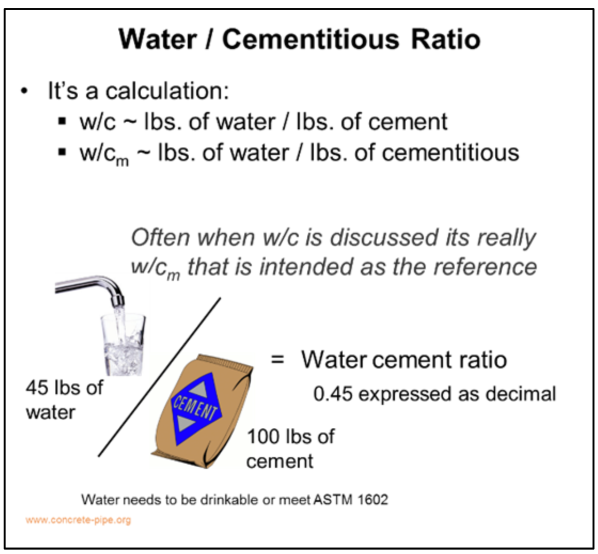


Fig. 1-2. Water / Cement Ratio definition.

Specific Gravity measures the relative density of a material compared to water, and is expressed as the ratio of a material's weight to the weight of an equal volume of water. It is used in calculating the Absolute Volumes in basic concrete mix design. Figure 1-3 illustrates the diffence between stone and water specific gravity as it relates to mass.

Bulk specific gravity (SSD) is used to determine the "solid volume" (absolute volume) of a material going into concrete. It is determined by submerging the material in water for 24 hours in order to fill any permeable voids.

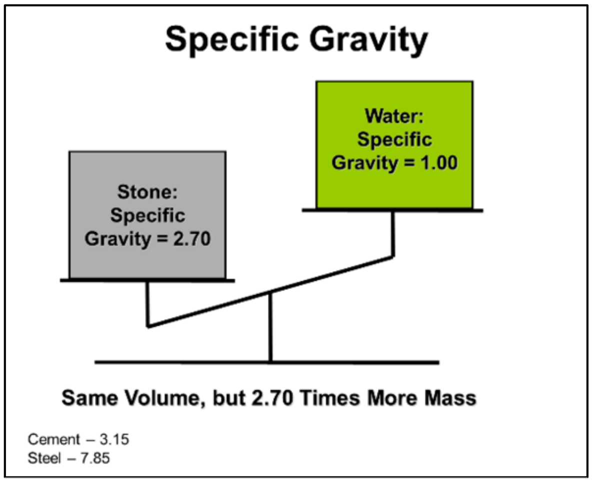


Fig. 1-3. Illustration of differences in specific gravity measurements.

Mix Proportioning Methods

There are number of ways to proportion mixes: Water-cement ratio method, Weight method, Absolute volume method, and using field experience (statistical data). This chapter will focus on the Absolute Volume Method.

Absolute Volume Method

Mix designs are calculated using the absolute volumes of the various concrete component materials, with the final mix design yielding one cubic yard (27 cubic feet). Since materials are weighed in pounds, it is important to understand the conversion between mass and volume. The relationship is as follows:

When calculating absolute volume, the following relationships of materials to volume are typically used.

$$\frac{\text{Pounds of Material}}{\text{Specific Gravity X Water Density}} = \text{Absolute Volume}$$

- Specific gravity of Type 1 Cement = 3.15
- Specific gravity of water = 1.0
- 1 gallon of water = 8.33 lbs
- Density of water = 62.4 lbs/ft^3

All material specific gravity and absorption information is typically available from the given material supplier.

Absolute Volume Calculation Examples

Basic Concrete Mix Design

In this example (Fig. 1-4.), the material, which consists of cement, stone, sand, and water, we are given the specific gravity of cement - 3.15, of stone - 2.6, of sand - 2.65, and of water - 1. Factoring in 62.4 as the density of water (as noted above), the calculated absolute volumes using the formula above are:

Basic Concrete Mix Design

Materials	Pounds of material	S.G.	Abs Volume
Cement	667	3.15	3.39
			-
Total Cementious	667		
Miller Stone	1590	2.6	9.80
Evert Sand	1242	2.65	7.51
Water	300	1	4.81
Air	5.5%		1.485
Total	3799		27.00
w / cm	0.45	Unit Wt.	140.72

Fig. 1-4. Basic Concrete Mix Design example.

Cement	667 lbs	÷	(3.15 x	62.4)	= 3.39	ft^3
Stone	1590 lbs	÷	(2.6 x	62.4)	= 9.80	ft^3
Sand	1242 lbs	÷	(2.65 x	62.4)	= 7.51	ft^3
Water	330 lbs	÷	(1 x	62.4)	= 4.81	ft^3

The **absolute volume of air** is figured separately by using the total absolute volume of the concrete and the percentage of air remaining in the concrete. To determine the absolute volume of air, multiply the percent of air present by the total absolute volume of the concrete. Therefore .055 of air multiplied by 27.00 ft^3 equates to 1.485 ft^3 of air.

Continuing with this example (Fig. 1-5), the water weighs 300 lbs and the cementitious materials, which is only cement, weighs 667 lbs. Therefore, the water to cement ratio is:

Materials	Pounds of material	S.G.	Abs Volume
Cement	667	3.15	3.39
			-
Total Cementious	667		
Miller Stone	1590	2.6	9.80
Evert Sand	1242	2.65	7.51
Water	300	1	4.81
Total	3799		27.00
w / cm	0.45	Unit Wt.	140.72

Water / Cement $\frac{300}{667}$

Unit Weight $\frac{3799}{27}$

Fig. 1-5. Concrete Mix Design Cont'd.

300 lbs ÷ 667 lbs = 0.45 w/cm

The **unit weight** is calculated by dividing the total material weight by the total absolute volume, which in this instance is 140.72 lb/ft^3.

3799 lbs ÷ 27 = 140.72 lb/ft^3

Mix Design with Cement and Fly Ash

In this next example (Fig. 1-6), the total cementitious materials weighs 667 lbs. This weight is the sum of the

Materials	Pounds of material	S.G.	Abs Volume
			-
Cement	534	3.15	2.72
Fly Ash	133	2.45	0.87
Total Cementious	667		
Miller Stone		2.60	0.00
Evert Sand		2.65	0.00
Water	295	1.0	4.73
Air	1.5%		0.405
Total	962		8.72
w / cm	0.44	Unit Wt.	110.33

Fig. 1-6. Cement and Fly Ash Mix Design example.

cementitious materials, those being cement and fly ash. The fly ash represents 20% of the total weight. The water weight in this example is now 295 lbs. Notice that the weight of the cement materials still equals 667 lbs, as in the previous example, but the water demand is now lower due to the fly ash, in order to maintain the same slump/workability. The water was reduced slightly from the previous example due to the lubricating effect of adding the fly ash (Ball-bearing shape particles of fly ash enhance workability). Replacing 20% of the cement with fly ash requires the adjustment of aggregate quantities, since the specific gravities of cement and fly ash are different. Replacing the cement with fly ash while maintaining the aggregate proportions constant would cause the final yield of the mix design to be inaccurate.

Aggregate Proportions

Continuing with the example in Fig. 1-6, the aggregate components must be proportioned to meet a total yield of 27 ft^3 for the mix. The total volume without the aggregate at this point is 8.72, then subtracting 8.72 from 27 equals 18.28 cubic feet of total aggregate required.

The volume of sand needed is calculated using a sand-to-aggregate ratio expressed as volume of sand divided by the total volume of aggregate. This ratio can be derived from aggregate blending data, density test, or past experience. For this example, we will use a sand to aggregate ratio of 0.42. Since the total volume of aggregate needed is 18.28 cubic feet, then the volume of sand needed is 7.68 cubic feet (derived by multiplying 18.28 by 0.42 (Fig. 1-7).

Given that:

$$\frac{\text{Pounds of Material}}{\text{S.G. X 62.4}} = \text{Absolute Volume}$$

and…

$$\frac{\text{Pounds of Material (sand)}}{\text{2.65 X 62.4}} = 7.68 \text{ ft}^3$$

Then…

Sand = 1270 lbs

Fig. 1-7. Applying the sand to aggregate ratio to determine the absolute volume of sand.

Once the volume of sand has been determined then the absolute volume of sand can be calculated by applying the absolute volume formula using the Evert Sand specific gravity of 2.65 (Fig. 1-8).

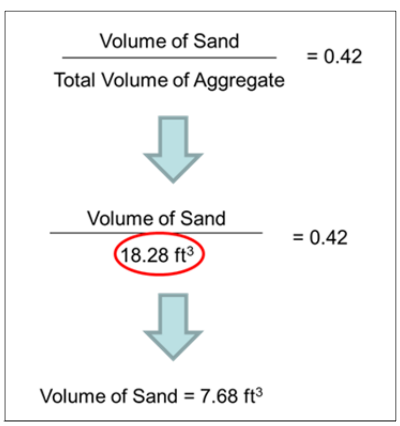


Fig. 1-8. Applying Specific Gravity to calculate absolute volume.

Next the absolute volume of stone is determined by applying the same formula. Given that the absolute volume of sand is 7.68 and the total aggregate volume is 18.28, then the volume of stone can be determined by subtracting 7.68 from 18.28 resulting in 10.60 ft^3 of stone required as shown in Fig 1-9, which results in 1720 lbs of stone needed.

Materials	Pounds of material	S.G.	Abs Volume
			-
Cement	534	3.15	2.72
Fly Ash	133	2.45	0.87
Total Cementious	**667**		
Miller Stone	1720	2.60	10.60
Evert Sand	1270	2.65	7.68
Water	295	1.0	4.73
Air	1.5%		0.405
Total	3952		27.00
w / cm	0.44	Unit Wt.	146.36
		Sand/Agg	0.42

Fig. 1-9. Completed materials calculations for cement with fly ash mix design.

Water

It's important to remember that changing the amount of any single ingredient can affect the proportions of the other ingredients and the properties of the mix. In fact, the impact of one gallon of water alone on a cubic yard of concrete can:

- Increase slump by 1",
- Decrease compressive strength by 5%,
- Waste the effect of 24 lbs./yd^3 of cement,
- Increase shrinkage by 10%,
- Increase permeability by up to 50%,
- Decrease freeze-thaw durability by 20%, and
- Decrease resistance to deicing salts and lowers quality in many other ways.

Given that aggregates are not solid and have different levels of moisture, this will impact the water demand as well since aggregates take up the largest amount of volume in the concrete. The size, shape and texture also affect the amount of water needed in the concrete.

Compensating for Moisture in Aggregates

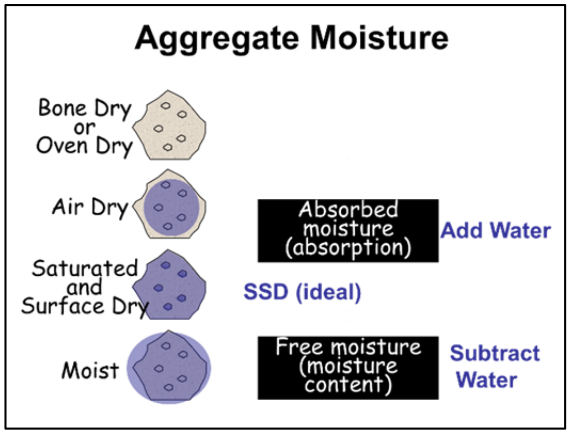


Fig. 1-10. Illustration of aggregate moisture content and when to add or subtract water.

Managing the moisture of aggregates is critical to concrete mix design. Figure 1-10 shows the different types of aggregate moistures. In the mix design, the ideal level of moisture is saturated and surface dry (SSD). If the aggregate is below the SSD state, it will absorb moisture from the batch leading to a number of quality issues. If the aggregate is wetter than SSD, which is the typical condition of the aggregate, the additional moisture (free water) in the aggregate will need to be accounted for in the batch and, therefore, the final quantity of batch water needs to be reduced. If compensation is not properly made for this difference, it will significantly affect the cost and quality of the concrete that is being producing. Adjustments made to the mix must meet the theoretical yield requirements of the approved mix design.

In the mix design process, the aggregates are designed for a saturated and surface dry (SSD) condition, therefore a moisture content measurement of the aggregate must be obtained and taken into account. This moisture measurement is provided as part of the inputs to the mix design process to determine the free moisture. As discussed in "Section 1, Chapter 4: Aggregates," the moisture in aggregates can be determined through a number of methods as previously mentioned. As a review, these methods include:

- **Moisture Probes** in the aggregate bin(s), which can be set to measure total moisture or free moisture depending on the calibration method.
- **Oven or Hot Plate** – The results obtained from this method is total moisture, therefore you need to adjust for absorption.
- **Chapman Flask** – This method determines free moisture.
- **Speedy Moisture Meter** – This instrument determines aggregate free moisture.

Batch Moisture Adjustment Calculations

To determine the moisture adjustment that may be needed, the following formulas are applied:

Total Aggregate Moisture (TM) = Absorption + Free Water

% Free Water x Total Weight of Aggregate = Moisture Adjustment

Using the previous example, the calculations for moisture adjustments in aggregates (stone and sand), given the total moisture in stone of 3% and sand of 5.5% (Absorptions are 1.5% and 0.85% respectively,) are:

Stone 3.0% total moisture − 1.5% absorption = 1.5% free water
Thus, 0.015 × 1720 lbs = 26 lbs of free water in the stone

Sand 5.5% total moisture - 0.85% absorption = 4.65% free water
Thus, 0.0465 × 1270 lbs = 59 lbs of free water in the sand

Based on our design water weight of 295 lbs, 85 lbs of free water in the aggregates must be subtracted to reach the batch water weight of 210 pounds (Fig. 1-11). Also, since there is water going into the batch with the aggregates, the aggregate quantities must be increased the same respective amount (as batched, Stone = 1746 lbs, Sand = 1329 lbs).

Materials	Pounds of material	S.G.	Abs Volume	SSD	Moisture Adjustment	Batch Weight yard
Cement	534	3.15	2.72	534		534
Type F ash	133	2.45	0.87	133		133
Miller Stone	1720	2.6	10.60	1720	26	1746
Evert Sand	1270	2.65	7.68	1270	59	1329
Water	295	1.0	4.73	295	-85	210
Air	1.5%		0.405	1.5%		
Total	3952		27.00	3952		3952
Density	146.4					146.4

SSD & batch totals will be the same

Fig 1-11. Final moisture adjustment calculations from Cement and Fly Ash Mix Design example.

Importance of Proper Yield

Yield is the volume of concrete produced in a batch. Mix designs always yield one cubic yard. Due to inaccuracies in weighing materials or when moisture adjustments are made, the actual concrete batch may not yield correctly. The following example will illustrate a situation where the concrete yield is off.

The mix design for the concrete (see top chart in Fig. 1-12) calls for 400 lbs of cement and 100 lbs of fly ash. The plant runs out of fly ash during the day and simply change the mix design to 500 lbs of cement.

Since mix designs are done volumetrically to yield one yard, replacing fly ash with cement pound-for-pound will change the yield because the two materials have a different specific gravity and therefore occupy a different volume for the given weight. This concrete batch will under yield (see bottom chart in Fig. 1-12) until proper adjustments are made. In order to

	design	actual	
Cement	400	500	lbs
Fly ash	100	0	lbs
Water	200	200	lbs
Stone*	1528	1538	lbs
Sand*	1826	1838	lbs
Total	4054	4076	Lbs/yd^3

	Weight	Volume
Cement	500	2.544
Fly ash	0	0
Water	200	3.205
Stone*	1528	9.137
Sand*	1826	11.169
Air	3%	0.810
Total	4054	26.865

Under yield

Fig. 1-12. Under yield example.

compensate for the change, aggregate portions required for this new mix design need to be recalulated, as shown in the earlier examples. This ensures that the mix yields properly.

An **under yield** situation occurs when not enough of one or more raw materials are batched, or material is substituted by weight and not corrected for volume. Since volume stays constant, more raw materials are needed to fill that volume. This equates to more cement and higher cost!

In an **over yield** situation, one or more raw materials are batched over the required weight. In this situation the batch occupies a larger volume, therefore, less of the other raw materials are used in the product. That might seem advantageous at first because of the cost savings, but it could lead to lower strengths, workability issues, and less cementitious material than allowed by the specifications.

Substituting or replacing raw materials (eg. fly ash for cement) by weight will also throw off the yield. Raw material substitution/replacement must be performed based on volume, NOT on weight. Aggregate moisture will affect the yield by adding water. The batch will need to be adjusted to maintain proper w/c and stone/sand ratio.

Self Consolidating Concrete Mix Design

“Self Consolidating Concrete is a highly flowable, non-segregating concrete that can flow into place, fill the formwork, and encapsulate the reinforcement without any mechanical consolidation.” [ACI International, Committee 237 SCC]

Fig. 1-13. SCC slump flow evaluation.

SCC is very flowable concrete that typically does not need vibration to fill the formwork. The consistency, or filling ability, is measured by what's called a slump flow, where the slump cone is filled and lifted, and the width of the resulting concrete patty is measured (Fig. 1-13). Slump flow for SCC varies from 19 to 30 inches.

Mix Design Approaches

Developing SCC consists of material combinations and relationships of admixtures, sand/aggregates, cementitious materials (cement, pozzolans), and water. There are currently three basic mixture proportioning approaches for developing SCC mixtures. They are:

- High powder content and high-range water-reducing (HRWR) admixture
- Low powder content, HRWR admixture and viscosity modifying admixture (VMA)
- Combination Type: moderate powder content, HRWR admixture, with or without moderate VMA addition.

The illustration in Fig. 1-14 shows the design mix in SCC vs. conventional concrete. SCC mixtures typically have a higher paste and mortar volume.

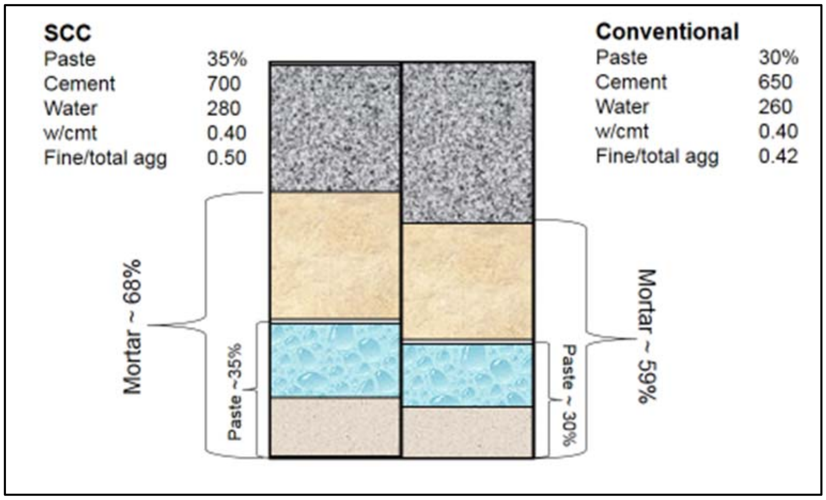


Fig. 1-14. SCC design mix vs. Conventional Concrete design mix.

Following are the common steps to proportioning SCC:

1. Determine required *slump flow*
2. Select *coarse aggregate size*
3. Determine the *required air content*
4. Estimate the *required powder content*
5. Estimate the *required water content*
6. Calculate coarse and fine aggregate amounts after Powder, Water and Air contents are determined
7. Calculate *paste* and *mortar volume*
8. Adjust *coarse and fine aggregate weights* based on *paste* and *mortar volumes*
9. Select *admixture types and dosage*
10. *Batch Trial Mixture – Make adjustments and batch again*

Admixtures in SCC Mix Design

Flowability and stability are key properties in SCC and since the advent of the polycarboxylate based superplasticizing admixtures SCC has become a lot more friendlier to produce. Viscosity modifiers prevent segregation by imparting thixotropic qualities to the mix (Fig 1-15). This means that when the concrete is under shear (as when mixed or poured) the mix becomes very fluid and apparent viscosity is lowered. This allows the concrete paste to move freely, carrying the aggregates in the matrix. When the shear stresses are removed the apparent viscosity is increased and the paste "gels" which has the effect of holding the aggregates suspended in the mix and preventing segregation.

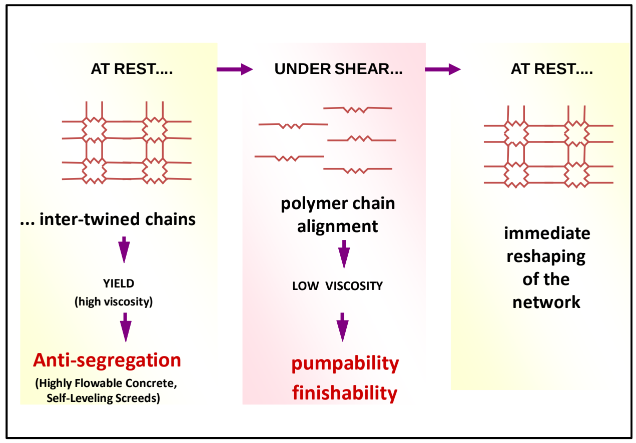


Fig 1-15. Affects of viscosity modifiers on SCC at rest and under shear.

There are three types of admixtures used in SCC mix design:

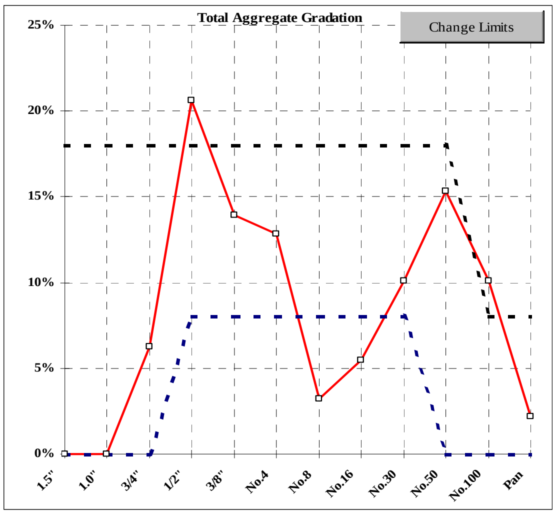
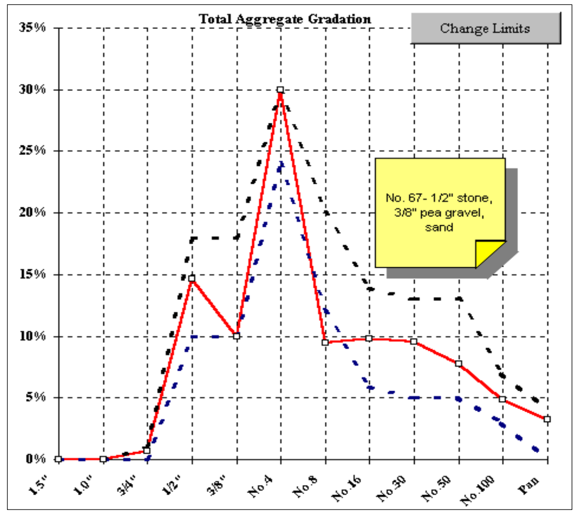
- **SCC Polycarboxylate Superplasticizers** - Excellent flowability with improved stability compared to superplasticizers for conventional concrete. Increased mix forgiveness.
- **Viscosity Modifying Agents -** For difficult aggregates and production conditions such as low cementitious and paste volumes. Increases mix forgiveness / water tolerance.
- **Extended Slump Life Polycarboxylate Superplasticizers** - Excellent flowability with improved stability; formulated for the concrete market for added workability retention

Additionally, common admixtures such as air entrainment, retarders, and accelerators also work with SCC.

Aggregates in SCC Mix Design

Many coarse aggregates available in North America are gap graded, and thus have low volumes of No. 8 and No. 16 sieve size particles. The optimized grading curve for SCC is much tighter than for conventional concrete (as shown in Table 1-1 on the following page). Optimizing mix packing density is critical for many SCC mixes, so it may be necessary to blend aggregate sources. SCC mixes typically contain more fine aggregate than conventional concrete mixes in order to achieving the desired flow without segregating the concrete.

Table 1.1. Gradation curve for SCC vs. gradation curve for conventional concrete.

Typical #57 blend, indicating a gap graded aggregate.	An optimized SCC aggregate grading with blended aggregates.
	

Adjusting SCC Mixes

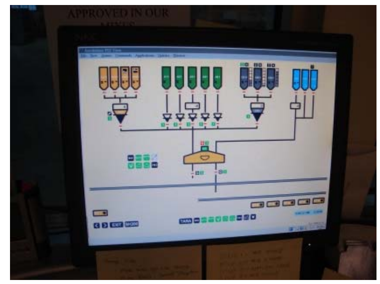
The following can be used as a guideline when making adjustments to trial batches:

Property	Powder Content	Water Content	Maximum Coarse Aggregate Size	Sand-to-Aggregate Ratio	VMA Dosage	HRWRA Dosage
Fluidity						
Too Low		↑			↓	↑
Too High		↓			↑	↓
Viscosity						
Too Low	↑	↓			↑	
Too High		↑			↓	
Insufficient Passing Ability	↑	↓	↓	↑	↑	
Stability						
Excessive Segregation	↑				↑	
Aggregate Pile			↓	↑		
Mortar Halo	↑	↓			↑	↓

Notes

Notes

Chapter 2: Batching, Mixing, Handling and Transporting Concrete



After the mix design is complete, it's time for the batching and mixing of concrete. Batching is the process of measuring concrete mix ingredients by mass and introducing them into the mixer. Once the mixing is complete, the concrete is discharged and transported for placement. It is important that handling and transport of the concrete is done in a way that protects the concrete from damage and ensures a quality product. This chapter will cover what is needed to ensure the production concrete of uniform quality.

Objectives

At the end of this chapter, you will be able to:

- ✓ List the key requirements to ensure accuracy of weighing during batching.
- ✓ Identify how to compensate for moisture in aggregates.
- ✓ Identify the correct sequence for adding a given admixture.
- ✓ Determine the quantity of concrete needed per day and per hour, given job specifications.
- ✓ Identify the typical proportional output of most mixers.
- ✓ Recall the recommended sequence of feeding ingredients into the mixer.
- ✓ Select the type of mixer to use in a given situation.
- ✓ Identify the types of damage that can occur when handling and transporting concrete, which seriously affect the quality of the finished work.
- ✓ Describe the correct method for discharging concrete from the mixer.
- ✓ Recognize when segregation can occur when transporting and handling concrete.
- ✓ Identify the correct pouring method when using flat forms and vertical forms.

Batching Concrete

Batching concrete is the process of accurately measuring the ingredients as specified by the concrete mix design. The output of the concrete mix design process is a set of mixture proportions known as batch weights. These batch weights provide the amount of each ingredient to be measured and mixed in the concrete batch.

Fig. 2-1. Control room for batching equipment.

Keys to Accurate Batching of Concrete

Accurate measurement is the key to producing uniform quality concrete. It is important that the materials are being measured as appropriate for each and according to specifications; this includes making compensation for added moisture in aggregates (Fig 2-1). Ensuring accurate measurement also includes making sure that the scales are in proper working order and they are capable of measuring within specified tolerances regardless of the size of the batch.

Accuracy of Weighing and Measuring Equipment

The first key to accurate batching is to ensure accurate measurements are being taken within the specified percentages of accuracy; these are called *tolerances*.

Batching Tolerances. According to ASTM C94, the typical batching tolerances for Ready-mix Concrete include:

- Cementitious: +/- 1%
- Water: +/- 3%
- Fine Aggregates: +/- 2%
- Coarse Aggregates: +/- 2%
- Cumulative Aggregates: +/- 1%
- Admixtures: +/- 3% or +/- dosage per bag of cement, whichever is greater

These tolerances are for ready mix concrete and may not apply to dry cast mixes. It is important that you check your local specifications.

Measuring equipment capability and operation. To ensure accurate measurements, the accuracy of the scales (along with batching equipment) should be checked on a regular basis, including zeros, and adjusted when necessary. Scales must hang free and the gates or valves must not leak. After each batch the scales must be completely empty before weighing other materials. Zero on scales should be checked on a regular basis.

In addition to scales, there is other equipment that must be maintained and calibrated to ensure quality and consistent measurement. If you are using **moisture probes** to compensate for moisture in aggregates, ACI 304 states that moisture probes should be recalibrated to oven dried samples monthly or whenever the slump (workability) of the concrete produced is inconsistent. Always check the local specifications which may be different. The aggregate samples for testing should be taken as close to the probe as possible.

Weighing Materials. All materials batched shall be measured by mass. Cement and supplemental cementitious materials can be measured cumulatively, and different aggregates can also be measured cumulatively, as long as separate scales and hoppers are used for both cementitious materials and aggregates.

Compensating for Moisture in Aggregates

According to ASTM C94, "Batch mass measurements shall be based on dry materials and shall be the required mass of dry materials plus the total mass of moisture (both absorbed and surface) contained in the aggregate." When measuring aggregates, it is important to compensate for moisture to ensure batch consistency, predictable strengths and production efficiency. Compensating for moisture in aggregates involves the process of measuring the amount of moisture in the aggregates and making the necessary adjustments to the quantity of aggregate batched and the added batch water.

One of the methods for measuring moisture, mentioned in the previous chapter, is the use of moisture probes, which are used in aggregate bins. Moisture probes can also be used in mixers to make compensation for the weight of water detected during the mixing of the dry materials.

Once the added moisture is determined, the device will deliver the amount of batch water required to within the accuracy required by specifications. Measuring tanks should also be equipped to provide calibration of outside taps and valves for quick and accurate determination of the amount of water in the tank.

Sequencing

The typical sequencing of the cement and other raw materials is recommended by manufacturers as shown in the following two options:

Option 1	Option 2
1. Aggregates 2. Cementitious 3. Water 4. Admixtures (per admix manufacturer recommendation)	1. Aggregates 2. Water 3. Cementitious 4. Admixtures (per admix manufacturer recommendation)

Aggregates. Aggregates are the first to be added to the mixer. As previously discussed, compensation must be made for moisture in the aggregates before adding other materials.

Water. There are a couple of ways to add the required batch water into the mixer. Some of the water can be added with the aggregates as pre-water and the remainder added after all the other materials are in the mixer. The full quantity of batch water can also be added after all the dry materials have been batched and mixed.

Cement. The sequencing of cement depends on the mixing system. Generally, cement should be discharged when all aggregates are in the mixer. If cement balling occurs, the cement should be discharged sooner or later depending on your mixer. Ask your mixing manufacturer for a recommended sequence and timing schedule.

Admixtures. The sequence in which admixtures are added to the mix is important to ensure mix consistency and reduce the amount of additive cost. The type of admixture influences the sequencing as well as when multiple admixtures are used in the same batch. It is important to always work with your admixture supplier on correct sequencing to ensure maximum effectiveness of the admixture(s) used.

Air Entraining. Air entraining should be added with the mix water or aggregates. Air entraining should be mixed with aggregates for a few seconds before adding cement.

Water Reducers. After air entraining, water reducers should be added with the mix water.

Lubricants/Surfactants. For drycast products, lubricant/surfactant should be added with the aggregates and water.

High Range Water Reducers. These super / superplasticizers additives should be added at the end of the batch after all ingredients are thoroughly mixed.

Sequencing for SCC. The following diagram outlines the typical SCC mixing cycle (Fig. 2-2).

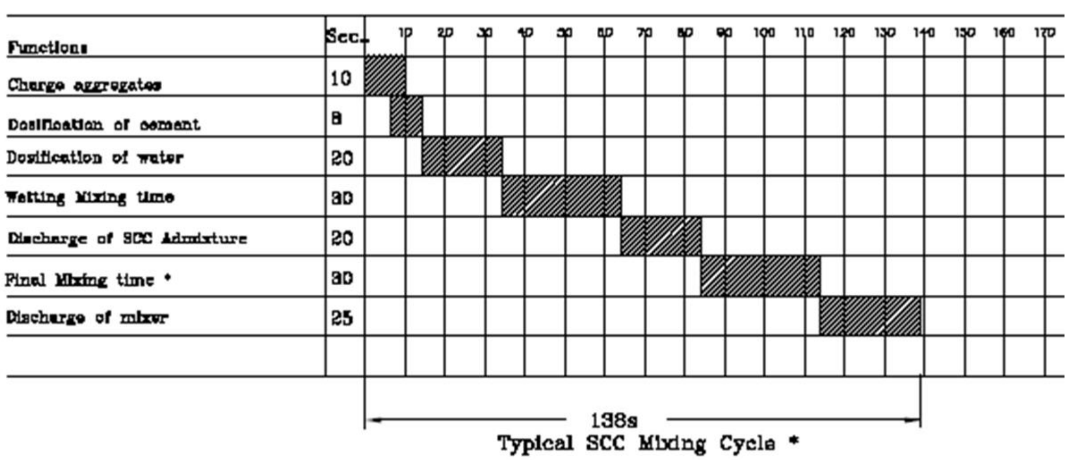


Fig 2-2. Self Consolidating Concrete Mixing Cycle, from Advanced Concrete Technologies.

Mixing Concrete

All concrete should be mixed thoroughly until it is uniform in appearance, with all ingredients evenly distributed. If the concrete is adequately mixed, samples taken from different portions of a batch will have essentially the same density, air content, slump, and coarse-aggregate content.

The properties for a uniform batch of mixed concrete are:

1. Consistency – the ability to flow
2. Stability – the resistance to segregation
3. Uniformity – homogenous mixer constituents
4. Workability – ease of placing, consolidating and finishing
5. Finishability – ease of performing finishing operations to achieve specified surface characteristics

Fig. 2-3. Stationary mixer.

Common Types of Mixing Equipment. For concrete pipe products, concrete is generally mixed in stationary mixers (Fig. 2-3) and transported via conveyors or traveling buckets to be discharged into flat or vertical forms; therefore, only stationary mixing equipment is addressed in this manual.

Stationary Mixers

Typical output of mixed concrete is specified in cubic feet, cubic yards or cubic meters. Each mixer will have a capacity which pertains to the output. However, when figuring quantity of output needed per day or per hour from a particular mixer, you can only consider two thirds of the rated capacity because the raw ingredients take more room than the mixed result. Some mixer manufacturers state output capacity in volume of mixed concrete, so you will need to ask what the minimum and maximum output capacity is for a given mixer.

Following are examples of the kind of stationary mixers that are used, along with an overview of how they operate and their rated capacity.

Paddle Mixers (aka Single-Shaft mixer).

As its model name suggests, the single shaft mixer has two of more mixing paddles attached to the mixing arms on horizontal shaft that rotates in single direction (Fig 2-4). Paddles are installed in an angle relative to its rotational direction. Very similar to “Spiral Blade Mixer”, and is often configurable to be spiral blade mixer.

Fig. 2-4. Paddle Mixer.

Single shat paddle mixers comes in several sizes, commonly from $0.2Y^3$ to $2.5Y^3$. Single discharge outlet with a trap-door is most common type of batch discharge in paddle mixers.

The Paddle Mixer has its strong presence in concrete block and paving industry. Less common among concrete pipe and precast prestressed concrete products producers, often due to its less efficient mixing action and longer mixing times.

Ribbon/Spiral Blade Mixers


Fig. 2-5. Ribbon Blade Mixer.

Much like Paddle Mixer, Ribbon Blade Mixer has one horizontal shaft rotating in single direction. Two or more ribbon blades are attached on arms on the shaft (Fig. 2-5). The low shear mixing action of the Ribbon Mixer offers low material degradation. Concrete is discharged through the single trap-door type outlet.

The ribbon blade mixer is often configurable into Paddle Mixer type by replacing ribbon blades with paddles.

Ribbon mixers are made in various sizes up to $6Y^3$ of compacted concrete output. These mixers are used in various manufactured concrete products applications such as concrete block, paver and pipe manufacturing. Less likely used to produce high slump (wetcast) concrete due to its low shear mixing action.

Countercurrent Pan Mixer

Pan mixers come in two varieties: counter-current and turbine. Countercurrent mixers are the most popular type of concrete mixers among concrete pipe manufacturers.


Fig. 2-6. Countercurrent Planetary Pan Mixer.

The Countercurrent Planetary Mixer is a type of counter-current mixer. In this mixer, intense mixing action is achieved by rotating mixing “stars” with arms and paddles that rotate independently around their vertical axis (Fig. 2-6). One or more mixing star assemblies (depending on mixer size) are rotating around a center vertical axis of the mixer pan. This mixing action delivers large amounts of mixing energy directly into the concrete. Its undeniably effective mixing action is proven to provide homogeneous mix in relatively short mixing time.

Various paddle configurations and paddle shapes are used in different mixer makes and models. This versatile design offers multiple discharge outlet locations whereas horizontal (twin/single/ribbon/paddle) shaft mixers can only have a single discharge outlet. Countercurrent mixers are typically available is sizes from $0.25Y^3$ up to $3Y^3$, however the largest available countercurrent mixer is made to produce $5.2Y^3$ of zero slump compacted concrete.

Turbine Pan Mixers (stationary pan)

The Turbine Pan Mixer is one of the oldest pan mixer designs. It has a rotating center “console” where all the mixer arms with paddles are attached. Typically, the mixer arms are spring loaded providing shock absorption and adjustment for paddle wear. More advanced models also offer rotating agitator "stars" for advanced mixing action. The mixer can be configured with more than one discharge door locations. A wide range of output capacities from $0.2Y^3$ up to $6Y^3$ are available from multiple mixer manufacturer.

The Turbine Pan Mixer has an advantage when the plant has limited height available for the concrete mixer. It has a very low profile as its drive unit is typically on the side. However, the mixing action is not as aggressive as countercurrent and twinshaft mixers, which makes it less likely to be first choice for wetcast and SCC production.

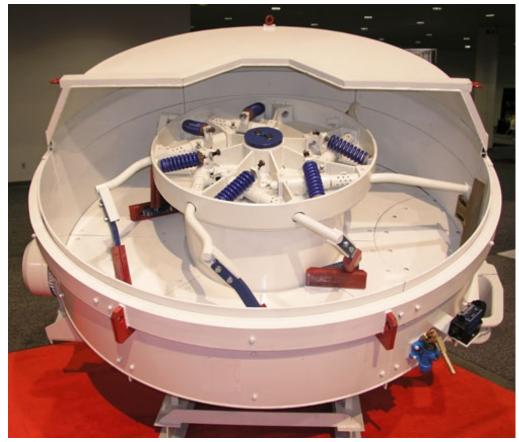


Fig. 2-7. Turbine Pan Mixer.

Rotating Pan Mixers

Rotating Pan Mixers (Fig. 2-8) deliver their high-shear, multi-velocity, agitation as the mixing pan is rotating with filled materials. Stationary, counter-rotating mixing stars on top of the mixer pan revolve through the mix at different speeds, and delivers the mix through a single discharge outlet in the center of the pan.

Fig. 2-8. Rotating Pan Mixer.

Rotating Pan Mixers comes with a compacted concrete output capacity of $1.5Y^3$ - $3Y^3$. The mixing action is comparable to countercurrent mixer, however the physical size of the rotating pan mixer is typically much larger than the equivalent capacity countercurrent mixer due to enclosed center drum, which acts as a discharge door. Although this mixing technology used in rotating pan mixer is suitable for several concrete manufacturing applications, this type concrete mixer is seldom seen in today's manufactured concrete products industry.

Twin-Shaft Mixers

Twinshaft Mixers are much like the paddle mixers but with dual horizontal shafts holding multiple mixing arms and paddles. Mixing paddles and arms are positioned to create "auger"-like turbulence in the mixing tub. Both shafts are running in opposite direction moving concrete up and over in the middle of the tub where the paddles on both horizontal shaft passes each other.

As the Twinshaft Mixer (Fig. 2-9) offers high shear mixing action with very large capacity mixers. Compacted concrete output capacity ranging from $0.7Y^3$ up to $12Y^3$ per batch depending on manufacturer. Given its capacity, it is popular in wet-cast production requiring large quantities of

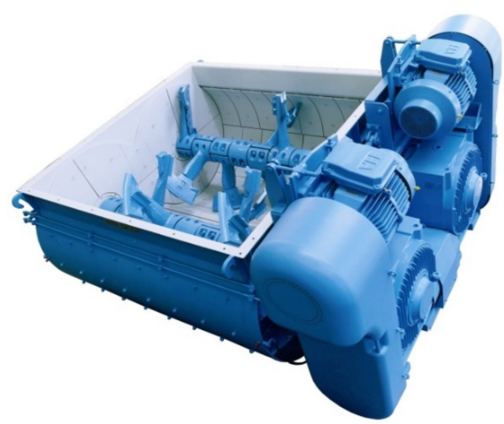


Fig 2-9. Twin-shaft Mixer.

concrete in a single batch, and is often seen in pre-stressed concrete products manufacturing plants. Typically, it has only a single discharge door on the bottom of tub; however some manufacturers are offering a split discharge gate design that allows using two outlet chutes.

According to ASTM C94, "stationary mixers shall be equipped with a metal plate or plates on which are plainly marked the mixing speed of the drum or paddles, and the maximum capacity in terms of the volume of mixed concrete. When used for the complete mixing of concrete, stationary mixers shall be equipped with an acceptable timing device that will not permit the batch to be discharged until the specified mixing time has elapsed."

Mixing Cycle

Careful attention should be paid to the required mixing time. Many specifications require a minimum mixing time of one minute plus 15 seconds for every cubic meter (yard), unless mixer performance tests demonstrate that shorter periods are acceptable and will provide a uniform concrete mixture. Short mixing time can result in non-homogenous mixtures, poor distribution of air voids (resulting in poor frost resistance), poor strength gain, and early stiffening problems. The mixing period should be measured from the time all cement and aggregates are in the mixer drum, provided all the water is added before one-fourth of the mixing time has elapsed (ACI 304R).

Transporting and Handling Concrete

The selection of the best transportation/handling method must consider the distance (both vertical and horizontal), the quantity, timing, and the type of concrete to be transported, to ensure that the quality of the product to be produced is maintained and no damage occurs throughout the process until poured. One of the most common forms of damage, being segregation, can occur during discharge, transport and placement.

Handling Concrete

It is important that the mixed concrete be handled in a way as to avoid *segregation, loss of mortar* and *loss of slump* during discharge and placement of the concrete.

Discharge. Discharge from the mixer is the first step in handling the concrete in which damage that can occur. To avoid segregation, the concrete should be vertically discharged into the center of the bucket or hopper from the mixer at a free-fall distance of no less than six to ten feet (Fig. 2-10). This is acceptable due to the fact that producers are pouring lengths of eight feet, but pouring as close as possible to the form is best. If discharged from open chutes, the chutes must be less than 20 feet long with a slope of the concrete.

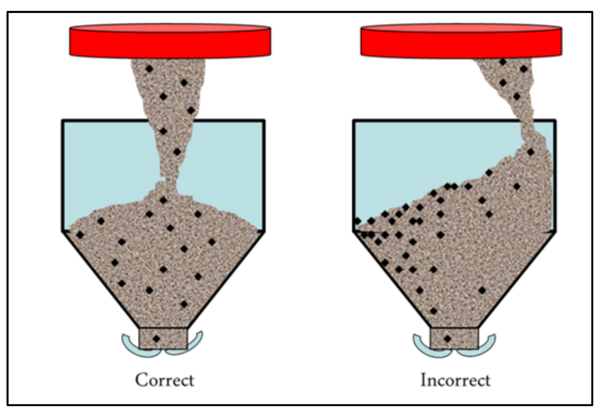


Fig. 2-10. Illustration of proper and improper discharge of concrete into the center of the bucket.

Pouring Concrete. When pouring, place concrete in the form near its final location. Be sure to keep free-fall of the concrete to a minimum. How the concrete is poured, is dependent on the type of form that is being used:

- *Flat forms*: If using flat forms, begin pouring at the corner or edge and pour the concrete in equal lifts.
- *Vertical forms*: If using vertical forms, pour the concrete in horizontal layers. For large blockouts, pour on one side to avoid trapping air, which can occur when pouring from both side, and allow the concrete to flow underneath.

Transporting the Concrete

The most common transportation methods for transporting concrete to be poured into forms are belt conveyors and buckets. The transportation method used should be designed to accommodate a sufficient volume of concrete to allow for timely placement to ensure minimal segregation, slump or workability loss and the elimination of cold joints or pour lines.

Fig. 2-11. Belt conveyor.

Belt Conveyors. Belt conveyors (Fig. 2-11) are used for moving concrete horizontally or to a higher or lower level. They are usually positioned between the main discharge point and secondary discharge point. The advantage to using conveyors is that they can place a large volume of concrete quickly when access is limited. It is important to watch for end-discharge arrangement in a way that prevents segregation and leaves no mortar on the belt. In adverse weather, the long reaches of the belt may need a cover.

Fig. 2-12. Pour bucket.

Pour buckets: Pour buckets (Fig. 2-12), or crane buckets, are used with cranes or forklifts (or other methods for large projects) to move the concrete directly from the central discharge point to the formwork. This method allows for a clean discharge and a wide range of capacities.

Traveling bucket conveyors: Traveling concrete bucket systems offer automatic concrete batch transportation from mixing plant to production area quickly and safely. An overhead rail system is fixed and custom designed to each plant's specific needs and layout. The typical traveling bucket has a rotating drum type bucket, however, bottom discharge buckets are also available. The advantages of using traveling concrete buckets are: quick delivery time, standalone operation, and minimum concrete handling time, which results in less air exposure, less evaporation, than belt conveyor method. Automatic traveling bucket systems are more costly than other commonly used concrete transportation system.

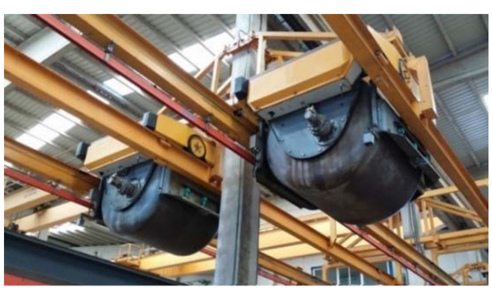


Fig. 2-13. Traveling bucket conveyor.

Notes

Chapter 3: Testing Concrete

Producers, Installers, Design Engineers, and owner agencies depend and rely on accurate product standards and test methods for the successful completion of almost every project constructed. Due to our long history and continued use, our products and their components are well understood and the standards for our products have continued to improve and develop over the past 100 years. Almost every aspect of our product development has been built on a very conservative approach. It is not enough to say you produce a quality product; you must be able to document that strength and quality through testing. It is not enough to say your installation gives the installer flexibility; you must be able to back that up with national standards and research. It is not enough to say our product is a structure; you must be able to prove that statement by actual finished product testing. By properly utilizing our National Standards, we can honestly say and prove we have the strongest, most durable, most installation friendly product available in the storm drain market today.

The American Society for Testing and Materials (ASTM) and the American Association of State Highway and Transportation Officials (AASHTO) standards are two of the most commonly referred groups of standards for our products as well as other competitive drainage products. There are test methods set forth for the material components of reinforced concrete pipe (RCP), completed RCP product, components used in conjunction with RCP, and even test methods that confirm the field performance of installed RCP. For example, ASTM C-497 Standard Test Methods for Concrete Pipe, Manhole Sections, or Tile includes test methods used for the production and quality control of RCP. These tests are completed to properly evaluate all the various properties required for the completion of a quality finished product. C-497 includes and discusses the following critical test procedures: Three-Edge Bearing Test Method, Core Strength Test Method, Absorption Test, Hydrostatic Test Method, Cylinder Strength Test, Joint Shear Test. There are test methods covered in ASTM for almost all of the components of RCP (Fig. 3-1), as well as test methods to confirm conformance of the installed product including joint materials and joint tightness.

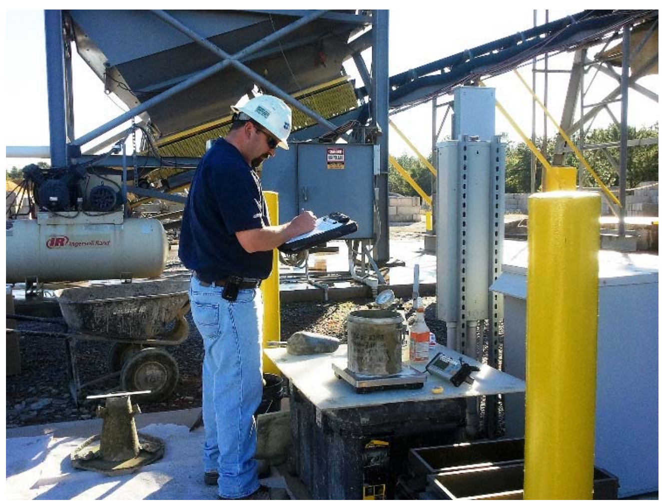


Fig. 3-1. Equipment setup for the ASTM Pressure Meter Air Test for Concrete.

Objectives

At the end of this chapter, you will be able to:

- ✓ List the types of tests required for wet cast and Self Consolidating Concrete (SCC).
- ✓ Identify the recommended timeline for performing each test.
- ✓ Summarize the slump test method for wet concrete, as stated in ASTM C-1430.
- ✓ Summarize the slump flow test method for SCC, as stated ASTM C-1611.
- ✓ Summarize the SCC evaluation testing methods for flowability, stability and passing ability, as stated in Q-Cast.
- ✓ Summarize the test method for air content tests of fresh wet cast concrete, as stated in ASTM C-231.
- ✓ Summarize the test method for unit weight tests of fresh wet cast concrete, as stated in ASTM C-138.
- ✓ Summarize the test method for concrete temperature tests, as stated in ASTM C-1064.
- ✓ Summarize the test method for concrete compression tests, as stated in ASTM C-39.

Testing Wet Cast and Self Consolidating Concrete

In order to properly test wet cast and self consolidating concrete it is of the utmost importance to obtain truly representative samples. Test results can be misleading if the sample is not representative. Samples should be obtained and handled in accordance with ASTM C172 – *Standard Practice for Sampling Freshly Mixed Concrete*.

In the sections that follow, you will learn about some of the most commonly used testing methods for both wet cast and self consolidating concrete (SCC). For wet cast concrete, we will review the testing methods and standards for

- slump tests,
- air content tests,
- unit weight tests,
- temperature tests, and
- compression tests.

For SCC, we will review the testing methods and standards for:

- flowability = slump flow test;
- stability = column segregation test; and
- passing ability = J-Ring test

Slump Test of Wet Cast Concrete

The slump test, as described by **ASTM C143 – Standard Test Method for Slump of Hydraulic-Cement Concrete**, is the most generally accepted method used to measure the consistency, or relative fluidity, of fresh concrete. The testing equipment consists of a slump cone 12 inches in height, an eight inch diameter base with a 4 inch diameter top, and a steel rod that is 5/8 inches in diameter and 24 inches long with hemispherically shaped tips.

Slump Test Procedure

To perform a slump test, the following steps are performed:

1. The internal surface of the mold is thoroughly cleaned and applied with a light coat of oil.
2. The mold is placed on a smooth, horizontal, rigid and nonabsorbent surface.
3. The mold is then filled in three layers with freshly mixed concrete of approximately equal volume.
4. Each layer is rodded 25 times by the rounded end of the steel rod (strokes are distributed evenly over the cross section).
5. After the top layer is rodded, the concrete is struck off the level with a trowel.
6. The mold is removed from the concrete immediately by raising it slowly in the vertical direction and is then placed next to the settled concrete.
7. The difference in level between the height of the mold and that of the highest point of the settled concrete is measured (Fig 3-2.).
8. This difference in height is the slump of the concrete.

Figure 3-2. Illustration of a slump test.

According to ASTM C143, slump tests shall be performed daily at a minimum, on each wet cast mix design being used that day. Additional slump tests shall be run if results are outside the desired range, or if any mix component is adjusted. Maintain results on file.

ACPA QCast Requirements

Slump tests shall be performed daily at a minimum, on each wet cast mix design being used that day. Additional slump tests shall be run if results are outside the desired range, or if any mix component is adjusted. Results should be maintained on file.

Air Content Tests of Fresh Wet Cast or SCC Concrete

A number of methods for measuring air content of freshly mixed concrete can be used. ASTM methods include:

- ASTM C231 – Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method.
- ASTM C173 - Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method.

Pressure Method

The pressure method (Fig. 3-3) is the most common method in determining the air content in fresh concrete. Many commercial air meters of this type are calibrated to read air content directly when a predetermined pressure is applied. The applied pressure compresses the air within the concrete sample, including the air in the pores of aggregates. Aggregate correction factors that compensate for trapped air in normal-weight aggregates are relatively constant and, though small, should be subtracted from the pressure meter gauge reading to obtain the correct air content.[1]

Fig. 3-3. Illustration of pressure testing concrete.

Volumetric Method

The volumetric method (Fig. 3-4) is less commonly used and is based on the removal of air from a known volume of concrete by agitating the concrete in a fixed volume of water-isopropyl alcohol mixture. An aggregate correction factor is not necessary with this test. Care must be taken to agitate the sample sufficiently to remove all air. The addition of one pint or more of alcohol accelerates the removal of air, thus shortening test times; it also dispels most of the foam and increases the accuracy of the test.[1]

Fig. 3-4. Illustration of volumetric air meter for fresh concrete.

ACPA QCast Requirements

When required by specification of local climate conditions, air content test reports shall be maintained for each concrete mix being used in production each day that mix is used. Test frequency shall be performed at a minimum of one air test on the first batch of the day and on subsequent batches as necessary until acceptable batches are produced. The test location shall be at the point of placement.

ACPA CERTIFIED PLANT™ QCAST.org

Additional air tests shall be performed at a minimum frequency of one test per 50 continuous yards of concrete poured. A continuous pour is defined as succession of batches where less than one hour elapses between consecutive batches of a single mix design.

If batching and mixing is interrupted by a batch of concrete (with a different mix design) being mixed between consecutive batches. This is considered a new pour and an air test shall be taken on the first batch following the different batch, unless documentation exists that switching batches does not affect air content beyond specified limits.

Unit Weight Tests of Fresh Wet Cast or SCC Concrete

A balance or scales sensitive to 0.3% of the anticipated mass of the sample and container, and a container (typically the air pot used in air testing) is used to determine the density and yield of freshly mixed concrete. Care is needed to consolidate the concrete adequately by either rodding or internal vibration, for SCC no added consolidation is required. Strike off the top surface using a flat plate so that the container is filled to a flat smooth finish. The density is expressed in pounds per cubic foot and the yield in cubic feet. Yield is determined by dividing the total batch weight by the density.[1]

ACPA QCast Requirements

Per the ACPA QCast requirements and in accordance with ASTM C138, you should maintain a copy of unit weight test results at a minimum of one test per week on each wet cast or SCC mix used that week.

Self Consolidating Concrete Evaluation Methods

Self consolidating concrete is evaluated by looking at three key characteristics: flowability, stability and passing ability. As previously discussed in the Section 1, *Chapter 7: Self consolidating Concrete*.

High flowability is the ability for concrete to flow easily into the finest details of formwork or molds and around reinforcing under its own weight. This is also called workability or filling ability (meaning it fills a form easily). Flowability is impacted by slump flow, viscosity (T20), aggregate shape and ratio, placing methods, and size and configuration of the forms.

Passing ability is the ability to flow through tight spaces, like congested steel reinforcing bars or narrow spots in the formwork, without "blocking." Passing ability is impacted by slump flow, viscosity (T20), aggregate shape, ration and size, placing methods, and form or rebar spacing.

Stability is the big difference between SCC and simply wet sloppy concrete. Stability implies that even at very high slumps (or slump flows) the concrete doesn't segregate, that it remains homogenous and there is no separation of the aggregate from the cement paste. There are actually two kinds of stability: *dynamic stability* (meaning it stays stable while being transported and placed) and *static stability* (meaning it stays stable--the aggregate doesn't settle and it doesn't bleed excessively--while it is in the forms but not yet hardened). Stability is impacted by slump flow, viscosity (T20), aggregate size, ration and specific gravity, powder content, air content, paste content, mortar content, transportation and placing methods, admixture content and water content.

Following is an examination of the tests and standards for each of these SCC characteristics.

Flowability - Slump Flow Test (ASTM C 1611)

Fig. 3-5. Illustration of measuring self consolidating concrete spread in slump flow test.

For SCC the slump cone mold is filled with fresh concrete without rodding. The mold is raised and the concrete is allowed to spread (Fig. 3-5). After spreading has ceased, the average diameter of the concrete mass is measured and reported as the slump flow.

ACPA QCast Requirements

According to ASTM C1611 and the ACPA QCast certification requirements, slump flow tests for self consolidating concrete shall be performed daily at a minimum, on the first two batches and every fourth batch thereafter for each continuing pour, for each SCC mix design used. Additional slump flow tests shall be run if results are outside the desired range, or if any mix component is adjusted.

For each slump flow test, a **relative measure of flow rate and viscosity** as well as a **VSI Index** shall be recorded. For measuring the Flow Rate and Viscosity, using a stopwatch, you will record the time it takes for the outer edge of the concrete to reach a diameter of 20 inches. The VSI Index, on the other hand is a visual estimate of the stability of the SCC, the scale ranges from 0-3, from highly stable to highly unstable.

Stability – Column Segregation Test (ASTM C1610)

Fig. 3-6. Illustration of column segregation test being performed for self—consolidating concrete.

According to ASTM C1610, the column segregation test (Fig. 3-6) for SCC is used to develop self consolidating concrete mixtures with segregation not exceeding specified limits. Self consolidating concrete is a fluid concrete that can be prone to segregation if not proportioned to be cohesive. A cohesive self consolidating concrete is important for all applications but is especially critical for deep-section applications such as walls or columns. Therefore, the degree of segregation can indicate if a mixture is suitable for the application. Some level of segregation is tolerable as long as the desired strength and durability performance is achieved.[2]

This test method covers the determination of static segregation of self consolidating concrete (SCC) by measuring the coarse aggregate content in the top and bottom portions of a cylindrical specimen (or column). This test method is not applicable to self consolidating concrete containing lightweight aggregate. [ASTM C1610.][3]

The column segregation test is conducted by filling concrete into a 26-inch tall, 8-inch diameter column, which is split into 3 sections. The top and bottom sections are 6.5 inches in height and the middle section is 13 inches in height. The concrete is left undisturbed for 15 minutes, after which the concrete in the top and bottom sections is collected and washed over a No. 4 sieve to retain all coarse aggregate. The relative amounts of coarse aggregate in the top and bottom of the column is used as an indication of segregation resistance.[4]

Passing Ability – J-Ring Test (ASTM C1621)

The J-Ring is a measure of the concrete's passing ability—how easily it flows through obstructions and reinforcing. The J-Ring test is standardized as **ASTM C 1621, "Passing Ability of Self Consolidating Concrete by J-Ring."** The J-Ring is a cage of rebar that is set up around the slump cone. The slump flow test is run both with and without the J-Ring in place and the passing ability is the difference in slump flow (Fig. 3-7). A difference greater than two inches indicates poor passing ability.[5]

Fig. 3-7. Illustration of rapid assessment test being performed for self consolidating concrete.

Temperature Tests

Concrete temperature is measured in accordance with **ASTM C1064 – Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete**. The thermometer should be accurate to +/- 1^{o}F (0.5^{o}C) and should remain in a representative sample of concrete for a minimum of two minutes or until the reading stabilizes. At least three inches of concrete should surround the sensing portion of the thermometer. The temperature test should be completed within five minutes after obtaining the sample.

ACPA QCast Requirements

ACPA CERTIFIED PLANT QCAST.org

In accordance with ACPA and **ASTM C1064**, temperature tests shall be taken at the same frequency that cylinders are taken for dry cast methods, and at the same frequency as the slump test for wet cast methods. Additional temperature tests shall be run if results are outside the desired range, or if any component is adjusted. Results should be maintained on file.

Concrete Compression Tests

Compressive strength of cylindrical concrete specimens (ASTM C 39)

Concrete compression tests are performed to determine concrete compressive strength (Fig. 3-8). A number of specimen are prepared from the batch of concrete being tested, the total number of cylinders made will depend on the specific product specification. Two cylinders are tested and the average strength will be used to represent the strength of the concrete. Typical time period for the strength testing can range from 1 day up to 28 days.

The testing procedure is as follows:

1. Measure the diameter of the concrete specimen(s) and calculate the cross sectional area and record.
2. Turn on the machine. Place one concrete specimen in the center of loading area.
3. Lower the piston against the top of the concrete specimen by pushing the lever. Now the piston is on top of the specimen.
4. Begin to apply the load by pulling the lever into holding position. Start the compression test by pressing the zero button on the display board.
5. By turning pressure increasing valve counter-clockwise, adjust the pressure on piston so that it matches concrete compression strength value. Apply the load gradually without shock.
6. Test is complete: Observe the concrete specimen. When it begins to break stop applying load.
7. Record the ultimate load as shown on the machine's display screen.
8. Calculate concrete compressive strength.

Fig. 3-8. Illustration of concrete compression testing equipment.

ACPA QCast Requirements

Compression tests determining concrete compressive strength of wet cast concrete shall be made, according to **ASTM C31**, on standard rodded or vibrated concrete cylinders and cured in like manner as the product (unless otherwise specified by local or project specifications), or on cores drilled from the product. The manufacturer shall have a written procedure for casting wet-cast cylinders.

As per **ASTM C39**, you will maintain copies of compression test results for all mixes used in production. For pipe that are three-edge bearing tested, a minimum of five cylinders per week for each mix design used that week shall be prepared and tested (See *Section 4, Chapter 3 – Finished Product Testing*). For pipe not required to be three-edge-bearing tested, and all other products, a minimum of five cylinders per day per mix design used shall be prepared and tested. For box culvert production, an additional minimum of two cylinders per week shall be cast and tested to verify adequate stripping/handling strengths are being achieved. Stripping strength cylinders shall be cured with the product, or in a like manner.

Compression Tests on Sample Cores Removed from Concrete (ASTM C497 or C42)

To determine the compressive strength of the concrete in the pipe (ASTM C497) or structure (ASTM C42), crushing tests are performed on cores cut from the pipe (Fig. 3-9). The testing procedure is similar to the process testing concrete compressive strength cylinders. Care must be taken when coring the product so as not to create cracks which could skew the results. After the core has been tested, a correction factor is applied based on the height to diameter ratio of the core.

Fig. 3-9. Illustration of core samples removed for concrete for testing.

ACPA QCast Requirements

The method of obtaining cores, the number of cores, and acceptability of core compression test results shall be in accordance with ASTM C497 and the test methods in C42, or as determined by product or specification requirements.

Notes

Section 2: Review Questions

The following questions provide a review of the key concepts introduced in this section. An Answer Key is provided at the end of the questions.

Questions

Chapter 1: Designing Concrete Mixes

1. As a general rule, the mixing water used to make quality concrete ______________________.
   a. Should be potable (drinkable)
   b. Must be distilled
   c. Can be any water obtained anywhere
   d. Can be sea water
2. Which of the following statements is true?
   a. Surface water on batched concrete aggregates is NOT important and does not become part of the mix water.
   b. The surface moisture content on aggregates is equal to the total moisture contained in a sample minus the moisture absorbed within the aggregate.
   c. The w/c ratio of the mix is NOT impacted by the amount of surface water batched with the concrete aggregates.
3. Given 450 lbs of Cement, 100 lbs of Fly Ash and 25 gal of Water per cubic yard of concrete, calculate the w/c ratio of the mix.
   a. 0.46
   b. 0.56
   c. 0.38
   d. 0.27

4. Water/cementitious ratio is____.
    a. Weight of water divided by the weight of fly ash
    b. Weight of water divided by the weight of cementitious material
    c. Weight of cementitious material divided by the weight of water
    d. A name used to describe the amount of air in a mix
    e. The ratio of water reducers to cement
5. If a precast structure is designed to be watertight and durable, w/c should be____________.
    a. Zero
    b. 0.60 or greater
    c. Exactly 0.50
    d. 0.45 or lower
    e. Anything, as long as the mix includes fiber reinforcement
6. Adding too much water to the batch can ____.
    a. Decrease compressive strength
    b. Increase shrinkage
    c. Increase permeability
    d. All of the above
    e. None of the above
7. The stone and sand (coarse and fine aggregates) in your mix design have a combined free moisture percentage of 5%, or 85 lbs of additional water. In order to compensate for moisture, what should be done to the mix design?
    a. Add 85 lbs of cement to "soak up" the moisture.
    b. Do not adjust the mix. Instead, just reduce the vibrating frequency to account for a "wetter" mix.
    c. Reduce the batch water by the equivalent amount of 85 lbs of water.
    d. Nothing needs to be done, this is a normal condition.
8. When the total moisture in the sand is greater than absorption,________________________.
    a. I must add more sand and less water to the batch to maintain design yield.
    b. I must add more sand and more water to the batch to maintain design yield.
    c. I must add less sand and more water to the batch to maintain design yield.
    d. I must add less sand and less water to maintain design yield.

Chapter 2: Batching, Mixing, Handling and Transporting Concrete

1. Is the sequence of feeding the ingredients into the mixer important?
    a. Yes, but only for watertight structures
    b. No, except for architectural concrete
    c. Yes, always
    d. No, never
    e. No one knows
2. For most mixers, which of the following concerning the output of a mixer is correct?
    a. The weight of the output is always more than the sum of the weights of inputs
    b. The output is 2/3 rated capacity
    c. The weight of the output is always less than the sum of the weights of inputs
    d. A 4-yard mixer will always output 4 yards of concrete
    e. A 4-yard mixer can usually output more than 4 yards of concrete
3. True or False, Batching tolerances are not needed for dry cast concrete production?
    a. True
    b. False
4. According to ACI 304, moisture probes should be re-calibrated:
    a. Annually
    b. Quarterly
    c. Monthly
    d. They don't need to be re-calibrated
5. True or False, to avoid segregation, the concrete should be vertically discharged into the center of the bucket or hopper from the mixer at a free-fall distance of no more than six to ten feet.
    a. True
    b. False

Chapter 3: Testing Concrete

1. According to the QCast program, how many times at a minimum should the slump test be performed on wet cast concrete during the production day?
    a. 1
    b. 2
    c. 5
    d. Every five batches
2. What is the accuracy requirement for the thermometer used to check fresh concrete temperature?
    a. +/- 0.1^{o}F
    b. +/- 0.5^{o}F
    c. +/- 1.0^{o}F
    d. +/- 2.0^{o}F
3. When making compressive strength cylinders, how many cylinders are required to be made for dry cast concrete?
    a. 3
    b. 5
    c. 6
    d. 8
4. True or False: Two additional cylinders shall be made weekly to verify box culvert tip out strength.
    a. True
    b. False

Answer Key

Chapter 1: Designing Concrete Mixes

1. a
2. b
3. c
4. b
5. d
6. d
7. c
8. a

Chapter 2: Batching, Mixing, Handling and Transporting Concrete

1. c
2. b
3. b
4. c
5. a

Chapter 3: Testing Concrete

1. a
2. c
3. b
4. a

SECTION 3
CONCRETE PRODUCTS MANUFACTURING

Once the concrete mixture is tested and approved, the manufacturing of the actual concrete products can begin. This section describes the concrete products manufacturing process, which includes reinforcement fabrication, pre-pour inspections, consolidation, and curing. Reinforcement manufacturing is controlled by fabrication, welding, bending and splicing requirements. The pre-pour inspection focuses on the quality and set up of form equipment and reinforcement. Once the pre-pour inspection is passed, the concrete is poured into the forms and consolidated using internal or external vibration equipment, or in the case of SCC no vibration is required. Proper curing is the final step in the manufacturing process which protects the product from loss of moisture and keeps it within a reasonable temperature range, to allow the concrete to hydrate and reach the desired stripping/handling strengths.

The following illustration depicts the key steps in the concrete products manufacturing process.

Page left intentionally blank.

Chapter 1: Reinforcement Fabrication

Reinforced concrete products are composite structures specially designed to use the best features of both concrete and reinforcement. Steel is the most common material used as reinforcement (Fig 1-1), although other materials such synthetic fibers can be used as well for reinforced concrete pipe. The type, size, steel area and placement of the reinforcement are critical to ensure that the reinforced concrete product meets the strength and serviceability requirements of the given project. Steel reinforcement will either conform to ASTM A1064 for wire and welded wire reinforcement, or A615 or A706 for reinforcing bars.

Fig. 1-1. Illustration of concrete pipe reinforcing cages.

Objectives

At the end of this chapter, you will be able to:

- ✓ Differentiate between the three types of wire cages that are fabricated for concrete pipe reinforcement.
- ✓ Explain the wire cage fabrication process.
- ✓ Recall the ASTM specification for the materials used in the manufacture of reinforced concrete pipe, manholes and reinforced box culverts.
- ✓ Recall the ASTM specifications for fabricating the reinforcement in concrete pipe, manholes and box culverts respectively.
- ✓ Interpret mill certifications with respect to welding requirements.
- ✓ Recall the welding requirements for welding rebar.
- ✓ Recall when to use the preheating guidelines for welding rebar.

Welded Wire Reinforcement

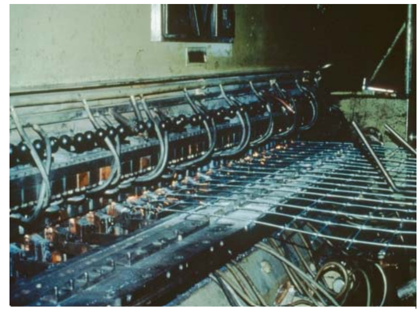


Fig. 1-2. WWR welding machine.

Welded wire is the main material that provides the reinforcement in steel reinforced concrete pipe. Welded wire reinforcement is produced on automatic welding machines (Fig. 1-2) which are designed for long, continuous operation. Longitudinal wires are fed continuously through the machine. Transverse wires, entering from the side or from above the welder, are resistance welded to the longitudinal wires each time the longitudinal wires advance through the machine. The resistance welding completely fuses the two wires together (Fig. 1-3). These automatic machines can produce long rolls of mesh for concrete pipe cages or single sheets typically used for box culvert cages. All welded wire reinforcement must conform to the requirements of ASTM A1064.

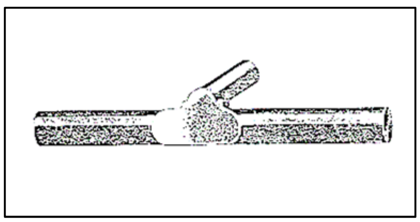


Fig. 1-3. WWR Weld.

The wire producers use different nomenclature than the pipe producers. The longitudinal wire referred to by the wire producer is called the circumferential wire, and the transverse wire is called the longitudinal wire by the pipe producers. This is important for example when discussing issues with the wire producer about the wire mesh that was received at the plant.

Wire Cage Fabrication

The *reinforcement cage* is an assembled unit of **steel reinforcement consisting of circumferential and longitudinal bars or wires.** The cages are produced on mesh bending tables, wire mesh rollers or automated cage welding machines (Fig. 1-4) to ensure tight tolerances for our engineered products. The amount of steel reinforcement is specified by ASTM standards or special designs. The type of reinforcement used depends on production processes and local availability. Reinforcement is provided to the pipe producer by steel companies under certified testing procedures (See Section 1, Chapter 6: Reinforcement)**.**

Fig 1-4. Welding machine for reinforcing cages.

Pipe Cage Nomenclature

The following nomenclature is used to describe the dimensions of the welded wire reinforcement (Fig 1-4). It describes the spacing and size of the circumferential and longitudinal wires, as well as the dimensions of the fabric sheet including longitudinal overhangs.

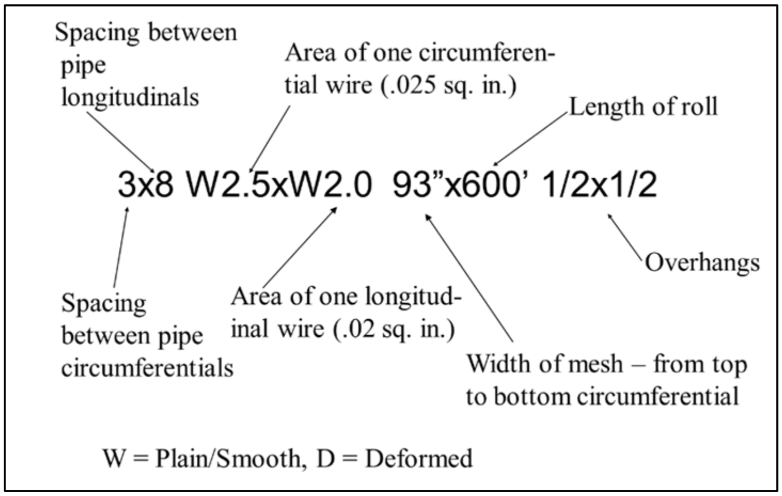


Fig. 1-4. Description of welded wire fabric dimensions.

The wire designation (for example W2.5 as shown below) represents the cross-sectional area of the wire, multiplied by 100. Therefore, to convert a wire designation to a single wire cross-sectional area, divide the designation by 100 (eg. W2.0 wire, 2/100 = 0.02 sq.in.).

Steel Area

Steel Area is a term used to describe the reinforcement in concrete pipe. It refers to the square inches of circumferential steel per linear foot. The formula for steel area is:

$$\textbf{Steel Area } (in^2/ft) = (\textbf{Wire Area } [in^2]) \times 12 / (\textbf{Wire Spacing}(in))$$

For example, given the measurements from the Fig. 1-8 of 3 x 8, W2.5 x W2.0, the steel area per foot of pipe is:

$$\textbf{Steel Area} = 0.025 \times 12/3 = 0.10\ in^2/ft$$

Fabrication Equipment

Cage machines and wire rollers are most commonly used to fabricate reinforcing cages for concrete pipe, and a few producers are also using mandrels to fabricate the cages.

Cage Machines

A cage machine uses cold drawn steel wire supplied on a reel or fed directly into the machine from the drawing die. The longitudinal wires are placed/fed into the adjustable guides. As the machine spins, the circumferential wire is wrapped in a helix around the longitudinal wires. Intersections of the circumferential and the longitudinal wires are automatically welded (Fig 1-5). Depending on the cage machine, the process produces a single cage or a continuous cage, when the desired cage length has been reached, the wires are cut with shears.

Fig. 1-5. Wire Cage Fabrication Machine.

Wire Rollers

Wire Rollers use welded wire reinforcement in rolls with desired size and spacing of longitudinal and circumferential wires (Fig 1-6). Certain rollers can be programmed to produce not only circular cages but also elliptical or arch cages. When the proper length of the reinforcing mesh has been formed by the roller, it is cut and welded to form the cage.

Fig. 1-6. Wire roller used in wire cage fabrication.

Fig. 1-7. Mandrel wire cage fabrication.

Mandrels

A Mandrel (Fig 1-7) can be used to form the reinforcing cage. The mandrel is adjusted to the required diameter. The longitudinal steel is placed on the mandrel, and the circumferential steel is helically wrapped around the turning mandrel. The intersections of the circumferential and longitudinal wires are automatically welded.

Pipe Cage Configurations

Four cage configurations are commonly used in reinforced concrete pipe; single circular cage, double circular cage, single elliptical cage, and a combination of an elliptical cage and one or more circular cages. Additionally, quadrant reinforcement can be used to provide increased steel areas in the tensile zones of the pipe. (Fig. 1-8). Quadrant reinforcement can be provided by overlapping cages and incorporating mats.

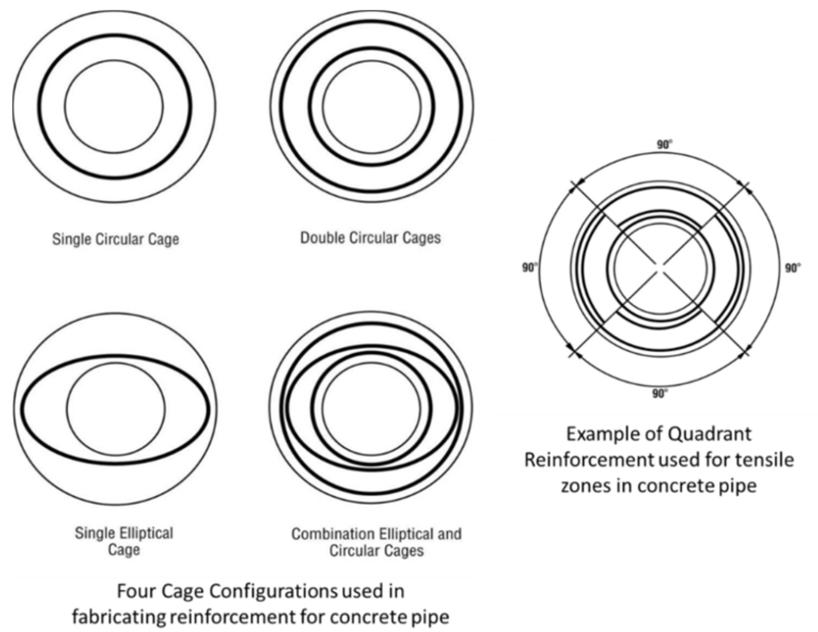


Fig. 1-8. Examples of cage configurations commonly used in reinforcing concrete pipe.

Cage Fabrication Processes

Box Culvert Cages

Fig. 1-9. Wire mesh bender used in fabrication of box culvert reinforcing.

Wire cages for box culverts are fabricated using wire mesh mats which are formed into a box-shaped cage using a mesh bender (Fig. 1-9). The box culvert reinforcement cage is assembled by using either single or multiple layers of welded-wire reinforcement depending on design specifications. Requirements for the separation and fastening of layers are detailed in ASTM C1433 and C1577. Longitudinal distribution reinforcement shall be welded wire reinforcement or deformed billet-steel bars and shall meet the spacing requirements (as described in the requirements for laps welds and spacing). The ends of the longitudinal distribution reinforcement shall not be more than 2 inches from the ends of the box section. The exposure of the ends of longitudinals, stirrups, and spacers used to position the reinforcement shall not be a cause for rejection.

The assembly of reinforcement for box culverts requires that you be familiar with the nomenclature used when discussing the structure of the box as follows (Fig. 1-10):

As1 = Sidewall outside face

As2 = Top slab inside face

As3 = Bottom slab inside face

As4 = Sidewall inside face

As_5 = Top slab inside distribution steel

As_6 = Top slab outside distribution steel

As_7 = Top slab outside face

As_8 = Bottom slab outside face

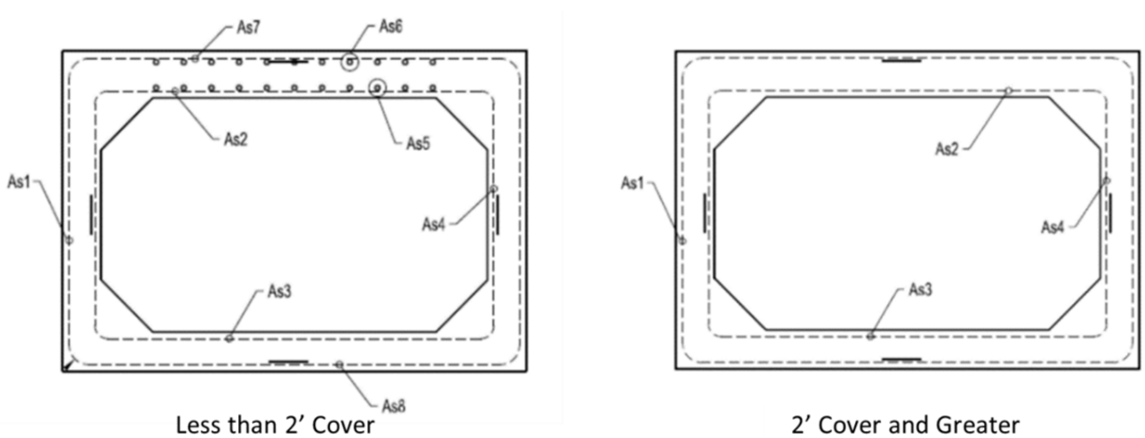


Fig 1-10. Diagram showing box culvert steel area nomenclature.

Manhole Cages

Welded Wire Reinforcement is commonly used for reinforcing risers and conical sections. Conventional Reinforcing Steel (Rebar) is typically used in base slabs and flat slab tops (Fig 1-11). Additional bars should be placed around blockouts. All reinforcement used shall conform to the relevant ASTM Standards, A1064 for WWR and A615 & A706 for Rebar.

Fig 1-11. Typical manhole base section reinforcement.

Hoop Steel Reinforcement (Fig. 1-12) is allowed for reinforcing risers and conical tops up to 48 inches in height and 48 inches in diameter, but not allowed for reinforcing base sections. For risers and conical tops less than 24 inches in height, no fewer than two hoops of steel wire or reinforcing bars should be used. For risers and conical tops greater than 24 inches and less than 48 inches in height, no less than three hoops of steel wire or reinforcing bars should be used. The hoops must have a minimum cross-sectional diameter of 0.250 inches. (ASTM C478)

Fig. 1-12. Hoop Steel Reinforcement.

Precast Plant-Fabrication Welding, Splicing and Bending Requirements

Arc Welding Requirements and Temperature Guidelines

Welding of reinforcement should be performed according to welding requirements as specified to maintain product integrity. There are two weld-ability limits:

1. Maximum carbon content = 0.30%
2. Carbon equivalent (CE)
    a. For #6 And smaller - 0.55%
    b. For #7 And larger - 0.45%

The lower the CE is, the better weld-ability of the steel. For rebar with larger CE value, the rebar must be preheated, if using A615 bars.

Pre-heating Guidelines (if applicable)

If the chemical compositions of the rebar are not known, the following preheating guidelines are offered by ANSI/AWS D1.4.

1. For bars number 6 or less, use a minimum preheat of 300°F.
2. For bars number 7 or larger, use a minimum preheat of 400°F.
3. For all ASTM A706 bar sizes, use tabulated values for CE values over 0.45% to 0.55% inclusive.

Laps, Welding and Splicing

Concrete Pipe

Lapping: "If splices are not welded, the reinforcement shall be lapped not less than 20 diameters for deformed bars and deformed cold-worked wire, and 40 diameters for plain bars and cold-drawn wire. In addition, where lapped cages of welded-wire fabric are used without welding, the lap shall contain a longitudinal wire." [ASTM C76]. Figure 1-13 illustrates the results of improper lap welding.

Fig. 1-13. Example of improper lap/welding.

Welding: "When splices are welded and are not lapped to the minimum requirements above, there shall be a minimum lap of 2 inches and a weld of sufficient length such that pull test of representative specimens shall develop at least 50% of the minimum specified tensile strength of the steel. For buttwelded splices in bars or wire, permitted only with helically wound cages, pull tests of representative specimens shall develop at least 75% of the minimum specified tensile strength of the steel." [ASTM C76/C478]

Box Culverts

Splicing: "Splices in the circumferential reinforcement shall be made by lapping. The overlap measured between the outermost longitudinal wires of each reinforcement sheet shall not be less than the space containing two longitudinal wires of each mesh plus 2 inches, but not less than 10 inches. If A_{s1} is extended to the middle of either slab and connected, welded splices or lapped splices shall be used in the connection." [ASTM C1433/C1577]

Lapping: "When used, A_{s7} and A_{s8} shall be lapped with A_{s1} as shown in Fig. 1-14, Fig. 1-15, or Fig. 1-16 and are not prohibited from being connected by welding. If welds are made to circumferential reinforcement, they shall be made only to selected circumferential wires that are not less than 18 inches apart along the longitudinal axis of the box section. Also, when spacers are welded to circumferential wires, they shall be welded only to these selected circumferential wires. There shall be no welding to other circumferential wires, except A_{s4} is not prohibited from being lapped and welded at any location or connected by welding at the corners to A_{s2} and A_{s3}." [ASTM C1433/C1577]

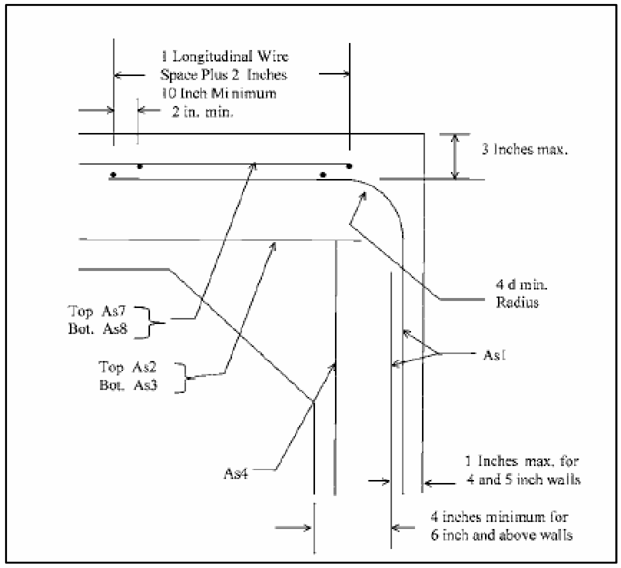


Fig 1-14. ASTM 1433 - Detailed Reinforcement Arrangement.

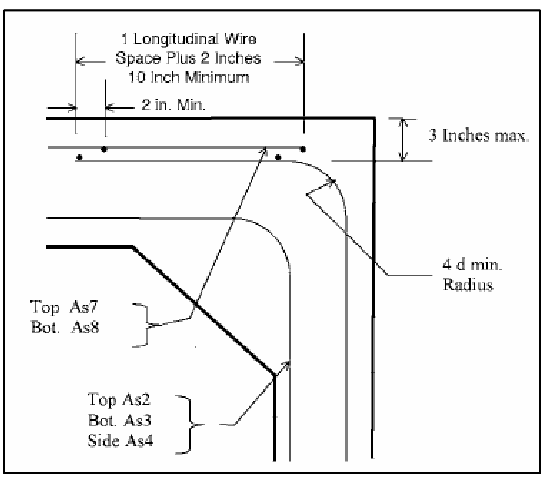


Fig. 1-15. ASTM 1433 Detail Option.

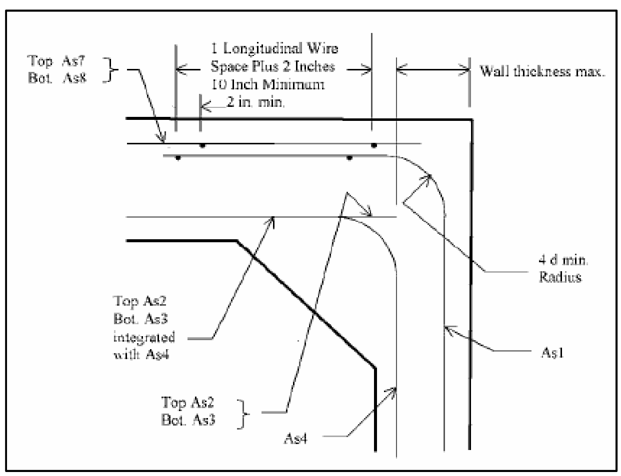


Fig. 1-16. ASTM 1433 – Alternate Detail Option.

Restricted Welding Zones for Box Culverts

"There shall be no welding to other circumferential wires, except A_{s4} is not prohibited from being lapped and welded at any location or connected by welding at the corners to A_{s2} and A_{s3}. No welds shall be made to A_{s2} or A_{s3} circumferential wires in the middle third of the span as shown in Figure 1-17 below. The spacing center to center of the circumferential wires shall not be less than 2 inches nor more than 4 inches. The spacing center to center of the longitudinal wires shall not be more than 8 inches." [ASTM 1433/C1577]

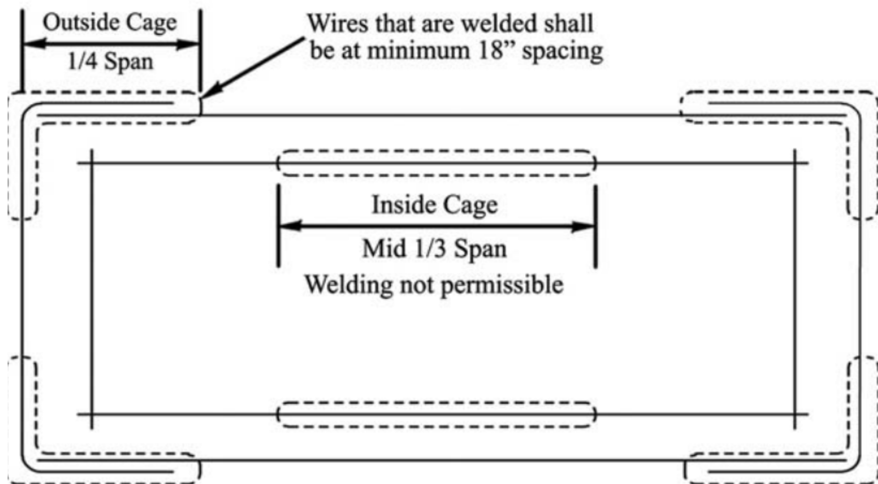


Fig. 1-17. Restricted welding zones for box culverts.

Bending Requirements

All bends are described in terms of inside diameter. The factors affecting minimum bend diameter include the feasibility of bending without breaking and the avoidance of concrete crushing inside the bend. The minimum bending requirements are:

A1064	**C1433/C1577**
W7 and smaller - 1 d_b	**Box Culvert**
All plain wire (w) sizes - 2d_b	WWR Mesh - 4d_b
D6 & smaller - 2d_b	**Rebar**
Larger than D6 - 4d_b	No.3 – No.8 - 6db
	No.9 – No.11 - 8 db
	No.14 and No.18 - 10 db

ACPA QCast Requirements for Reinforcement

As part of the QCast Program, plants seeking QCast Certification need to meet the following requirements as outlined in the Common Program Requirements section in the ACPA QCast Plant Certification Manual.

Reinforcement Design

Detailed design information, including cage diameter tolerances and minimum lap, shall be available in the reinforcing fabrication area for cages/reinforcement being fabricated. Steel reinforcing shall comply with the requirements of the project specifications.

Plants shall maintain on file the following reinforcing design information:

- Mesh Style
- Cage Diameter
- Cage Length
- Steel Area - specified
- Cage Location in the Product Wall
- Cage Lap (welded or tied)
- Bell Reinforcing (convoluted or hoop)
- Shear Steel

Certified Mill Test Reports (Mill Certs)

Mill Certs shall be maintained at a frequency of one per month for each type of reinforcing product. If more than one supplier is used, the documents shall be obtained from all suppliers. The heat number from the mill cert should match the heat number in the tag attached to the bundle of rebar or roll mesh, or the bundle of mesh sheets. In the mill cert illustration (Fig. 1-19), note the test results for C.E. and carbon content to indicate whether the rebar is weldable (without pre-heating) or not, as well as the mills certification that the steel was melted and manufactured in the United States (Buy America).

Page: 1

SOLD TO:

CERTIFIED MILL TEST REPORT

Ship from:

SHIP TO:

Date: 29-Jul-2008
B.L. Number: 363694
Load Number: 209828

Material Safety Data Sheets are available at www.nucorbar.com or by contacting your inside sales representative.

HEAT NUM. *	DESCRIPTION	YIELD P.S.I.	TENSILE P.S.I.	ELONG % IN 8"	BEND	WT% / DEF	C / Ni	Mn / Cr	P / Mo	S / V	Si / Cb	Cu / Sn	C.E.
	PHYSICAL TESTS						CHEMICAL TESTS						
PO# =>	9297												
SE0810245201	Nucor Steel Seattle, Inc.	65,096	96,818	18.0%	OK	-3.6%	.26	.76	.014	.042	.19	.37	.41
	16/#5 Rebar 20'	449MPa	668MPa			.049	.11	.10	.030	.037	.003		
	A706M (A706)												
	ASTM A706/A706M-06a												
	TEN/YD = 1.49												
PO# =>	9297												
SE0810276301	Nucor Steel Seattle, Inc.	66,237	88,094	16.4%	OK	-4.2%	.28	.74	.012	.041	.21	.35	.42
	13/#4 Rebar 20'	457MPa	607MPa			.038	.11	.10	.030	.032	.003		
	A706M (A706)												
	ASTM A706/A706M-06a												
	TEN/YD = 1.33												
PO# =>	july,aug,sept												
SE0810386702	Nucor Steel Seattle, Inc.	65,034	105,911	14.1%	OK	-5.1%	.46	.86	.010	.032	.19	.34	.62
	19/#6 Rebar 20'	448MPa	730MPa			.049	.09	.07	.020	.005	.019		
	A615M Gr 420 (Gr60)												
	ASTM A615/A615M-08 GR 60[420]												

I HEREBY CERTIFY THAT THE ABOVE FIGURES ARE CORRECT AS CONTAINED IN THE RECORDS OF THE CORPORATION.

ALL MANUFACTURING PROCESSES OF THE STEEL MATERIALS IN THIS PRODUCT, INCLUDING MELTING, HAVE OCCURRED WITHIN THE UNITED STATES. ALL PRODUCTS PRODUCED ARE WELD FREE. MERCURY, IN ANY FORM, HAS NOT BEEN USED IN THE PRODUCTION OR TESTING OF THIS MATERIAL.

QUALITY ASSURANCE: ______________________

Fig 1-19. Illustration of a Mill Cert.

Notes

Chapter 2: Pre-pour Inspection

Preparation prior to pouring concrete for pipe, manholes and box culvert entails the visual and dimensional inspection of forms being used, placement and condition of reinforcing steel, and the proper use of materials such as release agents. This is the point in production where it is still possible to make changes to the product. Once the concrete is poured in to the forms it will be too late and any changes will require extensive repairs or re-pouring of the product. Therefore these inspections are critical in ensuring that the finished product meets the design requirements.

Form/Equipment Inspections and **Reinforcement Inspections** are the two main areas of pre-pour inspections. Both have a visual inspection and a dimensional, or measurement inspection. The Form/Equipment Inspection (Fig. 2-1) includes looking at the condition of the equipment, measuring incoming equipment and ensuring proper storage and maintenance of equipment. The Reinforcement Inspection (Fig. 2-2) includes looking at the condition of lap, welds/ties, bells, spacers, and shear steel, measuring the cage diameter and length, and placement of reinforcement.

Fig. 2-1. Example of an equipment dimension inspection being taken.

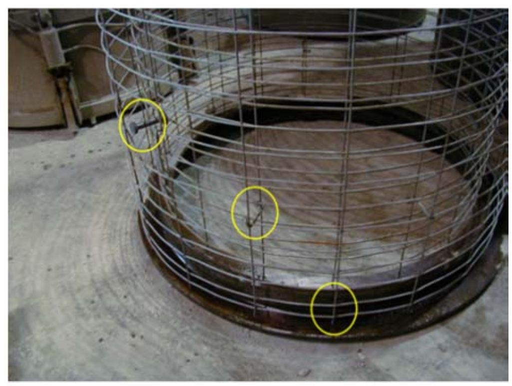


Fig 2-2. Example of reinforcement points of inspection.

It is important to document the pre-pour inspection as a means of legal record and quality control. It also allows others to duplication our successes, analyze our failures and prove our compliance to industry standards. A number of pre-pour inspections forms have been provided in the Appendix of the ***ACPA QCast Certification Manual*** for your use. Other required documentation includes initial shop drawings for pre-cast structures and documentation of sanitary sewer pipe and manhole spigot gasket-sealing surface measurements (go/no go).

Objectives

At the end of this chapter, you will be able to:

- ✓ Identify the two main areas of pre pour inspections.

- ✓ Name the areas of focus when inspecting forms and reinforcement respectively.
- ✓ Identify areas to check when inspecting reinforcement.
- ✓ Recall how often forms should be inspected.
- ✓ Explain the purpose of a release agent.
- ✓ Distinguish between barrier release agents and chemically active release agents.
- ✓ Explain what seasoning is and how it's used.

Precast Pipe and Manhole Inspections

Pre-pour inspections for precast pipe and manholes are performed to ensure the production of a quality product that meets customer specifications and expectations. A qualified individual should make visual and dimensional inspections prior to each pour and correct any deviations prior to the start of placement activities. In general, pre-pour operations include:

- Cleaning, preparing and setting forms.
- Positioning steel reinforcement according to structural design specifications.
- Placing blockouts.
- Positioning and securing embedded items.

The following sections outline the specific items to inspect both visually and dimensionally for concrete pipe and manholes in accordance with ACPA QCast Certification requirements.

Form/Equipment Inspection

Forms that are properly designed, cleaned, maintained and stored are essential to producing a quality product. Visual and dimensional inspections are the key to ensuring that the forms are in proper condition, adequately braced and constructed in a manner to result in the desired dimensions and finish of the product being produced.

Visual Inspection

Prior to pouring concrete into pipe or manhole forms, it's important to take a close look at the forms to make sure they are in the proper condition and dimension according to product specifications. Visual inspections of forms and equipment should include looking for:

- Cleanliness to ensure that there is no excess build-up, rust, or other impurities on the form (Fig. 2-3).
- Proper condition of the form or equipment

Fig 2-3. Example of a dirty joint ring.

with respect to chips, cracks, or other damage that will impact a uniform finish.

- Proper placement of vibrator mounts, seams, gates, lifting devices, latching devices, bolts and welds, step holes and, and plugs are in proper working condition.

Dimensional Inspection

Dimensional inspections of forms and equipment occur prior to each use and include looking at and verifying the form and equipment for proper shape and roundness. Forms and equipment should also be inspected to ensure that the proper size and dimension required is being used.

Proper storage/maintenance

It is also important to inspect the forms and equipment after each use to ensure that they are kept clean and free of concrete build-up. This includes:

- Storing headers/pallets flat (storing on end will result in the equipment being out of tolerance). (Fig. 2-4)
- Keeping the equipment/forms covered or coated while it is being stored.
- Periodically sandblasting, priming and re-painting equipment/forms.
- Cleaning after each use.

Fig. 2-4. Illustration of improper storage.

Reinforcement Inspection

Visual Inspection

"Visual inspection of reinforcement starts with the mill test report, which in some cases is supplemented by a report from an independent testing laboratory. Both reports should provide data as to grade of steel, tensile properties (yield strength, ultimate tensile strength, and percentage of elongation), bend tests, chemical composition and carbon equivalent (C.E.) in the event the reinforcing bars are to be welded, and the spacing and height of deformations."[1] The report should also certify that the reinforcing meets the "Buy America" requirements of being melted and manufactured in the USA.

For rebar, a visual examination of the mill markings on a bar will identify the producing mill, the bar size, the type of steel, and the grade of steel. The placement of the bars in the form is done by visual examination of the layout pattern, and by measurement of cover, spacing and the number of bars. The bar diameter and the bar shape, if bent, can be visually checked. Bar lengths, bar spacings, embedments, and bearings on walls or beams are normally checked by measurement and should comply with the requirements of the project specifications.[2]

Visual inspections of reinforcement should include looking for:

- Properly fabricated lap, welds and ties (Fig. 2.5)
- Proper reinforcing of the pipe bell
- Proper placement of spacers
- Shear steel, when used

Fig 2-5. Example of a poor lap/ weld.

Dimensional Inspection

The ACPA QCast Certification program requires that you maintain reports documenting the inspection of reinforcing used for each size and class produced. At a minimum, measure and document one cage at the start of each production run, one cage at the start of each new shift after that, and one cage if any component or setting is changed.

This dimensional inspection should include:

- Verifying the style, steel area and dimensions of the reinforcing steel.
- Verifying the cage diameter, length and location according to design.

Additional Inspections for Manholes and Precast Structures

The design, tolerances and location of embedded items and blockouts should be inspected and documented on the shop drawing.

Embedded Items

All embedded items should be inspected for proper placement and type required for the intended use of the product and as specified on the drawing. Inspection can be documented by initialing the shop drawing.

Blockouts

Blockouts (Fig. 2-6) may be made of any rigid, non-absorptive material that will not harm the concrete and that can be held in place during the casting and curing of concrete. These materials include:[3]

- Aluminum
- Ceramic
- Plastic
- Fiberglass
- Steel
- Wood

Figure 2-6. Illustration of blockouts placed on a manhole core.

- Rubber
- Neoprene
- Styrofoam

Dimensional tolerances should be specified for each product and blockout type. Blockouts should be held in place during casting with non-corrosive supports and not with reinforcing steel.

Blockouts must be properly designed and secured to withstand placement stresses, achieve design location of the hole, and achieve adequate concrete cover for all reinforcement. Blockout inspection guidelines include looking for the following:[3]

- Flush contact between form and blockouts
- Form is clean and in good shape
- Blockout is clean and in good shape
- Properly applied Release Agents
- Blockouts sized as specified
- Blockout surface exposed to concrete smooth and solid
- Blockout width = Structure wall width

Box Culvert Inspections

Pre-pour inspections for Box Culverts involve essentially the same Form/Equipment Visual Inspection and Reinforcement Inspection requirements as those outlined for Pipe and Manholes. However, there are a few inspection areas that are unique to equipment and reinforcement used in the production of box culverts.

Form/Equipment Inspection

In addition to the pre-pour inspection items listed for pipe/manhole, there are few additional items to check with respect to box culvert production with respect to verifying the dimensions per specification.

Dimensional Inspection

In addition to the dimensional inspection items listed for pipe and box, the following measurements should be taken and verified:

- Thickness of top, bottom and side walls of the form
- Core rise and span
- Both core diagonal measurements
- Document measurements

These measurements should be recorded on the "Box Culvert or Three-Sided Pre-Pour Inspection" form which can be found in Appendix A of the *ACPA QCast Certification Manual*.

Release Agents

The pre-pour inspection of pipe, manholes and box includes ensuring the proper application of release agents to the forms. The purpose of release agents is to:

- prevent hardened concrete from adhering to the form;
- provide form protection; and
- improve product appearance.

Release agents, when properly used, aid in the stripping process, assist in producing sound defect-free concrete surfaces, simplify form cleaning and increase the working life of quality form surfaces.[4] There are two main categories of form release agents: **Barrier** and **Reactive**.

Barrier Release Agents

Barrier release agents provide a physical barrier between the form and the concrete (such as petroleum-based products, soaps, synthetic resins, waxes). There are advantages and disadvantages to using these agents:

- The advantage to using barrier release agents is that they create a physical barrier between form and fresh concrete.
- The disadvantages to using barrier release agents are that they:
- Require a heavy application for easy release (200-400 ft^2/gal).
- Can cause staining and bugholes.
- May not meet volatile organic content (VOC) requirements.
- Can cause buildup on forms.

Reactive Release Agents

Reactive release agents contain fatty acids or other ingredients that react with the free lime in fresh concrete to produce a metallic soap interface between the form and the concrete (such as proprietary products and vegetable oils that are typically found in petroleum-based carrying agent products). There are also advantages and disadvantages to using reactive release agents:

- The advantages to using reactive release agents are that they:
- prevent bonding of concrete to form.
- provide Ultra-thin Layer (≈0.005").
- reduce bugholes, stains, dusting.

- typically meets VOC requirements (verify).
- The disadvantage to reactive release agents is that they are typically more costly per gallon.

Poor application of release agents can have a damaging effect on the finish of the product (Fig 2-7). For that reason, it is important that you follow the manufacturers' recommendations for proper application and make sure that the appropriate amount is being applied. It is best to start with a clean form before the reinforcement has been applied to minimize the chance of the release agent coming into contact with the reinforcement. The less that is applied, the better chance there is of any release agent being inadvertently applied to the reinforcement. If this happens, it should be wiped clean before placing the concrete.

Fig. 2-7. Illustrating of the end of a bell, where concrete stuck to the pallet and pulled from the pipe, as a result of not having enough release agent.

Seasoning

The most common form of release agents used in precast and pipe production are the those that contain mild fatty acids, called *reactive* form release agents. These release agents react with the metal in the reinforcement to form a protective coating called metallic oleate (Fig.2-8). This reactive process is known as "seasoning." The process of seasoning happens when the fatty acids in the release agents react with the metal in the form to create a protective coating. This coating helps to keep the fatty acid on the product surface where it reacts with the free lime and away from the metal in the form. Frequently, a coating may have been applied to forms prior to transit to help prevent rusting until they are sold or delivered. This coating must be removed, either with solvents or grinding, before the release agent can be applied liberally and allowed to set for 24 hours.

Figure 2-8. Illustration showing the application of the form release agent.

The primary purpose for seasoning is two-fold: it makes it easier to release the form from the product and thus reduces the amount labor needed to strip or tip out from the forms; and secondly, it allows the free air to rise more freely from the surface thereby minimizing few defects on the surface. Release agents may also be applied as a protective coating on equipment being stored for short or long periods of time. For this type of coating, a biodegradable type is preferred in case some is spilled or splashed onto the ground.

Notes

Chapter 3: Consolidation

As the concrete is placed into the forms, the process of consolidation begins. Consolidation, as it relates to concrete, is the *process* of packing the mix by removing the air in the concrete, which if left in the concrete could result in undesirable rock pockets, honeycomb, and entrapped air (Fig. 3-1). However, care should be taken so as not to destroy the air void matrix when working with intentionally air-entrained concrete.

Fig. 3-1. Example of defects in concrete due to improper consolidation.

Proper consolidation results in the even distribution of all ingredients in the concrete mix. The process of consolidation should not be confused with the process of "compaction", which results in the reduction of size or volume. Consolidation is the process of removing the air, whereas compaction is the dynamic process of "densification" as the air is removed, resulting in very dense concrete, the desired state to achieve. Therefore, good consolidation allows for better compaction.

Objectives

At the end of this chapter, you will be able to:

- ✓ Explain the purpose and importance of consolidation in the concrete production process.
- ✓ Describe the different methods of vibration.
- ✓ List the factors to consider when selecting the appropriate vibration method for curing.
- ✓ Differentiate between the characteristics of proper vibration and improper vibration.
- ✓ Recognize the effects of over vibration.
- ✓ Recognize the effects of under vibration.
- ✓ Explain the important differentiation between wet cast and dry cast vibration systems.

Consolidation as it Relates to Concrete

In the production of concrete pipe, manholes and box culverts, vibration (internal or external) is the most widely used method for consolidating concrete. The purpose of vibration is make the concrete more fluid. When vibration is applied to the concrete, pressure waves from the vibration separate the aggregate particles thereby reducing friction. It also drives out the air as the concrete the concrete settles, which increases density resulting in optimum strength, durability, water tightness and quality appearance.

Consolidation through Vibration

Why Vibration?

As established, voids will reduce the strength of the concrete when not properly consolidated, regardless of the water/cement ratio. Figure 3-2 illustrates how substantial this effect can be. Depending on the mix type, slump, how it's placed and other factors such as reinforcement, field placed concrete can contain anywhere from 5% to as much as 20% entrapped air. Given a constant water to cement ratio, each percent of entrapped air will decrease the compressive strength of the concrete anywhere from 3% to 5%. By vibrating the concrete mix, the air is driven out of the concrete thereby increasing the strength while decreasing the concrete's permeability.

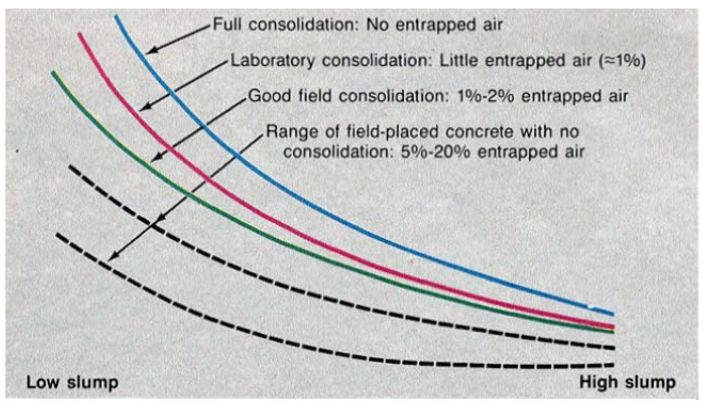


Figure 3-2. How vibration impacts compressive strength

Theory Behind How Vibration Works

To understand how vibration works, you must understand the six characteristics that contribute to vibration:

1. Mass: an unbalanced weight in the vibrator head that creates the vibration.
2. Amplitude: the distance that the vibrator will influence the concrete; it is affected by frequency, i.e., higher the frequency the lower the amplitude or the lower the frequency the higher the amplitude. This amplitude is affected by the Centripetal acceleration of the weight.
3. Centripetal Acceleration: moving with uniform acceleration in a circular direction.
4. Frequency: how fast the vibrator shaft rotates at either revolutions per minute (RPM) or vibrations per minutes (VPM).
5. Force: the pounds of impact that the vibrator puts into the concrete.
6. Resonance: when all of the materials vibrate together.

Given the mass inside the vibrator, a frequency is determined. The frequency effects the lighter mass in the concrete (moves the paste) and governs the liquefaction. The amplitude (as impacted by the frequency) affects or moves the heavier mass (i.e., aggregate, Fig. 3-3) and determines the radius of action by the vibrator. The amplitude is affected by the centripetal acceleration which results in the force of the vibrator. It is through the working of this force that the concrete is consolidated.

Amplitude	Frequency
Effects heavier mass	Effects lighter mass
Moves the aggregate	Moves the paste
Determines the radius of action	Governs liquefaction

Fig. 3-3. How Amplitude and Frequency of vibration affects concrete.

Consequences of Improper Vibration

As established, proper consolidation results in the desired density and strength of concrete. However, improper vibration, be it *under vibration* or *over-vibration*, can result in a variety of defects.

Over-vibration

Over-vibrated concrete looks and feels wet on the surface due to the layer of mortar without coarse aggregate. This rarely occurs in dry-cast production and therefore is not a significant concern in the production of pipe, box culverts and other precast structures. In wet-cast production, if segregation due to over-vibration is observed, the slump of the concrete should be reduced to mitigate the issue.

Defects from over-vibration include: (1) segregation as vibration and gravity causes heavier aggregates to settle while lighter aggregates rise; (2) sand streaks; (3) loss of entrained air in air-entrained concrete; (4) excessive form deflections or form damage.

- **Segregation** happens when the vibration and gravity cause heavier aggregates to settle while the paste rises to the surface. The resulting concrete is weak, inconsistent and poor durability.
- **Sand streaks** results when heavy bleeding washes mortar out from along the form. A wet, harsh mixture that lacks workability because of an insufficient amount of mortar or fine aggregate may cause sand streaking.
- **Loss of entrained air** can affect the durability and strength of the concrete and leave it vulnerable to destructive weathering. As you recall from Section 1, Chapter 5, air entrainment is used to protect the concrete from damage due to freezing and thawing. Loss of the air entrainment may result in not only internal damage but also a loss in strength.
- **Form deflection and damage** results in defects in the product and can also be expensive for the manufacturer when resulting repairs or even form replacement have to be made prematurely.

Under-vibration

If the vibration is stopped too soon, some of the smaller air bubbles won't have time to rise to the surface. Vibration must continue until most of the air entrapped during placement is removed. As a result, some of the defects that may be caused by under-vibration include: (1) honeycomb; (2) excessive amount of entrapped air voids, often called bugholes; (3) and unbonded reinforcement. These defects may result in poor appearance or, even more importantly, inadequate concrete strength and durability.

Figure 3-4. Illustration of honeycomb in finished concrete.

Honeycomb happens when the spaces between coarse aggregate particles do not become filled with mortar (Fig. 3-4). Faulty equipment, improper placement procedures, a concrete mix containing too much coarse aggregate or congested reinforcement can cause honeycomb.

Fig. 3-5. Illustration of bugholes in

Excessive entrapped air voids (bugholes as shown in Fig. 3-5) are similar to, but not as severe as honeycomb. Excessive entrapped air voids are primarily due to vibratory equipment and how it's operated, but the other causes associated with honeycomb may apply as well.

Vibration Methods

As established, proper vibration is used because it increases density by driving out entrapped air (vs. entrained air which we want to remain). This results in optimum strength, durability, water tightness, and a quality appearance. When performed properly, vibration will eliminate voids and honeycomb, release entrapped air and more fully encase reinforcement, embedded items and blockouts in fresh concrete.

Vibration Methods

There are a variety of methods that can be used to consolidate concrete. Selecting the optimal method to select will depend upon the concrete mix design, the casting method (dry-cast or wet-cast) and the type of product being produced. Dry-cast vibration is very different from wet-cast vibration. For example, dry-cast forms are designed for specific vibration systems, therefore, it is important not to mix and match dry and wet-cast systems, as each are meant to accomplish different results.

Proper consolidation is also affected by selection of the proper vibrator (weight settings, direction of rotation), its proper mounting and the method chosen. The type and size of the vibrator must match the requirements of the concrete and the formwork. For example, if the mix is harsher or stiffer, it will require a vibrator that provides more power. Conversely, if the mix has more flowability, a vibrator that has less power should be selected.

External vibration can be accomplished with forms and tables, these vibrator systems are mounted on external and/or internal forms, while some systems utilize a vibrating table that imparts vertical vibratory forces to the concrete. Always consult with the form equipment manufacturer for proper placement and sizing of vibrators.

All vibrators should be adequately secured, and the formwork should be sufficiently sturdy to resist the repeated vibration and/or shock loads. Locking mechanisms are recommended on connectors (i.e., bolts), as needed.

Internal Vibration

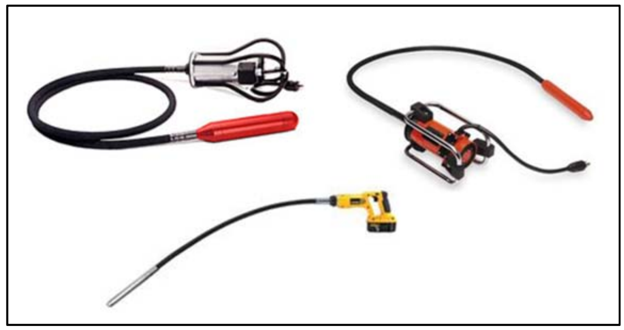


Fig. 3-6. A variety of Stinger Vibrators used in consolidating concrete.

Internal vibrators, also called stingers (Fig. 3-6), are commonly used commonly used for smaller wet cast items and flat work such as concrete in walls, columns, beams, and slabs. They have a flexible-shaft that connects the vibrating head to a driving motor. Inside the head, an unbalanced weight connected to the shaft rotates at high speed, causing the head to revolve in a circular orbit. When selecting a stinger, consideration should be given to size and frequency. Stinger vibrators usually have a very high frequency of 10,000 to 17,000 vpm, which typically decreases by 20% when inserted into the concrete. As a rule of thumb when selecting size, the head diameter should be approximately one quarter of the size of the wall thickness.

Stinger Operation. Proper use of the internal vibrator is important for best results. Follow these steps to ensure the the proper use of the stinger and effectiveness of the vibration.

1. Start the vibration when the stinger is completely submerged into the concrete.
2. Completely immerse the stinger into the concrete. Immerse vertically and quickly (about one foot per second), but withdraw slowly (about three seconds per foot). Put the stinger into each area of concrete only once. Caution: Never drag a stinger horizontally through the concrete as this will create a mortar channel in the concrete, thus making it structurally weak in that area of the finished product.
3. Overlap the "field of action" (vibrating radius) throughout the pour (Fig. 3-7). This will ensure that the concrete is uniform throughout and no pockets of air are left in the concrete which could be detrimental to the finished product.

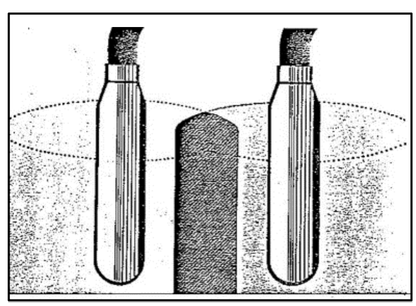


Fig. 3-7. Illustration of stinger overlapping field of action.

4. When concrete is poured in layers, place the stinger

about four to six inches into the previous layer.

5. Stop vibration when the surface becomes shiny and there are no more breaking air bubbles.

External Vibration

External vibrators do not get immersed in the fresh concrete, they are placed on the external and/or internal forms, as well as vibrating tables. External vibrators are best for very stiff mixes or thin/congested formwork where internal vibrators can't be used. The size and the number of vibrators needed on a given product will vary by plant, forms size and raw materials. It is recommended that you work with your equipment suppliers on sizing the vibrators.

Fig. 3-8. Illustration of different types of form vibrators.

Form Vibrators

Form vibrators are attached to the internal and/or external formwork. The vibrators can be either pneumatically, hydraulically, or electrically operated (Fig. 3-8.). The vibrator output, usually expressed as a frequency, is controlled in a different way for each type of vibration:

- An electric vibrator uses voltage,
- A pneumatic vibrator uses air pressure, and
- A hydraulic vibrator uses pressure and flow rate of hydraulic fluid.

Fig. 3-9. Example of vibrator mounting bracket welded to the form stiffeners.

Selection Size and Location. The vibrators should not be fastened directly onto the form. Instead, mounting brackets should be welded onto a form stiffener with the vibrator attached to the mounting bracket (Fig. 3-9). When attaching vibrators to forms, the bolts must be properly torqued according to the manufacturer's recommendations. If the attachments are not properly fastened and are loose, then significant vibration energy may be lost, resulting in inadequate consolidation. It is recommended that you check with the supplier for orientation and location of vibrators on forms and/or the number of vibrators to use.

Vibrators should be mounted in the most optimum locations where the intensity of vibration is distributed uniformly over the form. It is recommended that form vibrators be equipped with controls to regulate their frequency and amplitude in order to achieve best results.

Form Operation. For effective operation following are a few tips:

- Fully tie the rebar cages to ensure that their positions are maintained during the consolidation effort and to reduce the potential for adverse vibrations that could compromise the concrete-rebar bond.
- Ideally start when concrete is 6" above vibrator (which may not always be the case).
- Stop when concrete is level, glossy surface, and there are no more large breaking bubbles.
-

Table Vibrators

Vibration tables (Fig. 3-10) are commonly used but only in the precast industry. Vibration tables are rigid decks mounted on flexible supports which operate at 3,000 to 6,000 vibrations per minute (vpm). Specialized equipment, with product-specific benefits, is also available to provide more uniform control and greater overall economy if needed.

Fig. 3-10. Illustration of a vibrating table.

Table vibrators vary according to the type of vibrator and whether the concrete is wet or dry cast. Eccentric shaft to shaker tables utilize rotary or linear vibrators are used for wet-cast concrete to tables. Table vibrators for dry-cast concrete provide unidirectional vibration forces, where all of the vibration forces are vertical (up and down), while the horizontal vibration is zero. It is important for the vibration forces to be unidirectional to avoid "walking" the concrete, where the concrete moves horizontally instead of being consolidated vertically. It is suggested that there be at least two rotating in opposite directions.

Sizing. As a general rule, for dry-cast concrete, the vibrator should be sized with an impact force that is 1.5-2 times larger than the total weight of the concrete and the form, but specific supplier recommendations should be followed.

Notes

Chapter 4: Curing

As soon as the concrete is mixed and the concrete product is formed, the curing process begins. Curing is more than just the hardening of concrete, it is a chemical process where the cement and water react together to form calcium silicate hydrate (C-S-H), the "glue" that holds the concrete together. Proper curing of the concrete is critical to ensure that the final hardened concrete properties are achieved (Fig. 4-1). Poor curing practices can lead to lower concrete strengths and permeability, cracking, poor resistance to various environmental conditions, and overall inferior durability. Proper curing will increase the following hardened concrete properties:

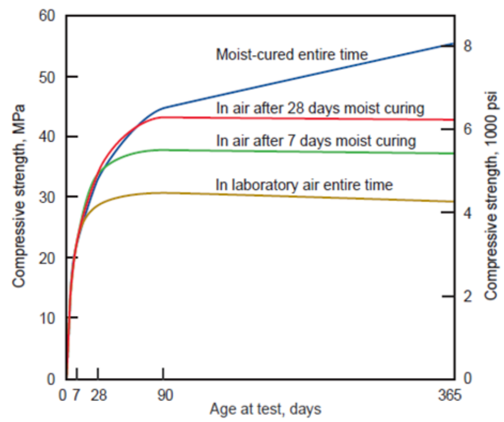


Fig. 4-1. Effect of moist curing time on strength gain of concrete (Gonnerman and Shuman 1928).

- Durability
- Strength
- Watertightness
- Abrasion resistance
- Volume stability
- Resistance to freezing, thawing and deicers

Objectives

At the end of this chapter, you will be able to:

- ✓ Explain the impact that proper curing has on concrete.
- ✓ Recall the methods of curing.
- ✓ Describe the essentials for proper curing.
- ✓ Describe the methods for accelerated curing and when to use them.
- ✓ Describe the typical accelerated steam curing cycle.
- ✓ Explain the guidelines for curing wet cast vs. dry cast products.
- ✓ Recall the target temperatures for concrete pipe and precast/prestress products respectively.
- ✓ Describe the curing guidelines under hot and cold weather conditions.
- ✓ Describe "flueing."

Curing Methods

Depending on the production method, the concrete product is either cured while in the form or immediately removed from the form and cured. Curing is accomplished by a variety of procedures. In some cases, the product is placed in a permanent kiln, and in other cases, the product is covered by canvas, plastic, or other material which functions as a kiln. Regardless of the method chosen, the key to proper curing is to maintain adequate moisture and temperature conditions in the concrete. We will look at the following three curing methods:

- Maintaining moisture by wetting
- Prevent moisture loss by sealing
- Accelerated curing

Maintaining Moisture by Wetting

This method includes spraying or fogging, and saturated wet coverings that afford some cooling through evaporation, which is beneficial in hot weather.

Spraying or Fogging

Spraying or Fogging with water are excellent methods of curing when the ambient temperature is well above freezing and the humidity is low. According to PCA's *Design and Control of Concrete Mixtures,* "a fine fog mist is frequently applied through a system of nozzles or sprayers to raise the relative humidity of the air thus slowing evaporation from the surface" (Fig. 4-2).[2]

Caution: If using a Jay Bird, they must be high enough to avoid air movement that will crack the pipe.

If spraying is done at intervals, the concrete must be prevented from drying between applications of water by using burlap or similar materials; otherwise alternate cycles of wetting and drying can cause surface crazing or cracking.[3] Water should also be proper temperature to avoid cracking the pipe if the water is too cold.

Fig. 4-2. Illustration of a fogging/misting system.

Wet Coverings

Fabric coverings saturated with water, such as burlap, can be used for curing when applicable. Wet burlap should be placed as soon as the concrete has hardened sufficiently to prevent surface damage. The burlap should cover the whole exposed concrete surface and be kept continuously moist so that a film of water remains on the concrete surface throughout the curing period.[4]

Preventing Moisture Loss by Sealing

When using a sealant to cure concrete, methods for doing so include leaving the forms on the concrete, using plastic sheets, or applying membrane-forming curing compounds.

Forms

Forms provide satisfactory protection against loss of moisture if the top exposed concrete surfaces are kept wet. The forms should be left on the concrete as long as practical.[5]

Polyethylene Tarps

Plastic sheet materials, such as polyethylene film, can be used to cure concrete. Polyethylene film is a lightweight, effective moisture retarder and is easily applied to complex as well as simple shapes (Fig. 4-3).[6] Polyethylene film may also be placed over wet burlap or other wet covering materials to retain the water in the wet covering material. This procedure eliminates the labor-intensive need for continuous watering of wet covering materials.[7]

Fig. 4-3. Illustration of polyethylene film being used as an effective moisture barrier during concrete curing.

Curing Compounds

Liquid membrane-forming compounds can be used to retard or reduce evaporation of moisture from concrete. Curing compounds should be applied by hand-operated or power-driven spray equipment immediately after final finishing of the concrete. The concrete surface should be damp when the coating is applied. On dry, windy days, or during periods when adverse weather conditions could result in plastic shrinkage cracking, application of a curing compound immediately after final finishing and before all free water on the surface has evaporated will help prevent the formation of cracks. If the curing compound is not membrane forming, there is a potential for moisture loss.[8]

Accelerating Curing

This curing method is usually accomplished with live steam or dry heat from such objects as heating coils, or electrically heated forms or pads.

Steam Curing

Steam curing is advantageous where early strength gain in concrete is important or where additional heat is required to accomplish hydration, as in cold weather.

A typical steam-curing cycle consists of (1) **Preset** - an initial delay prior to steaming, (2) **Ramp** - a period for increasing the temperature, (3) **Hold (or soak)** - a period for holding the maximum temperature constant, and (4) **Cool down -** a period for decreasing the temperature (Fig 4-4.). Concrete is very sensitive to rapid temperature changes, changes in excess of 40 F per hour can cause thermal cracking in the concrete. Therefore it is critical that proper temperature ramping periods are followed during both the initial ramping phase as well as the cool down phase of the accelerated curing cycle.

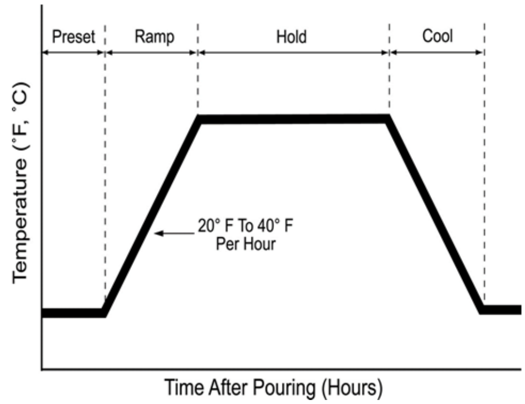


Fig. 4-4. Illustration of a typical steam curing cycle.

Dry Heat

Dry heat can also be used to accelerate the curing process. Dry heat systems can be effective as long as the environment is humid enough to ensure moisture doesn't evaporate from the product while curing. Dry heat with low humidity can crack the concrete. It is absolutely essential that the product doesn't lose any of the mix water that is so necessary to ensure hydration of all the cementitious particles. However, it should be used with caution: difference between accelerated curing and maintaining heat, the temperature needs to be at least 120°F to effectively accelerate curing. As a rule of thumb, every 18°F increase in temperature will double the rate of hydration. The types of equipment used in this method include: (1) Heated beds (hollow core), (2) Electric or gas heaters for producing convection heat, and (3) Infrared heating for producing radiant heat. Blower heaters are not recommended, because the dry air flowing over the product will cause evaporation of mix water from it. The use of heat blankets, electric heat and radiant heaters are examples of effective sources of dry heat as long as misting systems are utilized to provide a humid environment.

Target Temperatures and Special Conditions

Following are the desired concrete target temperatures:

- Concrete pipe should be 120°F to 140°F (50°C to 60°) for 4 to 6 hours.
- Precast/prestress products should be 140°F (60°C) in Canada and 160°F (71°C) in the United States for 8 to 12 hours.

Keep in mind that these temperatures are actual concrete temperatures, not air temperatures.

Special attention should be given to the curing guidelines for wet cast and dry cast products.

- For wet cast products, forms should remain in place as long as possible. Special care should be given to managing concrete and curing temperatures. Caution should be used for any thin sections with openings. It is always best to check with your supplier when using accelerated admixtures.

- For dry cast products, there must be a humidity level of 90% to 100%. These products have a shorter preset period and must be protected from drafts.

Following are a few guidelines to follow for hot and cold weather curing:

- For hot weather curing: utilize shade or sprinkle coarse aggregates; add ice to mix water or use water chiller; shelter product from direct sunlight.
- For cold weather curing: keep fresh concrete temperature > 50°F; heat aggregates; heat water.

Flueing Prevention

Flueing prevention has a direct effect on energy cost reduction. To prevent flueing, you will need to monitor what happens in the curing cell. This includes ensuring that direct steam only flows out at the bottom. This means that no steam leakage should occur along the sides or through the top of the cell.

Fig 4-5. Illustration of flueing--the problem of energy and stem being released out the top.

If there are holes in the sides or top of your curing hoods, you are likely “flueing” energy and wasting money. When the hood is filled with steam, the steam will escape through one or more holes by setting up what resembles an invisible flue pipe (Fig. 4-5). Once a flow has been established through a particular hole, the energy will rapidly escape. Energy may flue through one hole one day but through a different opening the next. Take a few minutes to immediately seal the holes with tape or replace with new material. Flueing will also occur in conventional kiln structures, through leaks in the block walls and through poorly sealed doors.

Mel’s Method for Detecting Flueing (Fig. 4-6): To check for flueing, light a match or cigarette, lift the kiln enclosure and observe the direction of the smoke. If the smoke flows into the kiln, you have flueing problems. You can also check for flueing based on the condition of the floor. If the floor of the cell is cold and dry, cold air will be pulled into the cell and flueing will occur (smoke flowing out of the cell). If the floor is warm and wet, steam will flow out of the kiln bottom and no flueing will occur.

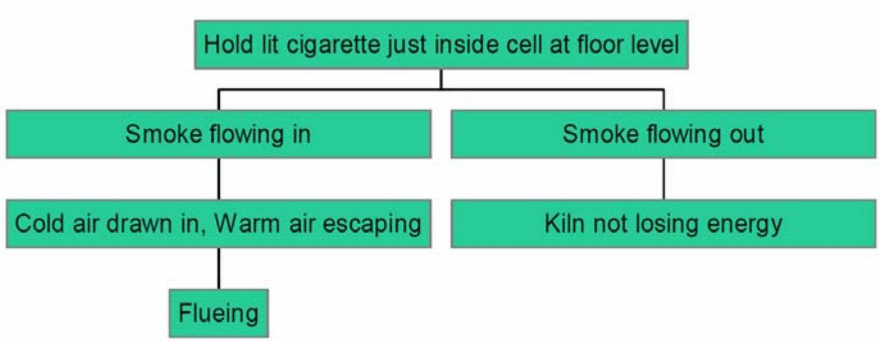


Fig. 4-6. Mel's Method for Detecting Flueing.

Notes

Section 3: Review Questions

The following questions provide a review of the key concepts introduced in this section. An Answer Key is provided at the end of the questions.

Questions

Chapter 1: Reinforcement Fabrication

1. "W5.0" wire size indicates that the reinforcing wire has a cross-sectional area of:
   a. 5 square inches
   b. 0.5 inches
   c. 0.05 square inches
   d. 0.005 square inches

2. What is the circumferential steel area per foot of length for the following mesh:

   3x6 W5.0xW3.0 94" x 600' 1/2x1/2

   a. 0.10 sq.in./ft
   b. 0.12 sq.in./ft
   c. 0.15 sq.in./ft
   d. 0.20 sq.in./ft

3. The production drawing calls for #4 rebar at 4" spacing, but all you have is #5 rebar in stock. What spacing of #5 rebar is required to meet approximately the same steel area provided by #4 @ 4"? (NEVER substitute any rebar size without formal approval.)

   Steel areas for #4 bar = 0.2 sq.in., #5 bar = 0.31 sq.in.

   a. 3"
   b. 4"
   c. 5"
   d. 6"
   e. 7"

4. What is the approximate diameter of the reinforcing wire labeled “W6”?
    a. 0.276”
    b. 0.252”
    c. 0.319”
    d. 0.226”
5. Given the wire diameter of 0.239 inches, what is the corresponding designation for the smooth wire area?
    a. W4.0
    b. W4.5
    c. W5.0
    d. W7.0

Chapter 2: Pre-pour Inspection

1. Forms and reinforcement have been set up prior to pouring. The reinforcement is touching the side of the form, is completely covered with form release, and has yet to be checked by the QC inspector. This inspector should say the piece________________________________.
    a. Is ready to be poured
    b. Must be redone and then poured
    c. Must be completely redone, checked and authorized by QC, and then poured
    d. Can be poured if the reinforcement is pulled away from the form
    e. None of the above
2. Forms should be inspected__________________________________.
    a. Weekly
    b. Only when you first buy them
    c. Yearly
    d. When product quality begins to degrade
    e. Prior to each use

3. When inspecting forms, inspectors should ____.
    a. Move all personnel away from the form
    b. Visually check form for vibrator mounts, seams, gates, cracks and cleanliness.
    c. Knock forms with a hammer
    d. All of the above

4. The purpose of release agent is to ____.
    a. Prevent hardened concrete from adhering to the form
    b. Provide form protection
    c. Improve product appearance
    d. All of the above

Chapter 3: Consolidation

1. True or False: Proper amplitude and frequency are both necessary for good consolidation.
    a. True
    b. False

2. A product is stripped from the form and the product has areas of honeycombing. One of the causes of this could be that the product was:
    a. Vibrated too long in a leaky form
    b. Not properly cured
    c. Removed from the forms too soon
    d. Allowed to sit in the sun too long
    e. Reinforced with defective reinforcing steel

3. Proper vibration will have which of the following results________________________.
    a. Optimum strength
    b. Optimum durability
    c. Optimum quality appearance
    d. Optimum water tightness
    e. All of the above

4. Segregation of concrete can be caused by________________________________.
    a. Improper handling of concrete
    b. Long free falls
    c. Horizontally moving fresh concrete
    d. All of the above
    e. None of the above

Chapter 4: Curing

1. Your product appears to be cured only at the top half. The bottom half looks green. You suspect that during curing you are flueing energy and hold a lit cigarette just inside the cell at floor level. You wait a moment and notice that the flow of smoke off the cigarette is floating into the cell. What do you conclude?
    a. Somewhere, hot air must be escaping.
    b. The kiln is not losing energy.
    c. You should take another drag of the cigarette and try a second time.
    d. Cold air is escaping the cell.
    e. There should be moisture on the floor within the cell .
2. To properly cure concrete it is important to:
    a. Do it outdoors
    b. Maintain a dry, warm environment
    c. Provide a humid environment and warm temperature
    d. Expose it to a draft
    e. Provide a humid, cold environment
3. Using dry heat without a humid environment will______________________________________.
    a. Provide a good cure
    b. Cure the product quickly
    c. Dry out the surface and cause cracking
    d. Have no effect
    e. Always result in a good final product

4. True or False: Minimum concrete stripping strengths are required prior to handling the product.
    a. True
    b. False

Answer Key

Chapter 1: Reinforcement Fabrication

1. c
2. d
3. d
4. a
5. b

Chapter 2: Pre-pour Inspection

1. c
2. e
3. b
4. d

Chapter 3: Consolidation

1. a
2. a
3. e
4. d

Chapter 4: Curing

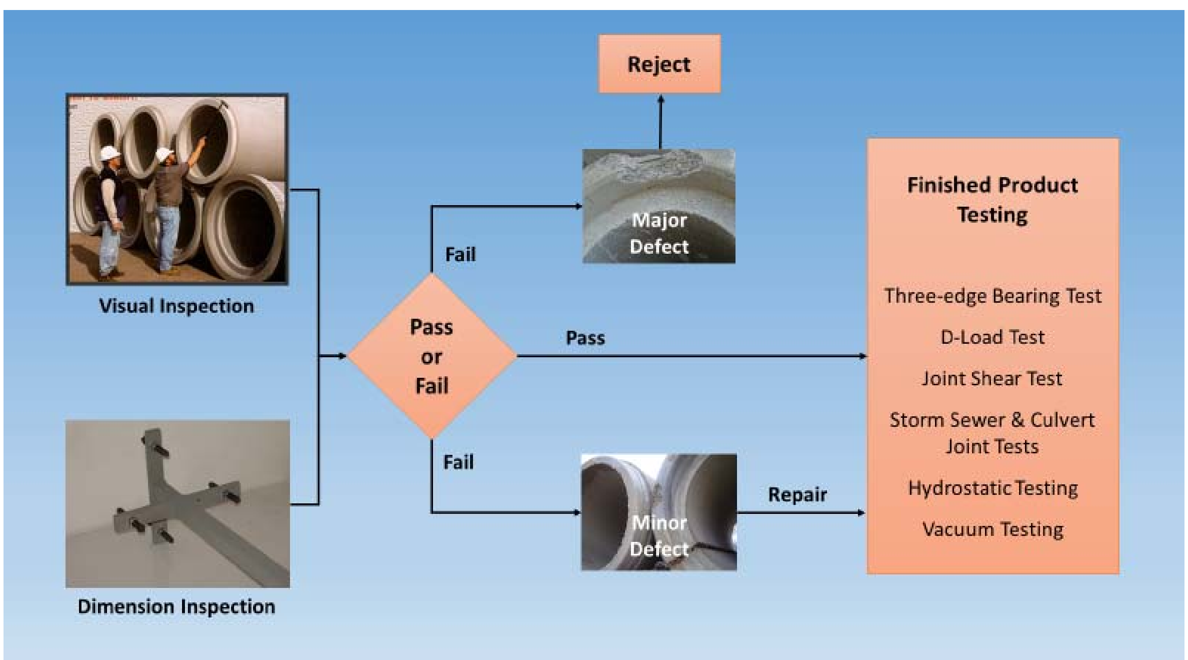
1. a
2. c
3. c
4. a

SECTION 4

FINISHED PRODUCT INSPECTION, REPAIRS, AND TESTING

At this point, you have gone through the concrete production process and the concrete products manufacturing process, now it is time for the final process of finished product inspection, repairs (if required) and product testing. In this section, you will learn about the various categories of inspection tasks and whether the product should be accepted, rejected or repaired based on the post-pour inspection. Should the product be repaired, the repairs section will cover the different types of repair categories (structural, performance, and cosmetic) and the most common repair techniques. Then, before the product is shipped to the customer, a thorough round of testing is conducted to determine the quality and durability of the finished product.

The following illustration provides a high-level view of the finished product inspection, repair and testing process.



Page left intentionally blank.

Chapter 1: Post-pour Inspections

Quality control, verification, and documentation of all aspects of the production process are critical components of the production of high quality pipe products. A poorly produced product that does not meet national standards but somehow reaches a job site rarely will provide a satisfactory installation. No other phase of the installation can overcome or hide poorly produced products.

Plant QC inspection (Fig. 1-1) requires much more than just making sure the product is aesthetically appealing. Every aspect of the production process must be completed, verified, and documented in some systematic way to confirm, control and monitor the quality of the finished product:

- Quality Material components must be confirmed and documented,
- Pre-Production checks must be completed before products are produced,
- Manufacturing Process must be monitored and confirmed,
- Storage and Handling of raw materials and finished goods must be verified and controlled,
- Post-Production inspections must be completed, and
- Pre-Delivery quality control measures must be established and completed before every shipment.

Fig. 1-1. Illustration of visual inspection of finished product.

Thorough inspection of the product after it has been poured is critical in ensuring that the customer receives a product that meets and exceeds their expectations. Post-pour inspections mirror the pre-pour inspections, the product is inspected visually for any defects as well as dimensionally to ensure it meets the applicable standards and tolerances, and any blockouts or embedded items have not floated during the pouring process. Any repairs need to be identified and then inspected after those repairs have been completed.

Objectives

At the end of this chapter, you will be able to:

- ✓ Identify the categories of inspection tasks for post pour inspection of all precast products.
- ✓ Identify the three important areas to check in order to minimize damage when stripping and handling finished product.

- ✓ List characteristics that would be unacceptable while visually inspecting pipe / manhole barrel products.
- ✓ List characteristics that would be unacceptable while conducting a joint visual inspection.
- ✓ List characteristics that would be unacceptable while visually inspecting box culverts.
- ✓ List areas to inspect after pipe and manhole joint repair and finishing.
- ✓ Identify the dimension aspects that should be recorded for pipe/manhole and box culvert.
- ✓ Identify the minimum number of boxes and three-sided structures inspections that should be recorded for each day's production.
- ✓ Explain the purpose of the go/no-go gauge and how it's used.
- ✓ Identify the ASTM specifications for rejecting products due to cracking or material defects.
- ✓ Distinguish between major defects and minor defects.

Proper Stripping and Handling

In addition to manufacturing defects, pipe can get damaged during the stripping process or during handling prior to delivery. If not handled properly, the pipe may end up cracking, breaking, or incurring damage to joints.

There are three important areas to check in order to minimize damage during post-pour operations: (1) required minimum strength, (2) proper stripping and form removal, and (3) proper handling.

Required Minimum Strength

It is critical that concrete gain sufficient strength before stripping the forms, or in the case of dry-cast products, before tipping the product out of the kiln. Stripping the forms or tipping the product before the minimum strength is achieved can lead to excessive product damage and reduction in long term strength gain. The engineering department should establish minimum stripping and tipping strengths for the products being manufactured, and periodic compressive strength testing of one-day or stripping- strength cylinders is required to confirm that proper concrete strength is attained.

Stripping and Form Removal

Fresh "green" pipe or box culvert should be placed on a level floor in the kiln area (Fig. 1-2). The products should be spaced out in a manner to allow for safe finishing operations to take place. The green product should be protected from drafts that can wick the surface moisture from the product and cause shrinkage cracking. Also additional moisture may need to be added by sprayers or

Fig. 1-2. Illustration of stripping forms from concrete pipe.

foggers, especially in hot and dry climates, to protect the fresh concrete from cracking.

When the forms are removed from the wet-cast products, the goal is to minimize damage to the product. Premature removal of the forms may cause sagging and cracking in the partially cured concrete. Attention must be given to proper handling when the forms are disassembled. In addition to standard QC checks, quality control inspections during form removal should focus on identifying any repetitive damage caused by the process, eliminating repetitive damage will help in reducing the resulting repair work significantly.

Product Handling

When stripping the form from the product, it is important that the appropriate rigging is in place and operable. Proper rigging involves making sure you have the proper equipment, in working order, to remove the forms from the product without causing any damage to the form or finished product. When the freshly cured product is removed from the curing area to the finishing area or yard, extreme care needs to be taken so as not to cause any damage from the forklift forks or potholes, grooves, debris etc. in the yard. A good practice is to cover the forks with a protective material and also maintain the yard in good condition to reduce the possibility for chips and cracks in the product.

Product Marking

Proper handling also includes the proper identification marking on the product, usually with waterproof paint. Finished products should be identified in the kiln or when forms are removed prior to further handling.

Marking Pipe/Manholes

According to ASTM C76 each section of pipe should be legibly marked with:

- The pipe class and specification designation,
- The date of manufacture,
- The name or trademark of the manufacturer, and
- Identification of plant.

For each of pipe with elliptical or quadrant reinforcement marking should be on the inside and the outside of opposite walls along the minor axis of the elliptical reinforcing or along the vertical axis for quadrant reinforcing.

Marking Box Culverts

According to ASTM C1433 and C1577, each box section shall be legibly marked by indentation, waterproof paint or other approved means. Labeling should include:

- Box section span, rise, table number, maximum and minimum design earth cover, and specification designation.

- Date of manufacture, and
- Name or trademark of the manufacturer.

Each section shall be clearly marked by indentation on either the inner or outer surface during the process of manufacture so that the location of the top will be evident immediately after the forms are stripped. In addition, the word “top” shall be lettered with waterproof paint on the inside top surface.

Fig. 1-3. Illustration of pipe stacking.

Yarding/Stacking

After the finishing and any repairs, the product is ready for yarding and/or stacking (Fig 1-3). Damage to the product can happen as a result of improper handling so minimizing the number of times the product has to be moved is critical. When stacking the product, maximum stack height needs to be established by the engineering department to ensure the product is not damaged from being stacked on top of each other.

Pipe / Manhole / Precast Inspections

A post-pour inspection is conducted to identify any defects that may have occurred as a result of the manufacturing process. These defects may range from minor defects that can be repaired to major defects that could ultimately result in product rejection. During the post-pour inspection process, there are two main parts to conducting the inspections: (1) visual inspection of product and (2) dimensional checks of the product. If defects are deemed repairable, then the inspection of repairs made also need to be done.

Visual Inspection

All products are to undergo a visual inspection of the appearance to identify any defects that may need to be repaired (according to policy and procedure) or result in rejection of the product. These visual inspections should be recorded on the appropriate form and maintained in files as required by the plant’s quality assurance program. Samples of these forms are provided in the ACPA QCast Certification Manual appendices.

Pipe/Manholes/Precast Visual Inspection (Barrel and Joints)

For pipe, manhole and precast products, inspection of the **pipe barrel** includes looking for the following:

- cracks,
- slumping,
- segregation,

- voids,
- bleeding,
- excessive bugholes,
- exposed steel (Fig. 1-4),
- cage twist,
- joint smoothness,
- swedging,
- slabbing,
- flashing,
- size and location of embedded items, and
- blockouts.

Fig. 1-4. Illustration of exposed steel found during a post-pour inspection.

In addition, pipe and manholes should be inspected for the **condition of joints** (Fig. 1-5) including:

- cracks,
- smoothness of bell and spigot, and
- snap ring positioning.

After patching, inspect joints for patching technique and quality, smoothness of bell and spigot, and a uniform snap ring width and depth.

Fig. 1-5. Illustration of poor quality joints.

Box Culvert Visual Inspection

Box culvert inspection includes inspection elements similar to pipe and manhole product, such as:

- appearance,
- cracks,
- voids,
- bleeding,
- flashing,
- slumping,
- exposed steel, and
- bug holes.

Dimensional Inspection

As part of the product inspection, dimensional inspections are conducted and recorded for specific aspects of the pipe and box structures.

Pipe/Manhole/Precast Dimensional Inspection (Barrel and Joints)

Dimensional checks of the barrel on pipe and manhole products should be conducted on one product for each size per shift. According to the ACPA QCast Certification Manual:

- Measure and record the pipe/manhole length, diameter and wall thickness, and calculate and record the difference in length of two opposite sides, when new equipment is put into production, at a minimum frequency of one per size per shift. The only exception to this practice is on low production wet cast where the minimum frequency shall be a minimum of 1/100 pieces or once every 6 months.
- Inspect the size and location of all embedded items and blockouts as required on shop drawings.

A record of dimensional reports from each pipe section on which a three-edge-bearing test has been performed (more on this in Chapter 3: Finished Product Testing) should also be maintained. Product Dimensional Inspection Instructions and Sample Product Dimensional Reports are included in Appendix A of the Certification Manual.

Pipe/Manhole Spigots – Sanitary Sewer Dimensional Inspection

Fig. 1-5. Go/No-Go Gauge.

In accordance with the ACPA QCast program, a dimensional check of pipe and manholes on sanitary sewer pipe should include a check of the gasket-sealing surface of the spigot. To conduct this check, a Go/No-Go gauge is used (Fig. 1-5), the gauge shown can be set for both the spigot and the bell. The Go/No-Go gauge is a simple, fast, and accurate tool to measure if the joint is within the allowable tolerances.

Fig. 1-6. Application of Go/No-Go Gauge to pipe.

On the spigot side of the gauge, one side of the gauge is set at the maximum spigot diameter (Go) and the opposite side is set at the minimum spigot diameter (No-Go).

On the bell side of the gauge, one side of the gauge is set at the minimum bell diameter (Go) and the opposite side is set at the maximum bell diameter (No-Go).

Dimensions of the joint should be checked on at least four places around the perimeter by placing the gauge across the joint and slightly rotating it through the points being checked. When measuring the spigot (Fig. 1-6), the side of the gauge that was set to the “Go” dimension should freely rotate around the spigot. Should the gauge get stuck, the spigot exceeds the maximum diameter. On the opposite side of the gauge, the “No-Go” side should get stuck when trying to rotate it through, should the gauge freely rotate on the “No-go” side, the spigot exceeds the minimum diameter and therefore is too small. The bell works the same way except the minimum and maximum dimensions are reversed.

The results of the Go/No-Go measurement should be recorded by date of manufacture. For each different gasket joint and size, a drawing should be maintained that shows the design and dimensions of the gauging system for the gasket sealing surface of the pipe spigots. A drawing of a sample gauge can be found in the ACPA QCast Certification Manual, Appendix A.

Go/No-Go Gauges should be properly and accurately calibrated. Documentation regarding calibration should also be maintained according to ACPA QCast Certification requirements.

Box Culverts and Three-sided Structures Dimensional Checks

Fig. 1-7. Conducting a dimensional check on a box culvert using measurement calipers.

When conducting dimensional checks on box culverts (Fig. 1-7) and three-sided structures, maintain a Post-Pour Inspection Record on 20% of all boxes and 100% of all three-sided structures produced each day, from each form used that day (minimum one per form per day).

Record the following dimensions for box culverts:

- Thickness of top and bottom slab
- Thickness of both side walls on both ends
- Inside rise on both ends
- Inside span on both ends
- Inside length: top, bottom, both side walls

Record the following dimensions for three-sided structures:

- Thickness of Deck and Precast Legs
- Span of Precast Structure
- Rise of Precast Structure
- Width of Precast Structure Section

Per the ACPA QCast Certifications requirements, these measurements should be recorded on "Box Culvert or Three-Sided Structures Post-Pour Product Inspection" form. The size and location of all embedded items and blockouts should also be inspected as required on shop drawings. Samples of these forms are included in Appendix A.

Inspecting Repairs

Often times the product can be repaired if necessary, due to the imperfections from manufacturing or handling damage. These repairs will be acceptable if the repairs are sound, properly finished, cured and in conformance with design and ASTM specifications. All repairs should be inspected and documented before the product is yarded.

Acceptance and Rejection Guidelines

Following are guidelines for determining if the defect is considered rejectable or acceptable. According to the ACPA QCast quality requirements, the individual responsible for product quality shall personally check a portion of each day's production before and after patching or "finishing". This inspection shall show that the correct production and patching techniques are being used.

Pipe/Manhole

According to ASTM C76, pipe and manholes shall be subject to rejection if they fail to conform to any of the specification requirements. Pipe and manholes may be rejected because of any of the following:

- Fractures or cracks passing through the wall, except for a single end crack that does not exceed the depth of the joint.
- Defects that indicate problems with proportioning, mixing, and molding, or surface defects indicating honey-combed or open texture that would adversely affect the function of the pipe or long term integrity of the pipe.
- Ends of the pipe are not normal to the walls and center line of the pipe, within the limits of variations given in the specification.
- Damaged or cracked ends, where such damage would prevent making a satisfactory joint (Fig. 1-8).
- Any continuous crack having a surface width of 0.01 inch or greater regardless of position in the wall of the pipe, for a pipe not installed or under load.

Fig. 1-8. Illustration of a crack in a spigot that extends all the way through and the entire depth of the joint; should be rejected.

Box Culvert

According to ASTM C1433 and C1577, box sections shall be subject to rejection if it fails to conform to any of the specification requirements. Box may be rejected because of any of the following:

- Fractures or cracks passing through the wall, except for a single end crack that does not exceed the depth of the joint.

- Defects that indicate mixing and molding not in compliance with 9.1, or honeycombed or open texture that would adversely affect the function of the box sections.
- Abnormalities in the ends of the box sections to the walls and center line of the box section, within the limits of variations given in Section 11 of the specification, except where beveled ends are specified.
- Damaged ends, where such damage would prevent making a satisfactory joint (Fig. 1-9).

Fig. 1-9. Illustration of a damaged end that should be rejected.

Product Repair Inspection

After the repair is completed, the person responsible for quality must re-inspect the work to ensure that the product conforms to the requirements within the ASTM specifications for finished product. An inspection should focus on the repair materials and technique used, the soundness and the quality of the repair, and the dimensional correctness of the repair.

Notes

Chapter 2: Repair and Finishing

While our goal is to have zero repairs, it does not always work that way. There are typically two main reasons that you will need to repair precast products:

- Manufacturing imperfections
- Handling damage

ASTM C76, ASTM C1433 and ASTM C1577 address when repairs to pipe and box sections should be conducted. They state that pipe and box sections, "may be repaired, if necessary, because of imperfections in manufacture or damage during handling and will be acceptable if, in the opinion of the owner, the repaired pipe and box section conforms to the requirements of this specification." Additionally, these standards describe examples of when a product should be rejected or repaired. These specifications will be discussed later in this chapter.

Almost every imperfection can be repaired if proper techniques and materials are used. However, you need to remember that not everything should be repaired. The basic guideline to use, when determining if a repair is needed, is to ask "Will the product meet all the requirements after the repair?" This refers not only to dimensional requirements, but to strength, durability and water-tightness as well.

Objectives

At the end of this chapter, you will be able to:

- ✓ Identify the two main reasons for doing repairs.
- ✓ List the three classifications of repairs that may be needed on finished product and give an example of each.
- ✓ Identify the types of basic materials to use when making repairs.
- ✓ Identify the appropriate repair method for a given type of repair (structural, performance, cosmetic).
- ✓ Recall the appropriate patching recipe for each type of patch work.
- ✓ Recognize the conditions under which it is appropriate to use pre-packed materials for repairing defects.
- ✓ Recall the steps to take when making a structural repair.
- ✓ Recall the steps to take when making a performance or functional repair.

Classifications of Repairs

Below are some examples of assessing whether or not a concrete product is repairable or non-repairable. When evaluating repairs, it is important to understand both the cause of the damage, as well as the intended use of the product. Similar defects may or may not be repairable, depending on the requirements of the installation. Different markets will have different levels of expectations and requirements for repaired products. Economy and reputation also contributes to deciding whether to repair the product or not, especially in cases where it is cheaper to build or substitute another one, or when the repair may tarnish the manufacturer's reputation in the industry.

Fig. 2-1. Illustration of damaged pipe.

Figure 2-1 highlights damage on a piece of pipe that should not be stacked in a pile of good pipe as shown. In this situation, the safe thing to do would be to scrap the pipe. However, this pipe could be repaired for mortar joint applications. If the pipe is repaired, the Quality Control department should check the repair with a go/no-go gauge to ensure the repaired joint meets the tolerances. As followup, investigation into how the damage occurred may also be warranted to mitigate further instances.

Fig. 2-2. Illustration of minor defect on top of older repair.

This is a minor defect, shown in the next illustration (Fig. 2-2), is on top of an older repair due to handling. In these cases, it is recommended that you start by investigating the handling practices and mitigating the cause of the problem. The defect shown here is certainly repairable; therefore, it should be removed from the truck and properly repaired and cured prior to shipment. Another potential issue in this picture is the chain holding the pipe for transport. Notice that there is no chain guard, which could lead to more damage to the pipe, by the time the truck arrives at the jobsite.

Fig. 2-3. Illustration of crack in pipe.

The defect example, shown in Fig. 2-3, illustrate a type of defect that may not be as apparent as it looks and would require closer inspection. Further investigation would help to determine if the crack is just a simple surface defect, or if it extends into the barrel indicating delamination. The question as to what caused the defect would also need to be answered in order to determine the root cause and how it may be eliminated. Depending on the outcome of the investigation, this pipe could either be repaired or scrapped.

When determining if concrete is repairable or non-repairable and how to make a durable repair, three classifications of concrete repairs have been identified:

- Structural
- Performance (Functional)
- Cosmetic

Structural Repairs

Structural repairs are defined as a major defect repair because it compromises the structural integrity or designated use of the product. All structural repairs need to be inspected by qualified individuals and documented. If it cannot be repaired, it must be rejected. Below are examples of repairable and not repairable structural defects.

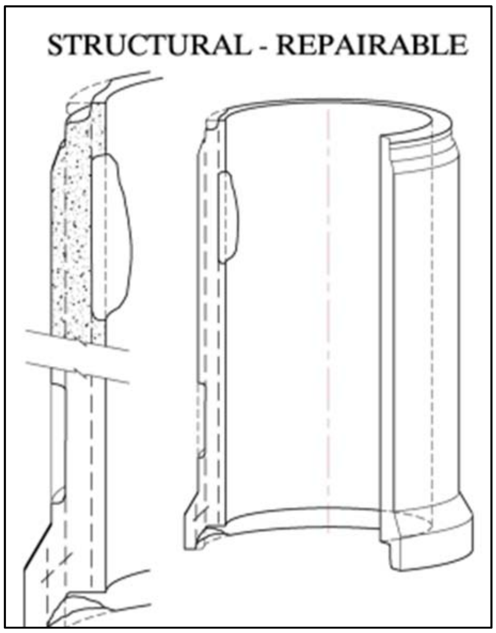


Fig. 2-4. Illustration of a pipe that has structural damage that can be repaired.

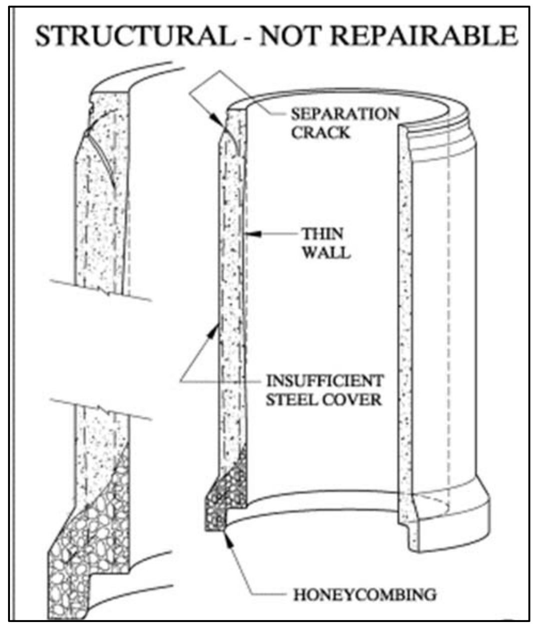


Fig. 2-5. Illustration of a pipe that has structural damage that cannot be repaired.

The first illustration (Fig. 2-4) shows a product that can be structurally repaired because of the following:

- Damaged tongue on the outside – it is not broken past reinforcing or through the wall
- Fall-out on the inside – small to medium fall-out
- Fall-out on the outside – small to medium fall-out
- Damaged bell on the inside -it is not broken past reinforcing or through the bell

The second illustration (Fig. 2-5) shows a product that should be rejected because of the following:

- If manufactured with a thin wall or insufficient steel cover, there is nothing you can do to repair it.
- Separation cracks and honey combing can be disguised, but not repaired.

When performing a structural repair the following steps should be addressed:

1. Remove unsound concrete from area to be repaired.
2. Check the position of reinforcing and add additional reinforcing as necessary.
3. Form as necessary to reconstruct product to original shape.
4. Dampen mating surface with water, allow to surface dry, or apply bonding agent.
5. Make repair with low slump repair mortar consisting of:
    a. Mix used to produce original product or 1 part cement with 3 parts sand, depending on the size of repair and detail required.
    b. Air entrain repair mortar when necessary.
6. Tarp product or repaired area immediately after repair is completed to allow repair to pre-set and cure.
7. Steam cure after pre-set is recommended.

Performance (Functional) Repairs

Performance or functional repairs focus on the areas of the joints. The examples to the right illustrate areas needing repair to ensure the performance of the pipe. For example, precast concrete pipe joints are manufactured in two basic shapes: (1) tongue and groove, and (2) Bell and spigot which generally use a rubber gasket.

In the first example (Fig 2-6), there are pock marks in the tongue and bell which may ultimately interfere with the proper installation and sealing of the bell to the spigot.

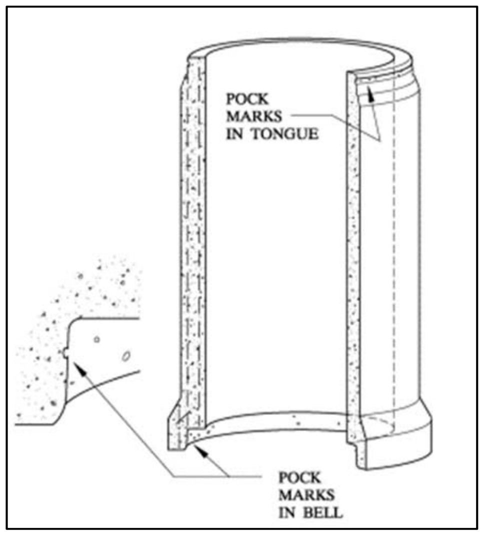


Fig. 2-6. Illustration of pipe defect that may affect the performance of the pipe seal.

In cases where you have a bell and spigot joint with an o-ring gasket, you may see defects to the sealing area as shown in Fig. 2-7. Both of these types of defect would require a repair of the joint to ensure the performance of a tight seal for water-tightness as designed.

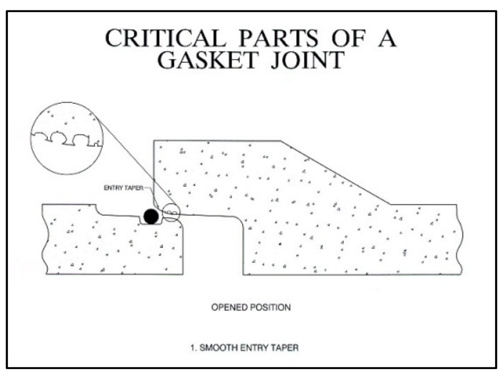


Fig. 2-7. Illustration of critical parts of a gasket joint that have a defect in the sealing area of the joint.

ASTM C443 section 14 defines the allowable joint repairs as follows:

- Circumferential length of a single area to be repaired shall not exceed ¼ of the inside diameter or equivalent diameter.
- Circumferential length of several areas combined shall not exceed ½ of the inside diameter or equivalent diameter.

- Owner may require testing to prove performance

When addressing performance or functional repairs, it is important that you only repair what needs to be repaired. There is a good possibility that you may create more problems if you make repairs when they are not needed. Appearance should be taken in to consideration with performance repairs.

Making the Repair

When conducting a performance/functional repair, the following steps should be addressed:

1. Remove unsound concrete from area to be repaired (if any).
2. Dampen mating surface with water, allow to surface dry.
3. Make repair with very stiff repair mortar consisting of: 1 part cement to 1 ½ - 3 parts sand and water, depending on size or imperfection.
4. Remove excess material (especially on joint sealing surfaces).
5. Cure properly to prevent premature drying and shrinkage

Cosmetic Repairs

Cosmetic repairs are all about appearance. Product appearance can be your best sales person or your worst sales person! Cosmetic repairs are considered to be a minor defect repair—one that does not impact the functional use or expected service life of the product (e.g. chips, bugholes). Figure 2-8 shows an example of a product that needs cosmetic repair due to hairline cracks, pock marks and some minor bleeding.

Making the Repair

When conducting a cosmetic repair the following steps should be addressed:

1. Areas to be repaired must be clean, sound and free of contaminants.
2. Provide an aggregate fractured surface.
3. Saturate the repair with water and allow to dry to SSD. Do not wet if using polymer repair materials.
4. Fill the area with a thoroughly mixed approved repair material in accordance with the manufacturer's recommendations, or a mortar mix.
5. Cure the repaired area in accordance with the manufacturer's recommendations for a minimum of 24 hours.

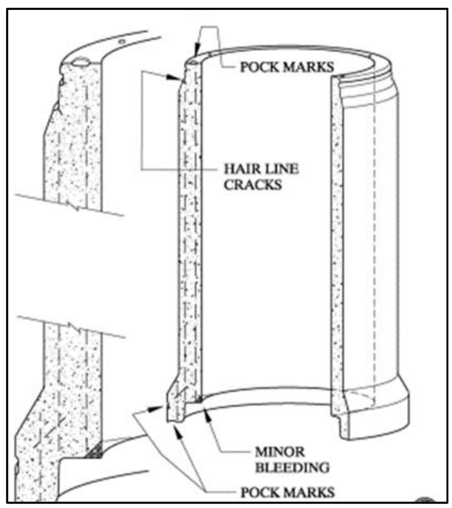


Fig. 2-8. Illustration of cosmetic defects on a freshly cast concrete pipe.

6. The repaired area should closely match both the texture and integrity of the undamaged adjacent concrete surfaces.

Repair Materials

When repairing concrete, the repairs should be made with like materials. Therefore, repair concrete with concrete. Basic repair materials include:

- Cement
- Sand
- Water

Producers have a wide choice of patching materials in making the final repair**. Cementitous mortars** are commonly used in patching. These materials normally have a 1:2 or 1:3 ratio of cement to sand, and may contain a specialty admixture to densify the system, reduce shrinkage, or improve the bond. Proper curing is essential when using these materials.[1] Basic recipes for patching with cementitious mortars are:

- For very large patches, use the same concrete as the product was produced from or a stiff mixture of 1 part cement, 3 parts sand + water.
- For smaller, more refined patches, use very stiff paste. 1 part cement, 2 ½ to 3 parts sand + water.

Several manufacturers offer **prepackaged cement mortars**. These can be very effective, as the manufacturers have matched appropriate admixtures to the cements to provide a standard strength gain and enhanced durability of the patch.[1] However, some rapid set patch materials are not durable in wet conditions and therefore should be avoided. Prepackaged materials are good to use when the following conditions are present:

- Very thin patches or overlays
- Need for quick setting
- Need for high early strength
- Special curing requirements
- Non-shrink applications
- Flowable materials

When using prepackaged materials, it is critical that you read and follow all labeled directions exactly. Most reasons for the failure of prepackaged materials revolve around failure to follow the directions. These reasons include adding too much water or re-tempering, wrong proportions, improper mixing, improper application, and/or improperly cured.

Epoxy mortars and fine aggregate are another option for patching (Fig. 2-9). The mixture usually maximizes the sand content to minimize heat of reaction and any cracking. It is important to test these materials before using them. When using epoxy mortars, do not pre-wet the area as they bond better to dry surfaces.

Bonding agents are especially effective when the patch surface is large and thin (Fig. 2-10). Make sure to work the material into the existing concrete, pushing the repair material into the parent material to ensure the best bond. Bonding agents should be used with care and in accordance with the manufacturer's recommendations.

Guidelines for Repair of Cracking and Material Defects

As mentioned in the introduction to this chapter, each type of repair has standards that specify when a product should be considered in need of repair or rejected. The following table describes the specifications for determining when structural, performance or cosmetic repairs are needed due to cracking or material defects.

Fig. 2-9. Illustration showing epoxy mortar being applied

Fig. 2-10. Illustration of a bonding agent being applied to concrete defect area.

ASTM Standard	Cracking Repairs	Material Defect Repairs
ASTM C76 **ASTM C478**	Fractures or cracks passing through the wall, except for a single end crack that does not exceed the depth of the joint Damaged or cracked ends where such damage would prevent making a satisfactory joint. Any continuous crack having a surface width of 0.01” or more for a length of 12” or more (unloaded)	Defects that indicate proportioning, mixing, and molding not in compliance with 10.1 or surface defects indicating honeycombed or open texture that would adversely affect the function of the pipe. The ends of the pipe are not normal to the walls and center line of the pipe, within the limits of variations given in 12.3 and 12.4
ASTM C1433 **ASTM C1577**	Fractures or cracks passing through the wall, except for a single end crack that does not exceed the depth of the joint	Defects that indicate mixing and molding not in compliance with 9.1, or honeycombed or open texture that would adversely affect the function of the box sections Abnormalities in the ends of the box sections to the walls and center line of the box section, within the limits of variations given in Section 11, except where beveled ends are specified, and Damaged ends, where such damage would prevent making a satisfactory joint.

Notes

Notes

Chapter 3: Finished Product Testing

Finished product testing provides assurance that the materials and the manufacturing process used meet the standards and quality that is expected from the product. Testing is a critical component of the manufacturing process as it ensures the final product matches the requirements of the design.

The finished product tests discussed in this chapter include three edge bearing testing (Fig. 3-1), joint testing and water-tightness testing methods, the significance of these tests and the required apparatus for each test as governed by ASTM C497 and the ACPA QCast Certification requirements.

Fig. 3-1. Three-edge bearing testing equipment.

Objectives

At the end of this chapter, you will be able to:

- ✓ Explain the purpose of the three edge bearing test for concrete pipe and recall the equipment used to complete it.
- ✓ Describe the two criteria used for determining the strength of pipe (0.01 crack and ultimate load).
- ✓ Explain the term D-load and how it is expressed in terms of testing the strength of pipe.
- ✓ Calculate the required load rates for the D-load test.
- ✓ Calculate the required test load in pounds, and the pipe length and diameter, for a given class of pipe.
- ✓ Calculate the actual D-load from a given applied test load, length and diameter of the pipe.
- ✓ Recall the ASTM pipe classes and the corresponding 0.01” crack and ultimate D-loads.
- ✓ Explain the purpose of the joint shear test and summarize how it’s setup and conducted.
- ✓ Identify the three types of storm sewer and culver joint tests as per QCast.
- ✓ Summarize the hydrostatic testing procedure and when it’s used.
- ✓ Summarize the vacuum testing procedure and when it’s used.
- ✓ Describe the two performance requirements for joints tested by hydrostatic pressure.

Types of Tests

According to the ACPA QCast Certification requirements, there are number of different types of tests required for the finished products. These tests include:

- Three-edge Bearing Test (Fig 3-2)
- Differential Joint Shear Tests,
- Off-center Joint Tests,
- Storm Sewer and Culvert Joint Tests,
- Water Tightness Tests, and
- Manhole Step test

Fig 3-2. Illustration of a three-edge bearing test.

The purpose, frequency and methods used, as well as the documentation required, for evaluating each of these areas is discussed in this chapter.

Three-Edge Bearing Test

Pipe strength classifications established by manufacturing and material standards for reinforced concrete pipe are based on three-edge bearing test strengths expressed in pounds per linear foot. These test strengths are directly related to the load carrying capacity of the buried pipe. ASTM C497 specifies the three-edge bearing test as the method of determining the maximum D-load of the pipe. In the three-edge bearing test, a piece of pipe, chosen at random, is supported on two lower bearing strips and loaded from above through an upper bearing block. The reinforced pipe is loaded until a crack is produced having a width of 0.01 inches throughout a continuous length of one foot.

Three-edge Bearing Method and Setup

The three-edge bearing tests are conducted on each size of concrete pipe produced throughout the year, to determine the strength of the pipe using two different criteria: 1) the load to produce a crack with a width of 0.01 inch, and 2) the ultimate load. Unlike most reinforced concrete structures, reinforced concrete sewer and culvert pipe is designed to meet a specified cracking load rather than a specified stress level in the reinforcing steel. This is both reasonable and conservative since reinforced concrete pipe may be pretested in accordance with detailed national specifications.

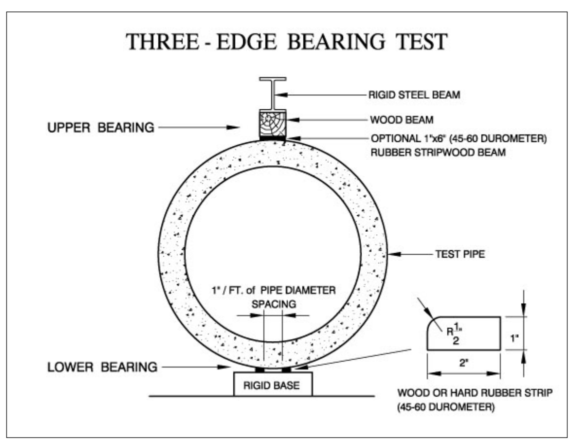


Fig. 3-3 Illustration of the setup for a three-edge bearing test.

The three-edge bearing test (Fig. 3-3) is a method commonly used to determine structural strength, by applying the most severe loading to which any pipe may be subjected. The three-edge bearing test is conducted by placing the test pipe squarely in the test frame (Fig. 3-4), which is designed to apply a crushing force in a true vertical plane, parallel to one diameter or the vertical centerline, and extending the full length of the wall of the pipe. The load is applied by a top bearing beam (one edge) pushing down on the pipe, which is supported on two parallel longitudinal strips (the other two edges), hence the three-edge bearing method. When applying pressure, the load must be applied in a way to ensure that it is distributed evenly along the pipe, in order to avoid point loading (Fig. 3-5), which would result in a false D-load reading.

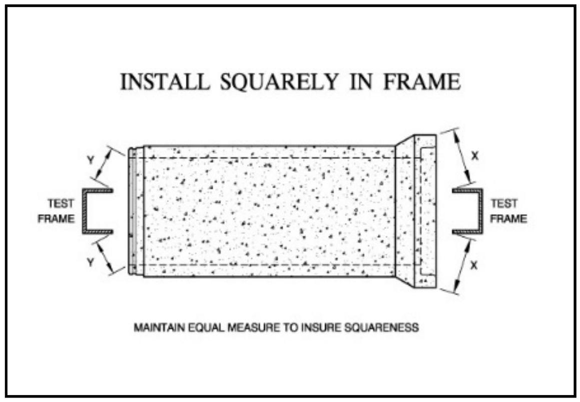


Fig. 3-4. Illustration of maintaining squareness when setting up for a three-edge bearing test.

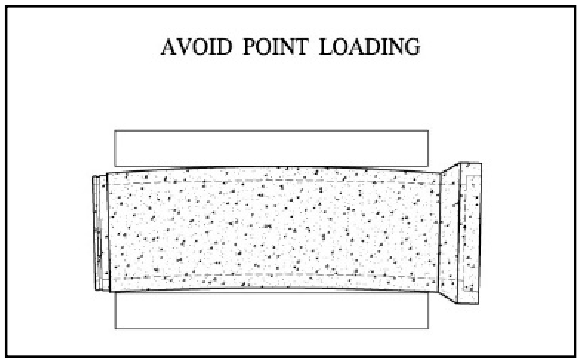


Fig. 3-5. Illustration of uneven pressure causing point loading.

The load is applied at a steady rate along the pipe length until the formation of a 0.01-inch wide crack, which is measured using a specialized gauge. A 0.01-inch crack is considered formed when the point of the gage, without forcing, will penetrate 1/16 inch at close intervals throughout a one foot length of crack. The ultimate load is reached when the pipe does not support a greater load. (Failure)

Test Load Calculations: 0.01-inch crack D-Load and Ultimate Load

D-loads are expressed in pounds per linear foot per foot of inside diameter. Since numerous reinforced concrete pipe sizes are available, three-edge bearing test strengths are classified by D-loads. The D-load concept provides strength classification of pipe independent of pipe diameter. For reinforced circular pipe the three-edge-bearing test load in pounds per linear foot equals D-load times inside diameter in feet. For a given three-edge bearing test, The 0.01-inch crack D-load is calculated by dividing the test load required to produce the 0.01-inch crack by the manufactured length (lbf) and by the pipe inside diameter or horizontal span.

The following is an example of load rate calculations for a Test Class III, 24-inch pipe that is 8 feet long. According to ASTM C76:

- Class III D-Load to produce 0.01 inch crack = 1350
- Class III D-Load to produce the ultimate load = 2000

To calculate 0.01 inch Load:

1350 (D-load) x 8 ft (length) x 2 ft (diameter) = 21,600 lbs load for 0.01” crack

According to ASTM C497, for Reinforced Concrete Pipe, any rate of load application up to a maximum of 7500 lbf/lineal foot of pipe per minute shall be used up to 75% of the specified design strength, at which time the rate of loading shall be reduced to a maximum uniform rate of 1/3 of the specified design strength of the pipe per minute. This rate of loading shall be continuous until the specified acceptance design strength is reached. The design strength is the maximum load, expressed as a D-Load [ASTM 497].

To calculate the rate of applying the load:

Applying the specifications in ASTM 497, the first 75% of the 21,600 lb. load can be applied at a rate up to 7500 lbf per lineal foot per minute:

7500 lbf x 8 (ft) per minute = 60,000 lbs/min. = 1000 per second.

21,600 lbs x 0.75 = 16,200 lbs

Therefore 16,200 lbs / 1000 (lbs/sec) = 16 seconds, minimum time to reach 16,200 lbs.

Then, the time frame to apply the remaining load of 5400 at the rate of 1/3 design strength of 21,600 (which is 7200) is calculated as:

Given 7200 lbs. per minute/ at maximum = 120 lbs per second.

Then 5400 lbs. applied at 120 lbs. per second = 45 seconds more to reach total load.

Therefore, the total test would take approximately 1 minute (16 + 45) depending on the pipe size and class. Remember that the load rates can always be slower!

To calculate Ultimate Load:

2000 (D-Load) x 8 ft (length) x 2 ft (diameter) = 32,000 to load to destruction

Measuring Cracks

In the early days of the concrete pipe industry, the first visible crack observed in a three-edge bearing test was the accepted criterion for pipe performance. However, the observation of such cracks was subject to variations depending upon the zeal and eyesight of the observer. The need soon became obvious for a criterion based on a measurable crack of a specified width. Eventually the 0.01-inch crack, as measured by a feeler gage leaf, became the accepted criterion for pipe performance.

The gage is made from a leaf 0.01 inches in thickness (as in a set of standard machinist gages), ground to a point of 1/16 in. in width with corners rounded and with a taper of 1⁄4 in./in. as shown in Figure 3-6.

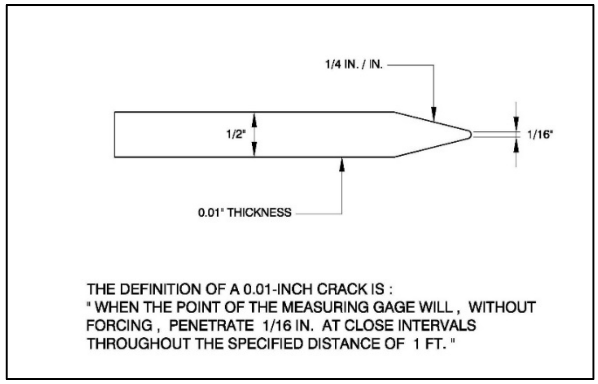


Fig 3.6. Illustration of the Gage Leaf used to measure D-Load crack in a three-edge bearing test.

The most valid basis for selection of a maximum allowable crack width is the consideration of exposure and potential corrosion of the reinforcing steel. If a crack is sufficiently wide to provide access to the steel by both moisture and oxygen, corrosion will be initiated. Oxygen is consumed by the oxidation process and in order for corrosion to be progressive, there must be a constant replenishment.

Bending cracks are widest at the surface and get rapidly smaller as they approach the reinforcing steel. Unless the crack is wide enough to allow circulation of the moisture and replenishment of oxygen, corrosion in the buried condition is unlikely. Corrosion is even further inhibited by the alkaline environment resulting from the concrete surrounding the steel.

Testing Requirements and Frequencies

According to the American Concrete Pipe Association (ACPA), a minimum of five cylinders per week for each mix design used that week shall be prepared and tested, for pipe that are three-edge bearing tested per requirements in the ACPA QCast Certification manual. Pipe shall be tested to the D-Load specified in the ASTM tables for the 0.01-inch crack. Pipe meeting these requirements shall be accepted for use.

Testing is required at the following minimum frequencies:

Pipe Size	Class	Frequency
12 - 15"	Class V and below	1/1000 pieces
18 - 36"	Class IV and below	1/800 pieces
18 - 36"	Class V	1/400 pieces
42 - 60"	Class III and below	1/400 pieces
42 - 60"	Class IV and V	1/200 pieces
66" and larger	All Classes	As required by project specs

ACPA also requires that one piece per size and class produced shall be tested to the ultimate D-load at least one per year. Three-edge-bearing tests are not required on sizes produced that are less than 100 pieces production per year, as long as the plant has proof of design testing and cylinders are cast and tested as per Section 9.7 (Compression Strength Testing) in the QCast Certification Manual.

Requirements for three-edge bearing tests of non-reinforced round concrete pipe, and reinforced arch or elliptical pipe, are also performed according to ASTM C497.

Documentation Requirements

A sample form for recording three-edge bearing test results is provided in the Appendix A of the QCast Certification Manual.

Joint Tests

The function of a pipeline generally determines the performance requirements of the pipe joints. Whether the purpose is to convey sanitary sewage or storm water, joints are designed so that when sections are laid together they will make a continuous line of pipe with an interior free from irregularities. Joints can be designed to provide soil-tightness, or water tightness, with the ability to accommodate lateral or longitudinal movement, and strength to handle shear or vertical movement.

The three types of joint tests covered in this section are:

- Differential Joint Shear Test,
- Off-center Joints Tests (Hydrostatic and Vacuum), and
- Storm Sewer and Culvert Joint Test

Differential Joint Shear Tests – Sanitary Sewer Certification Only

A Differential Joint Shear Test is performed as a proof-of-design test that evaluates the structural capability of the pipe joint when subjected to a differential load. During this test, a shear force, normal to the longitudinal axis of the pipes, is applied across the assembled joint between two concrete pipes. The differential shear test provides an objective value of the structural strength of a concrete pipe joint. There is no widely accepted method of analysis for differential shear through the joints in buried concrete pipes. [ASTM 497]

Differential Joint Shear Test (Three-edge Bearing) Frame Setup

A differential joint shear test is required for sanitary sewer pipe. The setup and procedure for the test is similar to that of the three-edge bearing test in that it utilizes the same test frame to apply pressure to one section of pipe that is connected (see ASTM 497 for specifics).

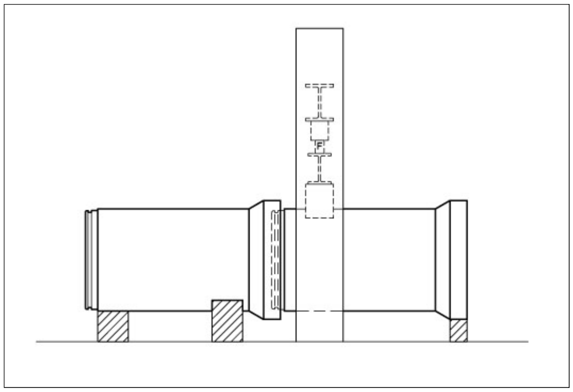


Fig. 3-7. Joint Shear Test w/Three-edge Bearing Test Frame

To perform the test, two test pipes shall be assembled with one pipe fully supported and the spigot or tongue end of the second pipe installed in the bell or groove end of the first pipe as illustrated in Fig 3-7. Both pipes shall be supported so a uniform invert elevation is maintained. A vertical test load is applied to the suspended part of the test joint until the total differential load, including the weight of a pipe, is 4000 pounds per foot of pipe diameter. The shear strength limit shall be noted by a sudden reduction in the applied load or shearing of the concrete.

The joint shear test shall be run without water in the pipe or bulkheads installed on the pipe. During this test, 4000 lbs/ft diameter of pressure is loaded to the joint. Cracks that occur during the test load are not considered failure, provided the cracks are close to a width of less than 0.01 inch on release of the load.

For safety reasons the pipe supports can be constructed as shown in the Fig. 3-8. (**WARNING**—Block or restrain the test pipe assembly horizontally to prevent any inadvertent pipe movements. The blocking or restraints shall be designed to avoid beneficial effects on the test.)

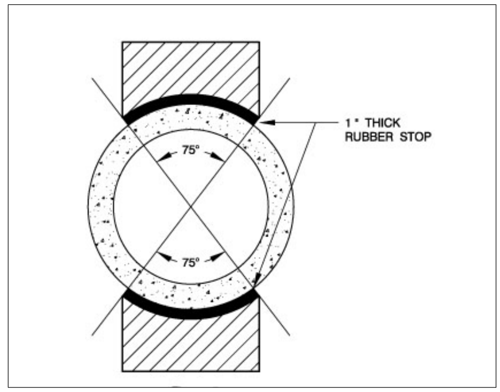


Fig 3-8. Illustration of shear joint test support block configuration

At the manufacturer's option, an alternative method of applying the load (such as at the bottom of the pipe), other than at the top, is allowed provided that the force across the joint meets or exceeds the load required with the pipe properly restrained. [ASTM 497]

Test Load Calculations

The shear force resisted by the test joint shall be calculated by the resolution of applied and gravity forces on the pipe section (Fig. 3-9). The total shear force (F) on the joint is the sum of the resultants of the pipe weight and the applied (F) as shown in Figure 3-10. [ASTM 497]. Here is an example of the calculations involved:

Pipe Data

Date Cast 1/0/00

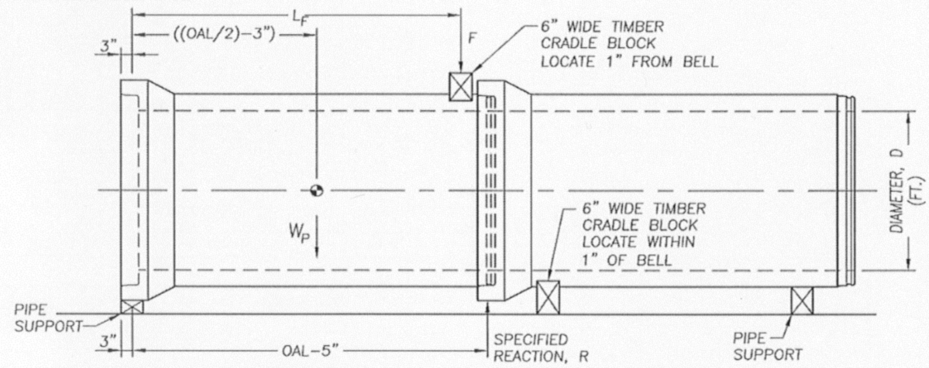
Date Tested 1/0/00

Description

Test Results

A force of 7,000 pounds was applied to the top radius block as shown on the attched drawing. The total shear load at the joint was 4000+ lbs/ ft of internal diameter. No cracks were observed.

Test Setup



OAL	Overall Length of Pipe	100.375	inches
OAL/2	Approximate center of gravity	50.2	inches
L_f	Measurement on Diagram above	89.75	inches
W_p	Nominal Weight of Test Pipe	2888	lbs
R	Test Requirement	8000	lbs
	R= 4000 lbs * Internal Diameter in feet		
F	Additional Test Force	6983	lbs
	F= (((OAL) - 5")R- ((OAL/2 -3") W_p)/ L_F		

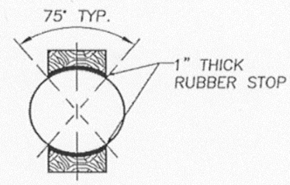
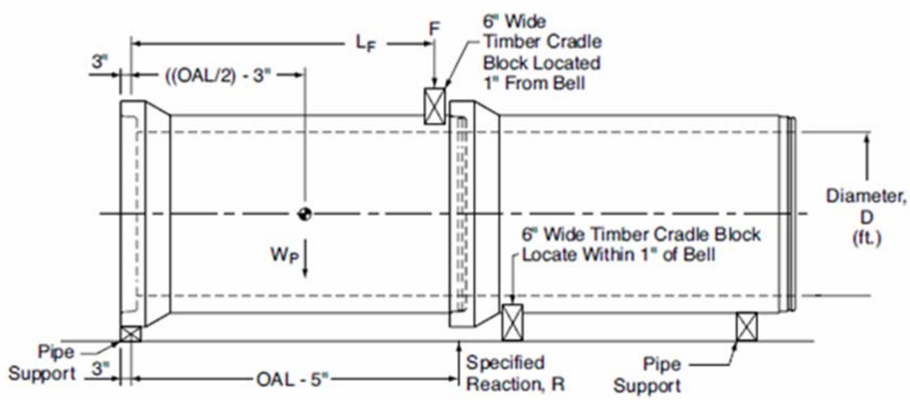


Fig. 3-9. Joint shear test setup and calculations.



R = Test Requirement

Wp = Nominal Weight of Test Pipe

F = Additional Test Force

R = 4000 lbs. x Internal Diameter in Feet

$$F = \frac{[(OAL) - 5"]R - [(OAL/2) - 3"]W_P}{L_F} \text{ (lbs.)}$$

Fig. 3-10. Illustration of joint shear test calculations per ASTM 497.

Testing/Documentation Requirements and Frequencies

For each pipe size and joint design, a proof of design test result for the lowest concrete strength and lowest class of pipe produced must be maintained. The test records shall, at minimum, record results on joints for each size pipe for the lowest class pipe produced (see example provided in the ACPA QCast Certification Manual Appendix A). These reports shall be retained for permanent record, and updated as reinforcing designs and joint configurations are changed.

NOTE: You should expect to run a joint shear test during an audit for sanitary sewer, unless it has been completed and certified at another certified company plant.

Hydrostatic and Vacuum testing apparatus

A standard hydrostatic or vacuum test setup consists of the pipe section(s) to be tested with the ends of the pipes closed off with bulkheads (Fig. 3-11). With bulkheads it is possible to test both the barrel of the pipe and the joint. Joints can also be tested either internally using an internal joint tester (Fig. 3-12), or externally (Fig. 3-13).

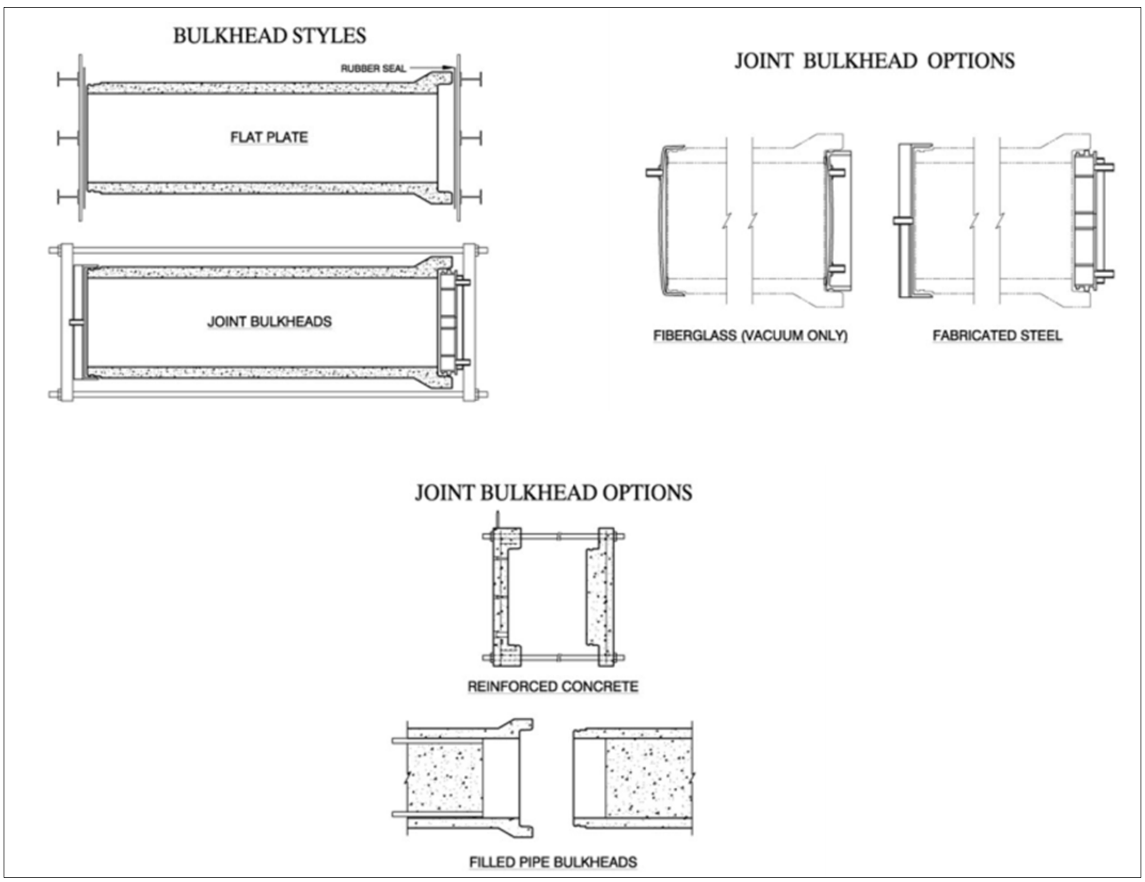


Fig. 3-11. Illustration of bulkhead styles used in hydrostatic and vacuum tests.

Fig. 3-12. Internal joint test.

Fig. 3-13. External joint test.

Off Center Joint Test (Sanitary only)

The off center joint test is an evaluation of the capacity of a pipe joint to remain sealed under pressure, with the spigot installed into the bell in the maximum off center position. The test medium may be hydrostatic or vacuum. To perform the test, two test pipes shall be assembled with one pipe fully supported and the spigot end of the second pipe installed in the bell end of the first pipe (Fig.3-14). For the hydrostatic test, the bulkheads are restrained longitudinally. The longitudinal restraints and bulkheads shall be designed so they do not exert beneficial axial or lateral forces on the test joint assembly. Flat plate bulkheads shall not be used for hydrostatic testing. The test joint shall not be open over 3/4 inches from the design-assembled position. The bell end of the second pipe shall be supported by a block. The supports for the pipes shall maintain a uniform invert elevation for both pipes.

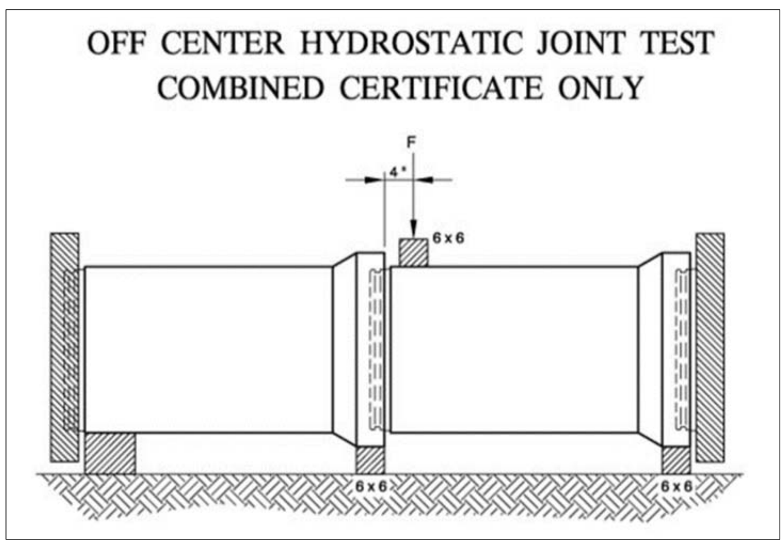


Fig. 3-14. Illustration of Off Center Hydrostatic Joint Test Setup.

CAUTION: The hydrostatic test with bulkheads requires internal pressure to be applied over a large cross-sectional area of pipe bulkheads, creating large axial forces on longitudinal tie rods. Tie rods, bulkheads, and fasteners shall be selected for adequate strength and minimum elongation.

The vertical test load, F, is applied to the suspended portion of the test joint until the total differential load, including the weight of the pipe filled with water shall be either a minimum 1,800 pounds per foot of pipe diameter or until there is concrete-to-concrete contact within the joint (Fig. 3-15). The pipe support blocks are not required to be contoured, but for safety reasons

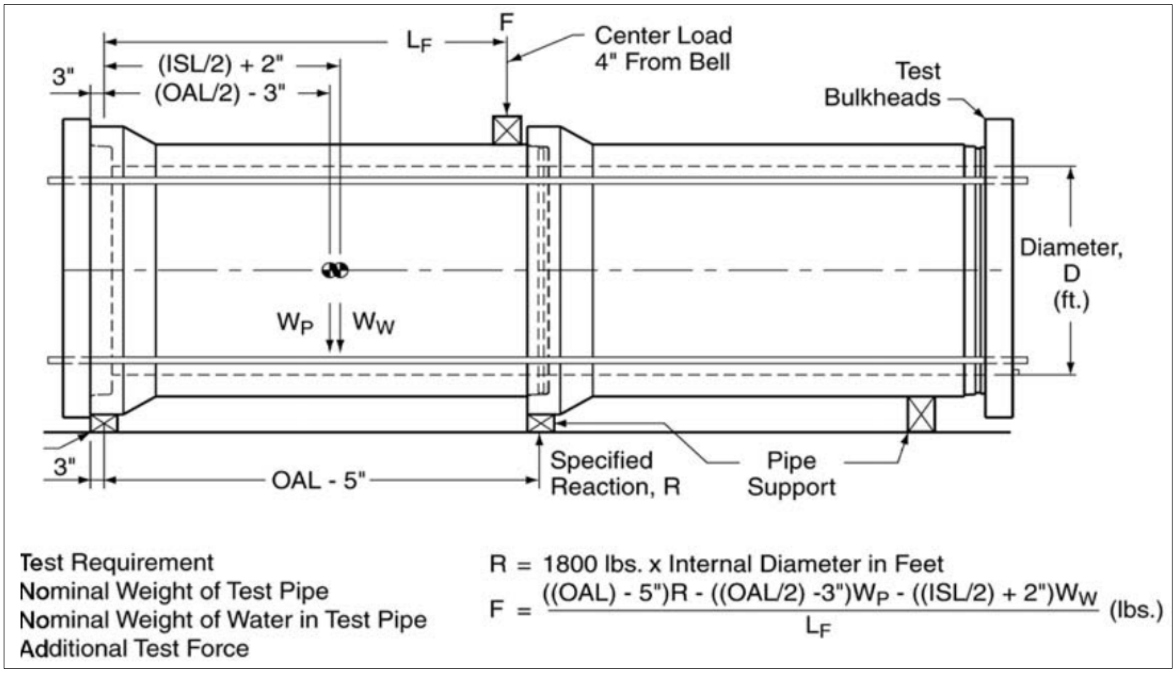


Fig 3-15. Illustration of vertical test load being applied during hydrostatic joint test.

theyshall be constructed to prevent the pipes from rolling from the test position. Moisture or beads of water appearing on the surface of the concrete are not considered leakage.

Test Load Calculations

The additional force required to cause the maximum off-center position in the test joint shall be calculated by the resolution of applied and gravity forces on the joint. The total force on the joint is the sum of the resultants of the pipe weight, the water weight, and the force applied by the test machine (see Figure 3-15).

Passing Requirements

For sanitary certification of 12-inch to 36-inch pipe, 100% of sanitary pipe must be tested at 13 psi for 2.5 minutes and for pipe 42 inches and larger, 1/100 (with a minimum of 2) are to be tested with no visible leakage.

Gasketed Joint Testing for Pipe and Manholes – Vacuum Method

According to the ACPA QCast Certification program, recently cured product should be allowed to cool to the ambient air temperature for greater test reliability before the vacuum test is conducted. Using a vacuum pump starting at 7 inches of mercury, all the air is removed from the bulkhead of the pipe until the internal air pressure is lowered to approximately 8 inches of mercury (Fig. 3-16). It is recommended that a manometer be used to accurately measure the pressure change in a small enough increment to keep test times to a reasonable length. Allow the air pressure and temperature to stabilize, generally 30 seconds to two minutes.

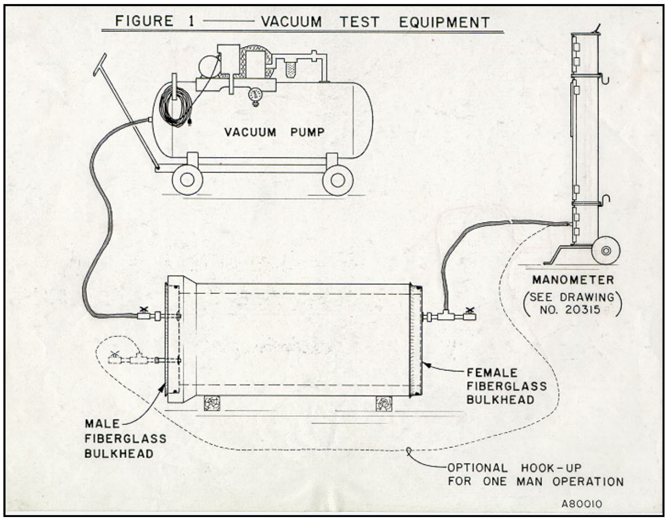


Fig 3-16. Illustration of vacuum test equipment setup.

When the pressure and temperature have stabilized, and the pressure is at or below the starting test pressure equivalent to 7 inches of mercury, begin the test by allowing the pressure to increase to the equivalent of 7 inches of mercury, at which point the time recording is initiated.

Passing Requirements

Using the Vacuum Test Table provided in the ACPA QCast Certification Manual and the appropriate pressure measuring devices (Fig. 3-17), determine if the pressure increase is less than or equal to 0.1083" Hg* in the test time specified in the table for acceptance of test specimen. If the specimen does not pass, either repair and retest or reject the pipe.

*__NOTE:__ A pressure increase of 0.1083" Hg was chosen because it corresponds to a change in water column height of approximately 1 ½ inches and a change in manometer oil column height (specific gravity 2.945) of ½ inch.

Plants wishing to modify the ACPA vacuum testing requirements may do so, as long as their modifications meet the requirements established by the ACPA QCast Certification program, outlined in the Section VI of the certification manual.

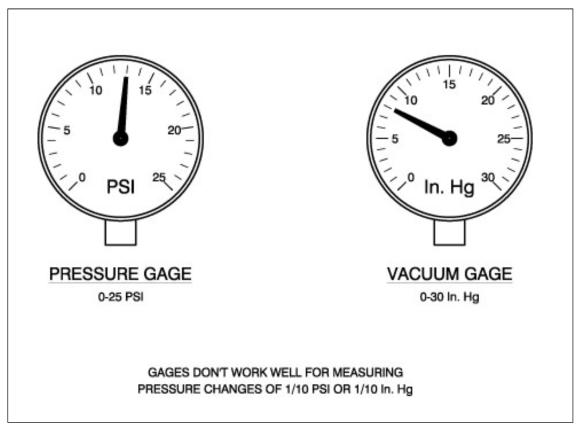


Fig. 3-17. Illustration of pressure measuring devices that can be used in vacuum testing.

Testing, Documentation and Certification Requirements (Hydrostatic and Vacuum Testing)

The ACPA QCast Certification programs requires that you maintain a proof of design test result for all pipe sizes and joint designs used for sanitary sewer pipe. The test records shall, at minimum, record results on joints for each size pipe for the lowest class pipe produced. These reports shall be retained as a permanent record and updated as reinforcing designs and joint configurations are changed.

Proof of design tests for all gasketed pipe sizes and joint designs are also required per ACPA.

Storm Sewer and Culvert Joint Test

The Storm Sewer and Culvert Joint Test is an evaluation of the pipe joint. The test medium may be hydrostatic or vacuum.

To perform this test, two pipes shall be assembled in straight and in deflected alignment as defined by the joint being open 1/2" more on one side, than on the opposite side (Fig. 3-18).

Hydrostatic testing of the joint may be performed either internally, externally, or using conventional bulkheads, the bulkheads shall be restrained longitudinally.

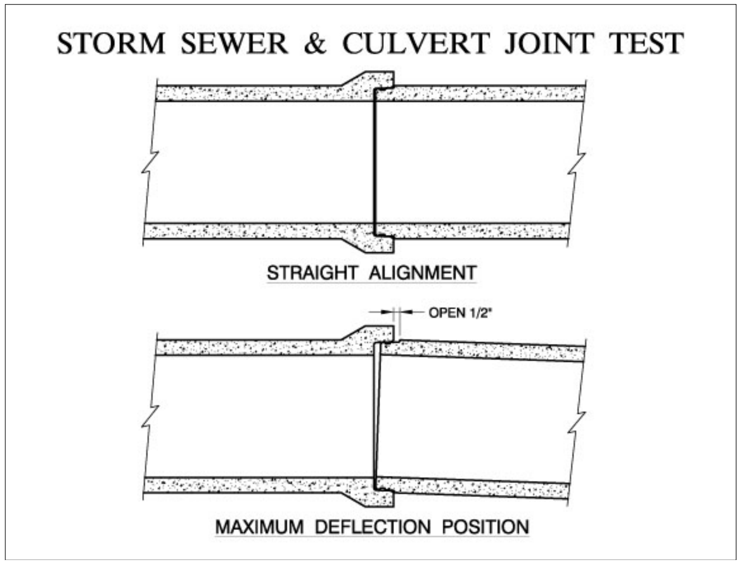


Fig. 3-18. Illustration of straight and deflected alignment setup for storm sewer and culvert joint tests.

According to ACPA, both the straight alignment and deflected assemblies shall be subjected to test criteria as defined by the type of test conducted, as follows:

1. **Vacuum Test:** Use the same criteria as those previously stated for gasketed joint testing.
2. **Hydrostatic Test:** Conduct test at 3 psi for 10 minutes with an allowable leakage rate of 200 gallons/(inch of internal diameter) (mile of pipe) (24 hours). The manufacturer shall have the option of allowing the assemblies to stand under 3 psi for up to 24 hours prior to the test. The test shall be performed according to the summary found in *ACPA QCast Plant Certification Manual*, Appendix A, page 97. For internal joint test, follow equipment manufacturers recommended procedure.

CAUTION: The Hydrostatic Test with bulkheads requires internal pressure to be applied over a cross-sectional area of pipe bulkheads, creating large axial forces on longitudinal tie rods. Tie rods, bulkheads, and fasteners shall be selected for adequate strength and minimum elongation.

Notes

Section 4: Review Questions

The following questions provide a review of the key concepts introduced in this section. An Answer Key is provided at the end of the questions.

Questions

Chapter 1: Post-our Inspection

Answers to the Review Questions are found in the Appendix.

1. Which of the following should be inspected by QC personnel during a post-pour inspection of a pipe/box product?
   a. Cracks on product surface
   b. Product measurements
   c. Excessive bugholes
   d. All of the above
   e. None of the above

2. Maintain a Post-Pour Inspection Record on ______% of all boxes produced each day from each form used that day.
   a. 10%
   b. 20%
   c. 50%
   d. 100%

3. True or False: According to QCast, the plant needs to establish and verify minimum stripping and tipping strengths for the products being manufactured.
   a. True
   b. False

4. True or False: Post-pour inspections are really not needed since the product has already been inspected pre-pour.
   a. True
   b. False

5. How should the pipe be marked when using elliptical reinforcement?
    a. No need for any special markings
    b. Scratch "Elliptical" to the outside of the pipe
    c. Inside and the outside of opposite walls along the minor axis
    d. Springline of the pipe should be marked with waterproof ink

Chapter 2: Repair and Finishing

1. A major defect ____.
    a. Is usually cosmetic
    b. Should be evaluated by a qualified person
    c. Should be immediately sent to the customer and installed
    d. All of the above
    e. None of the above
2. A minor defect ____.
    a. Can never be seen with the naked eye
    b. Is one that does not impair the functional use of the products
    c. Will cause a product to fail before its life expectancy
    d. Should never be documented
    e. Renders the product unusable
3. Exposed steel on the surface of the product should have _________________.
    a. Steel removed before patching
    b. Rub slurry over to hide it
    c. Exposed steel in most cases is cause for rejection of product
    d. All of the above
4. All patches should be ______________________________ when patch has been completed.
    a. Allowed to cure in the open air
    b. Covered to prevent moisture loss
    c. Heated with a torch to speed up cure process
    d. Cured in the same manner as original product
    e. Both b and d are acceptable

Chapter 3: Finished Product Testing

1. For the three-edge bearing test, the “D-load” is expressed in:
    a. Pounds per square inch (psi)
    b. bPounds-force per linear foot per foot of diameter of the pipe
    c. Pounds per foot of pipe length
    d. Pounds per foot of pipe diameter

2. Ultimate D-Load is reached when________________________.
    a. Larger cracks than 0.01” develop in the invert of the pipe
    b. The pipe reaches 3500D
    c. The load reaches 115% of the 0.01” crack strength
    d. The pipe can not carry more load

3. Eight foot long, 24” CL3 B-Wall RCP was observed to develop a 0.01” D-load crack at 19,500 lbs. Does this meet the CL3 0.01” D-load requirement?
    a. Yes
    b. No

4. In the example above, what is the required load to produce the 0.01” D-load crack for the RCP?
    a. 18,500 lbs
    b. 20,250 lbs
    c. 21,600 lbs
    d. 32,000 lbs

5. Inadequately designed tie rod bolts can become projectiles during the hydrostatic test, due to the large axial force generated by the water pressure on the bulkheads.
    a. True
    b. False

Answer Key

Chapter 1: Post-Pour Inspection

1. d
2. b
3. a
4. b
5. c

Chapter 2: Repair and Finishing

1. b
2. b
3. c
4. e

Chapter 3: Finished Product Testing

1. b
2. d
3. b
4. c
5. a

SECTION 5

ACPA QCAST PLANT CERTIFICATION

The American Concrete Pipe Association offers the QCast Plant Certification on a voluntary basis to participating manufacturers of concrete pipe, manholes, engineered precast products, box culverts and three-sided structures. Its main purpose is to continue the advancement of quality in precast concrete pipe and products.

In this section, you will be introduced to the QCast Plant Certification program, which includes program and product requirements, procedures and forms to use, and audit expectations. Plants must meet these requirements and demonstrate compliance to a third-party audit in order to receive certification.

The following illustration depicts the three main elements of the ACPA QCast Certification program for obtaining plant certification as covered in this section.

Page left intentionally blank.

Chapter 1: Introduction to the QCast Certification Program

The greatest strength of the precast concrete pipe and box culvert industry is its ability to manufacture durable products with a service life of more than 100 years. The ACPA's "Quality Cast" Plant Certification Program provides an industry-wide quality control program to ensure superior production throughout the country. QCast is a 124-point audited inspection program, which covers the inspection of materials, finished products and handling/storage procedures, as well as performance testing and quality control documentation.

Guidelines and requirements for completing the QCast Certification Program are contained within the QCast Plant Certification Manual. Details of the following are included in the manual:

Calibration and certification of production, testing, and inspection equipment and instrumentation,

Ongoing plant (internal) inspection and test documentation,

Product tests and documentation,

Raw material certification documentation,

Third party audit verification,

Product design documentation,

Product storage, handling, and repair.

Objectives

At the end of this chapter, you will be able to:

- ✓ Recognize the benefit of obtaining the ACPA QCast Certification.
- ✓ Recall the options for ACPA QCast Certification.
- ✓ Recall the components of the certification program.
- ✓ Recall the qualification requirements for the QC person on-site according to the QCast program.
- ✓ State the scoring requirements for passing for overall and for critical items, respectively.
- ✓ Recall the minimum documentation requirements for initial certification of first time plants.

QCast Plant Certification Program Components

Program Manual

In an effort to improve the overall quality of all concrete pipe products, the ACPA Plant Certification Task Group developed the QCast Plant Certification Program and companion manual, which is offered to members and non-member companies seeking certification. The manual serves to establish the certification requirements and guide companies through the process. It is organized into "common" and "product specific" sections for easy retrieval of applicable requirements, as follows:

I. Common Program Requirements

II. Pipe Requirements

III. Manhole Requirements

IV. Engineered Precast Products

V. Box Culvert and Three-sided Structures Requirements

VI. Appendix A: Procedures & Forms

VII. Appendix B: Audit Expectations

If a plant chooses to go through the Plant Certification process, products to be certified are selected and then audited according to the requirements of this Manual. To assist plant preparations, the *QCast Plant Certification Manual* is available for download from the ACPA website at http://www.concretepipe.org/qcast/.

Program Certification Elements

As stated in the ACPA QCast Certification Program manual, the certification program consists of the following three elements:

1. **Procedures:** Each participating manufacturer of concrete storm sewer and culvert pipe, manholes, sanitary sewer pipe, sanitary manholes, precast products, box culverts and three-sided precast structures maintain sufficient procedures and documentation to assure that these types of products are consistently manufactured and tested in accordance with the requirements of the manual.
2. **Initial and Recertification Audits:** The plant shall be audited in accordance with the ACPA Plant Certification Manual and the elements specified therein. Audits shall be performed by a recognized professional audit firm with knowledge of the products covered in the manual. A resumé of each auditor shall be retained in the auditing firm's files and provided to participating manufacturers upon request. The

auditors shall be trained in the requirements of this program prior to performing an audit. Should a participating manufacturer have doubts as to the qualifications or competence of an auditor, the participating manufacturer may petition the ACPA for relief, following appeal procedures outlined in the manual.

3. **Enforcement:** Achievement and maintenance of the ACPA certificate of compliance is contingent on full compliance with these procedures. No participating manufacturer may use or reference an expired certificate. Legal action may be taken against manufacturers for violating this precept.

QCast Plant Certification Process

In order to receive certification, plants shall meet the requirements of the ACPA's Plant Certification Manual and demonstrate compliance to a third party audit. The plant must follow the steps outlined below when they first apply for certification:

Submit Application(s) – Manufacturers, who voluntarily desire to obtain certification that their manufacturing plant is producing precast concrete products in compliance with this program, shall submit an application to the ACPA. In the application, the manufacturer shall specify the plant to be audited and the certification(s) sought. If more than one plant is to be audited, a separate application shall be submitted for each plant.

Submit a Copy of Plant Quality Control Manual – The manufacturer shall submit a copy of their Plant Quality Control Manual with the initial application. The manual should address each aspect of the certification for which they are being audited. Based on the review, revisions to the plant's manual and procedures may be necessary prior to scheduling the initial audit. It is the manufacturer's responsibility to ensure that adequate product, required documentation, and tests are available for the third-party audit agency to perform a complete audit.

Have All Elements Available for Inspection – Within 20 working days of receipt of the certification application, the ACPA will arrange the auditor assignment and audit schedule with the applicant manufacturer. Applicants shall be notified of the audit date a minimum of 2 weeks prior to the audit. The applicant shall have all elements available for inspection.

Receipt of Satisfactory Audit from ACPA – Upon receipt of a satisfactory audit, the ACPA shall award the applicant a certificate of compliance for a specified period of time. Then another application and payment of fees shall be due to the ACPA to remain in compliance. Compliance certification shall be awarded on the basis of:

Acceptable compliance with product requirements specified in the plant certification manual, and

Maintenance of sufficient documentation to demonstrate continued compliance with the plant certification manual.

In addition to the requirements for initial certification, the *QCast Certification Manual* outlines the process for re-certification, new process notification and re-audits within the Certification Bylaws section.

Benefits of Certification

There are a number of benefits to becoming a QCast Certified Plant. QCast continues to grow with more than 100 certified plants and additional plants are being certified each year. In addition, every year, more state departments of transportation are requiring QCast certification from their suppliers. By becoming QCast certified, your plant can benefit not only from lower costs and higher efficiencies that go along with certification, but also gain recognition as being a plant that produces quality product in accordance with state requirements.

The plant that successfully completes the program requirements will be awarded a certificate of compliance. The certificate may be displayed for customers and employees to identify the plant as being certified. An electronic logo is also available to the plant to create a QCast stencil. The stencil may then be used to mark product as being produced by an ACPA certified plant.

QCast Plant Certification Options and Requirements

Certification Options

Plants may elect any single or multiple product specific certification or full Plant Certification to meet local or state requirements. Current certifications offered include:

- Storm Sewer and Culvert Pipe,
- Sanitary Sewer pipe,
- Manhole,
- Sanitary Sewer Manholes,
- Box Culvert and Three-Sided Structures, and
- Engineered Precast Products
- Full Certification.

QC Personnel Qualification Requirements

Each plant shall have at least one individual, on staff during all production hours, who is currently accredited in one or more of the following:

ACPA Quality School,

ACI Concrete Field Testing Technician Grade 1,

ACI Concrete Laboratory Testing Technician Level 1 or equivalent (such as DOT Certified Concrete Quality Technician)

It is also advised that a second individual be certified as a backup (such as Plant QC Director). These certifications shall be renewed every five years from the date of accreditation.

Scoring Requirements

In order to be awarded the certificate of compliance, participating plants must:

- Receive a minimum overall score of 80 out of a possible 100.
- Receive a score greater than 75 on identified critical audit elements including reinforcing inspections, concrete testing and three-edge bearing testing.

Plants that fail a Combined Storm Sewer and Culvert, and Sanitary Sewer Pipe Certification audit may still gain Storm Sewer and Culvert Pipe Certification or conditional certification if the plant passes all Storm Sewer and Culvert Pipe Certification requirements with an overall score greater than 80, and a score greater than 75 on critical items.

In the next chapter, you will learn about the required contents of the quality documentation, specifications, and information file.

Notes

Chapter 2: QCast Documentation

Why is documentation necessary? It is not just for posterity – it is actually a legal record. Without documentation quality control means nothing! The key reasons for documentation are that it allows us to duplicate our successes, analyze our failures and prove our compliance.

The ACPA Concrete Pipe, Manhole, Box Culvert and Precast Products Certification Program requires that documentation files be maintained in each plant. This chapter will describe the required Document Management System for the QCast Certification Program as well as the types of documents and forms that should be utilized. Sample documents (Fig. 2-1) can be found in the QCast Plant Certification Manual Appendix A.

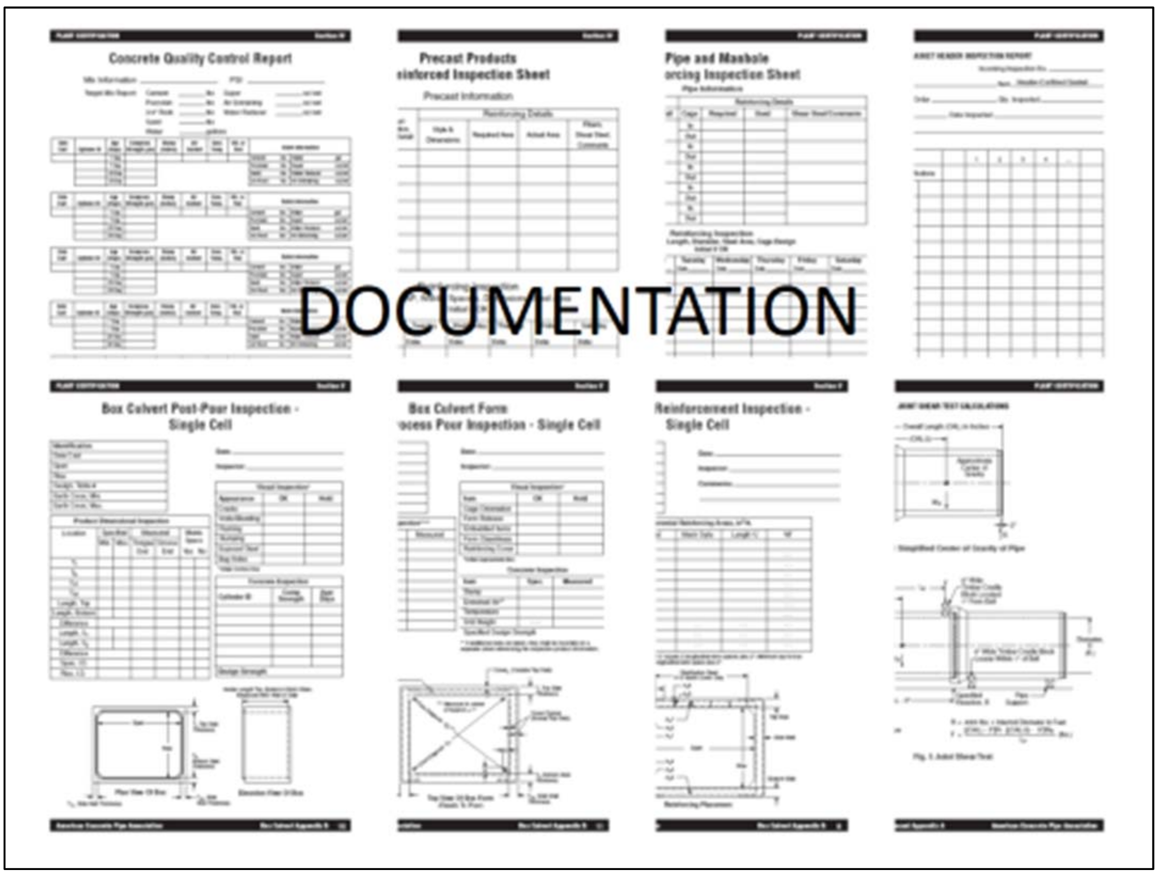


Fig. 2-1. Types of documents to be maintained in quality control files for QCast Certification program.

Objectives

At the end of this chapter, you will be able to:

- ✓ List the items that must be contained and up-to-date in Quality Documentation, Specifications and Information file.
- ✓ Develop an organization chart for all required measurements and tests.
- ✓ Recall the retention period for all documentation unless otherwise specified.
- ✓ Organize your document filing system according to given program recommendations.

Program Documentation Filing System

The QCast documentation filing system should be organized into the following sections:

I. Common Program Requirements

II. Concrete Pipe Requirements

III. Manhole Requirements

IV. Buried Precast Products Requirements

V. Box Culvert and Three-sided Structures Requirements

The documentation files, within each section, shall be retained for the previous three calendar years plus year-to-date, unless otherwise specified. For initial certification, a minimum of two months of documentation is required. Documentation may be paper or electronic files.

Section 1 – Common Program Requirements

The first section of the filing system should be dedicated to common ACPA QCast program requirements. Each of these following items have a number, which corresponds to the list in Section I of the ACPA Qcast Certification Manual. These items are:

- 1.0 Quality Control Documents
- 2.0 Raw Materials
- 3.0 Calibraton
- 4.0 Mix Designs
- 9.0 Concrete Testing
- 10.0 Curing
- 12.0 Product Marking
- 14.0 Storage, Handling, Shipping and Final Inspection

1.0 Quality Control Documents

The Quality Control Documents file shall contain a current copy of each of the items shown in Figure 2-2.

Fig. 2-2. List of Quality Control Documents.

Company/Plant Quality Control Manual

The Company or Plant Quality Control Manual should contain a detailed description of the policy on quality and the quality management structure. This manual should serve as a reference source to enable all staff to work properly and consistently. All plant quality records must be maintained in such a way that they can be easily retrieved. The manual and standard QC documentation (control documents) shall have a version number and/or the date of the current version so that the most recent version can be clearly distinguished.

Following is a list of items and actions that are required within the control manual.

- A description or reference to standard industry procedures which constitute the working quality system
- All necessary technical information for carrying out the plants quality systems or must make clear where the relevant information is to be found
- The document control system

It is recommended that you obtain this manual from the Plant or Company Quality Control Director and evaluate it to ensure that it meets or exceeds all ACPA requirements.

Current ACPA QCast Plant Certification Manual

This section should contain the latest copy of the ACPA Plant Certification Manual. You can obtain a copy from the American Concrete Pipe Association website at www.concretepipe.org.

Current Applicable ASTM Standards

This section should contain both the required ASTM Standards and the recommended Standards and Documents as required by local specifications or product mix. A book containing all required ASTM Standards may be purchased from the ACPA.

A list of Recommended Standards and Documents is included in Appendix A of the *ACPA QCast Plant Certification Manual*.

Documentation for Special Project Specifications

Any special project specifications that exceed the minimum ACPA requirements, or have different test methods, should be documented in this file. If no special projects exist, it may be of value to insert a sheet of paper dated to the current year that says "No special project specifications for the 20XX year to date." The documentation for this file can be obtained from your Project Specifications.

Management Structure and Quality Control Coordinator

The documentation must identify a management structure that oversees the areas of accountability relating to quality control. The plant's management has the obligation to ensure that activities are conducted in accordance with the requirements of the plant's quality system. Each plant shall designate a Quality Control Coordinator and Backup QC Coordinator who are responsible for the plant's quality control program.

Each plant shall have a chart that identifies the areas of accountability relating to quality control and lists the name of the individual(s) responsible for each QC function including final product inspection. If a Quality Control chart does not currently exist, it is recommended that a meeting be conducted with key personnel involved with production, quality and the certification program to identify responsibilities and complete the chart. A sample chart (shown here in Figure 2-3) can be found in Appendix A in the certification manual.

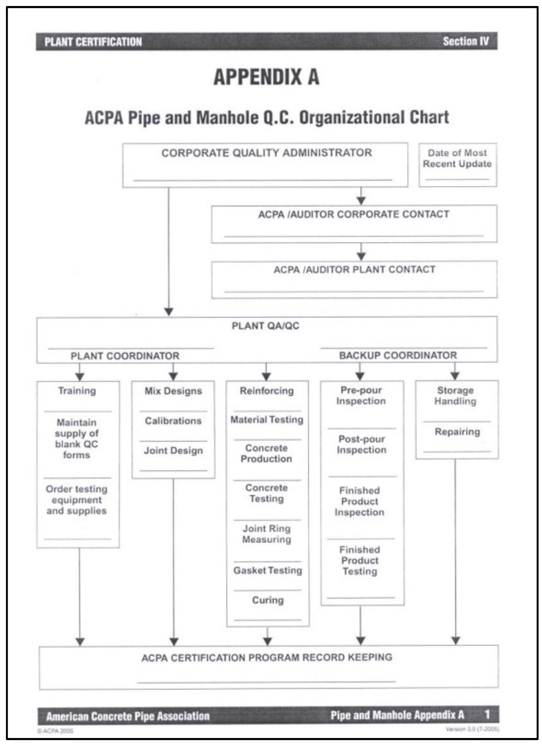


Fig. 2-3. Sample Quality Control Organization Chart template.

This chart should be modified as needed to properly align with plant QC operations. It shall be reviewed and updated at a minimum of annually, or whenever personnel changes are made.

Quality Authority / Hold Production Policy

The plant shall have on file a statement describing the authority of personnel to correct and/or stop production when quality issues arise, and to reject products not meeting requirements. This shall include a description of the authority to prevent product from being poured until after action has been taken to correct issues found during the pre-pour inspection process described in each product-specific requirement Section of the QCast Manual.

The policy should be written by plant/company quality director and approved by the manager responsible for the operation(s) to be certified. Once the policy is written, it should be shared with the entire plant.

QC Personnel Training

Each plant shall have at least one individual who is currently accredited in one or more of the following:

- ACPA Quality School, or
- ACI Concrete Field Testing Technician Grade 1, or
- ACI Concrete Laboratory Testing Technician Level 1 or equivalent, (such as DOT Certified Concrete Quality Technician)

The plant shall have a certified person on site during all production hours. It is also advised that a second individual be certified as a backup. These certifications shall be renewed every five years from the date of accreditation.

Each plant shall hold a quality control meeting at a minimum of once every six (6) months. Attendees shall include supervisory, quality control and production personnel. Each plant shall maintain personnel training records, including the minutes from training meetings and training given to quality control personnel.

Quality Audits

A file containing all audits and reviews of the quality system, including records of corrective and preventative actions taken, must be maintained. The plant Quality Manager, or other designated staff, shall perform audits of the plant's quality system in addition to ACPA QCast audits. The audits may be done at least annually, but it is preferred if they are performed on a rolling basis such that in any one year each aspect of the quality system is covered at least once. All audit procedures and checklists must be maintained in the plant quality manual. Make sure to document the need for any corrective or preventative actions. All QCast audit reports are to be maintained for a minimum of three calendar years.

2.0 Raw Materials

Files containing materials certification should be kept on file for future inspections (Fig. 2-4). These files should include certifications for:

Cement – Cement mill certifications should be received from the cement company once per month for each type of cement being used.

Aggregate – A Certificate of Compliance (ASTM C33) should be received once per year for each material from your aggregate supplier.

Aggregate Gradations – The plant should have gradations for each aggregate quarterly as per Pipe, Manhole and Precast Products Certifications and monthly for Box Certification.

Fig. 2-4. Materials Certifications to be maintained in Raw Materials file.

Fly Ash – A test report should be supplied by the supplier once per month.

Other Cementitious Material – A certification should be supplied by the supplier once per month.

Additives – Certification should be supplied by the additive supplier once per year for each material.

Reinforcing – Mill certification should be supplied by the supplier once per month for each type of product.

Gasket Material – Certification should be supplied by the manufacturer once per year for each type of gasket.

Joint Sealant – Certification should be supplied by the manufacturer once per year for each type of sealant.

Pipe to Manhole Seals – Certification should be supplied by the manufacturer once per year for each type of gasket.

3.0 Calibrations

Documentation verifying that production and testing equipment has been properly and accurately calibrated in accordance with local standards must be maintained with the specified frequency. The following Table 5-1 identifies the equipment, calibration requirements and frequency.

Checklists documenting calibration frequency and results may also be developed in-house to assist with maintaining these records for quality control purposes.

Table 2-1. Equipment calibration requirements and frequency for ACPA QCast program.

Equipment	Requirements	Frequency
Concrete Batching Equipment	Must be calibrated and certified by independent agency.	1 per year
Water Meter	In-house calibration using volumetrically calibrated 55 gallon barrel or water weight, or independent agency calibration.	1 per year
Additive Dispensing Equipment	In-house volumetric calibration using graduated cylinders, or supplier calibration.	1 per year
Concrete Compression Tester	Must be calibrated and certified by independent agency.	1 per year
3-Edge Bearing Tester	Must be calibrated and certified by independent agency.	1 per year
Go/No-Go Gages	In-house or independent agency calibration with micrometer or calibrated bars.	Minimum 1 per year
Laboratory Scales	In-house or independent calibration with certified test weights.	1 per year
Micrometers	In-house or independent calibration with certified micrometer or calibration bars.	1 per year
Vacuum Test Equipment	In-house or independent calibration with manometer column height using a liquid with a verified specific gravity or certified test gage.	1 per year
Pipe Air Test Equipment	In-house or independent calibration with manometer column height using a liquid with a verified specific gravity or certified test gage.	1 per year
Hydro Test Equipment	In-house or independent calibration with certified test gage.	1 per year
Air Content (PCC) Test Equipment	In-house calibration allowed.	1 per year
Curing temperature probes	In-house or independent calibration at high and low temperature. Can use mercury thermometer	

4.0 Mix Designs

File copies of all concrete mix designs must be maintained. These files must be updated as changes are made and they require frequent verification to ensure that the filed mixes are actually those being used in production. These mix designs may be obtained from the engineering department or the production office. Note that some State DOTs allow only pre-approved mix designs to be used. Copies should be maintained in the QC office as well as the batch plant. The following should be documented for all mix designs.

- **Water used in the production of concrete and for concrete curing** – Water shall be potable or non-potable that meets the requirements of ASTM C 1602.
- **Water/Cementitious Material Confirmation** – Confirmation must be documented for each concrete mix design produced. This should be done once per month for Pipe, Manhole and Precast Products and weekly for Box Culverts and Three-sided structures.
- **Concrete Batch Reports for In-Plant Batching** – A minimum of one batch report showing the quantities of all ingredients for one batch shall be documented and maintained on file for each mix design produced each day. Reports may be retained electronically as long as they can be accessed easily.
- **Concrete Batch Reports for Ready Mix Concrete** – Truck delivery receipts listing mix proportions and quantities of all materials, including total water at time of placing, shall be received with each load and maintained on file. The supplier of ready mix concrete shall be local DOT or NRMCA certified. A current supplier certificate shall be maintained on file for each year that supplier delivered product to the plant. Reports may be received electronically as long as they can be accessed easily.
- **Self-Consolidating Concrete (SCC) Quality Control Plan** – The plan shall include a description of the test methods as well as the frequency and requirements for the results of those tests.

9.0 Concrete Testing

Reports documenting slump/flow, temperature, air content, unit weight and absorption shall be kept on file, target values should be listed. Fresh concrete placed in products shall meet all required specifications. These reports should be completed by Quality Control, other plant personnel or other outside testing agencies. Concrete testing procedures must be demonstrated during the audit.

Compressive Strength Testing

Reports documenting compressive strength tests for all mixes used in production must be maintained. A minimum of 5 cylinders per week for pipe tested in TEB, otherwise 5 cylinders per day from each mix design used shall be made and tested. For box culverts, a minimum of 2 additional cylinders per week shall be tested for stripping strength.

Testing done in-house will need to demonstrate cylinder fabrication and concrete strength testing procedures during audit. Strengths should also be monitored to ensure they are adequate at shipping ages per shipping policy.

Concrete not meeting specifications shall not be used in production of certified products.

10.0 Curing

These records should contain reports showing temperature cure cycle of products, minimum one kiln per day/cycle. Maximum temperatures must be kept below 160^{o}F (71^{o}C) with a maximum rise or fall of 40^{o}F/hr (25^{o}C/hr). Plants should have instruments to measure the cure cycle of products daily.

12.0 Product Marking

No files are required here but you must understand the minimum requirements of ASTM or local standards for marking your products. Periodic checks of your products should be conducted to ensure that they are properly marked.

14.0 Storage, Handling, Shipping and Final Inspection

Handling and Storage

A maximum stacking height policy must be written for each class and size of product. Ensure that all products are handled to prevent damage. All rejected materials must be clearly marked and separated.

Shipping Policy

A Shipping Policy must be written that corresponds with your current shipping practices and how they relate to three-edge bearing (TEB) and concrete compression test results and inspection criteria. Use a reference so that QC personnel, shipping personnel and ACPA Auditor can verify product compliance at the time of shipping. Correlate age at shipping with strength or TEB test results.

Final Inspection

A Final Inspection Policy must be written that corresponds with your actual practices. Identify persons trained and responsible for the final inspection in the policy. Document final inspections to verify product compliance at the time of shipping.

Sections II – V Concrete Product Requirements

In addition to the Common Requirements in Section I of the ACPA's QCast Plant Certification, there are certification requirements for:

- Pipe (Section II),
- Manhole (Section III),
- Buried precast products (Section IV), and
- Box culvert and three-sided structures (Section V).

A plant undergoing pipe, manhole, buried precast products, box culvert and three-sided structures certification should refer to both Section I and the associated section to fulfill certification requirements.

All concrete products have certification requirements for the following:

- **Joints** – Includes detailed drawings of joints used for gasketed and non-gasketed pipe, manholes, precast and boxes with tolerances highlighted. Includes requirements about Joint Design Drawings, Joint Design Calculations, Spigot/Go-No-Go Gage, and Gasket Quality Testing and Procedures. For Sanitary pipe, include design calculations and Go/No-Go gaging system including gasket compression figures. Proper use of Go/No-Go gaging will also need to be demonstrated during an audit. For Gaskets, gasket QC test will have to be demonstrated during an audit with results being compared to acceptable results.
- **Equipment** – Includes requirements for new and repaired equipment inspection prior to casting. Forms and Joint Forming Equipment also have inspection requirements. This file should contain inspection reports for all new and repaired equipment to check dimensions and function. Reports can be completed in-house or by equipment suppliers. Plants should always verify critical measurements.
- **Reinforcing** – Requires detailed design information, including cage diameter tolerances and minimum lap, in the reinforcing fabrication area for cages/reinforcement being fabricated. This information may be obtained in-house or by a second-party contracted to complete standard or job-specific drawing. Drawing must include mesh style, diameter, length, steel area (design and actual), location in wall, lap, bell reinforcing, and shear steel. The design information should be retained on file and at the cage production area.
- **Pre-Pour Inspection** – Includes inspection requirements for documenting pre-pour inspection of reinforcing, forms (visual and dimensional) and embedded items. These reports should be completed by Quality Control and other designated plant personnel.
- **Post-Pour Inspection** – Requires a check of a portion of each day's production before and after patching or "finishing". This inspection shall show that the correct production and patching techniques are being used. Sample forms can be found in the QCAST Manual Appendix.
- **Testing** – Requires that the results of tests and inspections on the finished product be maintained. The documentation maintained should include: three-edge bearing tests, water tightness tests (for sanitary pipe); gasketed joint tests (off-center, differential shear, and storm sewer/culvert). Test methods and minimum test frequencies are described in the QCast manual and appendix. These tests procedures must also be demonstrated during a QCast audit.

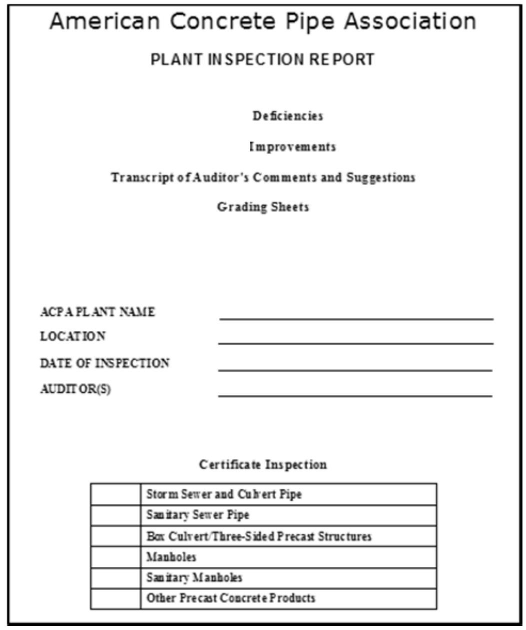
Additionally, a plant undergoing Engineered Precast Products Certification must fulfill certification requirements on production drawings of standard and non-standard/special products.

Notes

Notes

Chapter 3: The Audit

A quality control audit is defined as "a periodic onsite-verification by a certification authority to ascertain whether or not a documented quality system is being effectively implemented."[1] The ACPA QCast audit is an onsite verification conducted by third party auditors selected by ACPA to ensure that the Manufacturer is in compliance with the production requirements of quality precast products.



American Concrete Pipe Association

PLANT INSPECTION REPORT

Deficiencies

Improvements

Transcript of Auditor's Comments and Suggestions

Grading Sheets

ACPA PLANT NAME ______________________

LOCATION ______________________

DATE OF INSPECTION ______________________

AUDITOR(S) ______________________

Certificate Inspection

	Storm Sewer and Culvert Pipe
	Sanitary Sewer Pipe
	Box Culvert/Three-Sided Precast Structures
	Manholes
	Sanitary Manholes
	Other Precast Concrete Products

To be eligible for the audit, the Manufacturer must be engaged in the manufacturing of concrete products of the type for which the plant is being certified. Under no circumstances is a Manufacturer allowed to sell products manufactured in an uncertified plant as being from an ACPA certified plant.

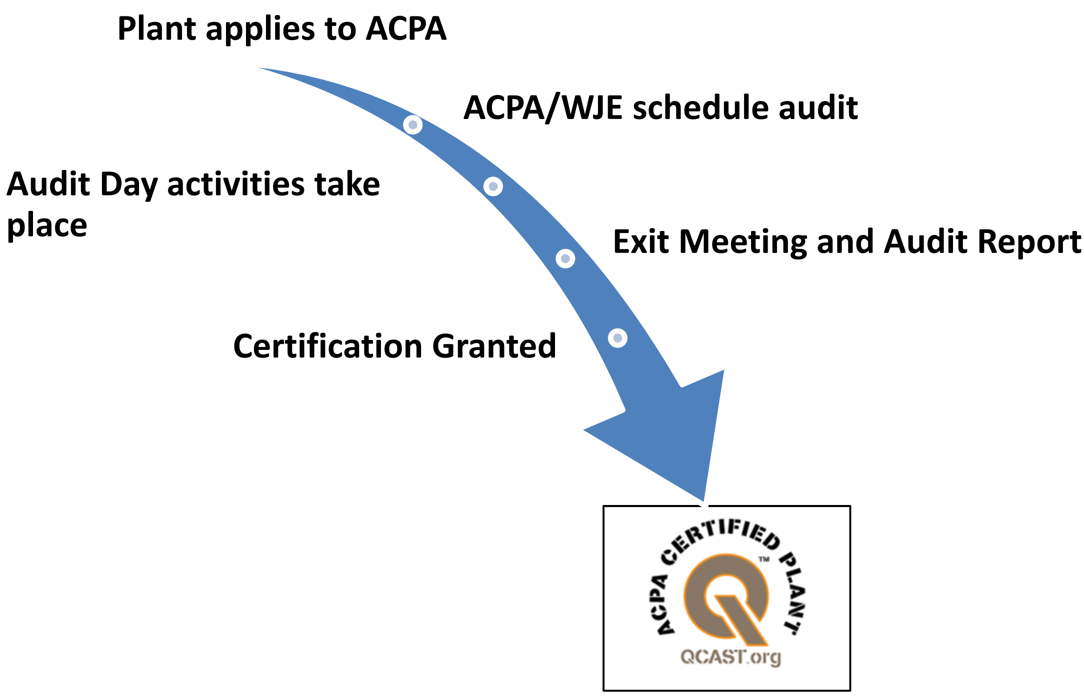
In this chapter, you will be introduced to the audit process, the audit verifications and the certification inspection report.

Objectives

At the end of this chapter, you will be able to:

- ✓ Summarize the areas that are checked and verified on Audit Day.
- ✓ Read and interpret the information provided on the Audit Manual Score Summary Sheet.

Audit Process



The QCast audit is initiated when the Manufacturer applies for QCast Certification, thereby entering into a contract with the ACPA for compliance with the production of quality precast concrete products. Within 20 working days of receipt of the QCast Plant Certification application, the ACPA will arrange the third-party auditor assignment and audit schedule with the applicant manufacturer. The ACPA retains sole authority for selection and appointment of the Audit Agency.

Applicants are notified of the audit date a minimum of two weeks prior to the audit. The applicant must have all elements available for the auditor's inspection. The Manufacturer is required to provide full cooperation with the Audit Agency, ACPA, and their employees or agents.

At the conclusion of the plant audit, the auditor will provide immediate feedback of the audit findings during an exit meeting with plant staff. Plants should arrange for available management and quality staff responsible for QCast to attend the exit meeting. The auditor will discuss the findings of the audit with plant staff and allow plant staff to provide any clarifications or additional supporting documentation. The exit meeting allows for plant staff to immediately address any needed improvements. Additional audits or re-audits are available on request of the Manufacturer on a cost as billed basis.

Audit Day Product Verification and Testing

During the audit, the auditor will check documentation files for completeness and content. The following documentation must be made available to the third party auditor on the audit day:

- Plant quality control manual (current)
- Quality documentation files
- Materials documents/specifications
- Calibration documents
- Copies of all concrete mix designs and batch reports
- Joints, equipment, reinforcing, pre-pour and post pour inspections for pipe, manholes, engineered precast products, and box culverts and three-sided structures
- Concrete and product testing documentation
- Written curing procedures
- Handling and storage maximum stack heights
- Written shipping policy
- Final inspection procedure

Additionally, you will be expected to provide the auditor with proof of adherence to quality requirements as listed in the tables to follow.

Product Verification and Testing

Audit Areas	**Requirements**
Reinforcing	• Have detailed reinforcing design in the fabrication area. • Show how cages are measured. • Measured cages being used must meet specifications.
Concrete Batching	• Batches proportioning must follow mix designs. • Show competence in batching.
Forms	• Inspect condition and cleanliness of forms.
Testing	Plant personnel shall show competency when performing the following tests: • Compressive strength: cylinder preparation, handling,

Audit Areas	**Requirements**
	curing and testing • Slump, Flow, Temp, Air content testing (as applicable) • Concrete absorption testing (If done in house) • Aggregate gradation testing (If done in house)

Inspections	Plant personnel shall show competency when performing the following inspections:
	• Gasket Testing (If done in house)
	• Sanitary (if done in-house):
	    o Pallet Inspection
	    o Header Inspection
	    o Truing Ring Inspection

Curing	Plant personnel shall demonstrate curing methods and retrieve temperature results.

Finished Product Inspections and Testing

Audit Areas	**Requirements**
Plant Procedures	Inspection and review of plant procedures for: • Pipe/MH barrel appearance • Pipe/MH joint appearance • Box appearance • Precast appearance
Inspections and Tests for Procedure, Equipment and Results	The auditor shall witness the following inspections and tests for <u>procedure, equipment</u> and <u>results.</u> • Barrel/Box dimensions • Joint design drawings and tolerances • Pipe/MH/Box joint inspection • Go/No-Go gauging (Sanitary) • Water tightness tests (sanitary)

Audit Areas	Requirements
	• Three-edge bearing tests • Off center hydrostatic joint test (sanitary) • Differential joint shear test (sanitary) • Storm sewer and culvert joint test (gasketed) • Compressive strength test • Gasket tests
Plant Procedure Verification	The auditor shall verify plant procedures for: • Product marking • Handling and storage • Repairs • Segregating of reject pieces • Final inspection
Manholes	• Pre-pour each piece (wet-cast) • Joint design calculations/drawings (Sanitary) • Joint forming equipment • Dimensional checks of spigots • Water-tightness Vacuum/Hydro (Sanitary) • Step testing
Precast	• Standard and non-standard products o ASTM or local specifications control • Reinforcing drawings and tolerances • Pre-pour min. one cage/shift/type • Post-pour critical dimensions/blockouts
Box Culvert	• Monthly Gradations • Air pot calibrations quarterly (if applicable) • Pre- and Post- product inspections • Fit test

Plant Inspection Report

The final deliverable from the audit is a Plant Inspection Report. Below is an illustration showing the cover page of the ACPA Plant Inspection Report Form (Fig. 3-1). This lists the types of documentation that will be included in the report as well as plant, date and auditor information. This cover page is used for all types of certificate inspections. At the bottom of the cover sheet is a place to check the type(s) of certificate inspections that are covered in the audit.

American Concrete Pipe Association

PLANT INSPECTION REPORT

Deficiencies

Improvements

Transcript of Auditor's Comments and Suggestions

Grading Sheets

ACPA PLANT NAME ____________________

LOCATION ____________________

DATE OF INSPECTION ____________________

AUDITOR(S) ____________________

Certificate Inspection

	Storm Sewer and Culvert Pipe
	Sanitary Sewer Pipe
	Box Culvert/Three-Sided Precast Structures
	Manholes
	Sanitary Manholes
	Other Precast Concrete Products

Fig. 3-1. ACPA Plant Inspection Report Cover Page format.

The sheet(s) that follow the cover sheet is known as Audit Manual Score Summary Sheet. There are score summary sheets for each type of product going through the certificate inspection process:

- Pipe,
- Manhole,
- Buried precast products, and
- Box culvert and three-sided structures.

The following example (Fig. 3-2) is a sample of the score summary sheet for pipe requirements. It shows the possible points for each section, the grade given by the auditor and the final score based on maximum points and grade given.

PIPE REQUIREMENTS

Plant ____________________ **Date of Audit** ____________________

Location ____________________ **Inspector** ____________________

Section	Description	Possible Points (A)	Grade (B)	Score (AxB)
	Product Documentation			
1.0	Quality Control Documents and Info	4	100	4.00
2.0	Raw Materials	3	85	2.55
3.0	Calibration	4	75	3.00
4.0	Mix Designs	4	100	4.00
	Joints			
5.1	Joint Design Drawings	2	100	2.00
5.2	Joint Design Calculations (SS)	2	NA	
5.3	Spigot Gauge System (SS)	2	NA	
5.4	Gasket Quality Control & Testing	3	100	3.00
	Equipment			
6.1	Forms	3	90	2.70
6.2	Joint Forming Equipment Inspection	4	90	3.60
	Pre-pour Product Inspection			
7.0	Reinforcing[1]	6	85	5.10
8.0	Pre-Pour Inspection	5	70	3.50
9.0	Concrete Testing	4	85	3.40
9.7	Compressive Strength Testing[1]	6	90	5.40
	Post-pour Product Inspection			
10.0	Curing	4	100	4.00
11.1	Repairs and Finishing	2	80	1.60
11.2, 11.4	Product Visual Inspection	2	90	1.80
11.3	Dimensional Test Reports	2	90	1.80
11.5	Sanitary Joint Dimensional Inspection (SS)	2	NA	
12.0	Product Marking	3	85	2.55
	Product Testing			
13.1	Water Tightness Test[1] (SS)	6	NA	
13.2	Three Edge Bearing Test[1]	6	85	5.10
13.3	Off Center Joint Test[1] (SS)	6	NA	
13.4	Differential Joint Shear Test[1] (SS)	6	NA	
13.5	Storm & Sewer Joint Test[2] (S)	6	67	4.00
	Storage, Handling, Shipping, and Final Inspection			
14.1	Storage and Handling	3	90	2.70
14.2	Shipping Policy	3	100	3.00
14.3	Final Inspection	3	100	3.00
	Total Applicable Points (S)	82		71.80
	Adjusted Score[3]			87.56

Fig. 3-2. Example of the ACPA Audit score summary sheet

The following information appears at the bottom of the score summary sheet and explains Product Testing grading stipulations as well as the Minimum Passing Score.

1. Critical Element: Minimum Passing Score = 4.5
2. 4 Points for Proof of Design, 2 Points for Testing

Minimum Passing Score = 80 / Conditional Certification Score = 75

(SS) = Sanitary Sewer Only

(S) = Storm Sewer and Culvert Only

About the Third-party Audit Agency

Wiss, Janney Elstner Associates, Inc. (WJE) is a national consulting engineering firm of engineers, architects and material scientists that has been serving clients for over 50 years. They routinely work with state highway agency staff and other clients to solve difficult problems. WJE was selected to be the third-party audit agency for the ACPA based on the qualifications of the firm and the quality of the people that work for them. Since the inception of the program in 1998, they have performed more than 850 audits and not only exceeded the expectation of the ACPA with regard to their detailed and thorough approach to auditing to the requirements of the QCast manual, but have helped push the industry forward by continuously working with the ACPA to “raise the bar,” by developing and implementing additional requirements to the program.

Please review the QCast Plant Certification Manual at www.concretepipe.org. For more information about QCast, contact the ACPA at (972) 506-7216 or info@concretepipe.org.

Notes

Notes

Section 5: Review Questions

The following questions provide a review of the key concepts introduced in this section. An Answer Key is provided at the end of the questions.

Questions

Chapter 1: Introduction to QCast Certification Program

1. What are the three main elements of the QCast certification program?
    a. Pipe, Box Culvert, Manholes
    b. Procedures, Audits, Enforcement
    c. Design, Inspection, Training
    d. Policy, Standards, Specifications

2. How many different certification options are available for the producer?
    a. 3
    b. 5
    c. 6
    d. 9

3. When being audited for the first time, plants should have a minimum of ________ documentation of required ACPA information.
    a. Two months
    b. One year
    c. Two years
    d. Three years

4. How often do the QC personnel certifications have to be renewed?
    a. Never
    b. Every year
    c. Every 5 years
    d. Every 10 years

5. What is the minimum overall score needed to pass the QCast audit?
    a. 90%
    b. 80%
    c. 70%
    d. 65%

Chapter 2: QCast Documentation

1. ASTM Standards filed at the plant should be updated every year.
    a. True
    b. False
2. The quality control organizational chart should be updated __________________________.
    a. Only when personnel changes are made
    b. Yearly
    c. Yearly and when personnel changes are made
3. All plants shall have a written Quality Authority/Hold Production Policy.
    a. True
    b. False
4. The designated QC person has the authority to correct and/or stop production when quality issues arise, and to reject products not meeting requirements.
    a. True
    b. False
5. A qualified QC person has to be on-site during production hours and be independent of production personnel.
    a. True
    b. False

Answer Key

Chapter 1: Introduction to QCast Certification Program

1. b
2. c
3. a
4. c
5. b

Chapter 2: QCast Documentation

1. a
2. c
3. a
4. a
5. a

Appendix A: References

Section 1: Concrete Fundamentals

Chapter 1

1 Wikipedia contributors, "Concrete," *Wikipedia, The Free Encyclopedia,* https://en.wikipedia.org/w/index.php?title=Concrete&oldid=686957223 (accessed October 30, 2015).

2 TIMELINE OF CONCRETE & CEMENT HISTORY From Egyptians to Engravers. (n.d.); Retrieved June 30, 2015, from http://www.concretenetwork.com/concrete-history/

3 https://en.wikipedia.org/wiki/John Smeaton

4 PCA - http://www.concretethinker.com/detail/History-Portland-Cement.aspx

5 https://en.wikipedia.org/wiki/Joseph-Louis_Lambot

6 From http://precast.org/dev/wp-content/uploads/2014/08 /Box_Culvert_Presentation.pdf

Chapter 2

1 Hewlett, P., ed. *Lea's Chemistry of Cement and Concrete, Fourth Edition*. Burlington, MA, Linacre House, 1988. page 2.

2 "Cement." (2016, January 21). Wikipedia. https://en.wikipedia.org/w/index.php?title=Cement &oldid= 700991524.

3 "Cement Types." Portland Concrete Association. http://www.cement.org/cement-concrete-basics/concrete-materials/ cements.

Chapter 3

1 Slag Cement Association. "Slag Cement in Concrete." No. 1. 2013. http://slagcement.org/ Publications/pdf/No1_Slag_Cement.pdf.

2 Ibid.

3 Kosmatka, S., Kerkhoff, B., & Panarese, W. C. *Design and Control of Concrete Mixtures 15th Edition*, pp. 71-72. Skokie, Illinois. Portland Cement Association, 2011.

4 Ibid.

Chapter 4

1 “History/Facts.” Cemex Products & Services, Aggregates. http://www.cemexusa.com/ProductsServices/AggregatesHistoryFacts.aspx

2 Ibid.

3 “Construction Aggregate.” (2016, May 29). In Wikipedia, The Free Encyclopedia. Retrieved from https://en.wikipedia.org/w/index.php?title=Construction_aggregate&oldid=722674238

4 Kosmatka, S., Kerkhoff, B., & Panarese, W.C. (2002), Design and Control of Concrete Mixtures, 14th Edition, Skokie, Illinois, Portland Cement Association, p. 92.

Chapter 5

1 Harris, T & Jeknavorian, A., PH.D. “Chemical Admixtures for Concrete: What’s Next?” January 13, 2014. http://precast.org/2014/01/chemical-admixtures-concrete-whats-next/.

2 Ibid.

3 Ibid.

4 Ibid.

Chapter 6

1 *Reinforcement for Concrete – Materials and Applications*, ACI Education Bulletin E2-00 (Reapproved 2006), Developed by Committee E-701, Materials for Concrete Construction), p 2-1.

2 Ibid. p. 2-7.

3 Ibid. p. 2-7.

Chapter 7

1 Vachon, Martin. “ASTM Puts Self-Consolidating Concrete to the Test.” ASTM Standardization News. http://www.astm.org/SNEWS?JULY_2002/vachon_jul02.html.

Chapter 8

1 “Durability.” Portland Cement Association. Skokie, Illinois. http://www.cement.org/for-concrete-books-learning/concrete-technology/durability.

2 "Durability." Portland Cement Association.

3 "Acid Resistance." Portland Cement Association. Skokie, Illinois. http://www.cement.org/for-concrete-books-learning/concrete-technology/durability/acid-resistance.

4 "Acid Resistance." Portland Cement Association.

5 "Acid Resistance." Portland Cement Association.

6 "Types of Chemical Attacks on Concrete Structures." The Constructor Civil Engineering Home. http://theconstructor.org/concrete/types-of-chemical-attacks-on-concrete-structures/7237/.

7 "Types of Chemical Attacks on Concrete Structures." The Constructor Civil Engineering Home.

8 "Corrosion of Embedded Materials." Portland Cement Association. Skokie, Illinois. http://www.cement.org/for-concrete-books-learning/concrete-technology/durability/corrosion-of-embedded-materials.

9 "Corrosion of Embedded Materials." Portland Cement Association.

10 "Corrosion of Embedded Materials." Portland Cement Association.

Section 2: Concrete Production

Chapter 3

1 Kosmatka, S., Kerkhoff, B., & Panarese, W. C. Design and Control of Concrete Mixtures 14th Edition, pp 350-351. Skokie, Illinois. Portland Cement Association, 2002.

2 ASTM 1610

3 Ibid.

4 Koehler, Eric P. & Fowler, David W. *Inspection Manual for Self-Consoidating Concrete in Precast Members*, pp. 7-8. http://www.utexas.edu/research/ctr/pdf_reports/0_5134_P1.pdf

5 ConcreteNetwork.com. "Testing Self-Consolidating Concrete." http://www.concretenetwork.com/self-consolidating-concrete/testing-scc.html

Section 3: Concrete Products Manufacturing

Chapter 1

ASTM C478 - Standard Specification for Circular Precast Reinforced Concrete Manhole Sections

ASTM C76 – Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewere Pipe

ASTM C1433 – Standard Specification for Precast Reinforced Concrete Monolithic Box Sections for Culverts, Storm Drains, and Sewers

ASTM C1577 – Standard Specification for Precast Reinforced Concrete Monolithic Box Sections for Culverts, Storm Drains, and Sewers Designed According to AASHTO LRFD

Chapter 2

1 "Field Inspection of Reinforcing Bars, Engineering Data Report 54," 2004, p. 2. Concrete Reinforcing Steel Institute.

2 Ibid., p. 2.

3 Gurley, E. " Pre and Post Pour Inspections, Your Most Important Checklists," p.11. National Precast Concrete Association. February 2014. http://precast.org/wp-content/uploads/2014/02/ Q5-Pre-Post-Pour-Evan-Gurley_FINAL.pdf.

4 "Proper Application of Release Agents, Tech Note," p.1-2. National Precast Concrete Association. March 2013. http://precast.org/dev/wp-content/uploads/2015/03/TechNote-Proper-Application-Form-Release.pdf.

Chapter 3

2 Suprenant, Bruce. "Concrete Vibration - *The why and how of consolidating concrete*." Department of Civid Engineering & Mechanics, University of South Florida. Tampa, Florida. https://www.scribd.com/document/95416591/2-Concrete-Vibration.

Chapter 4

1 Kosmatka, S., Kerkhoff, B., & Panarese, W.C. *Design and Control of Concrete Mixtures, 14th Edition*, p. 219. Skokie, Illinois. Portland Cement Association, 2002.

2 Ibid. p. 221

3 Ibid.

4 Ibid.

5 Ibid. p. 224

6 Ibid. p. 222

7 Ibid. p. 223

8 Ibid. p. 223

Section 4: Finished Product Inspection, Repair and Testing

Chapter 2

1 Yelton, Rick. "Patching Concrete Pipe." The Concrete Producer. Publication #J05E045. May 15, 2005. http://www.theconcreteproducer.com/Images/Patching%20Concrete%20Pipe_tcm77-1308070.pdf.

Section 5: ACPA QCast Plant Certification

Chapter 3

1 Business Dictionary. "Audit." http://www.businessdictionary.com/definition/audit.html#ixzz3knCO8QRR).

Appendix B: Images

Section 1

Chapter 1

1-1 File:The Hoover Dam and Mike O'Callaghan – Pat Tillman Memorial Bridge under construction.jpg. This image was originally posted to Flickr by David Jones at http://flickr.com/photos/45457437@N00/4430518713. It was reviewed on 7 November 2010 by the Flickreview R robot and was confirmed to be licensed under the terms of the cc-by-2.0.

1-2 "TIMELINE OF CONCRETE & CEMENT HISTORY From Egyptians to Engravers." Concrete Network. http://www.concretenetwork.com/concrete-history/

1-3 Magnus Manske on en.wikipedia [Public domain], via Wikimedia Commons from Wikimedia Commons. https://commons.wikimedia.org/wiki/File%3AJohn_Smeaton.jpg.

1-4 "History of Portland Cement." Portland Cement Association. http://www.concretethinker.com /detail/ History-Portland-Cement.aspx.

1-5 Jorune (Own work) [CC BY-SA 3.0. http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons August 26, 2011.

1-8 "Earthquake Glossary – tensional stress." United States Department of Interior, U.s. Geological Survey. http://earthquake.usgs.gov/learn/glossary/?term=tensional%20stress. "Hardened Concrete – Strength." The Concrete Portal. http://www.theconcreteportal.com/ hard_strength.html.

1-8 "Hardened Concrete – Strength." The Concrete Portal. http://www.theconcreteportal.com/ hard_strength.html.

Chapter 2

2-2 Kosmatka, S., Kerkhoff, B., & Panarese, W.C. *Design and Control of Concrete Mixtures, 14th Edition*. Skokie, p.21. Illinois. Portland Cement Association, 2002.

2-7 Kosmatka, S., Kerkhoff, B., & Panarese, W.C., p. 25

Chapter 3

3-1 Kosmatka, S., Kerkhoff, B., & Panarese, W. C. *Design and Control of Concrete Mixtures 14th Edition*, p 58. Skokie, Illinois. Portland Cement Association, 2002.

3-2 Kosmatka, S., Kerkhoff, B., & Panarese, W. C., p. 58.

3-4 Kosmatka, S., Kerkhoff, B., & Panarese, W. C., p. 58.

3-5 Kosmatka, S., Kerkhoff, B., & Panarese, W. C., p. 59.

3-6 U.S. Department of Transportation, Federal Highway Administration. *Silica User's Manual*, p. 5. Silica Fume Association. April 2005. http://www.silicafume.org/pdf/silicafume-users-manual.pdf.

3-7 Kosmatka, S., Kerkhoff, B., & Panarese, W. C., p. 61.

3-8 Kosmatka, S., Kerkhoff, B., & Panarese, W. C., p. 60.

Chapter 4

4-1 Kosmatka, S., Kerkhoff, B., & Panarese, W.C. (2002), *Design and Control of Concrete Mixtures, 14th Edition*, p. 79. Skokie, Illinois. Portland Cement Association, 2002.

4-2 Kosmatka, S., Kerkhoff, B., & Panarese, W. C., p. 79.

4-3 Oder Zeichner: unbekannt. National Park Service. http://www.nps.gov [Public domain], via Wikimedia Commons.

4-4 Public domain images website, http://www.public-domain-image.com/full-image/textures-and-patterns-public-domain-images-pictures/rock-stone-texture-public-domain-images-pictures/limestone-rocks.jpg.html. Author: Titus Tscharntke.

4-5 File: Quartz.jpg. Photographer: Siim Sepp This rock is a property of museum of geology of University of Tartu, 20 April 2005. https://commons.wikimedia.org/wiki/File:Quartzite.jpg.

4-6 Quarry: limestone quarry, Tennessee. [Photo]. In *Encyclopaedia Britannica.*Retrieved from https://www.britannica.com/place/Tennessee/images-videos/Limestone-quarry-Tennessee-US/149335, by M. Garard; 19:27, 21 September 2006.

4-7 Starkey, William. This work is licensed under the Creative Commons Attribution-Share Alike 2.0 Generic Licence. To view a copy of this licence, visit http://creativecommons.org/licenses/by-sa/2.0/ or send a letter to Creative Commons, 171 Second Street, Suite 300, San Francisco, California, 94105, USA.

4-8 Craven, Peter. Sand stockpiles Uploaded by High Contrast [CC BY 2.0 (http://creativecommons.org/licenses/by/2.0)], via Wikimedia Commons.

4-12 Kosmatka, S., Kerkhoff, B., & Panarese, W.C. (2002), *Design and Control of Concrete Mixtures, 14th Edition*, p. 82. Skokie, Illinois. Portland Cement Association.

4-23 *WSDOT Materials Manual, M46-01.10, January 2012*. "Reducing Samples of Aggregate to Testing Size," p. 5. http://www.wsdot.wa.gov/publications/manuals/fulltext/M46-01/t248.pdf.

Chapter 5

5-1 Kosmatka, S., Kerkhoff, B., & Panarese, W.C. *Design and Control of Concrete Mixtures, 14th Edition*, p. 105. Skokie, Illinois. Portland Cement Association, 2002.

5-2 "Chemical Admixtures for Concrete: What's Next?" January 13, 2014. http://precast.org/2014/ 01/chemical-admixtures-concrete-whats-next/

5-6 Kosmatka, S., Kerkhoff, B., & Panarese, W.C. *Design and Control of Concrete Mixtures, 14th Edition*, p. 115. Skokie, Illinois. Portland Cement Association, 2002.

5-7 Kosmatka, S., Kerkhoff, B., & Panarese, W.C., p. 131.

5-8 Kosmatka, S., Kerkhoff, B., & Panarese, W.C., p. 129.

Chapter 6

6-4 *Reinforcement for Concrete – Materials and Applications*, ACI Education Bulletin E2-00 (Reapproved 2006), Developed by Committee E-701, Materials for Concrete Construction), p. 2-9.

Chapter 7

7-9 "Advantages of Self-Consolidating Concrete." Concrete Network. http://www.concretenetwork. com/self-consolidating-concrete /advantages.html.

7-10 "Self-Consolidating Concrete Construction." Concrete Network. http://www.concretenetwork. com/self-consolidating-concrete/construction.html.

7-11 "Self-Consolidating Concrete Construction." Concrete Network.

7-12 "Self-Consolidating Concrete Construction." Concrete Network.

Chapter 8

8-3 "Freeze – Thaw Deterioration of Concrete." Concrete Experts International, Vedbæk, Denmark. http://www.concrete-experts.com/pages/ft.htm.

8-6 Kosmatka, S., Kerkhoff, B., & Panarese, W.C. *Design and Control of Concrete Mixtures, 14th Edition*, p. 95. Skokie, Illinois. Portland Cement Association, 2002.

8-10 "Mining and Manufacturing, Anti-Corrosive Protection." Bauer Epoxies. Hindmarsh, South Australia. https://www.bauerepoxies.com.au/case-studies/mining-and-manufacturing/22-severe-corrosive-chemical-attack.html

8-11 "Carbonation of Concrete." Concrete Experts International. Vedbaek, Denmark. http://www.concrete-experts.com/pages/carb.htm.

8-12 "Corrosion Resistance of Concrete." Portland Cement Association. Skokie, Illinois. http://www.cement.org/for-concrete-books-learning/concrete-technology/durability/corrosion-resistance-of-concrete.

Section 2

Chapter 1

1-1 "WHAT'S THE DIFFERENCE BETWEEN CEMENT AND CONCRETE?" CCC Transportation LLC. https://www.ccctrans.com/news/page/21/ https://www.ccctrans.com/wp-content/uploads/Concrete-Ingredients-with-Labels-2.jpg.

Chapter 2

2-6 "Planetary Concrete Mixers." Scale-Tron, Automation, Sensors and Weighing Systems. St. Regis, Dollard Des Ormeaux (DDO), Quebec, Canada. http://scaletron.com/code/planetary.htm.

2-7 "Turbine THZ 1125-2250 Pan Mixer." Toreuse.com, Machinery, Equipment and Tools. http://www.toreuse.com/turbine-thz-1125-2250-pan-mixer/

2-8 "Rotating Pan Mixer." Columbia, Complete Concrete Product Solutions & Support. Vancouver, WA. http://www.columbiamachine.com/products/concrete-batching-mixing/mixers/rotating-pan-mixers.

2-9 "Twin Shaft Mixers." Wigo Industries. Mumbai, India. Indian Mart. Ashtok Industries. Navi, Mumbai, India. http://dir.indiamart.com/pune/twin-shaft-mixers.html.

2-12 "Concrete Bucket for Tower." Indian Mart. Ashtok Industries. Navi, Mumbai, India. http://www.indiamart.com/ashokindustries-navimumbai/concrete-equipment.html#concrete-bucket-for-tower.

Chapter 3

3-1 R. Zellers and E. Veal. “A Fiber-reinforced Concrete Testing Primer for Ready Mix Concrete Producers (Part 2).” 2016.ABC Polymer Industries, LLC. http://abcpolymerindustries.com/a-fiber-reinforced-concrete-testing-primer-for-ready-mix-part-2.php.

3-2 University of Kentucky Center for Applied Energy Research. “Evaluating Fly Ash for Concrete.” July 25, 2016. http://www.caer.uky.edu/kyasheducation/testing-concrete.shtml.

3-3 University of Kentucky Center for Applied Energy Research. “Evaluating Fly Ash for Concrete.”

3-4 James Instruments, Non Destructive Testing Equipment. “James Air Meter for Fresh Concrete.” http://www.ndtjames.com/James-Air-Meter-for-Fresh-Concrete-p/a-a.htm.

3-5 National Ready Mix Concrete Association. “Self-Consolidating Concrete – Testing.” http://www.selfconsolidatingconcrete.org/testing.html.

3-8 KALGEn Consultants. “Material Testing Services.”http://www.kalgeninc.com/MATERIAL%20TESTING%20SERVICES.html.

3-9 Concrete Construction. “Strength Testing of Hardened Concrete.” March 2, 2012. http://www.concreteconstruction.net/how-to/construction/strength-testing-of-hardened-concrete_o.

Section 3

Chapter 1

1-15 “FIG. 5 Detailed Reinforcement Arrangement.” ASTM C1433 – Standard Specification for Precast Reinforced Concrete Monolithic Box Sections for Culverts, Storm Drains, and Sewers. Fig. 5, page 4.

1-16 “FIG. 6 Alternate Detail.” ASTM C1433 – Standard Specification for Precast Reinforced Concrete Monolithic Box Sections for Culverts, Storm Drains, and Sewers., page 4.

1-17 “FIG. 8 Alternate Detail.” ASTM C1433 – Standard Specification for Precast Reinforced Concrete Monolithic Box Sections for Culverts, Storm Drains, and Sewers., page 4.

Chapter 3

3-4 “Honeycombs in Concrete and Remedies.” The Constructor Civil Engineering Home. http://theconstructor.org/practical-guide/honeycombs-in-concrete-and-remedies/6889/.

3-5 Bashan, Kim. “Repairing Bugholes.” Concrete Construction. http://www.concreteconstruction. net/how-to/repairing-bugholes_o.

Chapter 4

4-1 Kosmatka, S., Kerkhoff, B., & Panarese, W.C. *Design and Control of Concrete Mixtures, 14th Edition*, p. 219. Skokie, Illinois. Portland Cement Association, 2002.

4-3 Kosmatka, S., Kerkhoff, B., & Panarese, W.C., p. 223.

Section 4

Chapter 1

1-8 Kentucky Transportation Cabinet, Kentucky Department of Highways. *Reinforced Concrete Pipe Pre-installation Inspection & Repair Manual*, p. 47. January 2014. http://transportation.ky.gov/ Materials/Documents/RCP%20Pipe%20Manual.pdf.

Chapter 2

2-9 Mandli, Craig. "CIPP/Pipe Repair – Substrate repair material." Municipal Sewer and Water." January 2015. http://www.mswmag.com/editorial/2015/01/cipp_pipe_repair_substrate_repair_material.

2-10 CPD Construction Products, CPD Concentrated Latex Adhesive (03 01 00). http://www.cpd.ca/products/division-3/bonding-agents-latex/.

Chapter 3

3-1 "Pipe Tester." New Hampton Metal Fab. New Hampton, IA Graphic. http://www.nhmfcorp.com /concrete-pipe-precast-industry/machinery/pipe-tester/.

Appendix C:

Appendix D:



Training Requirements

Quality Control Personnel Training

QC Personnel Training: Know Where to Find the Rules

- FDOT Section 105
- FDOT Materials Manual
  - Section 6.2 (RCP)
  - Section 6.3 (Precast Box Culverts)
- RCP and RCB Specs
  - Section 449
  - Section 410

QC Personnel Training

FDOT Section 105 – Contractor Quality Control General Requirements

105-5.11 Precast Concrete Drainage, Precast Box Culvert, Precast Concrete Pipe, Fiber Reinforced Concrete Pipe, Flexible Pipe, and Incidental Precast Manufacturing Facilities Quality Control Personnel

QC Personnel Training Requirements

105-5.11.1.1 Level I Quality Control Inspectors: Ensure that the Level I Inspectors have completed a **minimum of a 12-hour, Department approved, Level I Quality Control Inspector training course** in the respective work area.

As an exception to this, ensure Flexible Pipe Level I Quality Control Inspectors have completed a minimum of an 8-hour, Department approved, Level I Quality Control Flexible Pipe Inspector training course.

QC Personnel Training Requirements

105-5.11.1.2 Level II Quality Control Inspectors: Ensure that **Level II Inspectors have completed** Department approved **Level I** Quality Control Inspector training **and a minimum of a 5-hour, Department approved, Level II Quality Control Inspector training course** in the respective work areas.

QC Personnel
Training Requirements

105-5.11.1.3 Plant Quality Control Manager: Ensure that Quality Control Manager has completed Department approved **Level II** Quality Control Inspector training **and has a minimum of 2 years construction related experience in the specific work area**.

QC Personnel Training Requirements

105-5.11.1.4 Additional Requirements for Quality Control Personnel of Precast Concrete Drainage and Precast Concrete Box Culvert Manufacturing Facilities

Note that these QC training aspects will not be covered in this course. It is the responsibility of the individual companies to comply with these requirements outside of this training course.

Additional QC Personnel Training

105-5.11.1.4.1 Testing Personnel: Ensure the personnel performing plastic property tests have ACI Concrete Field Testing Technician-Grade I certification. Ensure the personnel performing laboratory compressive strength testing have ACI Concrete Laboratory Testing Technician- Grade 1 certification or ACI Concrete Strength Testing Technician certification.

ACI Field Testing Certification for Concrete Box Culvert Production

Note that inspectors of the steel-reinforced concrete pipe and dry-cast concrete box culverts are not required to have ACI Field Testing Technician, Grade I certification.

ACI Concrete Laboratory Testing Technical Grade 1 certification is required for wet cast and dry cast production of box culverts.

Additional QC Personnel Training

105-5.11.1.4.2: Batch Plant Operator: Ensure the concrete batch plant operator is qualified as a CTQP Concrete Batch Plant Operator. As an alternative to CTQP qualification, the Department will accept the completion of a minimum of a 6-hour, Department approved, Batch Plant Operator training course.

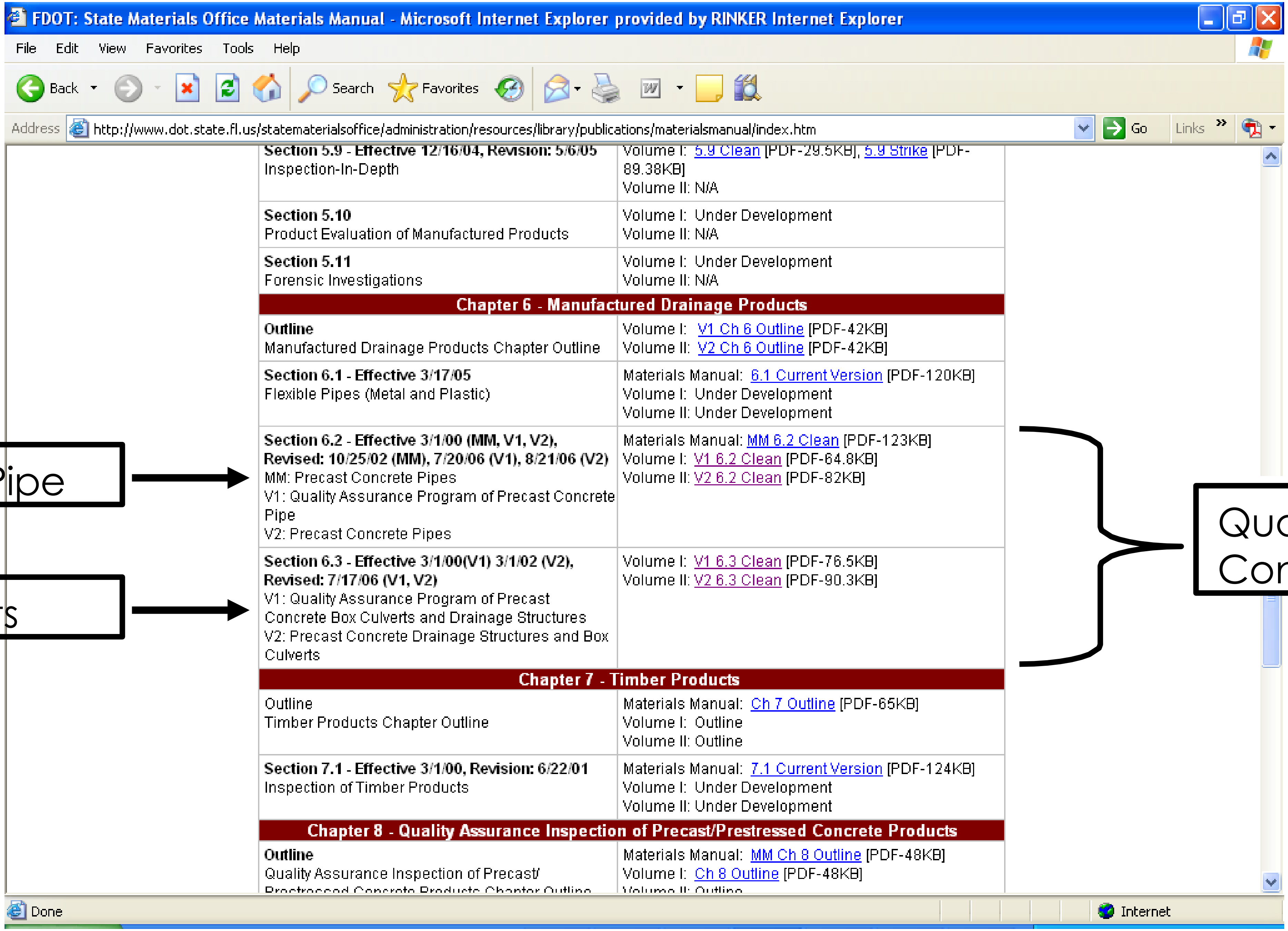
Batch Plant Operator Qualification

Note that the State Materials Office has stated that steel reinforced concrete pipe manufacturing plants and dry-cast concrete box culvert plants do not need the batch plant operator qualification.

Concrete Pipe

Box Culverts

Quality Control


FDOT: State Materials Office Materials Manual - Microsoft Internet Explorer provided by RINKER Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites

Address http://www.dot.state.fl.us/statematerialsoffice/administration/resources/library/publications/materialsmanual/index.htm Go Links

Section 5.9 - Effective 12/16/04, Revision: 5/6/05 Inspection-In-Depth	Volume I: 5.9 Clean [PDF-29.5KB], 5.9 Strike [PDF-89.38KB] Volume II: N/A
Section 5.10 Product Evaluation of Manufactured Products	Volume I: Under Development Volume II: N/A
Section 5.11 Forensic Investigations	Volume I: Under Development Volume II: N/A
Chapter 6 - Manufactured Drainage Products	
Outline Manufactured Drainage Products Chapter Outline	Volume I: V1 Ch 6 Outline [PDF-42KB] Volume II: V2 Ch 6 Outline [PDF-42KB]
Section 6.1 - Effective 3/17/05 Flexible Pipes (Metal and Plastic)	Materials Manual: 6.1 Current Version [PDF-120KB] Volume I: Under Development Volume II: Under Development
Section 6.2 - Effective 3/1/00 (MM, V1, V2), Revised: 10/25/02 (MM), 7/20/06 (V1), 8/21/06 (V2) MM: Precast Concrete Pipes V1: Quality Assurance Program of Precast Concrete Pipe V2: Precast Concrete Pipes	Materials Manual: MM 6.2 Clean [PDF-123KB] Volume I: V1 6.2 Clean [PDF-64.8KB] Volume II: V2 6.2 Clean [PDF-82KB]
Section 6.3 - Effective 3/1/00(V1) 3/1/02 (V2), Revised: 7/17/06 (V1, V2) V1: Quality Assurance Program of Precast Concrete Box Culverts and Drainage Structures V2: Precast Concrete Drainage Structures and Box Culverts	Volume I: V1 6.3 Clean [PDF-76.5KB] Volume II: V2 6.3 Clean [PDF-90.3KB]
Chapter 7 - Timber Products	
Outline Timber Products Chapter Outline	Materials Manual: Ch 7 Outline [PDF-65KB] Volume I: Outline Volume II: Outline
Section 7.1 - Effective 3/1/00, Revision: 6/22/01 Inspection of Timber Products	Materials Manual: 7.1 Current Version [PDF-124KB] Volume I: Under Development Volume II: Under Development
Chapter 8 - Quality Assurance Inspection of Precast/Prestressed Concrete Products	
Outline Quality Assurance Inspection of Precast/ Prestressed Concrete Products Chapter Outline	Materials Manual: MM Ch 8 Outline [PDF-48KB] Volume I: Ch 8 Outline [PDF-48KB] Volume II: Outline

Done Internet

(N) Record of the job specific shipping tickets, describing, size, type, and lengths of the delivered Pipe and the required notarized certification statement at the beginning of each project.

(O) Record all deficiencies found as a result of quality control inspection and testing or Verification inspection and testing and the corrective action taken. Maintain a copy of the deficiency reports in the Plant's permanent file.

6.2.8 TRAINING

6.2.8.1 General

The Plant's quality control personnel involved in the inspection and testing of the Pipe shall have the required qualifications in their respective work area as specified herein. The Pipe may include non-reinforced, steel reinforced, and fiber reinforced concrete pipe.

The applicants shall attend a Department accredited Pipe training course and receive a passing grade on the final examination for the course. Ensure that the Plant's quality control plan includes training certification copies for their qualified quality control personnel.

The State Materials Office maintains the list of the accredited Pipe training courses.

6.2.8.2 Quality Control Personnel of Pipe

Ensure that all personnel performing the quality control inspection and testing of the Pipe products at a manufacturing facility have the required qualifications as described herein:

6.2.8.2.1 Level I Quality Control Inspectors

Level I quality control inspectors are those who perform the routine concrete inspection and testing of the precast concrete Pipe products, including, concrete materials, pre-pour form and reinforcing steel/fiber placement inspections, concrete batching, mixing, placement, and post-placement inspections. The quality control inspectors shall be familiar with the precast concrete related plans and specifications and

have completed a minimum of 12-hour, Department approved, training course and examination.

6.2.8.2.2 Level II Quality Control Inspectors

Level II inspectors are those who are involved in the design and verification of the concrete mixes and evaluate the needed repair method and its implementation. Advanced knowledge of the shop drawings, specifications, test methods, and Standard Indices are the requirements for Level II qualifications. Ensure that Level II Inspectors have Level I Quality Control Inspector certification and have successfully completed a minimum of additional 5-hour, Department approved course, including the examination.

6.2.8.2.3 Quality Control Managers of Pipes

The quality control managers shall have Pipe- Level II Quality Control Inspector certification and a minimum of two years of experience, directly related to cement concrete production.

6.2.8.3 Re-qualification of the Quality Control Personnel and Department Inspectors

The Level I and II qualifications will expire at the end of five years, during which, the inspectors have the choice of attending the course and retaking the examination or only they take the examination to be re-qualified for an additional five years.

6.2.9 FORMS

There are no forms associated with this procedure.

FDOT Materials Manual Section 6.2 (Vol. II) for RCP and Section 6.3 (Vol. II) for Precast RCB describe the QC Personnel Training Requirements

Volume II

Section 6.2

PRECAST CONCRETE PIPE

6.2.1 PURPOSE

This procedure provides guidance for the development and implementation of the quality control program for the manufacture, storage, and transportation of the precast concrete pipe (Pipe) for the Florida Department of Transportation projects. The Pipe may include, but are not limited to, round concrete pipe, elliptical concrete pipe, mitered end sections, and underdrain pipe.

FDOT Materials Manual Section 6.2.8 Training
Reinforced Concrete Pipe (RCP)

The **applicants shall attend a Department accredited Pipe training course and receive a passing grade on the final examination** for the course. Ensure that the Plant's quality control plan includes training certification copies for their qualified quality control personnel.

The State Materials Office maintains the list of the accredited Pipe training courses.

VOLUME II

Section 6.3

PRECAST CONCRETE DRAINAGE STRUCTURES AND BOX CULVERTS

6.3.1 PURPOSE

This procedure provides guidance for the development and implementation of the quality control for the manufacture, storage, and transportation of the precast concrete drainage structures and box culverts (Structures) for the Florida Department of Transportation projects. The Structures may include, but are not limited to, inlets, manholes, junction boxes, endwalls, three-sided precast concrete culverts, and precast concrete box culverts.

The Department will perform periodic quality assurance inspections, sampling, and testing to ensure of the quality and acceptability of the materials, methods, techniques, procedures and processes being utilized by the manufacturer in the fabrication of precast concrete products. The quality assurance inspection and testing will be performed in accordance with ***Section 6.3. Volume I.*** of the ***Materials Manual***.

FDOT Materials Manual
Section 6.3.8 Training
Reinforced Concrete Box Culvert (RCB)

The applicants shall attend a Department accredited precast concrete training course and receive a passing grade on the final examination for the course. Ensure that the Plant's quality control plan includes training certification copies for their qualified quality control personnel.

The State Materials Office maintains the list of the accredited precast concrete courses.

Re-Qualification

The Level I and II **qualifications will expire at the end of five years**, during which, the inspectors have the **choice of attending the course and retaking the examination or only they take the examination** to be re- qualified for an additional five years.

Concrete Pipe University (CPU) Florida Training Agenda

Level I and Level II Training

Level I and Level II Exam / Certification

You Will Be Certified Level II QC Technicians

You Must Complete the Course and Pass the Exam

We Will Help You Achieve That Goal!

Concrete Pipe University (CPU) Florida QC Personnel Training

- Course intended to be used as a guide
- Familiarize with QC documents and procedures
- Not a substitute for contract documents
- Always read and understand the specification requirements of the contract documents for your jobs

Agenda

FDOT Rules for QC Staff

QC Personnel Responsibilities Navigating FDOT

Specs / Standards Material Certifications

Equipment Calibrations

Cement and Pozzolans Aggregates

Agenda (Continued)

Admixtures

Steel Reinforcement Concrete

Mix Properties Concrete

Batching

Pre-Pour Operations

Materials Storage and Handling Post-Pour

Inspections

Agenda (Continued)

Advanced Mix Design
Concrete Consolidation
Concrete Curing Repair and
Finishing QC Testing

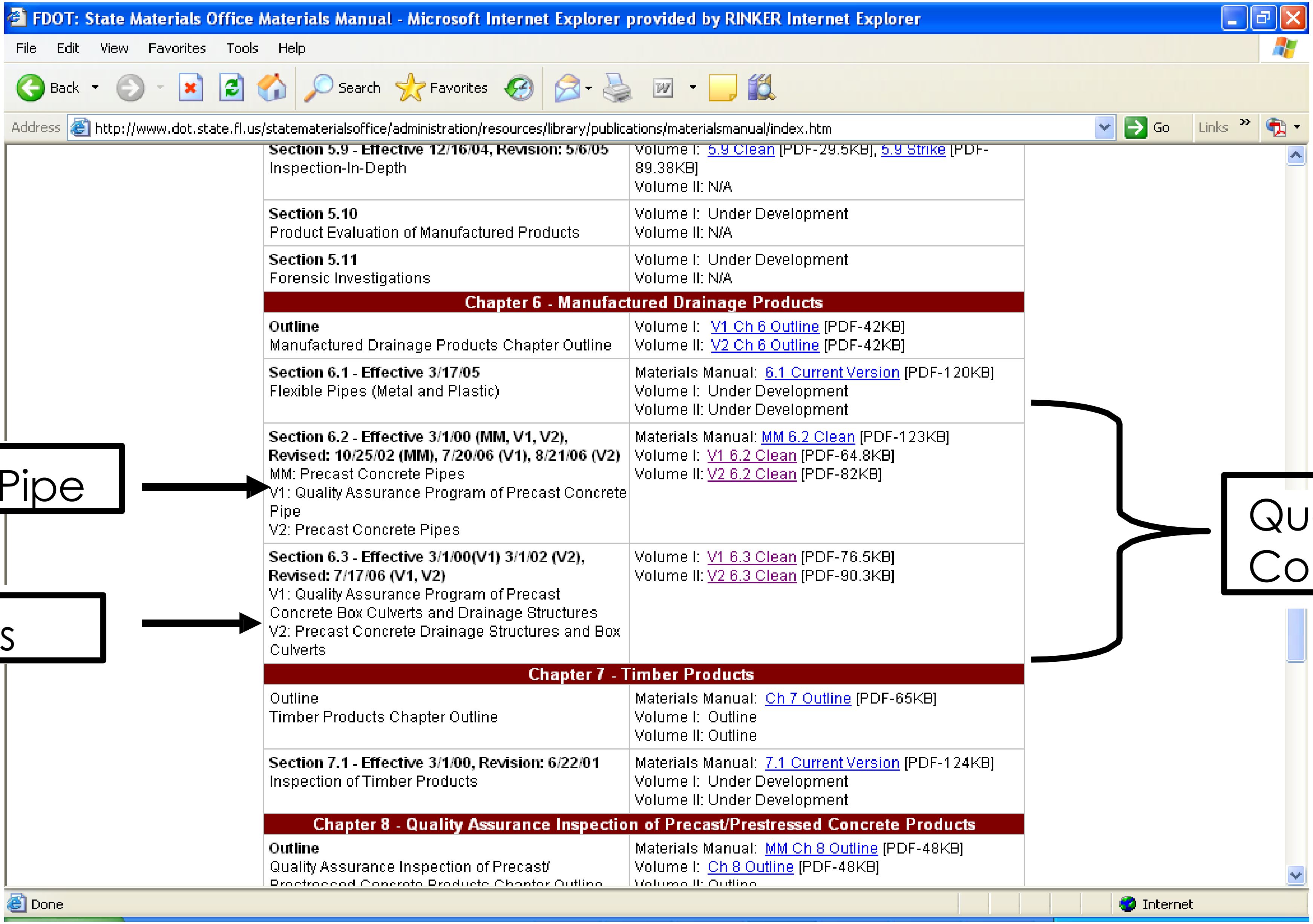
QC Personnel Responsibilities

FDOT Inspectors

&

Manufacturer Personnel

State Materials Manual



FDOT: State Materials Office Materials Manual - Microsoft Internet Explorer provided by RINKER Internet Explorer

File Edit View Favorites Tools Help

http://www.dot.state.fl.us/statematerialsoffice/administration/resources/library/publications/materialsmanual/index.htm

Section 5.9 - Effective 12/16/04, Revision: 5/6/05 Inspection-In-Depth	Volume I: 5.9 Clean [PDF-29.5KB], 5.9 Strike [PDF-89.38KB] Volume II: N/A
Section 5.10 Product Evaluation of Manufactured Products	Volume I: Under Development Volume II: N/A
Section 5.11 Forensic Investigations	Volume I: Under Development Volume II: N/A
Chapter 6 - Manufactured Drainage Products	
Outline Manufactured Drainage Products Chapter Outline	Volume I: V1 Ch 6 Outline [PDF-42KB] Volume II: V2 Ch 6 Outline [PDF-42KB]
Section 6.1 - Effective 3/17/05 Flexible Pipes (Metal and Plastic)	Materials Manual: 6.1 Current Version [PDF-120KB] Volume I: Under Development Volume II: Under Development
Section 6.2 - Effective 3/1/00 (MM, V1, V2), Revised: 10/25/02 (MM), 7/20/06 (V1), 8/21/06 (V2) MM: Precast Concrete Pipes V1: Quality Assurance Program of Precast Concrete Pipe V2: Precast Concrete Pipes	Materials Manual: MM 6.2 Clean [PDF-123KB] Volume I: V1 6.2 Clean [PDF-64.8KB] Volume II: V2 6.2 Clean [PDF-82KB]
Section 6.3 - Effective 3/1/00(V1) 3/1/02 (V2), Revised: 7/17/06 (V1, V2) V1: Quality Assurance Program of Precast Concrete Box Culverts and Drainage Structures V2: Precast Concrete Drainage Structures and Box Culverts	Volume I: V1 6.3 Clean [PDF-76.5KB] Volume II: V2 6.3 Clean [PDF-90.3KB]
Chapter 7 - Timber Products	
Outline Timber Products Chapter Outline	Materials Manual: Ch 7 Outline [PDF-65KB] Volume I: Outline Volume II: Outline
Section 7.1 - Effective 3/1/00, Revision: 6/22/01 Inspection of Timber Products	Materials Manual: 7.1 Current Version [PDF-124KB] Volume I: Under Development Volume II: Under Development
Chapter 8 - Quality Assurance Inspection of Precast/Prestressed Concrete Products	
Outline Quality Assurance Inspection of Precast/ Prestressed Concrete Products Chapter Outline	Materials Manual: MM Ch 8 Outline [PDF-48KB] Volume I: Ch 8 Outline [PDF-48KB] Volume II: Outline

Done Internet

Concrete Pipe

Box Culverts

Quality Control

VOLUME I

SECTION 6.2

QUALITY ASSURANCE PROGRAM OF PRECAST CONCRETE PIPE

6.2.1 PURPOSE

This procedure provides guidance to the Florida Department of Transportation personnel related to the development and implementation of the quality control and quality assurance programs for the manufacture, storage, and transportation of the precast concrete pipe for the Florida Department of Transportation projects.

VOLUME I

Section 6.3

QUALITY ASSURANCE PROGRAM OF PRECAST CONCRETE BOX CULVERTS AND DRAINAGE STRUCTURES

6.3.1 PURPOSE

This procedure provides guidance to Department personnel related to the implementation of the quality control and quality assurance programs for precast concrete box culverts and drainage structures (Structures).

Roles and Responsibilities

6.2.5 GENERAL INFORMATION

The Precast Concrete Pipe Plants (Plants) produce, inspect, store, and ship Precast Concrete Pipe (Pipe) meeting the requirements of the Specifications and other Contract Documents. The District Materials Offices verify that manufactured Pipe conforms to the requirements of the Contract Documents. The District Materials Office accepts (approves) their quality control plans and inspects the plants prior to commencement of any work.

QC Responsibilities

Manufacturer

- QC of production, inspection, storage, shipping
- Maintain QC Plan

FDOT District Materials Office

- Plant Verification Inspections / Material Testing
- Plant QC Plan Review and Maintenance

Level I QC Personnel Concrete Pipe / Box Culverts

Routine concrete inspection / testing Raw materials tests

Pre-pour form and steel inspection Concrete batching, mixing, and placement Post-pour inspection

Familiar with specifications

Completed / passed 12-hour course/exam

Level II QC Personnel Concrete Pipe / Box Culverts

- Design and verification of concrete mix
- Evaluate repairs and implementation
- Advanced knowledge of specifications, standard indices, test methods, and shop drawings
- Level I certified
- Additional 5 hours training and exam

Plastic Property, Laboratory, and Compressive Strength Testing

Precast Concrete Box Culverts

Plastic Property Test Personnel (wet cast only)

- ACI Concrete Field Testing Technician, Grade I

Laboratory Concrete Test Personnel

- ACI Level I Concrete Laboratory Technician- Grade I

Concrete Strength Test Personnel

- Either (1) or (2) certification:
  (1) ACI Level I Concrete Laboratory Technician- Grade I
  Or (2) ACI Concrete Strength Testing Technician

QC Manager
Concrete Pipe / Box Culverts

Level I Certification Level II
Certification

2 years concrete production related experience

Section 6.2
Plant Qualification Review Process

Plant submits proposed QC Plan District

Materials Office Review

- Manufacturing
- Quality Control Testing
- Inspections and Documentation
- Forming, Steel Placement
- Storage and Shipping

Approval – “A” on Qualified Producer List

Maintaining Quality Control Plan and Plant Qualification Status

- Annual plant qualification reviews
  - Test data representing all pipe diameters Submit any changes to QC Plan

TABLE 1 - VERIFICATION INSPECTION, SAMPLING, AND TESTING ACTIVITIES

Activities	Minimum Inspection, Sampling and Testing Frequency
Coarse Aggregate	Certification
Fine Aggregate	Certification
Cementitious Materials	Certification
Admixtures	Certification
Water Chemical Analysis	Check the Plant's testing record for compliance with Section 923: 1/30 days: Open bodies of water & recycled water 1/3 months: Wells and treated water
Reinforcing Steel	Sample from two LOTs per year per Plant
Welded-wire reinforcement	Certification
Pipe gaskets and gasket lubricant,	Certification
Patching materials	Certification
Priming materials for elliptical Pipes	Certification
Concrete compressive strength tests: core samples, Test cylinders, and Three-edge- bearing test	When the acceptability of Pipe is based on core or cylinder tests, at a minimum frequency of once per quarter, sample and test compressive strength cylinders or test core samples, provided by Plant. Observe the three-edge bearing test when compressive strength acceptability of Pipe is based on this test.
Absorption test	Perform absorption of core samples, for each category of pipe, at the frequency of one sample per quarter. Plant provides the core sample.
Hydrostatic Test of Pipe Joints	Verify that joint hydrostatic tests are performed in the presence of a representative from State Materials Office. The test is required for approval of new gasket or joint design.

Section 6.2 of the Materials Manual also lists the responsibilities of the District Materials Office inspector, such as reviewing test data, cylinders, testing apparatus, etc.

Topic No.: 675-000-000
Materials Manual
Manufactured Drainage Products

Effective: March 1, 2000
Revised: July 20, 2006

6.2.6.2.2 Responsibilities of Verification Inspectors

6.2.6.2.2.1 General

The following are the general responsibilities of Verification Inspectors:

(A) At a minimum frequency of once per quarter, reviews the records for materials received at the Plant and/or incorporated into the fabrication of Pipe, including the certified physical property reports.

(B) Verifies that the quality control Inspectors maintain the required certification documents.

(C) Randomly selects two Lots of reinforcing steel and takes sample from each LOT.

(D) Samples other Pipe material components, as needed.

(E) Checks the handling and storage for each material component of Pipe.

(F) Visually checks the condition of steel reinforcement.

(G) Ensures that the Plant's quality control manager and inspectors are performing inspections in compliance with the quality control plan.

(H) Performs random spot-checks of the finished Pipe to ensure that they are fabricated in compliance with the requirements of the Contract Documents.

(I) Performs in-depth review of some phases of work, as needed.

(J) Advises the quality control manager of any observed deficiency.

(K) Performs spot checks of the repair methods.

(L) Advises the quality control manager of the acceptability status of quality control test results.

6.2.6.2.2.2 Sampling and Testing of Pipe Material Components

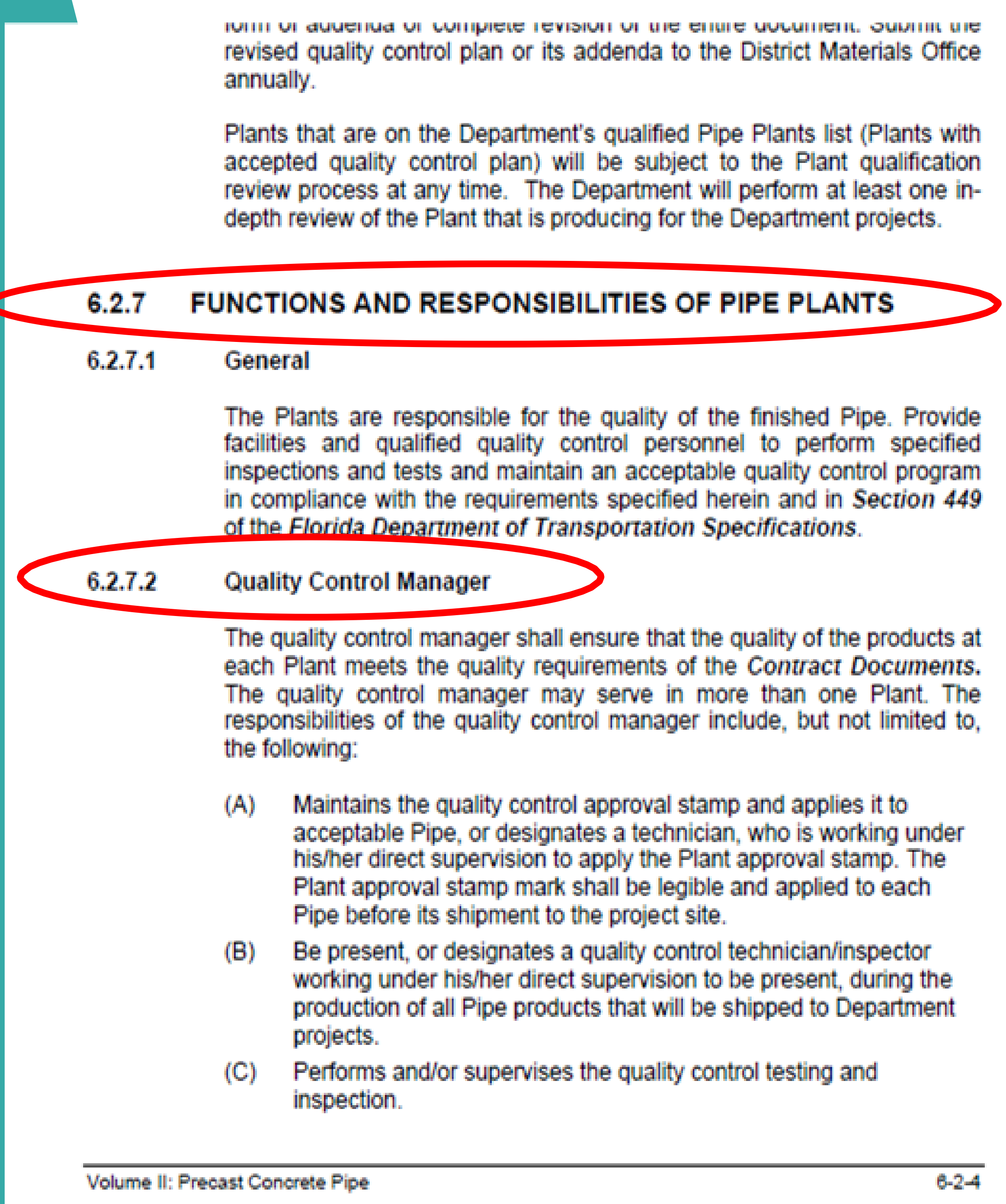
(A) Reinforcing Steel

Each LOT of the reinforcing steel is accepted based on the certified mill analysis of the steel manufacturing plant and Department's Verification samples. Take steel samples from at

Volume I: Quality Assurance Program of Precast Concrete Pipe 6-2-5

Section 6.2.6.2.2, Volume I of the FDOT Materials Manual describes the duties of the FDOT Verification Inspectors for inspecting pipe plants.

Similarly, Section 6.3.6.2.2, Volume I of the FDOT Materials Manual describes the FDOT Inspector duties for precast box culvert plants.



form of addenda or complete revision of the entire document. Submit the revised quality control plan or its addenda to the District Materials Office annually.

Plants that are on the Department's qualified Pipe Plants list (Plants with accepted quality control plan) will be subject to the Plant qualification review process at any time. The Department will perform at least one in-depth review of the Plant that is producing for the Department projects.

6.2.7 FUNCTIONS AND RESPONSIBILITIES OF PIPE PLANTS

6.2.7.1 General

The Plants are responsible for the quality of the finished Pipe. Provide facilities and qualified quality control personnel to perform specified inspections and tests and maintain an acceptable quality control program in compliance with the requirements specified herein and in *Section 449* of the *Florida Department of Transportation Specifications*.

6.2.7.2 Quality Control Manager

The quality control manager shall ensure that the quality of the products at each Plant meets the quality requirements of the *Contract Documents*. The quality control manager may serve in more than one Plant. The responsibilities of the quality control manager include, but not limited to, the following:

(A) Maintains the quality control approval stamp and applies it to acceptable Pipe, or designates a technician, who is working under his/her direct supervision to apply the Plant approval stamp. The Plant approval stamp mark shall be legible and applied to each Pipe before its shipment to the project site.

(B) Be present, or designates a quality control technician/inspector working under his/her direct supervision to be present, during the production of all Pipe products that will be shipped to Department projects.

(C) Performs and/or supervises the quality control testing and inspection.

Volume II: Precast Concrete Pipe 6-2-4

Section 6.2.7, Volume II of the FDOT Materials Manual describes the duties of pipe plant QC personnel.

A description of duties is listed in this section for QC Managers as well as Level I and Level II QC Technicians.

Other responsibilities of the QC Manager, such as records managementand supervision, are described throughout Section 6.2, Volume II.

6.2.7.3 Technicians/Inspectors

The quality control technicians may perform any or all of the inspections, sampling, or testing as directed by the quality control manager, and may stamp the Plant approved Pipe, when directed by the quality control manager.

Quality Control Rules and Resources

- Company Requirements
- Plant Quality Control Plan
- FDOT Materials Manual
- FDOT Specifications
- FDOT Standards Index
- ASTM Specifications
- AASHTO Standards and Specifications



Navigating FDOT Specifications and Standards

And How They Apply To Precast Concrete Pipe And Box Culverts

Important FDOT Documents…

- Special Provisions
- Technical Special Provisions
- Engineering plans
- Roadway Standard Indices
- Developmental Specifications
- Supplemental Specifications
- Standard Specifications

Additional FDOT Documents…

- Structures Design Guide
- Qualified Products List (QPL)
- Materials Manual
- Plant Quality Control Plan

  Developed by plants

  Subject to FDOT review / approval

Training Objectives

- Not to memorize every specification
- Focus on resources
- Learn where to find answers
- Reference
- Note: Always be familiar with contract document requirements of your job

FDOT State Specifications Office

Web Site

http://www.dot.state.fl.us/specificationsoffice/

Standard Specifications for Road and Bridge Construction (2007)

Other Versions May Govern Your Job

Specification Modifications / Workbooks Qualified Products List (QPL)

http://www.dot.state.fl.us/specificationsoffice/QPLindex.htm

FDOT Specification Terms

Section ###

FDOT specifications are referred to as "Sections" and have a numeric designation.

Example, "Section 430."

"Contractor" – Individual, firm, joint venture, or company contracting with Dept. to perform work.

Is your company considered a “contractor” when it provides pipe for a FDOT project?

Legally, the prime contractor is the installer / contractor. FDOT is contracted with the contractor / installer. The pipe/box plant is considered to be a sub- contractor.

However, there are many references to “contractor” in the pipe/box specs. There references are directed toward the manufacturer.

FDOT Specification Terms (Continued)

- “Engineer” – FDOT Office of Construction of representative.
- “Engineer of Record” – FDOT staff engineer or contracted consultant responsible for project’s concept, analysis, and Plans and Specifications.
- “Inspector” – Authorized representative of the Engineer to make official inspections of materials and work of the contractor.

FDOT Specification Terms (Continued)

- “Materials” – Any substances incorporated in the contracted work.
- “Specialty Engineer” – Florida P.E. that designs a special component of the work. May be employee of the Contractor or fabricator, of a supplier to a fabricator, or an independent consultant.

FDOT Specification Terms (Continued)

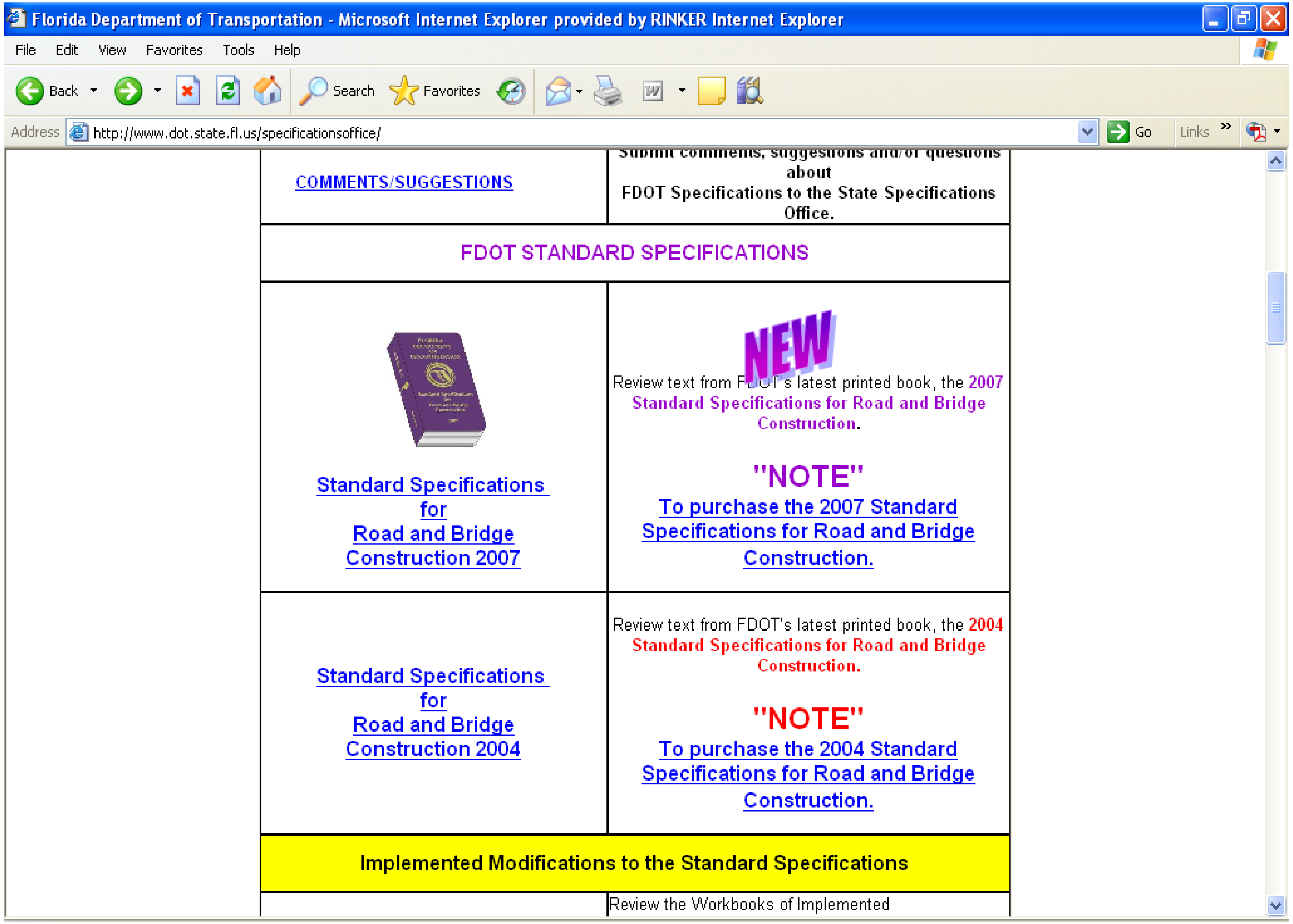
- "Standard Specifications" – Applicable to all Contracts.
- "Supplemental Specifications" – Approved additions / revisions, applicable to all Contracts.

FDOT Specification Terms (Continued)

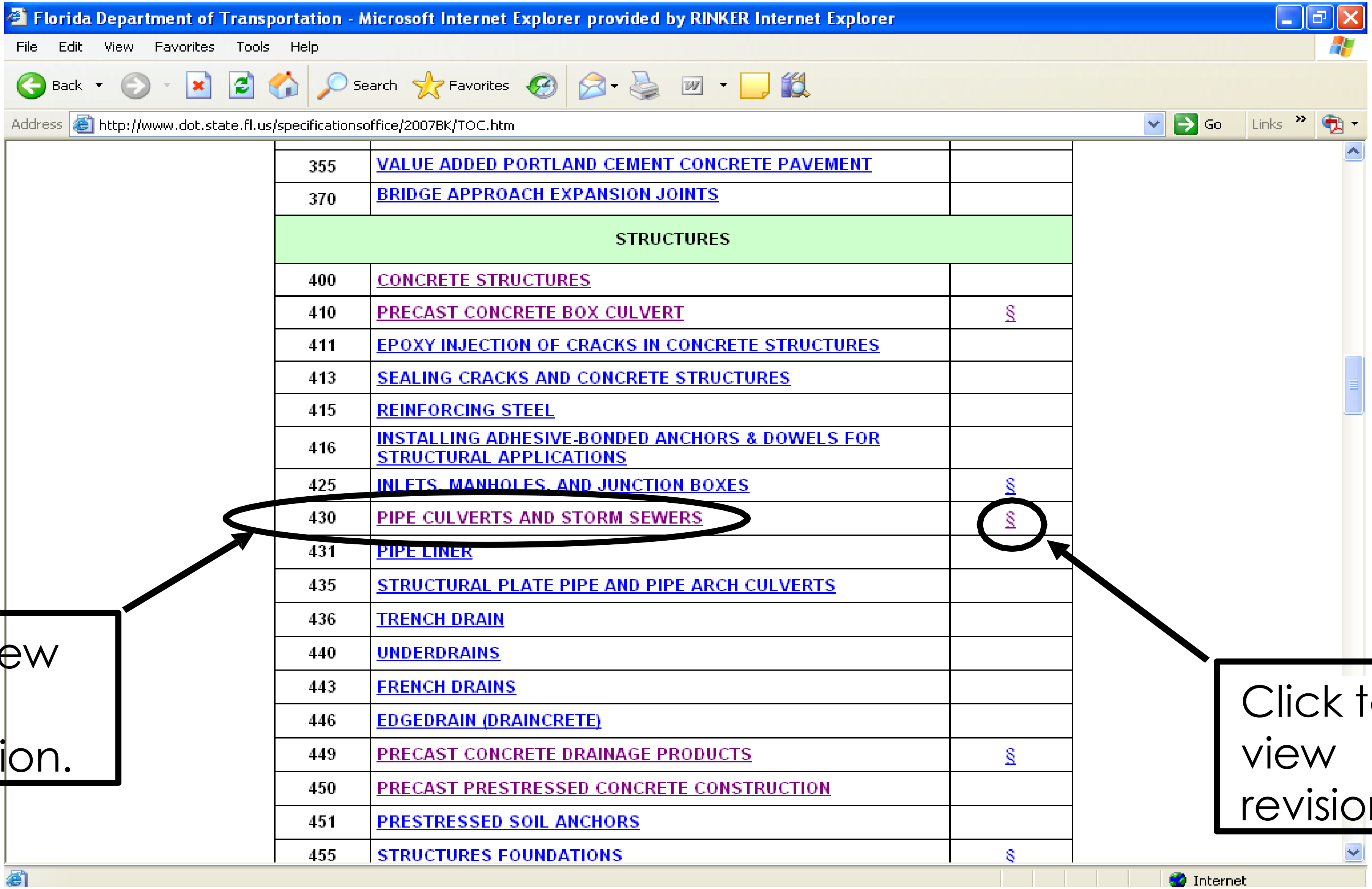
- “Special Provisions” – Specific clauses adopted by FDOT to revise Standard / Supplemental Specs, applicable to specific projects.
- “Technical Special Provisions” – Specs prepared outside the State Spec. Office, technical in nature, applicable to specific projects.
- “Developmental Specification” – Spec. that is developed based on a new process or material.

FDOT Specification Office Website

http://www.dot.state.fl.us/specificationsoffice/



FDOT Specifications Office Website (Continued)



Click to view full text of specification.

Click to view revision

Specifications Often Change

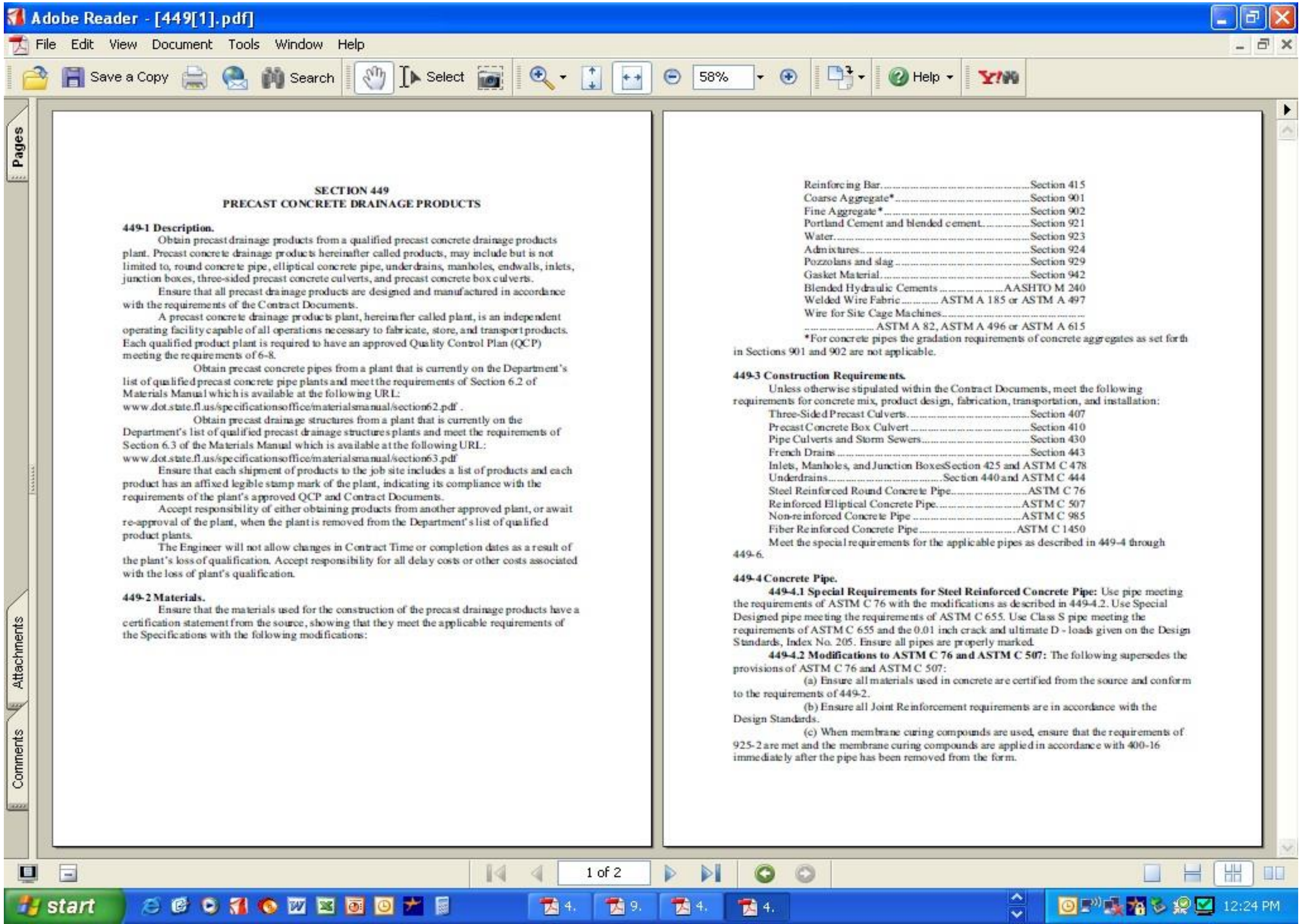
- Changes Published in “Workbooks”
  - Released in January and July
- Mandatory Revisions
- Proposed Spec. Modifications
  - Subscribe to FTBA News for Announcements
  - Designate Someone to Monitor Spec. Changes
  - FTBA News [news@FTBA.com]

Key RCP Specifications (FDOT)

Steel Reinforced Concrete Pipe (RCP)

- Section 430: Pipe Culverts and Storm Sewers (all pipe materials)
- Section 443: French Drains (slotted pipe)
- Section 449: Precast Concrete Drainage Products (RCP and FRCP)
- Section 942: Pipe Gaskets

Section 449



SECTION 449
PRECAST CONCRETE DRAINAGE PRODUCTS

449-1 Description.

Obtain precast drainage products from a qualified precast concrete drainage products plant. Precast concrete drainage products hereinafter called products, may include but is not limited to, round concrete pipe, elliptical concrete pipe, underdrains, manholes, endwalls, inlets, junction boxes, three-sided precast concrete culverts, and precast concrete box culverts.

Ensure that all precast drainage products are designed and manufactured in accordance with the requirements of the Contract Documents.

A precast concrete drainage products plant, hereinafter called plant, is an independent operating facility capable of all operations necessary to fabricate, store, and transport products. Each qualified product plant is required to have an approved Quality Control Plan (QCP) meeting the requirements of 6-8.

Obtain precast concrete pipes from a plant that is currently on the Department's list of qualified precast concrete pipe plants and meet the requirements of Section 6.2 of Materials Manual which is available at the following URL: www.dot.state.fl.us/specificationsoffice/materialsmanual/section62.pdf .

Obtain precast drainage structures from a plant that is currently on the Department's list of qualified precast drainage structures plants and meet the requirements of Section 6.3 of the Materials Manual which is available at the following URL: www.dot.state.fl.us/specificationsoffice/materialsmanual/section63.pdf

Ensure that each shipment of products to the job site includes a list of products and each product has an affixed legible stamp mark of the plant, indicating its compliance with the requirements of the plant's approved QCP and Contract Documents.

Accept responsibility of either obtaining products from another approved plant, or await re-approval of the plant, when the plant is removed from the Department's list of qualified product plants.

The Engineer will not allow changes in Contract Time or completion dates as a result of the plant's loss of qualification. Accept responsibility for all delay costs or other costs associated with the loss of plant's qualification.

449-2 Materials.

Ensure that the materials used for the construction of the precast drainage products have a certification statement from the source, showing that they meet the applicable requirements of the Specifications with the following modifications:

Reinforcing Bar	Section 415
Coarse Aggregate*	Section 901
Fine Aggregate*	Section 902
Portland Cement and blended cement	Section 921
Water	Section 923
Admixtures	Section 924
Pozzolans and slag	Section 929
Gasket Material	Section 942
Blended Hydraulic Cements	AASHTO M 240
Welded Wire Fabric	ASTM A 185 or ASTM A 497
Wire for Site Cage Machines	ASTM A 82, ASTM A 496 or ASTM A 615

*For concrete pipes the gradation requirements of concrete aggregates as set forth in Sections 901 and 902 are not applicable.

449-3 Construction Requirements.

Unless otherwise stipulated within the Contract Documents, meet the following requirements for concrete mix, product design, fabrication, transportation, and installation:

Three-Sided Precast Culverts	Section 407
Precast Concrete Box Culvert	Section 410
Pipe Culverts and Storm Sewers	Section 430
French Drains	Section 443
Inlets, Manholes, and Junction Boxes	Section 425 and ASTM C 478
Underdrains	Section 440 and ASTM C 444
Steel Reinforced Round Concrete Pipe	ASTM C 76
Reinforced Elliptical Concrete Pipe	ASTM C 507
Non-reinforced Concrete Pipe	ASTM C 985
Fiber Reinforced Concrete Pipe	ASTM C 1450

Meet the special requirements for the applicable pipes as described in 449-4 through 449-6.

449-4 Concrete Pipe.

449-4.1 Special Requirements for Steel Reinforced Concrete Pipe: Use pipe meeting the requirements of ASTM C 76 with the modifications as described in 449-4.2. Use Special Designed pipe meeting the requirements of ASTM C 655. Use Class S pipe meeting the requirements of ASTM C 655 and the 0.01 inch crack and ultimate D - loads given on the Design Standards, Index No. 205. Ensure all pipes are properly marked.

449-4.2 Modifications to ASTM C 76 and ASTM C 507: The following supersedes the provisions of ASTM C 76 and ASTM C 507:

(a) Ensure all materials used in concrete are certified from the source and conform to the requirements of 449-2.

(b) Ensure all Joint Reinforcement requirements are in accordance with the Design Standards.

(c) When membrane curing compounds are used, ensure that the requirements of 925-2 are met and the membrane curing compounds are applied in accordance with 400-16 immediately after the pipe has been removed from the form.

Key RCP Materials Specs (FDOT)

- Section 901: Coarse Aggregate
- Section 902: Fine Aggregate
- Section 921: Portland Cement and Blended Cement
- Section 923: Water
- Section 924: Admixtures
- Section 929: Pozzolans and Slag
- Section 942: Gasket Material
- Section 415: Reinforcing Bar

Other Key RCP Specifications: ASTM and AASHTO

- Cementitious
  - AASHTO M85: Portland Cement
  - ASTM C 618: Fly Ash
- Steel Reinforcement
  - ASTM A185 and A497: Welded Wire Reinforcement ASTM A82, A496, or A615: Wire for Site Cage Machines
- RCP Design, Fabrication, Performance
  - ASTM C76 (round pipe)
  - ASTM C507 (elliptical pipe)

Key RCB Specifications (FDOT)

- Precast Reinforced Concrete Box Culverts (RCB)
  - Section 410: Precast Concrete Box Culvert
  - Section 407: Three-sided Precast Culverts
- Concrete
  - Section 346: Portland Cement Concrete
- Reinforcing Steel
  - Section 415: Reinforcing Steel

Key Precast RCB Specifications: and AASHTO

- Precast RCB Design and Fabrication
  - ASTM C1433 / C1577 (not referenced by FDOT)
- Joints
  - ASTM C990
- Reinforcing Steel
  - ASTM A82, A496, or A615: Wire for Site Cage Machines ASTM A185, A497: Welded Wire Reinforcement
- Similar ASTM / AASHTO Specifications As Required For Concrete Pipe

FDOT State Materials Office

Web Site

http://www.dot.state.fl.us/statematerialsoffice/

Material Producer List

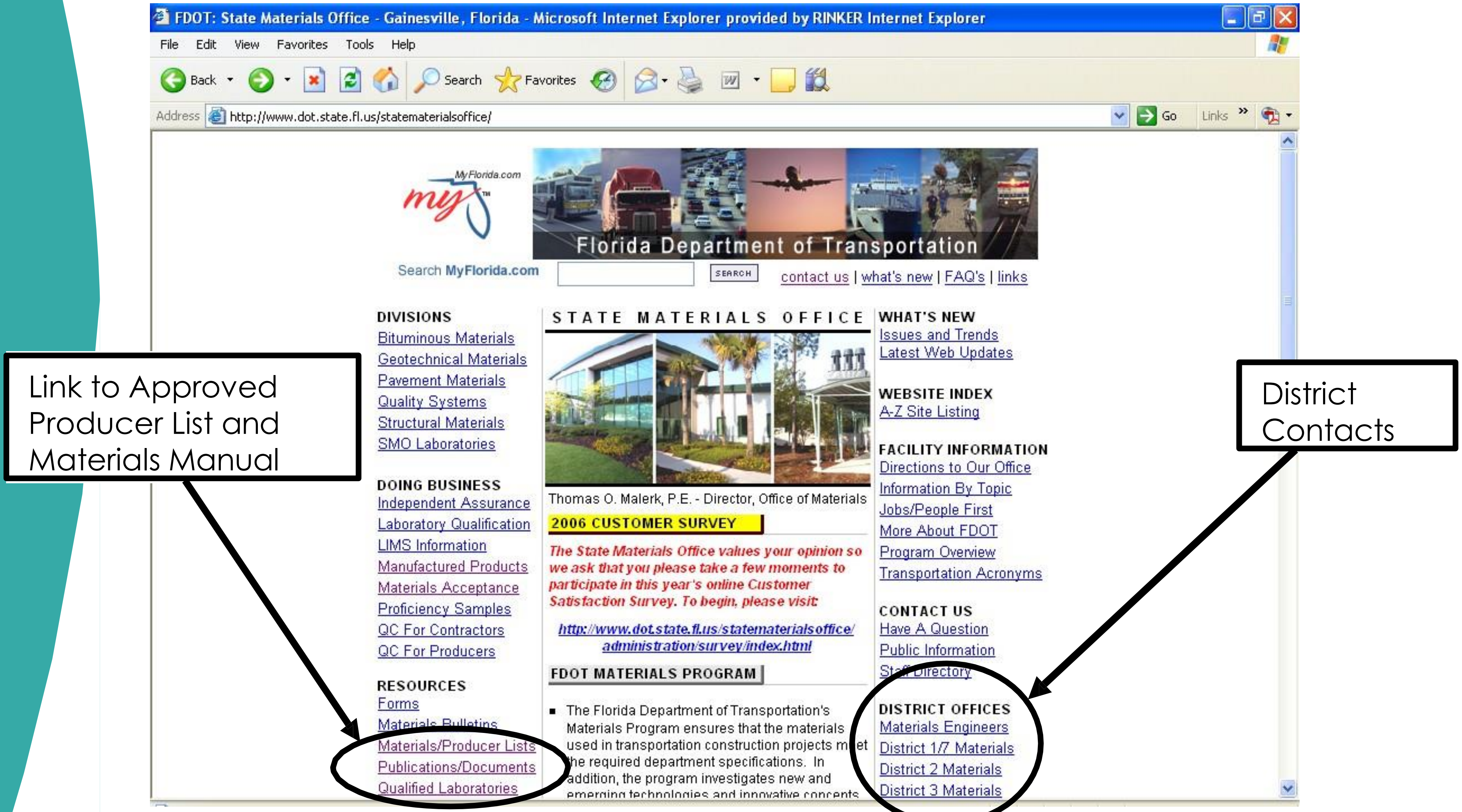
http://www.dot.state.fl.us/statematerialsoffice/quality/programs/qualitycontrol/materialslistings/postjuly2002.htm

Materials Manual

http://www.dot.state.fl.us/statematerialsoffice/administration/resources/library/publications/materialsmanual/index.ht m

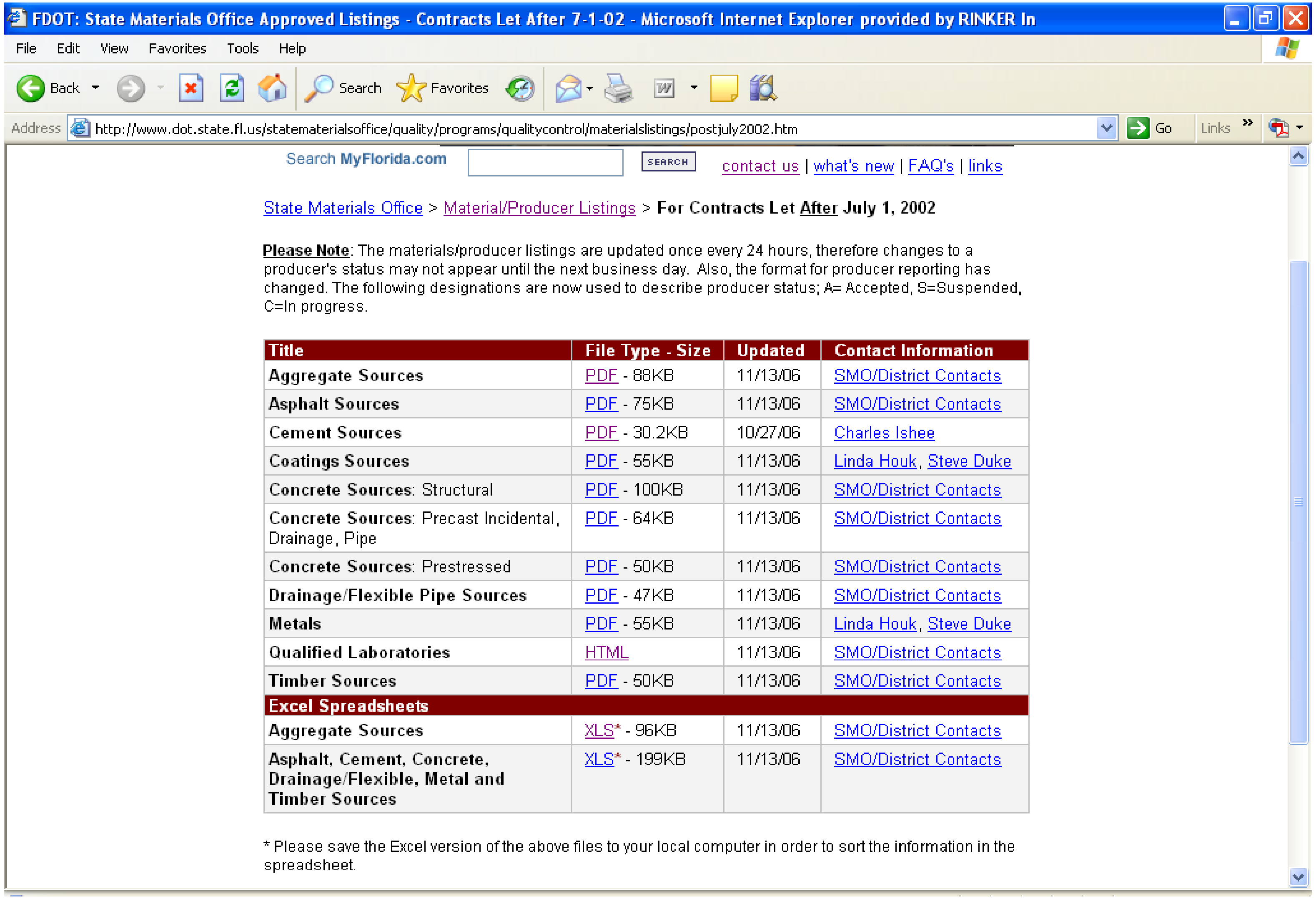
FDOT State Materials Office Website

http://www.dot.state.fl.us/statematerialsoffice/



Qualified Producer Lists

http://www.dot.state.fl.us/statematerialsoffice/quality/programs/qualitycontrol/materialslistings/postjuly2002.htm


FDOT: State Materials Office Approved Listings - Contracts Let After 7-1-02 - Microsoft Internet Explorer provided by RINKER In

File Edit View Favorites Tools Help

Back Search Favorites

Address http://www.dot.state.fl.us/statematerialsoffice/quality/programs/qualitycontrol/materialslistings/postjuly2002.htm Go Links

Search MyFlorida.com SEARCH contact us | what's new | FAQ's | links

State Materials Office > Material/Producer Listings > For Contracts Let After July 1, 2002

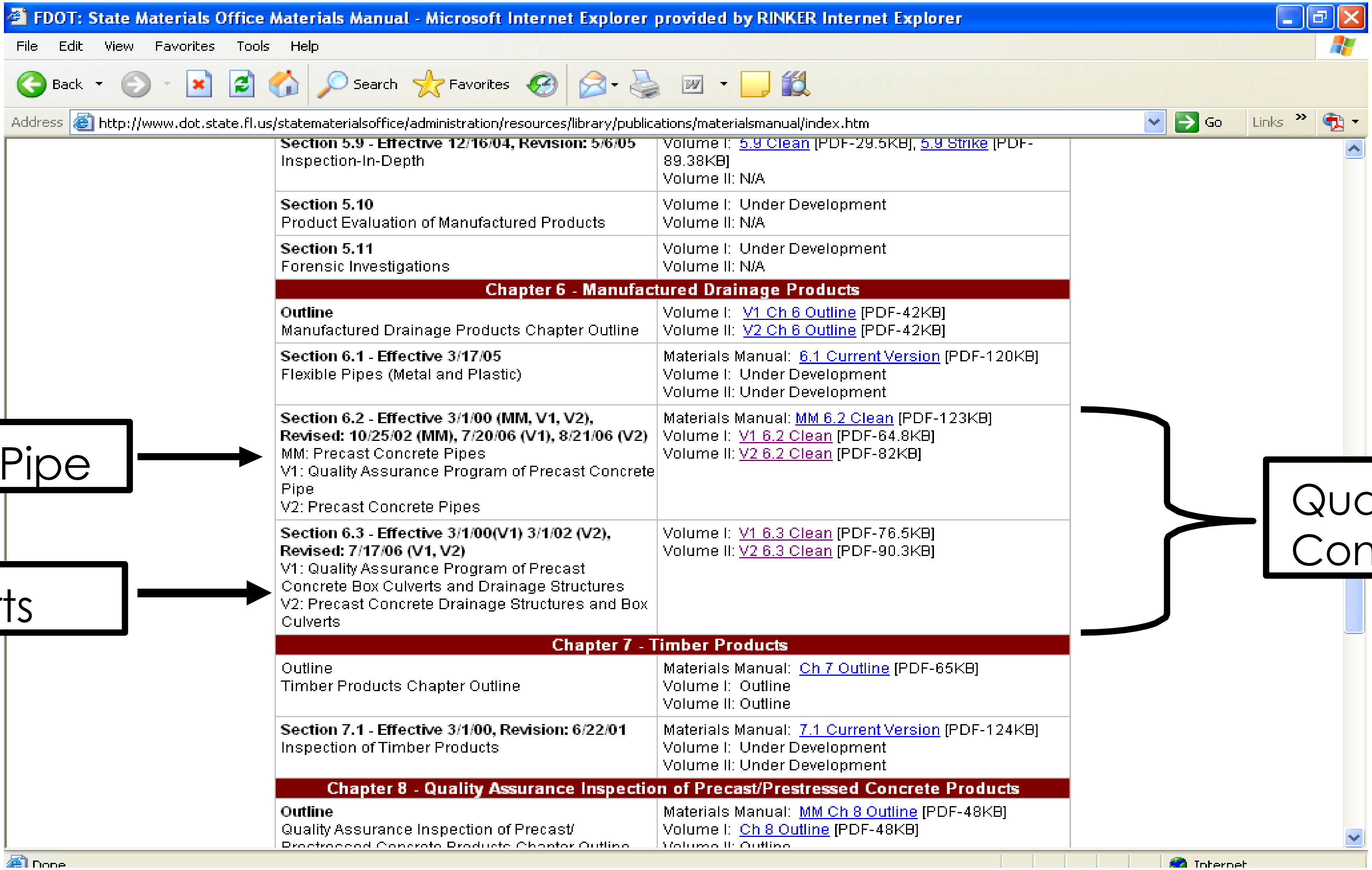
Please Note: The materials/producer listings are updated once every 24 hours, therefore changes to a producer's status may not appear until the next business day. Also, the format for producer reporting has changed. The following designations are now used to describe producer status; A= Accepted, S=Suspended, C=In progress.

Title	File Type - Size	Updated	Contact Information
Aggregate Sources	PDF - 88KB	11/13/06	SMO/District Contacts
Asphalt Sources	PDF - 75KB	11/13/06	SMO/District Contacts
Cement Sources	PDF - 30.2KB	10/27/06	Charles Ishee
Coatings Sources	PDF - 55KB	11/13/06	Linda Houk, Steve Duke
Concrete Sources: Structural	PDF - 100KB	11/13/06	SMO/District Contacts
Concrete Sources: Precast Incidental, Drainage, Pipe	PDF - 64KB	11/13/06	SMO/District Contacts
Concrete Sources: Prestressed	PDF - 50KB	11/13/06	SMO/District Contacts
Drainage/Flexible Pipe Sources	PDF - 47KB	11/13/06	SMO/District Contacts
Metals	PDF - 55KB	11/13/06	Linda Houk, Steve Duke
Qualified Laboratories	HTML	11/13/06	SMO/District Contacts
Timber Sources	PDF - 50KB	11/13/06	SMO/District Contacts
Excel Spreadsheets			
Aggregate Sources	XLS* - 96KB	11/13/06	SMO/District Contacts
Asphalt, Cement, Concrete, Drainage/Flexible, Metal and Timber Sources	XLS* - 199KB	11/13/06	SMO/District Contacts

* Please save the Excel version of the above files to your local computer in order to sort the information in the spreadsheet.

State Materials Manual

http://www.dot.state.fl.us/statematerialsoffice/administration/resources/library/publications/materials manual/index.htm



FDOT: State Materials Office Materials Manual - Microsoft Internet Explorer provided by RINKER Internet Explorer

File Edit View Favorites Tools Help

Address http://www.dot.state.fl.us/statematerialsoffice/administration/resources/library/publications/materialsmanual/index.htm

Section 5.9 - Effective 12/16/04, Revision: 5/6/05 Inspection-In-Depth	Volume I: 5.9 Clean [PDF-29.5KB], 5.9 Strike [PDF-89.38KB] Volume II: N/A
Section 5.10 Product Evaluation of Manufactured Products	Volume I: Under Development Volume II: N/A
Section 5.11 Forensic Investigations	Volume I: Under Development Volume II: N/A
Chapter 6 - Manufactured Drainage Products	
Outline Manufactured Drainage Products Chapter Outline	Volume I: V1 Ch 6 Outline [PDF-42KB] Volume II: V2 Ch 6 Outline [PDF-42KB]
Section 6.1 - Effective 3/17/05 Flexible Pipes (Metal and Plastic)	Materials Manual: 6.1 Current Version [PDF-120KB] Volume I: Under Development Volume II: Under Development
Section 6.2 - Effective 3/1/00 (MM, V1, V2), Revised: 10/25/02 (MM), 7/20/06 (V1), 8/21/06 (V2) MM: Precast Concrete Pipes V1: Quality Assurance Program of Precast Concrete Pipe V2: Precast Concrete Pipes	Materials Manual: MM 6.2 Clean [PDF-123KB] Volume I: V1 6.2 Clean [PDF-64.8KB] Volume II: V2 6.2 Clean [PDF-82KB]
Section 6.3 - Effective 3/1/00(V1) 3/1/02 (V2), Revised: 7/17/06 (V1, V2) V1: Quality Assurance Program of Precast Concrete Box Culverts and Drainage Structures V2: Precast Concrete Drainage Structures and Box Culverts	Volume I: V1 6.3 Clean [PDF-76.5KB] Volume II: V2 6.3 Clean [PDF-90.3KB]
Chapter 7 - Timber Products	
Outline Timber Products Chapter Outline	Materials Manual: Ch 7 Outline [PDF-65KB] Volume I: Outline Volume II: Outline
Section 7.1 - Effective 3/1/00, Revision: 6/22/01 Inspection of Timber Products	Materials Manual: 7.1 Current Version [PDF-124KB] Volume I: Under Development Volume II: Under Development
Chapter 8 - Quality Assurance Inspection of Precast/Prestressed Concrete Products	
Outline Quality Assurance Inspection of Precast/ Prestressed Concrete Products Chapter Outline	Materials Manual: MM Ch 8 Outline [PDF-48KB] Volume I: Ch 8 Outline [PDF-48KB] Volume II: Outline

Done Internet

Concrete Pipe

Box Culverts

Quality Control

VOLUME I

SECTION 6.2

QUALITY ASSURANCE PROGRAM OF PRECAST CONCRETE PIPE

6.2.1 PURPOSE

This procedure provides guidance to the Florida Department of Transportation personnel related to the development and implementation of the quality control and quality assurance programs for the manufacture, storage, and transportation of the precast concrete pipe for the Florida Department of Transportation projects.

Roles and Responsibilities

6.2.5 GENERAL INFORMATION

The Precast Concrete Pipe Plants (Plants) produce, inspect, store, and ship Precast Concrete Pipe (Pipe) meeting the requirements of the Specifications and other Contract Documents. The District Materials Offices verify that manufactured Pipe conforms to the requirements of the Contract Documents. The District Materials Office accepts (approves) their quality control plans and inspects the plants prior to commencement of any work.

Section 6.2
Plant Qualification Review Process

Plant submits proposed QC Plan District Materials Office Review

- Manufacturing
- Quality Control Testing Inspections and Documentation Forming, Steel Placement
- Storage and Shipping

Approval – “A” on Qualified Producer List

Maintaining Quality Control Plan and Plant Qualification Status

- Annual plant qualification reviews
  - Test data representing all pipe diameters Submit any changes to QC Plan
- Materials Manual, Section 5.6
  - Quality Control Program

Volume II

Section 6.2

PRECAST CONCRETE PIPE

6.2.1 PURPOSE

This procedure provides guidance for the development and implementation of the quality control program for the manufacture, storage, and transportation of the precast concrete pipe (Pipe) for the Florida Department of Transportation projects. The Pipe may include, but are not limited to, round concrete pipe, elliptical concrete pipe, mitered end sections, and underdrain pipe.

VOLUME I

Section 6.3

QUALITY ASSURANCE PROGRAM OF PRECAST CONCRETE BOX CULVERTS AND DRAINAGE STRUCTURES

6.3.1 PURPOSE

This procedure provides guidance to Department personnel related to the implementation of the quality control and quality assurance programs for precast concrete box culverts and drainage structures (Structures).

VOLUME II

Section 6.3

PRECAST CONCRETE DRAINAGE STRUCTURES AND BOX CULVERTS

6.3.1 PURPOSE

This procedure provides guidance for the development and implementation of the quality control for the manufacture, storage, and transportation of the precast concrete drainage structures and box culverts (Structures) for the Florida Department of Transportation projects. The Structures may include, but are not limited to, inlets, manholes, junction boxes, endwalls, three-sided precast concrete culverts, and precast concrete box culverts.

The Department will perform periodic quality assurance inspections, sampling, and testing to ensure of the quality and acceptability of the materials, methods, techniques, procedures and processes being utilized by the manufacturer in the fabrication of precast concrete products. The quality assurance inspection and testing will be performed in accordance with ***Section 6.3. Volume I.*** of the ***Materials Manual***.

FDOT Roadway Design Office

Web Site

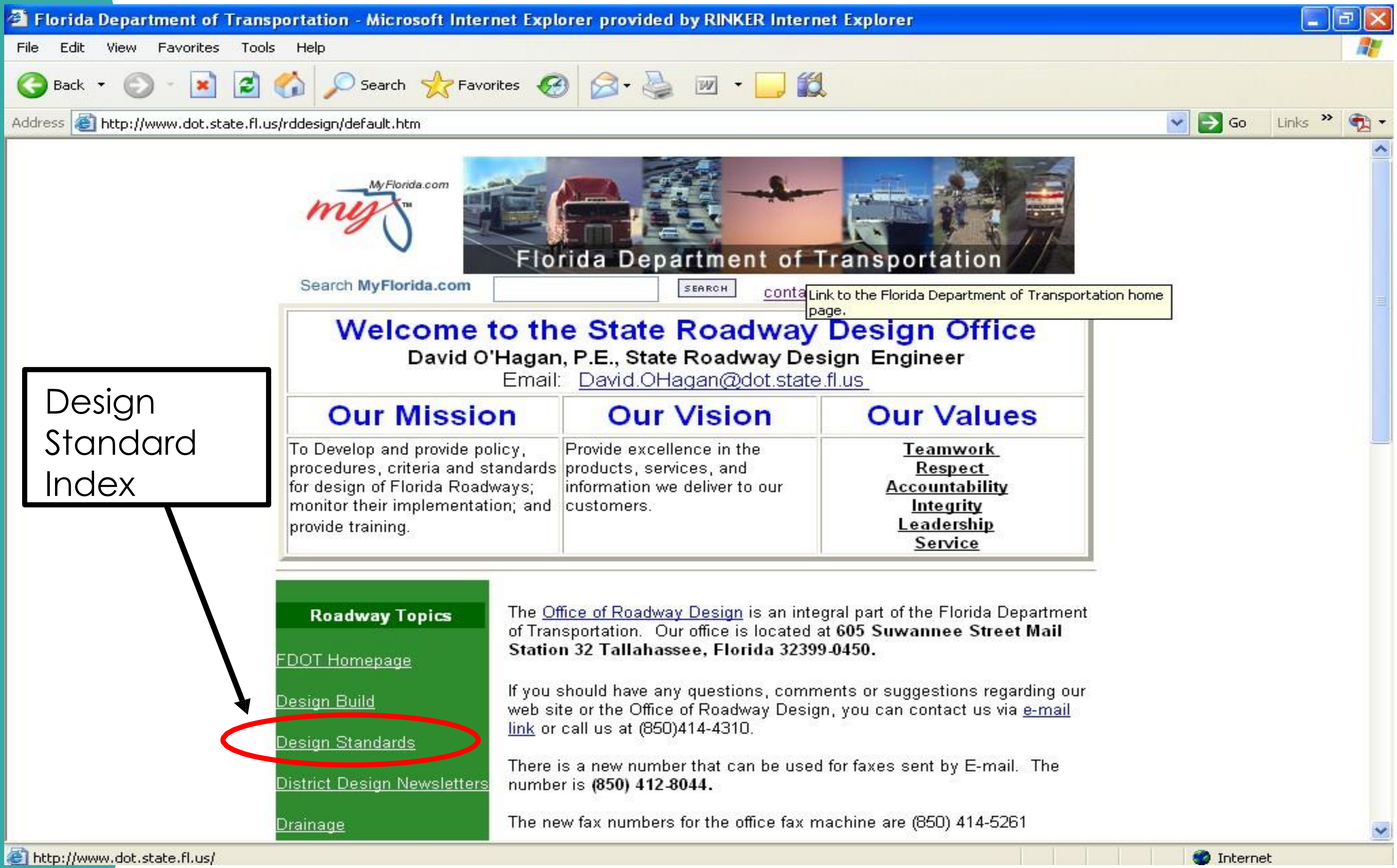
http://www.dot.state.fl.us/rddesign/default. htm

State Drainage Office

Oversees all Pipe Issues

Excluding Box Culverts (Structures)

Design Standard Index



Florida Department of Transportation - Microsoft Internet Explorer provided by RINKER Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites

Address http://www.dot.state.fl.us/rddesign/rd/RTDS/06/2006Standards-200.htm Go Links

200 Series

264	1 of 1	264.pdf	Dissipator - 30" To 72" Pipe	456 kb
266	1 of 1	266.pdf	Winged Concrete Endwalls - Single Round Pipe	215 kb
268	1 of 1	268.pdf	U-Type Sand-Cement Endwalls	330 kb
270	1 of 1	270.pdf	Flared End Section	306 kb
272	1-6 of 6	272.pdf	Cross Drain Mitered End Section	1750 kb
273	1-6 of 6	273.pdf	Side Drain Mitered End Section	1667 kb
280	1-4 of 4	280.pdf	Miscellaneous Drainage Details	1211 kb
281	1-2 of 2	281.pdf	Ditch Pavement And Sodding	587 kb
282	1 of 1	282.pdf	Back Of Sidewalk Drainage	314 kb
283	1 of 1	283.pdf	Median Opening Flume	186 kb
284	1 of 1	284.pdf	Concrete Shoulder Gutter Spillway	107 kb
285	1-2 of 2	285.pdf	French Drain	448 kb
286	1-2 of 2	286.pdf	Underdrain	515 kb
287	1-3 of 3	287.pdf	Concrete Pavement Subdrainage	821 kb
290	1-5 of 5	290.pdf	Concrete Box Culvert	1512 kb
293	1 of 1	293.pdf	Safety Modifications For Inlets In Box Culverts	60 kb
295	1 of 1	295.pdf	Safety Modifications For Endwalls	265 kb

Key RCP Standard Indices

Index 299 – Geotextile Material

D-3 Filter Fabric Standard Criteria

Index 205 – Cover Height

Pipe Class and D-Loads

Index 270 – Flared Ends

Indices 272 / 273 – Mitered Ends

Key RCP Standard Indices

Index 280 – Misc. Details

- Joint Designs
- RCP – CMP Jackets Integral
- Manhole Risers

Index 285 – French Drains

- Slotting Schedule

Precast Box Culvert Key Standard Indices

Index 290 – Box Culvert Details Index 291 – Supplemental Details

NEW

- Joint Details
- Connections to CIP Headwalls

Index 292 – Standard Steel Designs

NEW

- Release January 2007
- Steel tables similar to ASTM Standards

FDOT Structures Design Office

Web Site

http://www.dot.state.fl.us/structures/default.htm

Oversees precast box culvert issues

Does not oversee pipe issues

Structures Manual

http://www.dot.state.fl.us/structures/StructuresManual/CurrentRelease/FDOTBridgeManual.htm

Concrete and Environment

FDOT requires thicker concrete cover over the steel in precast RCB.

ASTM C1433 requires 1 inch cover.

FDOT requires 2 inches cover minimum and Requires 3 inches in "Extremely Aggressive" environments.

Ref. Table 1.2 (Concrete Cover), Structures Manual.

RCB concrete mix design properties are based on FDOT Section 346 and the Environmental Classification.

Refer to Table 1.3 (Structural Concrete Class Requirements), Structures Manual.

In “Moderately Aggressive” environments, Class IV concrete is to be used at a minimum.

1.4 Concrete and Environment [5.12.1]

1.4.1 Cover

Delete AASHTO *LRFD 5.12.3* and substitute the following requirements:

A. The requirements for concrete cover over reinforcing steel are listed in Table 1.2. Examples of concrete cover are shown in Figures 1.2 through 1.5.

B. When deformed reinforcing bars are in contact with other embedded items such as post-tensioning ducts, the actual bar diameter, including deformations, must be taken into account in determining the design dimensions of concrete members and in applying the design covers of Table 1.2.

Table 1.2 Concrete Cover

	CONCRETE COVER (inches)	
	S or M*	E*
Superstructure (Precast)		
Internal and external surfaces (except riding surfaces) of segmental concrete boxes, and external surfaces of prestressed beams (except the top surface):	2	
Top surface of girder top flange:	1	
Top deck surfaces: Short Bridges***:	2	
Top deck surfaces: Long Bridges***:	2 1/2**	
All components and surfaces not included above (including barriers):	2	
Superstructure (Cast-in-Place)		
All external and internal surfaces (ex. top surfaces):	2	
Top deck surfaces; Short Bridges 3:	2	
Top deck surfaces; Long Bridges 3:	2 1/2*	
Substructure (Precast and Cast-in-Place)		
External surfaces cast against earth and surfaces in contact with water:	4	4 1/2
Ext. formed surfaces, columns, and tops of footings not in contact w/ water:	3	4
Internal surfaces:	3	
Top of Girder Pedestals:	2	
Substructure (Precast):	3	4
Prestressed Piling (including cylinder piling):	3	
Drilled Shaft and auger cast piles:	6	
Retaining Walls (Cast-in-Place or Precast)(Excluding MSE walls4) :	2	3
Culverts (Cast-in-Place or Precast):	2	3
Bulkheads:	4	

*S = Slightly Aggressive; M = Moderately aggressive; E = Extremely Aggressive.
**Cover dimension includes a 0.5-inch allowance for milling.
3- See Short & Long Bridge Definitions in Chapter 4.
4- See SDG 3.13 for MSE wall cover requirements.

Structures Design Guidelines, Florida Department of Transportation, Structures Design Office, July 2006.

Table 1.3 Structural Concrete Class Requirements

CONCRETE LOCATION AND USAGE		ENVIRONMENTAL CLASSIFICATION		
		Slightly Aggressive	Moderately Aggressive	Extremely Aggressive
SUPERSTRUCTURE	Cast-in-Place (other than Bridge Decks)	Class II	Class IV	
	Cast-in-Place Bridge Deck (Including Diaphragms)	Class II (Bridge Deck)	Class IV	
	Approach Slabs	Class II (Bridge Deck)		
	Precast or Prestressed	Class III, IV, V, or VI	Class IV, V, or VI	
SUBSTRUCTURE	Cast-in-Place (other than Bridge Seals)	Class II	Class IV	Class IV, or V
	Precast or Prestressed (other than piling)	Class III, IV, V, or VI	Class IV, V, or VI	
	Cast-in-Place Columns located directly in splash zone	Class II	Class IV	
	Piling	Class V (Spec.) or VI		
	Drilled Shafts	Class IV (Drilled Shafts)		
	Retaining Walls	Class II or III	Class IV	

Corrosion Protection Measures: Calcium nitrite and/or silica fume admixtures may be required. Admixture use must conform to the requirements of “Concrete Class and Admixtures for Corrosion Protection.”

Structures Design Guidelines, Florida Department of Transportation, Structures Design Office, July 2006.

Environment and Cement Type

346-2.2 Types of Cement: Unless a specific type of cement is designated elsewhere, use Type I, Type IP, Type IS, Type IP (MS), Type II, or Type III cement in all classes of concrete.
Use only the types of cements designated for each environmental condition in structural concrete. A mix design for a more aggressive environment may be substituted for a lower aggressive environmental condition.

Table 1

BRIDGE SUBSTRUCTURE, DRAINAGE STRUCTURES AND OTHER STRUCTURES			
Component	Slightly Aggressive Environment	Moderately Aggressive Environment	Extremely Aggressive Environment
All Elements	Type I or Type III	Type I with Fly Ash and/or Slag, Type II, Type IP, Type IP (MS), or Type IS	Type II with Fly Ash or Slag

Portland Cement
FDOT Requires AASHTO M85

ASTM C150 permits up to 5% limestone addition, a 1% process addition, and has no cap on C3S.

AASHTO M85 allows only a 1% process addition and has a maximum C3S cap of 58%.

At this time, ASTM C150 and AASHTO M85 cement have different properties.

AASHTO and ASTM are coordinating to harmonize the specifications.

Environment and Cement Type

All AASHTO M85 Type II meets M85 Type I.

If your mill cert states "M85 Type I/II" that would imply that it meets M85 Type II and would therefore be acceptable for FDOT Class IV extremely aggressive concrete.

If your mill cert states only "ASTM C150 I/II" it likely will not meet AASHTO II.

Not all Class IV concrete requires AASHTO M85 Type II cement - only those in an extremely aggressive environment.

M85 Type I may be used in moderately aggressive environments.

Environment Classification

- Effects Precast Box Culvert Designs
  - Concrete Cover Thickness
  - Concrete Type and Mix Properties
  - Cement Type

Summary

- Know How to Find Specs and Standards
- FDOT Web Site
- Read the Specs
- Understand the Specs
- Do not assume specs are the same for all projects – check contract documents

Raw Materials
For Precast Concete Pipe and Box Culverts

FDOT Certification Requirements

Material Certification is Important

- Producer Statement of Product Quality
- FDOT Requirement
  - FDOT Section 6
  - FDOT Materials Manual
- ASTM Specification Requirements

FDOT Section 6

6-1.3 Certification:
6-1.3.1 Producer Certification: Ensure completeness and correlate certification(s) of materials provided. Furnish to the Engineer for approval, certification from the producer for all products listed on the Department's Qualified Products List (QPL) and when required by the applicable material Specification(s). **Do not incorporate any manufactured product(s) or material(s) into the project without approval from the Engineer.** Materials will not be considered for payment when not accompanied by Producer Certification. Producers may obtain sample certification forms through the Department's website. Ensure that the certification is provided on the producer's letterhead and is signed by a legally responsible person from the producer.

FDOT Materials Manual Volume II

4. Quality Control of Certified Materials

1. General

Ensure that all materials used to manufacture of Pipe are from Department approved sources and comply with all requirements as specified herein.

Concrete Pipe

4. Quality Control of Certified Materials

1. General

Ensure that all materials used to manufacture of Structures are from Department approved sources and comply with requirements as specified herein.

Box Culverts

Materials Certifications

Department Approved Sources Source Codes

Qualified Products List (QPL)

All materials used to manufacture RCP and RCB must be from FDOT approved sources.

What Materials Need Certification?

- Steel and Welded Wire Reinforcement
  - ASTM / AASHTO / Section 415
- Coarse and Fine Aggregates
  - Sections 901 and 902
- Cement
  - Section 921
- Pozzolans / Slag / Fly Ash
  - Section 929
- Water
  - Section 923

What Materials Need Certification?

- Gasket Material and Lubricant
  - Section 942
  - Round and Profile Rubber Gaskets
  - Cold Adhesive Preformed Plastic Material
- Geotextile Fabrics
  - Section 985
  - Standard Index 199, Type D-3
- Curing Materials
  - Burlap / Waterproof Paper / PE Sheets
  - Section 925

Materials From The Qualified Products List (QPL)

- http://www.dot.state.fl.us/specificationsoffice/QPLindex.htm
- Concrete Patching Materials
  - Section 926 Epoxy Compounds
  - Section 930 Materials for Concrete Repair
- Non-shrink Grout
  - Plug Lifting Holes /Repair Defects
  - Section 942

Materials From The Qualified Products List (QPL)

- Admixtures
  - Section 924
- Plastic Chairs / Spacers / Bolsters
  - Section 415 Steel Reinforcement
- Resilient Connectors
  - Connects Pipe to Structures
  - Section 934

Be Aware of Contract Documents

- Note that steel is not in the QPL
- Steel certifications must meet contract documents (e.g., standard specifications)
- Not all materials may be listed in FDOT QPL or FDOT Approved Source list
- Always understand material requirements of contract documents

How To Check For Certification

- Material supplier provides plant with a certification statement/delivery ticket
- Check FDOT Materials Office Web Site
  - Approved Sources
  - http://www.dot.state.fl.us/statematerialsoffice/quality/programs/qualitycontrol/materialslistings/index.htm
- Check QPL Web Site
  - http://www.dot.state.fl.us/specificationsoffice/QPLindex.h tm

FLORIDA DEPARTMENT OF TRANSPORTATION
STATE MATERIALS OFFICE

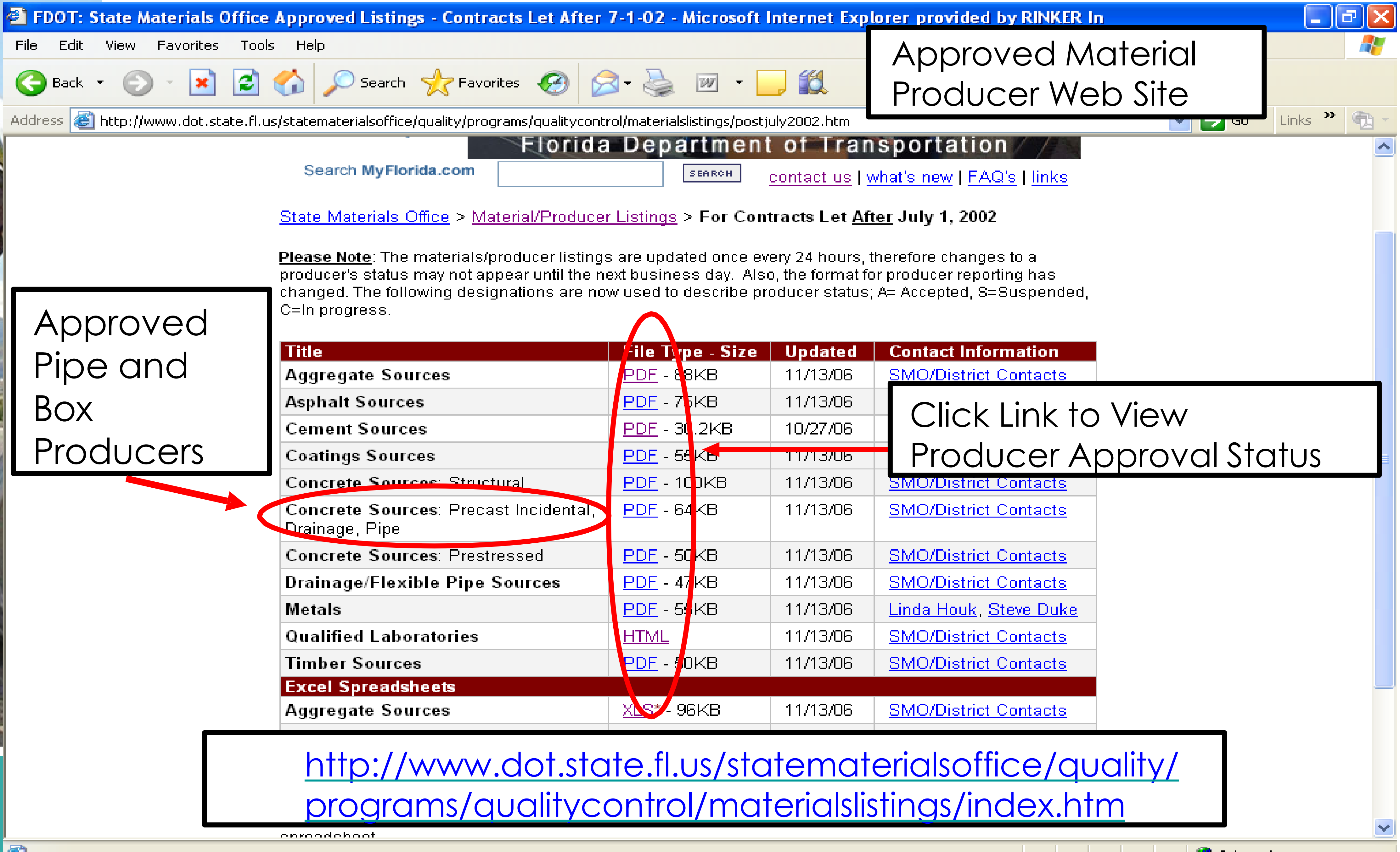
INSTRUCTIONS FOR CODING OF AGGREGATE TEST DATA FOR COMPUTERIZATION

Prepared by

Aggregate Control Unit
July 1994

Want to know the FDOT Source Codes that correspond to aggregate gradations and types?

The FDOT document, "Instructions for Coding of Aggregate Test Data for Computerization", lists all FDOT aggregate sources codes and describes the corresponding aggregate type and gradations.



Approved Material Producer Web Site

Approved Pipe and Box Producers

Click Link to View Producer Approval Status

http://www.dot.state.fl.us/statematerialsoffice/quality/programs/qualitycontrol/materialslistings/index.htm

Adobe Reader - [aggregatesource[1].pdf]

File Edit View Document Tools Window Help

Save a Copy | Search | Select | 91% | Help

Producers with Accepted QC Program *11/13/2006 8:09:18AM* Florida Department of Transportation

The materials/producer listings are updated once every 24 hours, therefore changes to a producer's status may not appear until the next business day.

AGGREGATE

District	Company Name Facility Number	Contact w/ email	Phone Number	Physical Address	Mailing Address	Status Date of Action
	Blackidge Emulsions 08643					APPROVED
01	CORAL ROCK INC. 01011	ROBIN ROEBUCK house486@cs.com	239-543-5023	13391 SR 31 PUNTA GORDA FL 33982 USA	41451 COOK BROWN ROAD PUNTA GORDA FL 33982 USA	APPROVED
01	EARTHSOURCE INC. 01305	Troy McDonald troylimestone@juno.com	239-339-7070	13500 SR 31 PUNTA GORDA FL 33982 USA	13500 SR 31 PUNTA GORDA FL 33982 USA	APPROVED
01	SOUTHWEST AGGREGATES 01495	HOWARD DEVANE rockcrush@aol.com OR	239-567-1800	16070 TAMIAMI TRAIL S. PUNTA GORDA FL 33955 USA	16070 TAMIAMI TRAIL S. PUNTA GORDA FL 33955 USA	APPROVED
01	QUALITY MINING, INC 01511	JEFF WEILER jeff@weilerengineering.org Mine	941-698-2974	14400 ROBIN RD PORT CHARLOTTE FL 33981 USA	1777 TAMIAMI TRAIL MURDOCK FL 33938-0874 USA	APPROVED
01	FLORIDA ROCK INDUSTRIES INC 03037	JOE DIMAS dimasj@flarock.com	239-657-3155	P.O. DRAWER 370 IMMOKALEE FL 33934 USA	P.O. DRAWER 370 IMMOKALEE FL 33934 USA	APPROVED
01	APAC GOLDEN GATE QUARRY 03616	LINDA SHEPPARD dlsheppard@ashland.com	941-483-3329	911 5TH ST. S.W. NAPLES FL 34117 USA	P.O. BOX 2579 SARASOTA FL 34230 USA	APPROVED
01	E.R. JAHNA INDUSTRIES INC 05045	Jim Lanier mineort@jahna.com	863-675-1454	P.O. BOX 786 LABELLE FL 33975 USA	P.O. BOX 786 LABELLE FL 33975 USA	APPROVED
01	RIDGDILL & SON CONST. INC 05354	Allen Ridgliol allenridgill@hotmail.com	941-946-1314	P.O. BOX 447 CLEWISTON FL 33440 USA	P.O. BOX 447 CLEWISTON FL 33440 USA	SUSPENDED
01	RINKER MATERIALS 05455	KEITH JOWERS mjowers@rinker.com	863-675-2862	P.O. BOX 110 MOOREHAVEN FL 33471 USA	P.O. BOX 110 MOOREHAVEN FL 33471 USA	APPROVED
01	FLORIDA ROCK INDUSTRIES INC 05505	CARL MANNING cmanning@flarock.com	863-675-5866	P.O. BOX 477 LABELLE FL 33975 USA	P.O. BOX 477 LABELLE FL 33975 USA	APPROVED
01	RINKER MATERIALS 12008	Mark Davila mdavila@rinker.com	941-267-8181	11840 ALICO RD FT. MYERS FL 33913 USA	11840 ALICO RD FT. MYERS FL 33913 USA	APPROVED
01	FLORIDA ROCK INDUSTRIES INC 12260	JOSE DIMAS dimasj@flarock.com	941-267-1803	14341 ALICO RD FT. MYERS FL 33913 USA	14341 ALICO RD FT. MYERS FL 33913 USA	APPROVED
01	RMC SOUTH FLORIDA MATERIALS INC 12507	Brian Thompson brianthompson@cemexusa.com	941-498-4900	14500 CORKSCREW RD ESTERO FL 33928 USA	14500 CORKSCREW RD ESTERO FL 33928	APPROVED

Sample Certification for Profile Rubber Gasket

Company Info Redacted

[redacted]

COMPOUND & SPECIFICATION DATA FOR PIPE GASKETS

Date 10/1/06 Compound : 40 Durometer Isoprene

Gasket Size : 15"- 66" Profile Gaskets Compound Lot No. : Speciman

Customer : [redacted]

TEST DESCRIPTION	ASTM C-443 C505	AWWA C-200	USBR	ASTM C-361	TEST RESULTS
TENSILE STRENGTH(PSI MIN) D412-90	**1200**	2300	2300	1500	**2200**
ELONGATION(%MIN) D412-90	**350**	350	425	425	**624**
SHORE DUROMETER(TYPE A-2) D2240-86	**35 - 65 ± 5**	50- 65	35-65	40 - 60 ± 5	**42**
COMPRESSION SET (%MAX) 22 Hrs. @ 158°F D395-89	**25**	20	20	20	**15**
ACCELERATED AGING IN AIR 96 Hrs. @ 158°F D55373-90 TENSILE RETAINED (%MIN) ELONGATION RETAINED (%MIN) DUROMETER INCREASE (%MAX)	**85 80 +/- 15**	80 - -	80 80 8	80 60 15	**96 88 3**
WATER ABSORPTION D471-79 CHANGE IN WEIGHT (%MAX)	**15**	-	5	15	**2.92**
SPECIFIC GRAVITY	-	.95 - 1.45	-	-	**1.07**
% POLYMER (VOLUME)	-	50%	-	-	**PASS**
SPLICE (NO VISIBLE SEPARATION) STRETCHED 100%	-	-	-	-	**PASS**
ACCELERATED AGING IN ASTM#3 OIL 70HRS @ 212°F(VOLUME CHG. MAX)	**80**			80	-
OZONE RESISTANCE D1149	**NO CRACKS**	-	-	NO CRACKS	**PASS**

This is to certify that the above tests were run in accordance with the requirements of each applicable specification.

[redacted]

Gasket Lubricant Certification

4. Certification:

1. The **lubricant manufacturer shall supply the purchaser written certification** that the gasket lubricant has met all test requirements specified to the gasket samples supplied.
2. **Tests shall be performed each year** on a gasket lubricant for **certification, which shall be valid for one year** provided there are no changes in the materials or process used in the manufacture of either the gaskets or the lubricant.
3. **No gasket lubricant shall be used** on concrete pipe joints meeting this specification **without valid certification** provided to the concrete pipe manufacturer.

Source: **ASTM C 497 Standard Test Methods for Concrete Pipe, Manhole Sections, or Tile**

ASTM C 618 TEST REPORT

Project Name: August QC
Sample Number: 6121-01

Report Date: 11/1/2006
Sample: [redacted]
Tested By:

TESTS	RESULTS	ASTM C 618 CLASS F/C	AASHTO M 295 CLASS F/C
[redacted] Monthly QC			
CHEMICAL TESTS			
Silicon Dioxide (SiO_2), %	55.59		
Aluminum Oxide (Al_2O_3), %	25.49		
Iron Oxide (Fe_2O_3), %	5.93		
Sum of SiO_2, Al_2O_3, Fe_2O_3, %	87.01	70.0/50.0 min.	70.0/50.0 min.
Calcium Oxide (CaO), %	2.54		
Magnesium Oxide (MgO), %	1.18		
Sulfur Trioxide (SO_3), %	0.38	5.0 max.	5.0 max.
Sodium Oxide (Na_2O), %	0.64		
Potassium Oxide (K_2O), %	2.48		
Total Alkalies (as Na_2O), %	2.27		
PHYSICAL TESTS			
Moisture Content, %	0.01	3.0 max.	3.0 max.
Loss On Ignition, %	4.00	6.0 max.	5.0 max.
Amount Retained on No. 325 Sieve, %	25.00	34 max.	34 max.
Specific Gravity	2.23		
Autoclave Soundness, %	-0.01	0.8 max.	0.8 max.
SAI, with Portland Cement at 7 days, % of Control	75.5	75 min.*	75 min.*
SAI, with Portland Cement at 28 days, % of Control	79.3	75 min.*	75 min.*
Water Required, % of Control	98.8	105 max.	105 max.

Meets ASTM C618, AASHTO M295, FDOT Section 929, SCDHPT and MDOT specifications for Class F Fly Ash.

*Meeting the 7 day or 28 day strength activity index will indicate specification compliance.

Approved By: [redacted]
QC Specialist

Approved By: [redacted]
Materials Testing Manager

Sample Certification from Fly Ash Supplier to Plant.

MILL TEST

This is to certify that one sample each of W5.0 W3.0 W5.4

Concrete reinforcement Wire Mesh manufactured by [redacted]

And sold to [redacted]

On XXXXXBL 4000 Dated 04/09/03 Tested as follows:

W5.0 90838 PSI W3.0 80965 PSI W5.4 92577 PSI

This mesh complies with ASTM A-185-97 and was manufactured in the United States, using American-made raw materials.

[redacted]

Customer Service Representative

Witness my hand and seal
This 09 Day of APRIL 2003

[redacted] Notary Public, State of Florida

[redacted]
MY COMMISSION # DD 074112

RCP and Precast RCB Products Need Certification Too

- Plant QC Plans Certified Material Certification Form 206
  - Notarized and Submitted with 1st Delivery Each Delivery Ticket is QC Stamped Applies to Pipe and Precast Box Culverts Applies to Incidental Precast
  - http://www.dot.state.fl.us/statematerialsoffice/administration/resources/library/publications/certifications/sampleforms.htm

Revised 3/6/06

"USE ON MANUFACTURER'S LETTERHEAD"

MATERIAL CERTIFICATION

FLORIDA D.O.T.

MANUFACTURED PRECAST CONCRETE PRODUCTS
MATERIAL NUMBER* (206)

Contractor:

F.D.O.T. Project Number:

F.D.O.T. Contract Number:

Project Location:

Description of Products:

___

We certify the described precast concrete products will be manufactured by our plant in accordance with the requirements set forth in the Florida Department of Transportation Contract Documents and the plant's approved quality control plan. The plant's quality control manager or the inspectors under his/her direct supervision will stamp the products prior to their shipment to the project site. The quality control manager's stamp is confirmation of the aforementioned certification. Each shipment of the precast concrete products to the project site will be accompanied with a signed or stamped delivery ticket, which will provide the description and list of the products.

Manufacturer Officer or Designee: ______________________

Signature: ______________________

Date: ______________________

(Notarized)

*Note: Use material number 205 for prestressed concrete products per Section 450 Specification and material number 206 for all other precast concrete products, including concrete pipes and other precast concrete drainage structures, incidental precast concrete products, and box culverts.

Sample Certification Form to be used for first delivery of pipe or precast box culvert to FDOT project.

Subsequent delivery tickets shall have a QC stamp and will not require notarization.

Material Certification Summary

- Applies to all raw materials
- Applies to finished RCP or RCB
- Certifies compliance with FDOT and applicable ASTM / AASHTO criteria
- Adhere to certification requirements in FDOT Materials Manual
  - Volume II, Section 6.2.7.4 (RCP)
  - Volume II, Section 6.3.7.4 (Precast Box Culverts)

Precast Concrete Pipe and Box Culvert Equipment Calibration

To Trust What We Measure

And To Maintain Consistency

Calibration of Testing / Inspection Equipment for RCP

6.2.7.6 Calibration of Equipment

Check all quality control testing equipment and calibrate them, as required in ***ASTM C 497***. A reputable licensed testing laboratory shall calibrate all jacks and gauges for the three-edge-bearing test equipment at least once every twelve-month period.

Source: FDOT Materials Manual, Section 6.2, Vol. II

Calibration of Testing / Inspection Equipment for Precast RCB

6.3.7.6 Calibration of Equipment

Check or calibrate all quality control testing equipment such as the batching scales, compressive strength testing machines, portable weighing scales, air meters, density buckets, and temperature recording devices for compliance with the applicable test methods.

Source: FDOT Materials Manual, Section 6.3, Volume II

Equipment Calibration

- Three Edge Bearing (3EB) Rack
- Compressive Strength Tester
- Hydrostatic Pressure Gauge
- Water Meter
- Batch Plant Scales
- Laboratory Scales
- Admixture Dispenser
- Joint Gauging Equipment
- Temperature Gauge (Thermometer)
- Micrometers

3EB Test Equipment



What is the history of the 0.01 inch crack in RCP?

In 1920s/1930s, everyone had their own idea of a "crack" when performing the 3EB test. There was no standard of d- load crack measurement.

A 0.01-inch thick feeler gauge was decided to be the standard by which the d-load crack width would be defined.

It is an arbitrary standard of measurement born out of the need for consistency and practical application.

3EB Calibration

4.4 *Calibration*—The loading device shall be one which **shall provide an accuracy of ± 2 %** at the specified test loads. A calibration curve shall be used. The machines used for performing the three-edge-bearing tests shall be verified in accordance with Practices E 4.

Source: **ASTM C 497 Standard Test Methods for Concrete Pipe, Manhole Sections, or Tile**

Weighing Scales for Absorption

7.4.5 *Scale Sensitivity*—Weigh specimens weighing **less than 1 kg to an accuracy of 0.10 %** of the specimen mass. Weigh specimens weighing **more than 1 kg to an accuracy of 1g.**

Source: **ASTM C 497 Standard Test Methods for Concrete Pipe, Manhole Sections, or Tile**

Hydrostatic Joint Test Pressure Gauge Calibration

3. *Apparatus:*

1. Hydrostatic pressure tests on joints shall be made on an assembly of two sections of pipe, properly connected in accordance with the joint design. **The hydrostatic pressure shall be measured with a gage or manometer accurate to ± 5 % of the test pressure.**

2. The testing machine shall be of any type that has sufficient capacity to apply the required test load, that is in addition to the weight of the pipe filled with water, or a suitable dead load shall be applied.

Source: **ASTM C 497 Standard Test Methods for Concrete Pipe, Manhole Sections, or Tile**

Compressive Strength Calibration

ASTM C 39

- Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens

Verify calibration:

- At least annually, not to exceed 13 months
- Upon installation or relocation
- After making repairs or adjustments…
- Whenever accuracy of loads is suspect

Paragraph 5 (Apparatus)

- 5.3 Load Indication

Thermometer Calibration

- ASTM C 1064
  - Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
- Calibrate using two thermometers
- Calibrate at two temperatures
  - At least 30 degrees difference between tests

Calibration Summary

- Consistency in Measurements Applies to all Test Instruments / Devices
- Check FDOT and ASTM Specs
  - ASTM Test Method Specification
  - Allowable Limits
  - Frequency of Calibration
  - Method of Calibration

ACPA QCast Quality School

NCDOT APPENDIX

Additional study materials for:

NCDOT Concrete Batching Technician Certification

QC and production personnel manufacturing products for NCDOT projects

In Accordance With:
North Carolina Department of Transportation
Materials and Tests Unit

Administered by:
American Concrete Pipe Association (ACPA)

July 2018 Update

This appendix focuses on specific NCDOT requirements that may differ from national standards or the ACPA QCast program requirements. Although every effort has been made to maintain the information presented in this appendix current and up to date, the reader should familiarize themselves with all the latest revisions of the applicable NCDOT standards and specifications and make adjustments to their QC/QA practices accordingly.

American Concrete Pipe Association

Transportation

PAT McCRORY
Governor

NICHOLAS J. TENNYSON
Secretary

October 3, 2016

Dear Concrete Pipe Producer,

The Department has been working closely with representatives of the Carolinas Concrete Pipe And Products Association (CCPPA) and the American Concrete Pipe Association (ACPA) to begin the effort of accepting certification for Batching Technicians through the ACPA's "Quality Cast" (QCast) Plant Certification Program.

Currently, the requirement to be certified as a NCDOT Concrete Batching Technician is an individual must attend and successfully pass the NCDOT Concrete Batch Technician Certification school conducted by the Materials and Tests Unit. Effective January 1, 2017, the NCDOT Concrete Batch Technician Certification will require completion of two phases. The first phase will consist of attending and successfully completing the certification program conducted by the Materials and Tests Unit, or attending and successfully completing the QCAST program. The QCAST program will be conducted by ACPA with scheduled classes, requirements, fees, and locations available on their web page. Technicians will be required to submit documentation to the Materials and Tests Unit after successfully completing the course.

The second phase consists of an on-site evaluation conducted by a Materials and Tests representative at the point of production of concrete. The technician will be evaluated on operations involved in the batching operations. This is an annual evaluation and is required for all certified Batching Technicians.

Only technicians who have attend the QCAST program after January 1, 2017, are eligible for this certification without attending the NCDOT Concrete Batch Technician Certification school. Additionally, Technicians who are responsible for conducting acceptance tests and/or samples (concrete cylinders) are required to achieve and maintain a NCDOT Concrete Field Technician Certification. The Materials and Tests Unit and its representatives are eager to assist you in the certification process and hope that you fully understand the importance, significance, and responsibility that these certifications carry.

If you have additional questions or concerns, please contact Cabell Garbee (cgarbee@ncdot.gov) at 919-329-4224 or Sam Frederick (sjfrederick@ncdot.gov) at 919-814-2220.

Sincerely,

Christopher A. Peoples, PE
State Materials Engineer

NCDOT approved Concrete Pipe producers

Producers Name	***Facility Number***	***Division***	***Facility Address***	***City***	***State***	***Zip***	***Phone***	***Facility contact***	***ACPA/QC***
Johnson concrete Pipe	**CP10**	9	217 Klumac Road	Salisbury	NC	28144	704-636-5231	Jody Wall	Y
Rinker Materials	**CP20**	10	5601 Pharr Mill Road	Harrisburg	NC	28075	(704) 455-1100	Adam Feser	Y
Mid-Atlantic Drainage	**CP23**	3	1124 White Oak Lane	Galivants Ferry	SC	29544	(843) 358-4206	David Henderson and Danielle McCrackin	N
Smith Setzer & Sons	**CP11**	12	4708 Hwy 10 West	Catawba	NC	28609	(828) 241-3161	Michael Setzer	N
Foltz Concrete Pipe Company	**CP6**	9	1185 N NC Hwy 150	Winston Salem	NC	27127	(336) 764-0341	Derek Secrist	N
Rinker Materials	**CP8, CP4**	0	300 Bill Street	Columbia	SC	29209	(800) 627-2986		Y
Oldcastle Precast	**CP3**	5	PO Box 548	Fuquay Varina	NC	27256	(919) 552-2252	Elliott Taylor	N
Rinker Materials	**CP9**	4	1600 Thorne Ave South	Wilson	NC	27893	(252) 243-6153	Robert Strickland	Y
Oldcastle Precast	**CP1**	6	3960 Cedar Creek Road	Fayettville	NC	28312	910-483-6960	Jeff Bledsole	Y
Oldcastle Precast	**CP13, CP14**	5	920 Wither Road	Raleigh	NC	27601	919-772-6301	Robert Amos	Y
Concrete Pipe & Precast, LLC	**CP33**	10	20047 Silver road	Oakboro	NC	28129	(704) 485-4614	John Field	Y
Foley Pipe Products	**CP37**	1	1291 Hardigree Road	Winder	GA	30680	(706) 249-7671	Dennis Morrissey	Y
Rinker Materials	**CP7**	9	208 Randolph St	Thomasville	NC	27360	336-475-1371	Steve Kitchen	Y
Gossett Concrete Pipe, Inc.	**CP5**	10	900 West Lee Street	Greenville	SC	29608	(864) 242-3593	Samuel Carter	Y

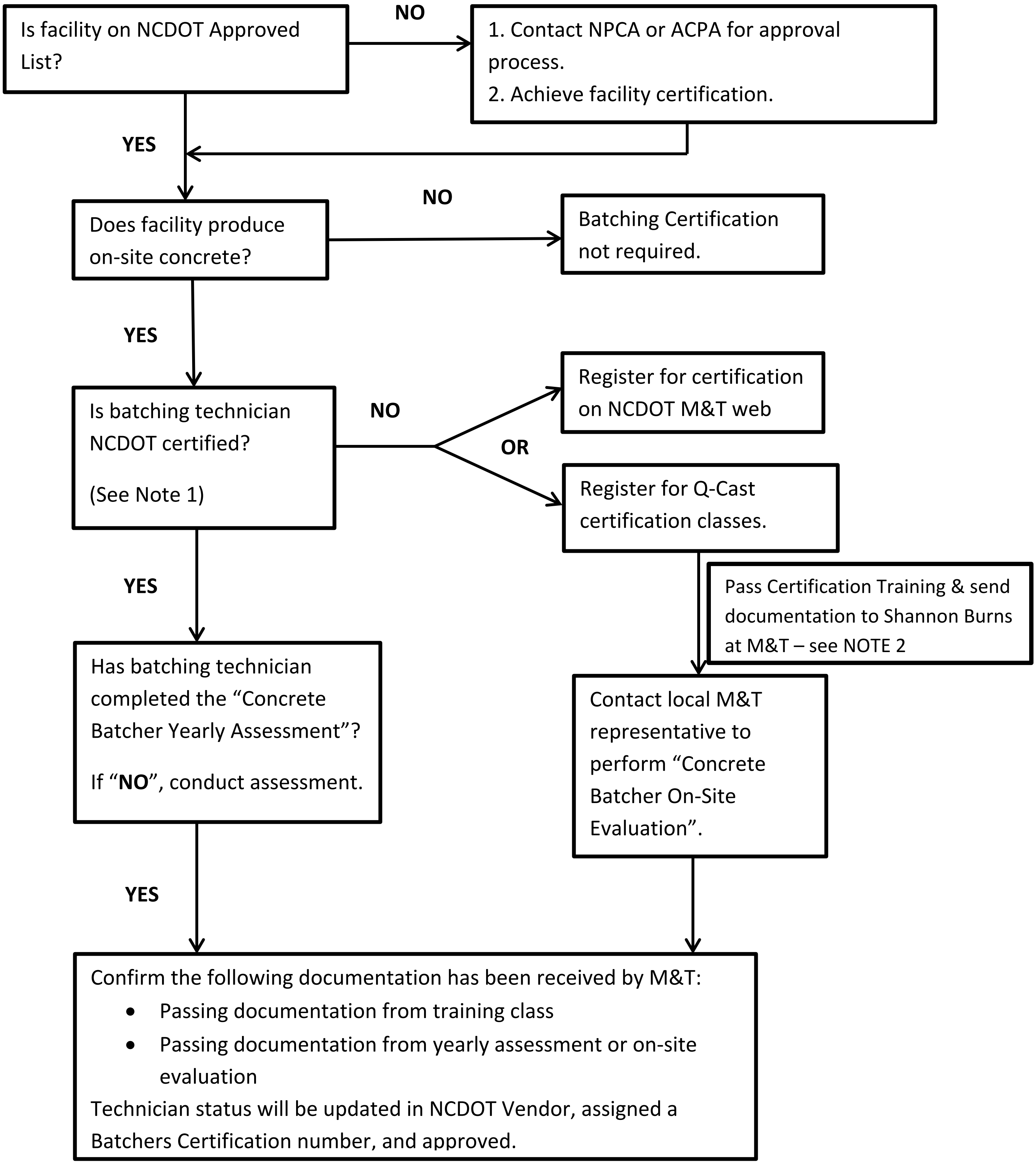
updated 9/22/2016

North Carolina Department of Transportation
Materials And Tests Unit

	Division 1		Division 2		Division 3		Division 4		Division 5
	Maria Bonds		James Cobb		BJ Maynard		Allen Strickland		Jason Fragnito
Email	mmbonds@ncdot.gov	Email	jrcobb@ncdot.gov	Email	wtmaynard2@ncdot.gov	Email	dastrickland@ncdot.gov	Email	jfragnito@ncdot.gov
Phone	252-792-7627	Phone	252-792-7627	Phone		Phone	252-296-3576	Phone	919-329-4241
Fax	252-792-3308	Fax	252-792-3308	Fax	910-455-2073	Fax	252-237-0804	Fax	919-329-4242
Cell	252-799-1056	Cell	252-217-5246	Cell	252-503-5413	Cell	919-274-8306	Cell	919-810-5978
	Counties		**Counties**		**Counties**		**Counties**		**Counties**
	Bertie		Beaufort		Brunswick		Edgecombe		Durham
	Camden		Carteret		Duplin		Halifax		Franklin
	Chowan		Craven		New Hanover		Johnston		Granville
	Currituck		Greene		Onslow		Nash		Person
	Dare		Jones		Pender		Wayne		Vance
	Gates		Lenoir		Sampson		Wilson		Wake
	Hertford		Pamlico						Warren
	Hyde		Pitt						
	Martin								
	Northampton								
	Pasquotank								
	Perquimans								
	Tyrrell								
	Washington								
	Division 6		**Division 7**		**Division 8**		**Division 9**		**Division 10**
	Guy Christian		Robert Fosque		Brandon Jackson		Mitchell Wagoner		Mark Thomas
Email	gchristian@ncdot.gov	Email	rfosque@ncdot.gov	Email	bmjackson@ncdot.gov	Email	rmwagoner@ncdot.gov	Email	markthomas@ncdot.gov
Phone	910-354-0838	Phone	336-256-2567	Phone	704-636-3367	Phone	704-636-3367	Phone	704-847-1314
Fax	910-437-0224	Fax	336-256-2569	Fax	704-636-3368	Fax	704-636-3368	Fax	704-847-0136
Cell	910-322-0956	Cell	336-312-3475	Cell	910-639-2209	Cell	704-534-8143	Cell	704-201-3916
	Counties		**Counties**		**Counties**		**Counties**		**Counties**
	Bladen		Alamance		Chatham		Davidson		Anson
	Columbus		Caswell		Hoke		Davie		Cabarrus
	Cumberland		Guilford		Lee		Forsyth		Mecklenburg
	Harnett		Orange		Montgomery		Rowan		Stanly
	Robeson		Rockingham		Moore		Stokes		Union
					Randolph				
					Richmond				
					Scotland				
	Division 11		**Division 12**		**Division 13**		**Division 14**		
	Tracy Church		Millie Adair		Robert Rhymer		Michael Wood		
Email	tgchurch@ncdot.gov	Email	madair@ncdot.gov	Email	rrhymer@ncdot.gov	Email	dmwood@ncdot.gov		
Phone	336-903-9105	Phone	336-903-9107	Phone	828-298-1516	Phone	828-891-7911		
Fax	336-667-5919	Fax	336-903-9247	Fax	828-299-7914	Fax	828-891-5026		
Cell	336-984-0421	Cell	704-575-4307	Cell	828-768-0375	Cell	828-553-4532		
	Counties		**Counties**		**Counties**		**Counties**		
	Alleghany		Alexander		Buncombe		Cherokee		
	Ashe		Catawba		Burke		Clay		
	Avery		Iredell		Madison		Graham		
	Caldwell		Cleveland		McDowell		Haywood		
	Surry		Gaston		Mitchell		Henderson		
	Watauga		Iredell		Rutherford		Jackson		
	Wilkes		Lincoln		Yancey		Macon		
	Yadkin						Polk		
							Swain		
							Transylvania		

NCDOT Batcher Certification Process

2018

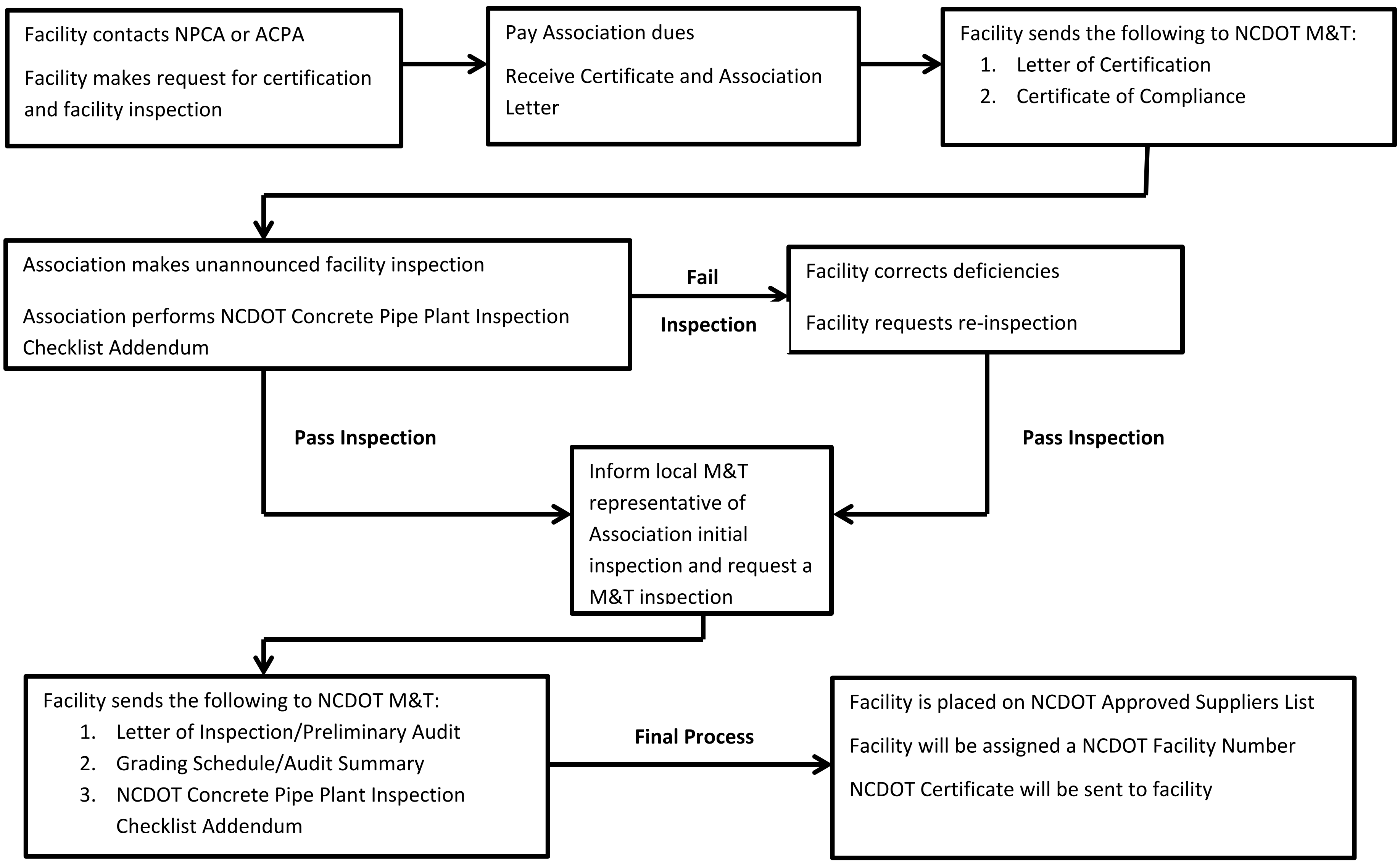


NOTE 1: If batching technician is performing acceptance tests and/or samples – technician must be Concrete Field Certified.

NOTE 2: If attending Q-Cast school, student must pass NCDOT additional test and send to Shannon Burns with M&T.

NCDOT Concrete Pipe Facility Approval Process

2018



M & T Form 250
Rev. 3/10

North Carolina Department of Transportation

DAILY PLANT REPORT ON READY MIXED CONCRETE OPERATIONS

Contract No. / Work Order No. ______________________________ Date ______________

Cement Producer ______________________ Cement Producer Location ______________________

Pozzolan Producer ______________________ Fine Agg Source ______________________

Ready Mix Facility & No. ______________________ Coarse Agg Source ______________________

Class of Concrete	Mix Design No.	Number of Loads	Total Yards Batched	Total Yards Rejected (To be completed by field inspector)

MOISTURE IN AGGREGATES

Fine Aggregate:

Trial 1 Time: ______________

Wet Wt. __________ Minus Dry Wt. __________ = __________ X 100 = __________ % Total Moisture

Dry Wt. __________

Total Moisture __________ Minus Absorbed Moisture __________ = __________ % Free Moisture

Trial 2 Time: ______________

Wet Wt. __________ Minus Dry Wt. __________ = __________ X 100 = __________ % Total Moisture

Dry Wt. __________

Total Moisture __________ Minus Absorbed Moisture __________ = __________ % Free Moisture

Coarse Aggregate:

Trial 1 Time: ______________

Wet Wt. __________ Minus Dry Wt. __________ = __________ X 100 = __________ % Total Moisture

Dry Wt. __________

Total Moisture __________ Minus Absorbed Moisture __________ = __________ % Free Moisture

Trial 2 Time: ______________

Wet Wt. __________ Minus Dry Wt. __________ = __________ X 100 = __________ % Total Moisture

Dry Wt. __________

Total Moisture __________ Minus Absorbed Moisture __________ = __________ % Free Moisture

Certified Batcher Signature: ______________________ Certification No. ______________

Certified Field Inspector Signature: ______________________ Certification No. ______________

M&T Form 250 is to be completed by certified batcher, pink copy of form shall be sent with first load, and the completed white (original) copy shall be sent with final load. If form is not completed and received on site, concrete is subject to rejection.

North Carolina Department of Transportation, Division of Highways, Materials and Tests Unit
Statement of Concrete Mix Design and Source of Materials

Contract No.	Concrete Producer
County	Plant Location & DOT No.
Resident Engr.	Contractor
Class of Concrete	Date
Mix Design No.	

Mix Design Proportions Based on SSD Mass of Aggregates

Material	Producer	Source	Qty. per Cu. Yd.
Cement, Type			lbs.
Pozzolan			lbs.
Fine Agg., + M			lbs.
Coarse Agg., + M			lbs.
Other Agg., + M			lbs.
Total Water			gals.
Air. Entr. Agent			oz.
Retarder			oz.
Water Reducer			oz.
Superplasticizer			oz.
Other			
Other			

Mix Properties and Specifications

Slump _____ in. _____ mm Mortar Content _____ cu. ft. _____ cu. meter
Max. Water _____ gals. _____ L Air Content _____ %

Aggregate and Pozzolan Data

Material	Specific Gravity	% Absorption	Unit Mass	Fineness Modulus
Fine Agg. Type (2S or 2MS)			NA	
Coarse Agg., Size (No. 57, 67, or 78M)				NA
Other Agg., Type or Size				
Pozzolan		NA	NA	NA

Cast-in-place concrete shall conform to Section 1000, precast concrete to Section 1077, and prestressed concrete to Section 1078 of the applicable edition of the Standard Specifications for Roads and Structures plus all applicable Special Provisions.

Special Use Criteria: Is mix design governed by Special Provision/Plan Note? Yes No
If Yes submit copy of Special Provision or Plan Note with this Form.

Signature and title of person who designed mix____

NCDOT Mix Design Certification No.____________________ **Or PE stamp or No.**___________________

Contractor Signature_______________________ **Resident Engineer Signature**_______________________

Rev. 02/22/2018

Materials & Tests Unit

NCDOT

Concrete Batcher Yearly Assessment

To Be Conducted Once Per Year on Active Batchers
Send to Shannon Burns

Batcher Name:	**Date of Assessment:**
Batch Certification Number:	**Date of Batch Class Attended:**
Producer Name & Location Assessment was Conducted:	**NCDOT State Plant # Assessment was Conducted:**

The batcher must successfully complete or demonstrate the correct operations with regards to NCDOT specifications and/or policies.

Operation	**Trial 1** (Pass/Fail)	**Trial 2** (Pass/Fail)
1. Verify the producer & source for the following:		
Cement	______	______
Pozzolan	______	______
Fine Aggregate	______	______
Coarse Aggregate	______	______
Water (Well or Municipal Source)	______	______
Air Entraining Agent	______	______
Retarder	______	______
2. Perform fine aggregate moisture determination:	______	______
Representative Sample obtained from area of use	______	______
Sample correct size	______	______
Wet weight correctly determined	______	______
Uniformly dried to consistent mass	______	______
Dry weight of sample correctly determined	______	______
Calculations correctly performed (Total and Free Moisture)	______	______
3. Perform coarse aggregate moisture determination:	______	______
Representative Sample obtained from area of use	______	______
Sample correct size	______	______
Wet weight correctly determined	______	______
Uniformly dried to consistent mass	______	______
Dry weight of sample correctly determined	______	______
Calculations correctly performed (Total and Free Moisture)	______	______

4. Calculate moisture adjustments/Batch Weights ______ ______
   - Cement ______ ______
   - Pozzolan ______ ______
   - Fine Aggregate ______ ______
   - Course Aggregate ______ ______
   - Water ______ ______
   - Air Entraining Agent ______ ______
   - Retarder ______ ______

5. Determine maximum water allowed on NCDOT concrete: ______ ______

6. Demonstrate procedure for moisture adjustments prior to batching Operations (Make Adjustments to Pull Weights) ______ ______

7. Batch Concrete ______ ______

8. Complete the batch record form: ______ ______

(Circle One)

Overall Score: Pass/Fail Pass/Fail

I certify that I have not helped, coached, or in any way interfered with the batcher during this Evaluation.

Evaluator: ________________________________ Date:______________________________

OFFICE USE ONLY	
Date Evaluation received:	
Date certificate granted:	

Rev. 02/22/2018

Moisture Determination Worksheet

Fine Aggregate:

Trial 1

Wet Wt. ____________ Minus Dry Wt. ____________ = ____________ X 100 = ____________ % Total Moisture

Dry Wt. ________________

Total Moisture _____________ Minus Absorbed Moisture _____________ = _____________ % Free Moisture

Trial 2

Wet Wt. ____________ Minus Dry Wt. ____________ = ____________ X 100 = ____________ % Total Moisture

Dry Wt. ________________

Total Moisture _____________ Minus Absorbed Moisture _____________ = _____________ % Free Moisture

Coarse Aggregate:

Trial 1

Wet Wt. ____________ Minus Dry Wt. ____________ = ____________ X 100 = ____________ % Total Moisture

Dry Wt. ________________

Total Moisture _____________ Minus Absorbed Moisture _____________ = _____________ % Free Moisture

Trial 2

Wet Wt. ____________ Minus Dry Wt. ____________ = ____________ X 100 = ____________ % Total Moisture

Dry Wt. ________________

Total Moisture _____________ Minus Absorbed Moisture _____________ = _____________ % Free Moisture

Materials & Tests Unit

NCDOT

Concrete Batcher On-Site Evaluation

To Be Completed After Successfully Completing Concrete Batch School or Q-Cast Certification training
Send to Sandra Williams

Date of Evaluation:	**Date of Class:**
Batcher Name:	**Batch Certification Number:**
Batch Certification School Location:	**Last 4 digits of Social Security #:**
Producer Name & Location Evaluation was Conducted:	**NCDOT State Plant # Evaluation was Conducted:**

The batcher must successfully complete or demonstrate the correct operations with regards to NCDOT specifications and/or policies.

Operation	**Trial 1** (Pass/Fail)	**Trial 2** (Pass/Fail)
1. Verify the producer & source for the following:		
Cement	______	______
Pozzolan	______	______
Fine Aggregate	______	______
Coarse Aggregate	______	______
Water (Well or Municipal Source)	______	______
Air Entraining Agent	______	______
Retarder	______	______
2. Perform fine aggregate moisture determination:	______	______
Representative Sample obtained from area of use	______	______
Sample correct size	______	______
Wet weight correctly determined	______	______
Uniformly dried to consistent mass	______	______
Dry weight of sample correctly determined	______	______
Calculations correctly performed (Total and Free Moisture)	______	______
3. Perform coarse aggregate moisture determination:	______	______
Representative Sample obtained from area of use	______	______
Sample correct size	______	______
Wet weight correctly determined	______	______
Uniformly dried to consistent mass	______	______
Dry weight of sample correctly determined	______	______
Calculations correctly performed (Total and Free Moisture)	______	______

4. Calculate moisture adjustments/Batch Weights ______ ______
   - Cement ______ ______
   - Pozzolan ______ ______
   - Fine Aggregate ______ ______
   - Course Aggregate ______ ______
   - Water ______ ______
   - Air Entraining Agent ______ ______
   - Retarder ______ ______

5. Determine maximum water allowed on NCDOT concrete: ______ ______

6. Demonstrate procedure for moisture adjustments prior to batching Operations (Make Adjustments to Pull Weights) ______ ______

7. Batch Concrete ______ ______

8. Complete the batch record form: ______ ______

(Circle One)

Overall Score: Pass/Fail Pass/Fail

I certify that I have not helped, coached, or in any way interfered with the batcher during this Evaluation.

Evaluator: ___________________________________ Date:________________________________

OFFICE USE ONLY	
Date Evaluation received:	
Date certificate granted:	

Rev. 2/22/2018

Moisture Determination Worksheet

Fine Aggregate:

Trial 1

Wet Wt. ______________ Minus Dry Wt. ______________ = ______________ X 100 = ______________ % Total Moisture

Dry Wt. __________________

Total Moisture _______________ Minus Absorbed Moisture _______________ = _______________ % Free Moisture

Trial 2

Wet Wt. ______________ Minus Dry Wt. ______________ = ______________ X 100 = ______________ % Total Moisture

Dry Wt. __________________

Total Moisture _______________ Minus Absorbed Moisture _______________ = _______________ % Free Moisture

Coarse Aggregate:

Trial 1

Wet Wt. ______________ Minus Dry Wt. ______________ = ______________ X 100 = ______________ % Total Moisture

Dry Wt. __________________

Total Moisture _______________ Minus Absorbed Moisture _______________ = _______________ % Free Moisture

Trial 2

Wet Wt. ______________ Minus Dry Wt. ______________ = ______________ X 100 = ______________ % Total Moisture

Dry Wt. __________________

Total Moisture _______________ Minus Absorbed Moisture _______________ = _______________ % Free Moisture

Materials & Tests Unit

NCDOT

Batching Certification Process- Concrete Pipe Producers 2018

The purpose of this documentation is to establish the procedures for becoming "Batch Certified" for a producer of concrete pipe. Prior to an individual becoming "Batch Certified", the facility must meet the certification requirements and be placed on the NCDOT "Approved List". Only "Certified Batchers" will be accepted to produce concrete pipe products for NCDOT projects and must be on-site and in direct control of batching operations during all pipe production.

A Batching Technician is the individual whose job responsibilities pertain to activity involved with the production of concrete. The production of concrete may be manufactured manually or by monitoring a computer base system. Both production methods are required to have a "Certified Batcher" if producing concrete pipe products for NCDOT projects. Individuals, who seek this certification for the first time, must successively complete the "Concrete Field Technician" training as a prerequisite.

The certification process will require completion of two phases. Phase one is to attend and successfully complete an approved certification training school. The options for an approved certification training school are: NCDOT Concrete Batch Technician school or attend the certification training Q-Cast (the student must take the additional NCDOT exam). Phase two involves the individual to successfully complete the "Concrete Batcher Onsite Evaluation".

PHASE ONE – CERTIFIED TRAINING SCHOOL:

NCDOT Concrete Batch Technician training:

- Search dates and locations on the NCDOT Materials & Tests web page.
- Register on line for the selected scheduled training date.
- This is a two day training program.
- Successfully complete the course.
- NCDOT will process documentation and place individual into tracking system.
- Potential Batcher will contact local M&T representative and request a "Concrete Batcher On-Site Evaluation" be performed.

Q-Cast Training:

- Search dates and locations on web page.
- Register for the selected scheduled training date.

- Individual must notify instructor their request to obtain the NCDOT training.
- Successfully complete the course.
- Passing documentation must be sent to M&T (Shannon Burns).
- Q-Cast instructor will submit roster and test results to M&T (Shannon Burns) for verification.
- M&T will process documentation and place individual into tracking system.
- Potential Batcher will contact local M&T representative and request a "Concrete Batcher On-Site Evaluation" be performed.

PHASE TWO – Concrete Batch On-Site Evaluation:

- This form is to be completed after an individual successfully completes either the NCDOT Concrete Batch School, or Q-Cast Certification School.
- This activity is **REQUIRED** for certification. If this activity is not conducted, the individual is **NOT** certified.
- The evaluation is to be conducted by a representative from M&T.
- The evaluation is to be completed ASAP after completion of school.
- All information is to be completed on the form- do not leave anything blank.
- The completed form is to be sent to M&T (Sandra Williams).

ACTIVE CERTIFIED BATCH TECHNICIAN:

To remain an "Active" certified batch technician, the following must be performed:

- If the Technician is molding test specimens and/or performing acceptance test, he/she must keep their NCDOT Concrete Field Technician certification active.
- If the Technician is actively responsible for "Batching" operations (this includes performing moisture analysis on aggregate), the Technician is required to complete the "Concrete Batcher Yearly Assessment".
- This assessment is to be completed once per year on all "Active" Batchers.
- This assessment is REQUIRED for certification. If this assessment is not conducted, the individual is NOT certified.
- The assessment is to be conducted by a representative from M&T.
- All information is to be completed on the form- do not leave anything blank.
- The completed form is to be sent to Shannon Burns (M&T).
- It is the responsibility of the Technician to contact the local M&T representative.

NCDOT Materials and Tests Unit
Standard Operating Procedure
Inspection of Reinforced Concrete Pipe
Effective July 1, 2018

Objectives:

The purpose of this SOP is to establish guidelines for the inspection, the acceptance and reporting of Reinforced Concrete Pipe. The guidelines are designed to insure all technicians/inspectors follow the same procedures and comply with all NCDOT, AASHTO and ASTM specifications. The technicians/inspectors will insure quality control techniques, quality control records, and testing equipment are being followed. The technician shall personally inspect each piece of pipe and place a "NCDOT Approved" stamp on each piece of pipe once it meets approval.

Concrete Pipe should meet Section 1032-6 of the NCDOT Standard Specifications, AASHTO M 170 and ASTM C 76 guidelines.

Materials Inspection and Acceptance:

It is mandatory for technicians/inspectors to follow these guidelines in order to establish, manage and monitor quality control, quality assurance and quality documentation. Following the proper inspection process will ensure effectiveness and efficiency in the quality systems of the NCDOT.

- Periodically review Reinforced Concrete Pipe guidelines.
- Periodically review ASTM C 76, AASHTO M 170 and NCDOT Standard Specifications Sub-Article 1032-6 to insure proper procedures are followed during the inspection
- Ensure all equipment required for testing the material and any safety equipment needed is in possession and serviceable before arrival.
- Verify that the facility is an approved NCDOT Producer with a NCDOT Annual Facility Inspection that is up to date.
- Verify that the facility has a current third party inspection with a copy of inspection and NCDOT Addendum available for inspection at the facility.
- Verify the facility technicians have all the required NCDOT certifications or approved alternatives required for the production of concrete pipe.
- Review the assigned NCDOT approved mix designs for the facility.

Safety Equipment List:

Safety Shoes with ANSI Z 41 rating
Hard Hat with ANSI Z89.1 rating
First Aid Kit
Fire Extinguisher
Safety Glasses
Gloves
Safety Vest
Ear Plugs
Sun Block (optional)
Lifting Belt (optional)
Dust Masks (optional)

Safety Concerns:

Pinch Points/Test Rack/Pipe Inspection
Heavy Equipment/Backing Incidents
Possible dusty conditions

Equipment Required for Product Inspection:

Concrete Pipe Inspection Field Worksheets
Tape Measure
0.01 Leaf Gauge
Micrometer
Calculator
Calipers (wall thickness)
Black Paint
Pencil or Pen
"NC Approved DOT" Stencil

M&T Inspector's Duties for Reinforced Concrete Pipe Inspection:

1. When arriving at the facility, inspectors should check into main office (if required).
2. Make contact with QC Technician to determine items to be inspected.
3. Concrete pipe will be accepted as a lot as described in the table below.

Concrete Pipe Lot Sizes

Diameter	**Lot Size/Description**
12"	4000 LF per consecutive day's production (max 5 days)
15"	4000 LF per consecutive day's production (max 5 days)
18"	4000 LF per consecutive day's production (max 5 days)
24"	2000 LF per day's production
30"	4000 LF per consecutive day's production (max 5 days)
36"	4000 LF per consecutive day's production (max 5 days)
42"	2000 LF per day's production
48	2000 LF per consecutive day's production (max 5 days)
D>48	2000 LF per day's production

(Example: Producer has 2800 LF of 24” 3-B concrete pipe that was produced on 03/01/2013. Producer is asking that this material be stamped. The NCDOT inspector will randomly select two pieces of pipe to be tested. One pipe will represent 2000 LF and the other will represent 800 LF)

4. Technician will randomly select from stock the concrete pipe for testing.
5. Technician shall make a determination at this point if the pipe lot has excessive defects. Section 1032-6 (E) of the NCDOT Standard Specification states the rejection of more than 20% of any lot of pipe due to cracks, fractures, variations in alignment or other manufacturing defects will be cause for the rejection of the entire lot.
6. If concrete pipe is 48” or larger in diameter, the concrete pipe can be accepted on cylinders or three edge bearing. If concrete pipe is <less than 48” in diameter then a three edge bearing test must be performed.
7. Verify the pipe has been stenciled with the proper Alternate ID identification. Alternate ID will be the assigned State #, diameter of pipe, and year pipe was produced. Example: CP1-24-13. This information also shall be on the Manufacture’s Bill of Lading.
8. Verify the pipe has required AASHTO M 170 markings. This will consist of pipe class and specification designation, the date of manufacture and the name or trademark or manufacture. Markings shall be indented (scratched) or painted with waterproof paint.
9. Three-Edge Bearing Tests
    a. If pipe selected is <less than 48” then a three edge bearing test is required. This test will consist of D-Loading the pipe which is external loading of the pipe. The readings you will get are pounds per foot of length per foot of diameter

Three Edge Bearing Test Schedule

Diameter	**0.01” Load Test**	**Ultimate Load Test**
12”	Each Lot	1/Quarter (each 4 months)
15”	Each Lot	1/Quarter (each 4 months)
18”	Each Lot	1/Quarter (each 4 months)
24”	Each Lot	Each Lot
30”	Each Lot	1/Quarter (each 4 months)
36”	Each Lot	1/Quarter (each 4 months)
42”	Each Lot	Each Lot

    b. Three-Edge Bearing test rack must be calibrated annually or when a question of accuracy arises.

    c. Before placing pipe in rack a calculation must be done to determine lower bearing width. Example:(24” (Pipe Size) / 12 = 2” (lower bearing width)

    d. Refer to AASHTO M 170-4 to determine specification requirements of selected pipe.

Three Edge Bearing Loading

Classification	D-Load 0.01" crack	D-Load ultimate load
Class I	800	1200
Class II	1000	1500
Class III	1350	2000
Class IV	2000	3000
Class V	3000	3750

e. Example: If a class III pipe is selected.
D-Load required to produce an 0.01" crack 1350
D-Load required to produce the ultimate load 2000

f. Example: Calculations for a 30" Class III 8' length pipe used to determine minimum readings required for acceptance in the test rack are as follows:

- 0.01" load = 1350 (D-Load) x 8' (length of pipe) x 2.5' (Diameter of pipe in decimal form) = 27000 lbs.
- Ultimate load = 2000 (D-load) x 8' (length of pipe) x 2.5' (Diameter of pipe in decimal form) = 40000 lbs.

g. The definition of a 0.01" crack is: "When the point of the measuring gage will, without forcing, penetrate 1/16" at close intervals throughout the specified distance of 1 FT."

h. The definition of Ultimate Load is: "Maximum load pipe will support."

i. Should the test pipe fail to meet the strength requirements, the manufacturer shall be allowed a retest two additional pipe for each pipe that failed, and the pipe shall be acceptable only when all of the retest specimens meet the strength requirements.

j. Failure of two consecutive lots of pipe to meet Three Edge Bearing Loading test requirements for either the 0.01" or Ultimate Load will result, as a minimum, in the lot size being reduced to 2000LF per day's production with Three Edge Bearing Loading testing for both the 0.01" and Ultimate Load being conducted for each lot until such time as the Producer can demonstrate that meeting specifications can consistently be produced.

17. Concrete Cylinder Compression Tests

a. Pipe diameters 48" or larger may be strength tested by means of compression testing of concrete cylinders, in lieu of three-edge bearing testing, at the manufacturer's discretion.

b. If concrete cylinders are to be used for acceptance. A minimum of four cylinders are to be made for each class, diameter and lot from that day's production. A NCDOT Certified Field Concrete Technician representing the manufacturer must perform tests and make cylinders for acceptance.

c. NCDOT will witness cylinder breaks at the manufacture's facility. Compression machine must be calibrated annually or when a question of accuracy applies. Acceptance is the average of two cylinders. Specified concrete strength for acceptance is listed in AASHTO M 170-4 for the size, class and wall. Testing shall be conducted in accordance with ASTM C39.

d. Should the average of two cylinders fail to meet the strength requirements, the manufacturer shall be allowed to perform a three-edge bearing test on pipe.

18. Visual/Walk Thru Inspection and "NCDOT Approved" stamp.

a. Repairs

- Repair materials and methods must be approved by the Engineer before their use.
- AASHTO M 170-13

  "Pipe may be repaired, if necessary, because of imperfections in manufacturing or damage during handling and will be acceptable if, in the opinion of the owner, the repaired pipe conforms to the requirements of this specification."

b. Technician will refer to AASHTO M 170-15. Causes of Rejection.

- Any fracture or crack that visibly passes through the wall of pipe.
- Any fracture or crack that is 0.01" wide or greater at the surface and 12" or longer regardless of position in the wall of the pipe.
- Offsets in form seam that would prevent adequate concrete cover over reinforcing steel.
- Delamination in the body of the pipe when viewed from the ends.
- Evidence of inadequate concrete cover for reinforcing steel.
- Any severe surface condition that affects the majority of the pipe section surface and could reduce the durability and service life of the pipe.
- Damaged or cracked ends where such damage would prevent making a satisfactory joint.

c. Technician shall personally inspect and accept each pipe. Technician must be able to visually look through pipe and inspect both ends of pipe.

d. Pipe will be accepted and individually stamped, by the NCDOT technician after all criteria meets specifications.

19. Reinforcement Check

a. Technician will randomly inspect reinforcement area and placement for concrete pipe at each visit. Refer to AASHTO M170-4 for specified areas for each class and wall thickness of concrete pipe.

b. Refer to AASHTO M 170-8 for reinforcement requirements for reinforced concrete pipe. Below is a list of some items from M 170-8 that will assist you in your inspection.

- If splices are not welded, the reinforcement shall be lapped not less than 20 diameters for deformed bars, and deformed cold-worked wire, and 40 diameters for plain bars and cold-drawn wire. In addition, where lapped cages of welded-wire fabric are used without welding, the lap shall contain a longitudinal wire.
- When splices are welded and are not lapped to the minimum requirements above pull tests of representative specimens shall develop at least 50 percent of the minimum specified strength of the steel, and there shall be a minimum lap of 2" for butt-welded splices in bars or wire, permitted only with helically wound cages, pull tests of representative specimens shall develop at least 75 percent of the minimum specified strength of the steel.

c. Basic Wire Calculations for Area:

Area =

$$\frac{(\text{Diameter of Wire in Inches})^2 \times (\text{\# of complete circumferential rolls}) \times (0.7854)}{\text{Length of Pipe in LF}}$$

20. Annual Samples

a. Cores for Absorption

- Absorption for concrete pipe shall not exceed 9 percent of the dry mass. Each sample shall have a minimum mass of 2.2 lbs. shall be free visible cracks (4" cores are normally used for this test). If absorption fails, the absorption sample shall be made on another sample from the same pipe.
- Concrete cores shall be taken for each diameter, class and wall annually, with additional samples taken for each diameter, class and wall after every 10,000 LF is produced and accepted.
- Cores shall be taken from pipe produced during the current year or the previous year if current year is not available.
- Samples will be sent to Materials and Tests Unit Physical Lab.

b. Reinforcement Sample

- Reinforcement wire and steel samples will be taken annually for each size, with additional samples taken for every 10,000 LF produced and accepted.
- Wire samples will be 30" with a minimum of three circumferential reinforcement wires.
- If wire reinforcement is welded at the lap, a representative sample shall be taken with the weld as part of sample. Sample shall be 30" with a minimum of three circumferential reinforcement wires.
- Reinforcing steel samples shall be two 30" bars for each diameter.
- All samples will be sent to Materials and Tests Physical Lab along with mill certs.

c. Cement Samples

- Cement samples shall be taken annually or if a questionable material is an issue.

d. Pozzolan

- Pozzolan samples shall be taken annually or if a questionable material is an issue.

e. Coarse Aggregate

- Coarse Aggregate samples shall be taken quarterly or if a questionable material is an issue.
- Material must come from the NCDOT's Approved List.

f. Fine Aggregate

- Fine Aggregate samples shall be taken quarterly or if a questionable material is an issue.
- Material must come from the NCDOT's Approved List.

Standards:

NCDOT Standard Specs 1032-6

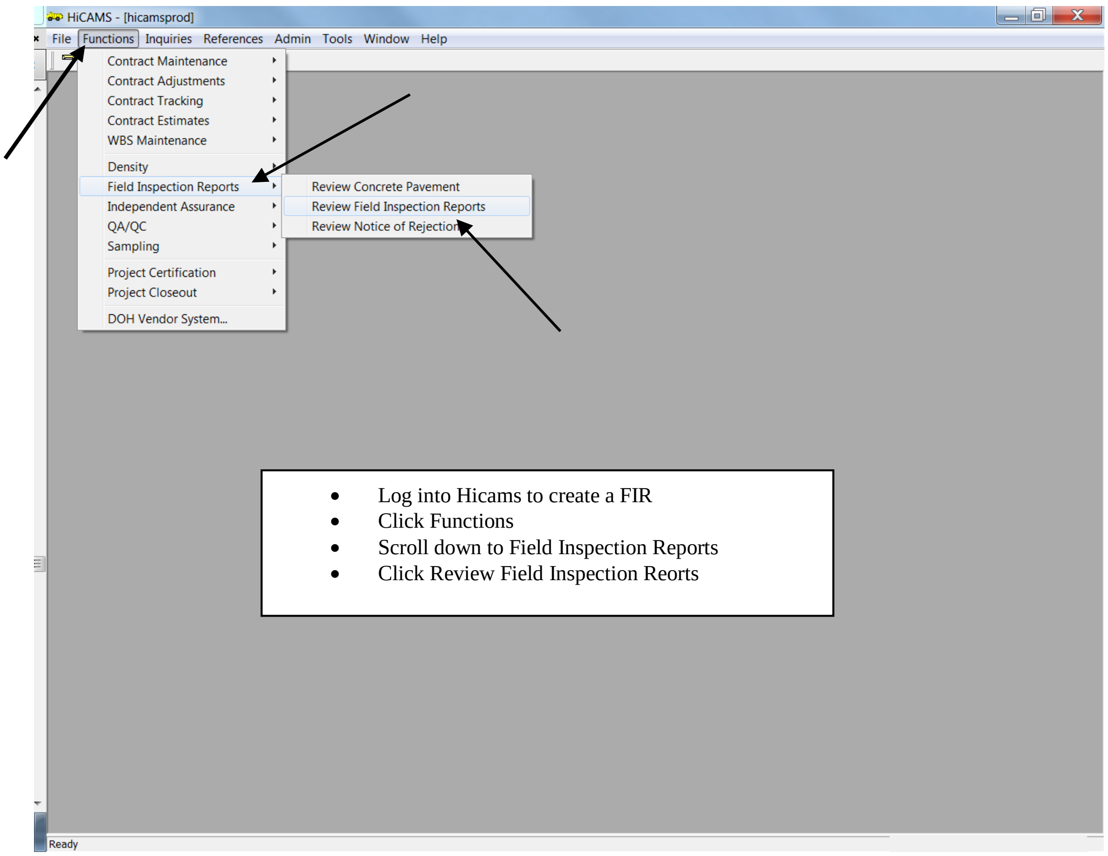
AASHTO M170

ASTM C76

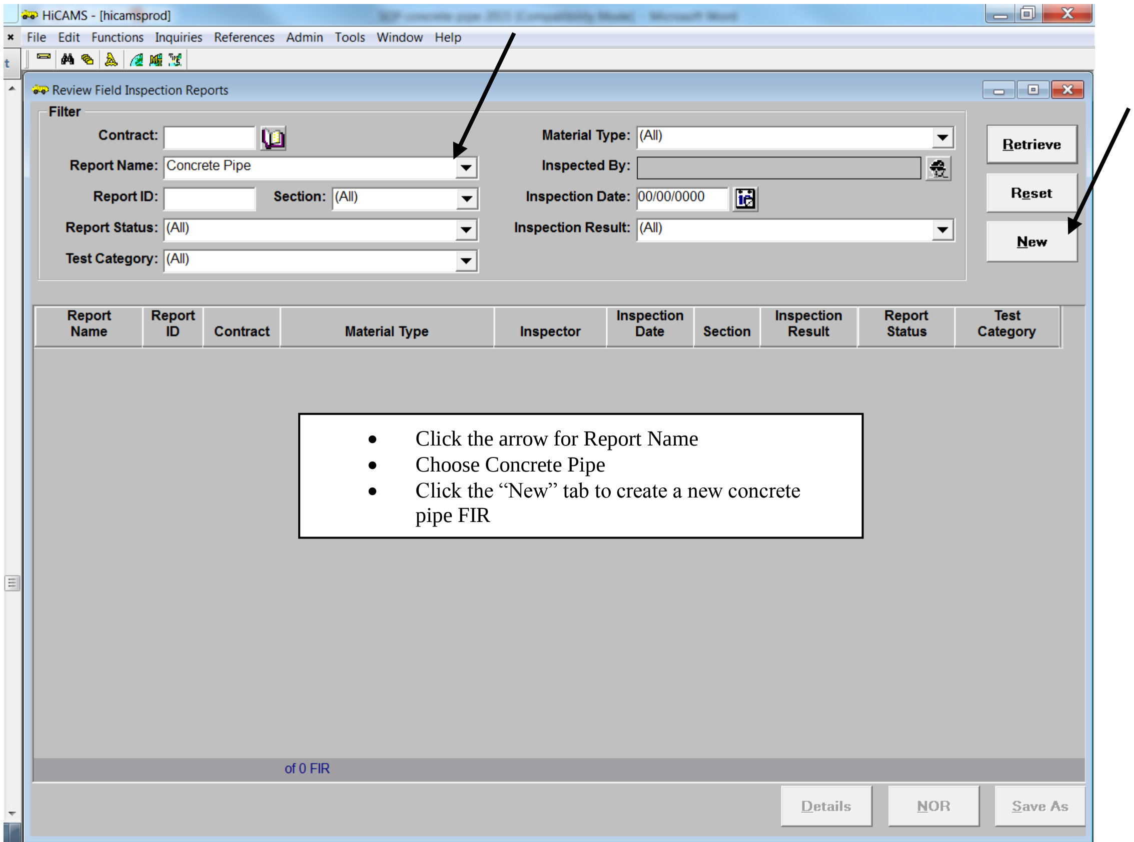
ASTM C39

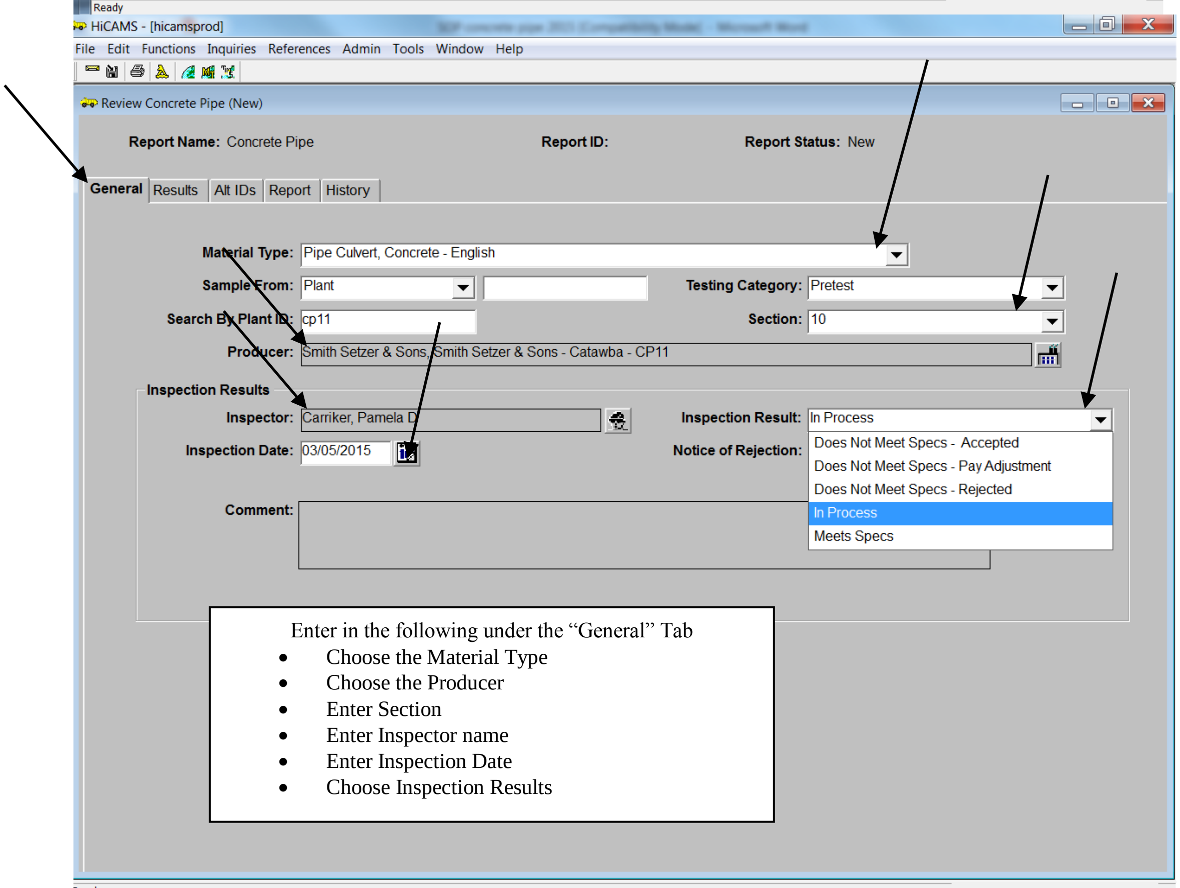
<u>Sample Prep and Submittal:</u>

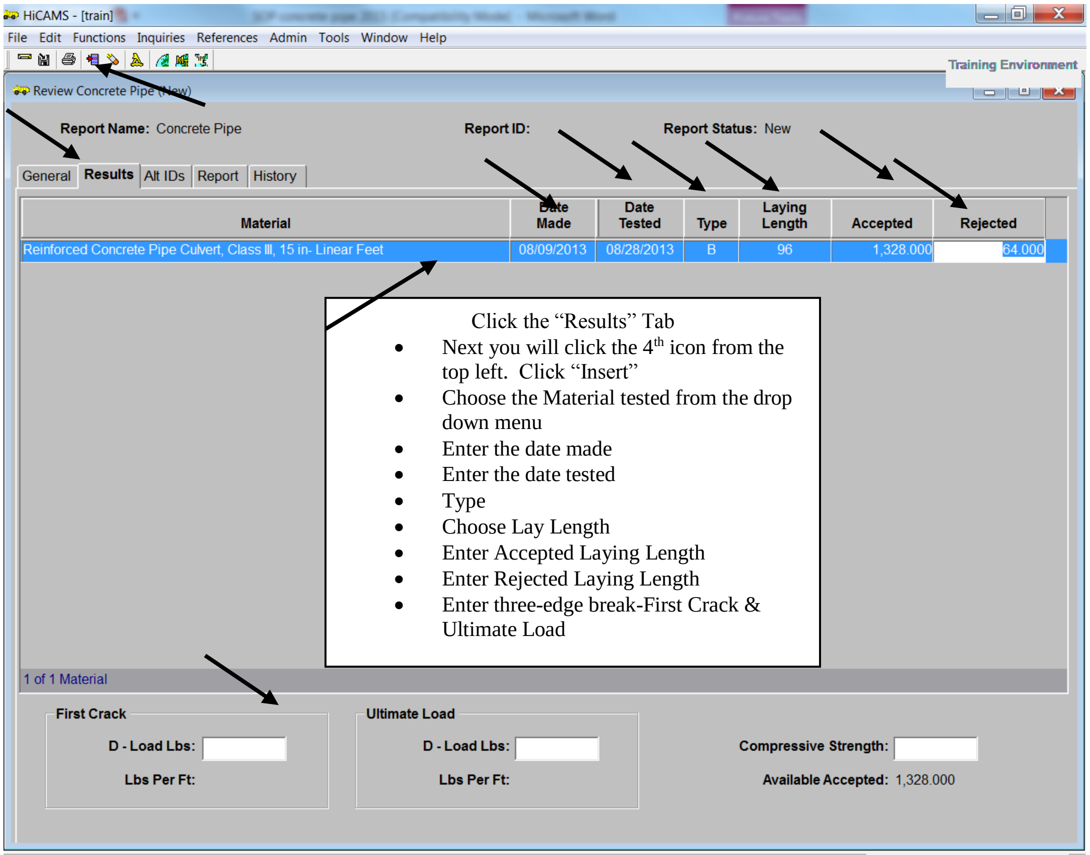
All inspections must be entered into Hicams under Field Inspection Report (FIR) within two working days.

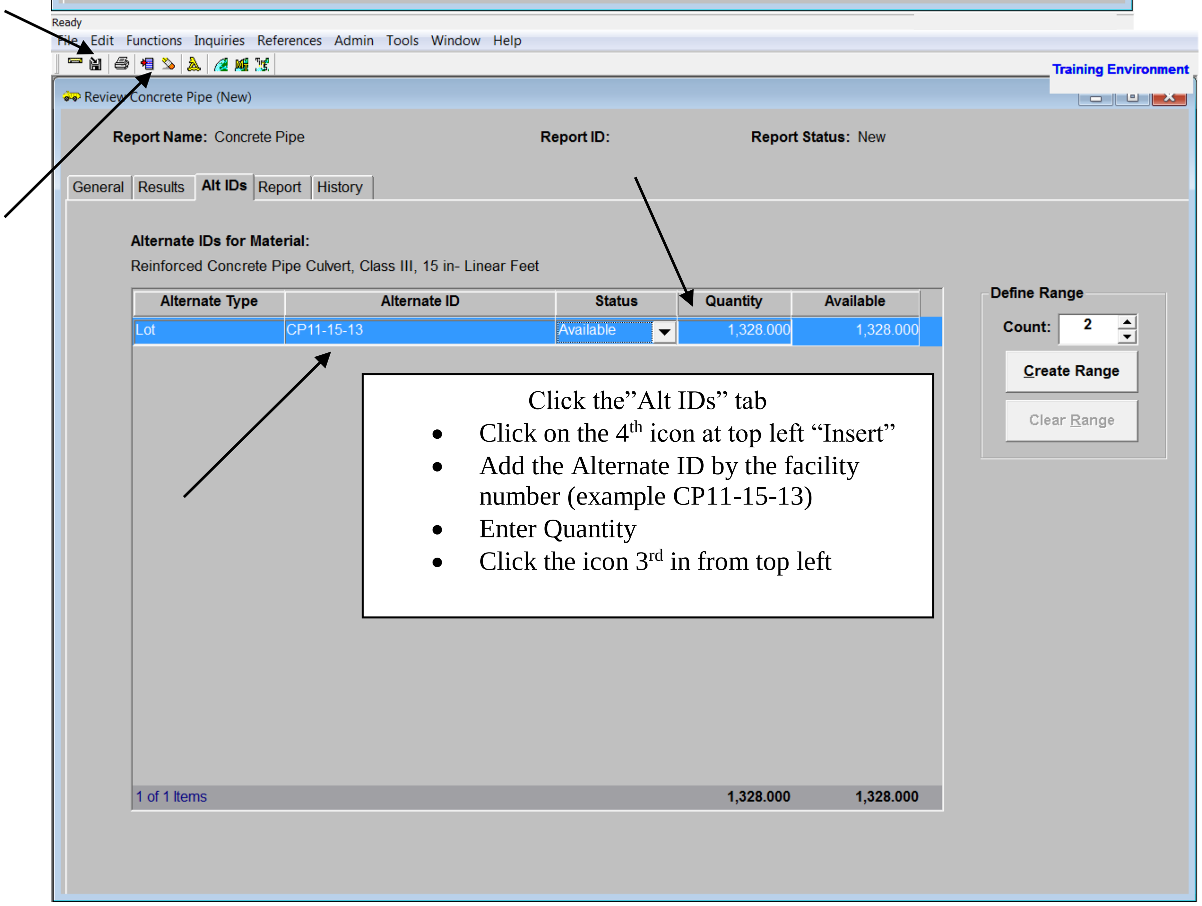


Rev 6/28/2018 WCG






HiCAMS - [train]
File Edit Functions Inquiries References Admin Tools Window Help
Training Environment
Review Concrete Pipe (New)
Report Name: Concrete Pipe
Report ID:
Report Status: New
General Results Alt IDs Report History
Material | Date Made | Date Tested | Type | Laying Length | Accepted | Rejected
Reinforced Concrete Pipe Culvert, Class III, 15 in- Linear Feet | 08/09/2013 | 08/28/2013 | B | 96 | 1,328.000 | 64.000
Click the "Results" Tab
• Next you will click the 4th icon from the top left. Click "Insert"
• Choose the Material tested from the drop down menu
• Enter the date made
• Enter the date tested
• Type
• Choose Lay Length
• Enter Accepted Laying Length
• Enter Rejected Laying Length
• Enter three-edge break-First Crack & Ultimate Load
1 of 1 Material
First Crack
D - Load Lbs:
Lbs Per Ft:
Ultimate Load
D - Load Lbs:
Lbs Per Ft:
Compressive Strength:
Available Accepted: 1,328.000


Ready
File Edit Functions Inquiries References Admin Tools Window Help
Training Environment
Review Concrete Pipe (New)
Report Name: Concrete Pipe
Report ID:
Report Status: New
General Results Alt IDs Report History
Alternate IDs for Material:
Reinforced Concrete Pipe Culvert, Class III, 15 in- Linear Feet
Alternate Type | Alternate ID | Status | Quantity | Available
Lot | CP11-15-13 | Available | 1,328.000 | 1,328.000
Define Range
Count: 2
Create Range
Clear Range
Click the"Alt IDs" tab
• Click on the 4th icon at top left "Insert"
• Add the Alternate ID by the facility number (example CP11-15-13)
• Enter Quantity
• Click the icon 3rd in from top left
1 of 1 Items
1,328.000
1,328.000

<u>Documentation Submittal:</u>

- The FIR will be reviewed and authorized within two working days after being completed.
- The M&T technician will file a hard copy of the " Concrete Pipe Field Worksheets" which is filled out during inspection.

North Carolina Department of Transportation
Materials & Tests Unit
Precast Concrete Plant Inspection Checklist Addendum - 2018

Date Of Inspection:		NCDOT Facility Number:	PC
Facility Company Name:			
Facility Address:			

The following are tasks to be performed during the plant inspection for a precast concrete producer seeking NCDOT Certification.

Aggregates

A1.	Pass	Fail	Aggregates are listed on approved list maintained by the Department.
A2.	Pass	Fail	Aggregates stockpiled at plant are confirmed by Department's approved concrete mix designs.
A3.	Pass	Fail	Aggregate stockpiles maintained above Saturated Surface Dry (SSD) condition.
Comments:			

Cement and Fly Ash

A4.	Pass	Fail	Proper Bill of Lading meeting Department criteria and certifications as outlined in Department's Specifications received.
A.5	Pass	Fail	Verify cement and fly ash source with Department approved concrete mix design.
Comments:			

Water

A6.	Pass	Fail	Water source has been sampled and tested by producer within the last 12 months. The water analysis report is on site and meets the requirements as stated in Section 1024-4, Table 1024-2.
A7.	Pass	Fail	Water source has been sampled and tested by M&T Technician within the last 12 months. This report is on site and states the sample "Meets Specification".
Comments: Producers Water Analysis Report Date: _____________ M&T's Water Analysis Report Date: ________________			

Mix Proportions

A8.	Pass	Fail	Department approved concrete mix designs are on hand and match materials on site.
A9.	Pass	Fail	Concrete mix design proportions adjusted for moisture content according to Department procedures.
Comments:			

Moisture Content

A10.	Pass	Fail	Percent total moisture for each aggregate is determined by Department's Certified Batcher during inspection. **Documentation must be accessible and on-site.**
A11.	Pass	Fail	Moisture equipment, including moisture probes, checked for accuracy and proper working operation.
A12.	Pass	Fail	Review moisture calculations and w/c calculated for each batch.
Comments:			

Routine Duties

A13.	Pass	Fail	Daily checks on cement received and used. **Does the BOL and Certifications match what is called for in the mix design?**
A14.	Pass	Fail	Constant testing and checking moisture contents of aggregates. **Initial moistures will be performed at startup of each day, a second moisture will be performed if production is greater than four hours. Additional checks may be needed if weather conditions dictate [rain, wind, high temps, etc].**
A15.	Pass	Fail	Daily report prepared and batch weight tickets kept on site.
Comments:			

Certifications

A16.	Pass	Fail	All personnel have current/active Department certifications for their job responsibility, and documentation is on site. (List Below) • NCDOT Concrete Field Technician
A17.	Pass	Fail	All personnel have current/active Department certifications for their job responsibility, and documentation is on site. (List Below) • NCDOT Concrete Batch Technician
A18.	Pass	Fail	Plant has been approved and displays current Department Plant Certification
Comments:			

Equipment

A19.	Pass	Fail	All equipment used in the batching operations has been calibrated within the last 12 months. Scales and dispensing devices must be calibrated by a third party entity or the manufacturer (in-house calibration is not acceptable).
A20.	Pass	Fail	All equipment used in the quality control sampling and testing has been calibrated within the last 12 months if applicable and is in good working order. Scales, compression machines, three edge bearing machine, etc., must be calibrated by a third party entity or the manufacturer (in-house calibration is not acceptable).
Comments:			

Personnel

Any personnel involved in the QC testing of the product must have a current NCDOT Field Testing Technician certification. Any personnel involved in the batching operations at the plant must have a current NCDOT Batch Technician Certification. List all Field Testing, and Batch Technicians below:

NCDOT CONCRETE FIELD TECHNICIAN (PCT)

Name	Title	NCDOT Certification Number - PCT	NCDOT Certification Expiration Date

NCDOT CONCRETE BATCH TECHNICIAN (PCB)

Name	Title	NCDOT Certification Number - PCB	NCDOT Certification Expiration Date

October 3, 2016

Dear Concrete Pipe Producer,

The Department has been working closely with representatives of the Carolinas Concrete Pipe And Products Association (CCPPA) and the American Concrete Pipe Association (ACPA) to begin the effort of accepting certification for Batching Technicians through the ACPA's "Quality Cast" (QCast) Plant Certification Program.

Currently, the requirement to be certified as a NCDOT Concrete Batching Technician is an individual must attend and successfully pass the NCDOT Concrete Batch Technician Certification school conducted by the Materials and Tests Unit. Effective January 1, 2017, the NCDOT Concrete Batch Technician Certification will require completion of two phases. The first phase will consist of attending and successfully completing the certification program conducted by the Materials and Tests Unit, or attending and successfully completing the QCAST program. The QCAST program will be conducted by ACPA with scheduled classes, requirements, fees, and locations available on their web page. Technicians will be required to submit documentation to the Materials and Tests Unit after successfully completing the course.

The second phase consists of an on-site evaluation conducted by a Materials and Tests representative at the point of production of concrete. The technician will be evaluated on operations involved in the batching operations. This is an annual evaluation and is required for all certified Batching Technicians.

Only technicians who have attend the QCAST program after January 1, 2017, are eligible for this certification without attending the NCDOT Concrete Batch Technician Certification school. Additionally, Technicians who are responsible for conducting acceptance tests and/or samples (concrete cylinders) are required to achieve and maintain a NCDOT Concrete Field Technician Certification. The Materials and Tests Unit and its representatives are eager to assist you in the certification process and hope that you fully understand the importance, significance, and responsibility that these certifications carry.

If you have additional questions or concerns, please contact Cabell Garbee (cgarbee@ncdot.gov) at 919-329-4224 or Sam Frederick (sjfrederick@ncdot.gov) at 919-814-2220.

Sincerely,

Christopher A. Peoples, PE
State Materials Engineer

NCDOT approved Concrete Pipe producers

Producers Name	***Facility Number***	***Division***	***Facility Address***	***City***	***State***	***Zip***	***Phone***	***Facility contact***	***ACPA/QC***
Johnson concrete Pipe	**CP10**	9	217 Klumac Road	Salisbury	NC	28144	704-636-5231	Jody Wall	Y
Rinker Materials	**CP20**	10	5601 Pharr Mill Road	Harrisburg	NC	28075	(704) 455-1100	Adam Feser	Y
Mid-Atlantic Drainage	**CP23**	3	1124 White Oak Lane	Galivants Ferry	SC	29544	(843) 358-4206	David Henderson and Danielle McCrackin	N
Smith Setzer & Sons	**CP11**	12	4708 Hwy 10 West	Catawba	NC	28609	(828) 241-3161	Michael Setzer	N
Foltz Concrete Pipe Company	**CP6**	9	1185 N NC Hwy 150	Winston Salem	NC	27127	(336) 764-0341	Derek Secrist	N
Rinker Materials	**CP8, CP4**	0	300 Bill Street	Columbia	SC	29209	(800) 627-2986		Y
Oldcastle Precast	**CP3**	5	PO Box 548	Fuquay Varina	NC	27256	(919) 552-2252	Elliott Taylor	N
Rinker Materials	**CP9**	4	1600 Thorne Ave South	Wilson	NC	27893	(252) 243-6153	Robert Strickland	Y
Oldcastle Precast	**CP1**	6	3960 Cedar Creek Road	Fayettville	NC	28312	910-483-6960	Jeff Bledsole	Y
Oldcastle Precast	**CP13, CP14**	5	920 Wither Road	Raleigh	NC	27601	919-772-6301	Robert Amos	Y
Concrete Pipe & Precast, LLC	**CP33**	10	20047 Silver road	Oakboro	NC	28129	(704) 485-4614	John Field	Y
Foley Pipe Products	**CP37**	1	1291 Hardigree Road	Winder	GA	30680	(706) 249-7671	Dennis Morrissey	Y
Rinker Materials	**CP7**	9	208 Randolph St	Thomasville	NC	27360	336-475-1371	Steve Kitchen	Y
Gossett Concrete Pipe, Inc.	**CP5**	10	900 West Lee Street	Greenville	SC	29608	(864) 242-3593	Samuel Carter	Y

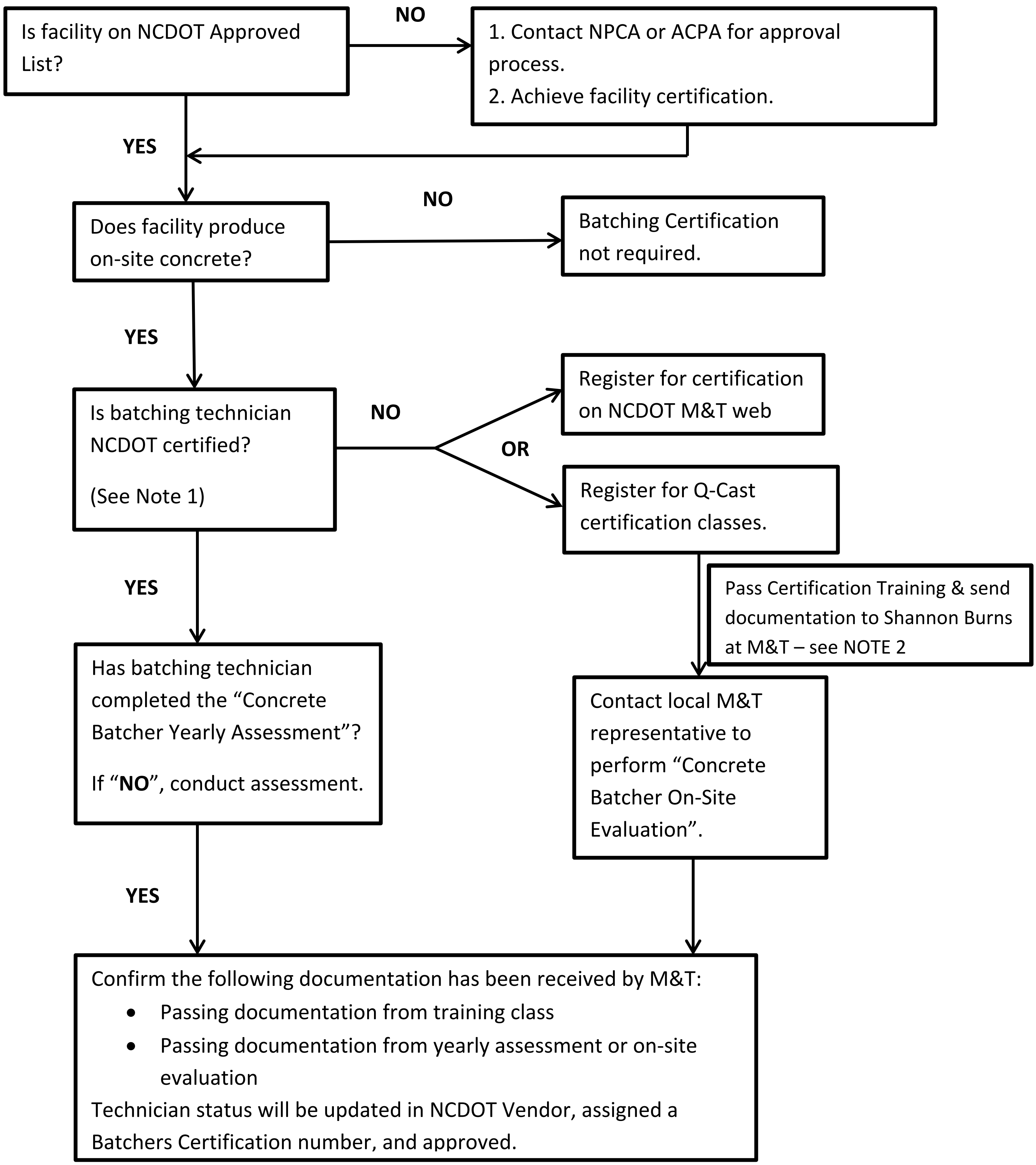
updated 9/22/2016

North Carolina Department of Transportation
Materials And Tests Unit

	Division 1		Division 2		Division 3		Division 4		Division 5
	Maria Bonds		James Cobb		BJ Maynard		Allen Strickland		Jason Fragnito
Email	mmbonds@ncdot.gov	Email	jrcobb@ncdot.gov	Email	wtmaynard2@ncdot.gov	Email	dastrickland@ncdot.gov	Email	jfragnito@ncdot.gov
Phone	252-792-7627	Phone	252-792-7627	Phone		Phone	252-296-3576	Phone	919-329-4241
Fax	252-792-3308	Fax	252-792-3308	Fax	910-455-2073	Fax	252-237-0804	Fax	919-329-4242
Cell	252-799-1056	Cell	252-217-5246	Cell	252-503-5413	Cell	919-274-8306	Cell	919-810-5978
	Counties		**Counties**		**Counties**		**Counties**		**Counties**
	Bertie		Beaufort		Brunswick		Edgecombe		Durham
	Camden		Carteret		Duplin		Halifax		Franklin
	Chowan		Craven		New Hanover		Johnston		Granville
	Currituck		Greene		Onslow		Nash		Person
	Dare		Jones		Pender		Wayne		Vance
	Gates		Lenoir		Sampson		Wilson		Wake
	Hertford		Pamlico						Warren
	Hyde		Pitt						
	Martin								
	Northampton								
	Pasquotank								
	Perquimans								
	Tyrrell								
	Washington								
	Division 6		**Division 7**		**Division 8**		**Division 9**		**Division 10**
	Guy Christian		Robert Fosque		Brandon Jackson		Mitchell Wagoner		Mark Thomas
Email	gchristian@ncdot.gov	Email	rfosque@ncdot.gov	Email	bmjackson@ncdot.gov	Email	rmwagoner@ncdot.gov	Email	markthomas@ncdot.gov
Phone	910-354-0838	Phone	336-256-2567	Phone	704-636-3367	Phone	704-636-3367	Phone	704-847-1314
Fax	910-437-0224	Fax	336-256-2569	Fax	704-636-3368	Fax	704-636-3368	Fax	704-847-0136
Cell	910-322-0956	Cell	336-312-3475	Cell	910-639-2209	Cell	704-534-8143	Cell	704-201-3916
	Counties		**Counties**		**Counties**		**Counties**		**Counties**
	Bladen		Alamance		Chatham		Davidson		Anson
	Columbus		Caswell		Hoke		Davie		Cabarrus
	Cumberland		Guilford		Lee		Forsyth		Mecklenburg
	Harnett		Orange		Montgomery		Rowan		Stanly
	Robeson		Rockingham		Moore		Stokes		Union
					Randolph				
					Richmond				
					Scotland				
	Division 11		**Division 12**		**Division 13**		**Division 14**		
	Tracy Church		Millie Adair		Robert Rhymer		Michael Wood		
Email	tgchurch@ncdot.gov	Email	madair@ncdot.gov	Email	rrhymer@ncdot.gov	Email	dmwood@ncdot.gov		
Phone	336-903-9105	Phone	336-903-9107	Phone	828-298-1516	Phone	828-891-7911		
Fax	336-667-5919	Fax	336-903-9247	Fax	828-299-7914	Fax	828-891-5026		
Cell	336-984-0421	Cell	704-575-4307	Cell	828-768-0375	Cell	828-553-4532		
	Counties		**Counties**		**Counties**		**Counties**		
	Alleghany		Alexander		Buncombe		Cherokee		
	Ashe		Catawba		Burke		Clay		
	Avery		Iredell		Madison		Graham		
	Caldwell		Cleveland		McDowell		Haywood		
	Surry		Gaston		Mitchell		Henderson		
	Watauga		Iredell		Rutherford		Jackson		
	Wilkes		Lincoln		Yancey		Macon		
	Yadkin						Polk		
							Swain		
							Transylvania		

NCDOT Batcher Certification Process

2018

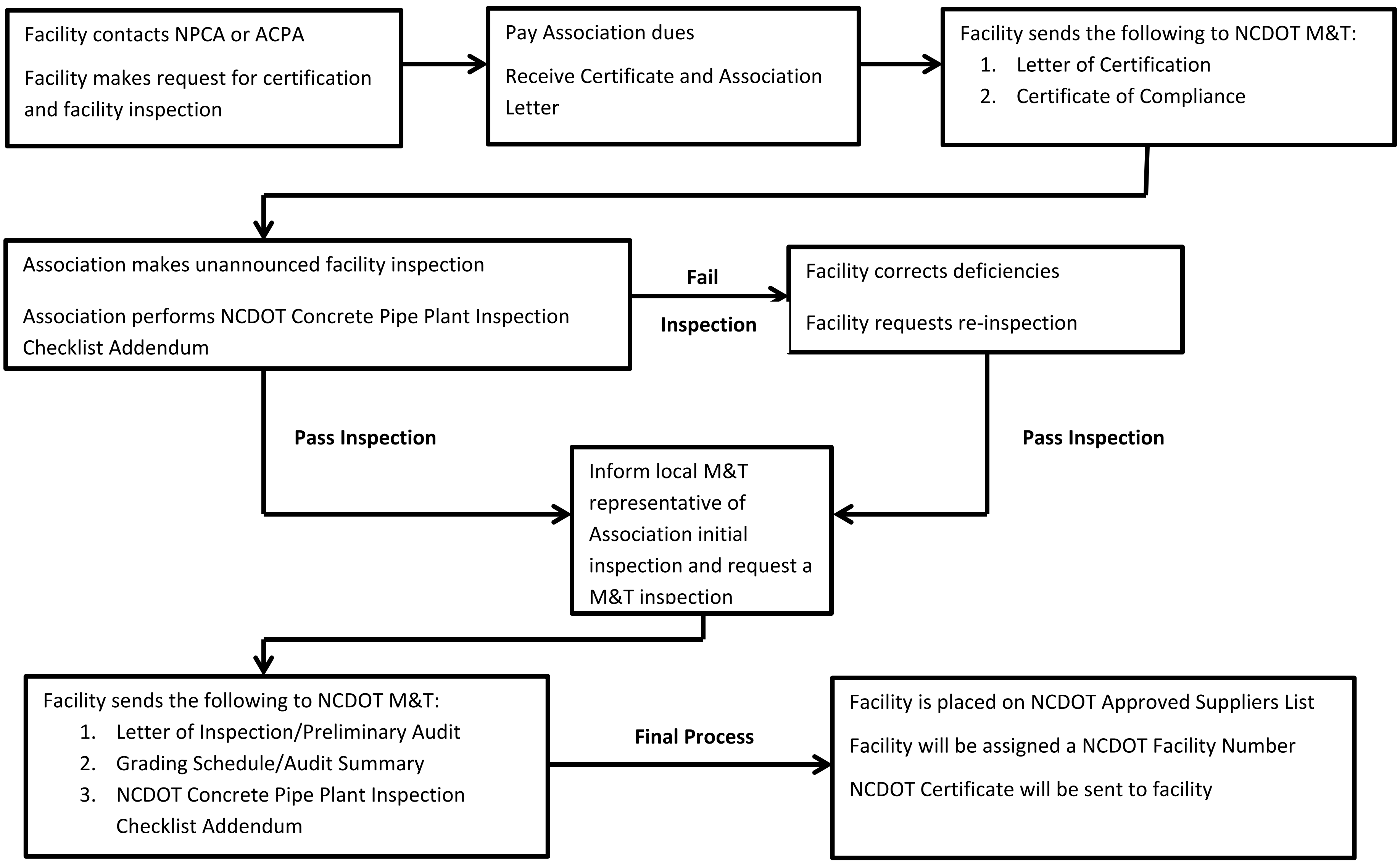


NOTE 1: If batching technician is performing acceptance tests and/or samples – technician must be Concrete Field Certified.

NOTE 2: If attending Q-Cast school, student must pass NCDOT additional test and send to Shannon Burns with M&T.

NCDOT Concrete Pipe Facility Approval Process

2018



M & T Form 250
Rev. 3/10

North Carolina Department of Transportation

DAILY PLANT REPORT ON READY MIXED CONCRETE OPERATIONS

Contract No. / Work Order No. ______________________________ Date ______________

Cement Producer ____________________ Cement Producer Location ____________________

Pozzolan Producer ____________________ Fine Agg Source ____________________

Ready Mix Facility & No. ____________________ Coarse Agg Source ____________________

Class of Concrete	Mix Design No.	Number of Loads	Total Yards Batched	Total Yards Rejected (To be completed by field inspector)

MOISTURE IN AGGREGATES

Fine Aggregate:

Trial 1 Time: ____________

Wet Wt. ________ Minus Dry Wt. ________ = ________ X 100 = ________ % Total Moisture

Dry Wt. ________

Total Moisture ________ Minus Absorbed Moisture ________ = ________ % Free Moisture

Trial 2 Time: ____________

Wet Wt. ________ Minus Dry Wt. ________ = ________ X 100 = ________ % Total Moisture

Dry Wt. ________

Total Moisture ________ Minus Absorbed Moisture ________ = ________ % Free Moisture

Coarse Aggregate:

Trial 1 Time: ____________

Wet Wt. ________ Minus Dry Wt. ________ = ________ X 100 = ________ % Total Moisture

Dry Wt. ________

Total Moisture ________ Minus Absorbed Moisture ________ = ________ % Free Moisture

Trial 2 Time: ____________

Wet Wt. ________ Minus Dry Wt. ________ = ________ X 100 = ________ % Total Moisture

Dry Wt. ________

Total Moisture ________ Minus Absorbed Moisture ________ = ________ % Free Moisture

Certified Batcher Signature: ____________________ Certification No. ______________

Certified Field Inspector Signature: ____________________ Certification No. ______________

M&T Form 250 is to be completed by certified batcher, pink copy of form shall be sent with first load, and the completed white (original) copy shall be sent with final load. If form is not completed and received on site, concrete is subject to rejection.

Form 312U
10-08

North Carolina Department of Transportation, Division of Highways, Materials and Tests Unit
Statement of Concrete Mix Design and Source of Materials

Contract No.	Concrete Producer
County	Plant Location & DOT No.
Resident Engr.	Contractor
Class of Concrete	Date
Mix Design No.	

Mix Design Proportions Based on SSD Mass of Aggregates

Material	Producer	Source	Qty. per Cu. Yd.
Cement, Type			lbs.
Pozzolan			lbs.
Fine Agg., + M			lbs.
Coarse Agg., + M			lbs.
Other Agg., + M			lbs.
Total Water			gals.
Air. Entr. Agent			oz.
Retarder			oz.
Water Reducer			oz.
Superplasticizer			oz.
Other			
Other			

Mix Properties and Specifications

Slump _____ in. _____ mm   Mortar Content _____ cu. ft. _____ cu. meter
Max. Water _____ gals. _____ L   Air Content _____ %

Aggregate and Pozzolan Data

Material	Specific Gravity	% Absorption	Unit Mass	Fineness Modulus
Fine Agg. Type (2S or 2MS)			NA	
Coarse Agg., Size (No. 57, 67, or 78M)				NA
Other Agg., Type or Size				
Pozzolan		NA	NA	NA

Cast-in-place concrete shall conform to Section 1000, precast concrete to Section 1077, and prestressed concrete to Section 1078 of the applicable edition of the Standard Specifications for Roads and Structures plus all applicable Special Provisions.

Special Use Criteria: Is mix design governed by Special Provision/Plan Note? Yes No
If Yes submit copy of Special Provision or Plan Note with this Form.

Signature and title of person who designed mix____

NCDOT Mix Design Certification No.___________________ **Or PE stamp or No.**__________________

Contractor Signature______________________ **Resident Engineer Signature**______________________

Rev. 02/22/2018

Materials & Tests Unit

NCDOT

Concrete Batcher Yearly Assessment

To Be Conducted Once Per Year on Active Batchers
Send to Shannon Burns

Batcher Name:	**Date of Assessment:**
Batch Certification Number:	**Date of Batch Class Attended:**
Producer Name & Location Assessment was Conducted:	**NCDOT State Plant # Assessment was Conducted:**

The batcher must successfully complete or demonstrate the correct operations with regards to NCDOT specifications and/or policies.

Operation	**Trial 1** (Pass/Fail)	**Trial 2** (Pass/Fail)
1. Verify the producer & source for the following:		
Cement	______	______
Pozzolan	______	______
Fine Aggregate	______	______
Coarse Aggregate	______	______
Water (Well or Municipal Source)	______	______
Air Entraining Agent	______	______
Retarder	______	______
2. Perform fine aggregate moisture determination:	______	______
Representative Sample obtained from area of use	______	______
Sample correct size	______	______
Wet weight correctly determined	______	______
Uniformly dried to consistent mass	______	______
Dry weight of sample correctly determined	______	______
Calculations correctly performed (Total and Free Moisture)	______	______
3. Perform coarse aggregate moisture determination:	______	______
Representative Sample obtained from area of use	______	______
Sample correct size	______	______
Wet weight correctly determined	______	______
Uniformly dried to consistent mass	______	______
Dry weight of sample correctly determined	______	______
Calculations correctly performed (Total and Free Moisture)	______	______

4. Calculate moisture adjustments/Batch Weights	_____	_____
Cement	_____	_____
Pozzolan	_____	_____
Fine Aggregate	_____	_____
Course Aggregate	_____	_____
Water	_____	_____
Air Entraining Agent	_____	_____
Retarder	_____	_____
5. Determine maximum water allowed on NCDOT concrete:	_____	_____
6. Demonstrate procedure for moisture adjustments prior to batching Operations (Make Adjustments to Pull Weights)	_____	_____
7. Batch Concrete	_____	_____
8. Complete the batch record form:	_____	_____

(Circle One)

Overall Score: Pass/Fail Pass/Fail

I certify that I have not helped, coached, or in any way interfered with the batcher during this Evaluation.

Evaluator: ________________________________ Date:______________________________

OFFICE USE ONLY	
Date Evaluation received:	
Date certificate granted:	

Moisture Determination Worksheet

Fine Aggregate:

Trial 1

Wet Wt. ______________ Minus Dry Wt. ______________ = ______________ X 100 = ______________ % Total Moisture

Dry Wt. __________________

Total Moisture _______________ Minus Absorbed Moisture _______________ = _______________ % Free Moisture

Trial 2

Wet Wt. ______________ Minus Dry Wt. ______________ = ______________ X 100 = ______________ % Total Moisture

Dry Wt. __________________

Total Moisture _______________ Minus Absorbed Moisture _______________ = _______________ % Free Moisture

Coarse Aggregate:

Trial 1

Wet Wt. ______________ Minus Dry Wt. ______________ = ______________ X 100 = ______________ % Total Moisture

Dry Wt. __________________

Total Moisture _______________ Minus Absorbed Moisture _______________ = _______________ % Free Moisture

Trial 2

Wet Wt. ______________ Minus Dry Wt. ______________ = ______________ X 100 = ______________ % Total Moisture

Dry Wt. __________________

Total Moisture _______________ Minus Absorbed Moisture _______________ = _______________ % Free Moisture

Materials & Tests Unit

NCDOT

Concrete Batcher On-Site Evaluation

To Be Completed After Successfully Completing Concrete Batch School or Q-Cast Certification training
Send to Sandra Williams

Date of Evaluation:	**Date of Class:**
Batcher Name:	**Batch Certification Number:**
Batch Certification School Location:	**Last 4 digits of Social Security #:**
Producer Name & Location Evaluation was Conducted:	**NCDOT State Plant # Evaluation was Conducted:**

The batcher must successfully complete or demonstrate the correct operations with regards to NCDOT specifications and/or policies.

Operation	**Trial 1** (Pass/Fail)	**Trial 2** (Pass/Fail)
1. Verify the producer & source for the following:		
Cement	______	______
Pozzolan	______	______
Fine Aggregate	______	______
Coarse Aggregate	______	______
Water (Well or Municipal Source)	______	______
Air Entraining Agent	______	______
Retarder	______	______
2. Perform fine aggregate moisture determination:	______	______
Representative Sample obtained from area of use	______	______
Sample correct size	______	______
Wet weight correctly determined	______	______
Uniformly dried to consistent mass	______	______
Dry weight of sample correctly determined	______	______
Calculations correctly performed (Total and Free Moisture)	______	______
3. Perform coarse aggregate moisture determination:	______	______
Representative Sample obtained from area of use	______	______
Sample correct size	______	______
Wet weight correctly determined	______	______
Uniformly dried to consistent mass	______	______
Dry weight of sample correctly determined	______	______
Calculations correctly performed (Total and Free Moisture)	______	______

4. Calculate moisture adjustments/Batch Weights ______ ______
   - Cement ______ ______
   - Pozzolan ______ ______
   - Fine Aggregate ______ ______
   - Course Aggregate ______ ______
   - Water ______ ______
   - Air Entraining Agent ______ ______
   - Retarder ______ ______

5. Determine maximum water allowed on NCDOT concrete: ______ ______

6. Demonstrate procedure for moisture adjustments prior to batching Operations (Make Adjustments to Pull Weights) ______ ______

7. Batch Concrete ______ ______

8. Complete the batch record form: ______ ______

(Circle One)

Overall Score: Pass/Fail Pass/Fail

I certify that I have not helped, coached, or in any way interfered with the batcher during this Evaluation.

Evaluator: ______________________________ Date:______________________________

OFFICE USE ONLY	
Date Evaluation received:	
Date certificate granted:	

Rev. 2/22/2018

Moisture Determination Worksheet

Fine Aggregate:

Trial 1

Wet Wt. ____________ Minus Dry Wt. ____________ = ____________ X 100 = ____________ % Total Moisture

Dry Wt. ________________

Total Moisture _____________ Minus Absorbed Moisture _____________ = _____________ % Free Moisture

Trial 2

Wet Wt. ____________ Minus Dry Wt. ____________ = ____________ X 100 = ____________ % Total Moisture

Dry Wt. ________________

Total Moisture _____________ Minus Absorbed Moisture _____________ = _____________ % Free Moisture

Coarse Aggregate:

Trial 1

Wet Wt. ____________ Minus Dry Wt. ____________ = ____________ X 100 = ____________ % Total Moisture

Dry Wt. ________________

Total Moisture _____________ Minus Absorbed Moisture _____________ = _____________ % Free Moisture

Trial 2

Wet Wt. ____________ Minus Dry Wt. ____________ = ____________ X 100 = ____________ % Total Moisture

Dry Wt. ________________

Total Moisture _____________ Minus Absorbed Moisture _____________ = _____________ % Free Moisture

Materials & Tests Unit

NCDOT

Batching Certification Process- Concrete Pipe Producers 2018

The purpose of this documentation is to establish the procedures for becoming “Batch Certified” for a producer of concrete pipe. Prior to an individual becoming “Batch Certified”, the facility must meet the certification requirements and be placed on the NCDOT “Approved List”. Only “Certified Batchers” will be accepted to produce concrete pipe products for NCDOT projects and must be on-site and in direct control of batching operations during all pipe production.

A Batching Technician is the individual whose job responsibilities pertain to activity involved with the production of concrete. The production of concrete may be manufactured manually or by monitoring a computer base system. Both production methods are required to have a “Certified Batcher” if producing concrete pipe products for NCDOT projects. Individuals, who seek this certification for the first time, must successively complete the “Concrete Field Technician” training as a prerequisite.

The certification process will require completion of two phases. Phase one is to attend and successfully complete an approved certification training school. The options for an approved certification training school are: NCDOT Concrete Batch Technician school or attend the certification training Q-Cast (the student must take the additional NCDOT exam). Phase two involves the individual to successfully complete the “Concrete Batcher Onsite Evaluation”.

PHASE ONE – CERTIFIED TRAINING SCHOOL:

NCDOT Concrete Batch Technician training:

- Search dates and locations on the NCDOT Materials & Tests web page.
- Register on line for the selected scheduled training date.
- This is a two day training program.
- Successfully complete the course.
- NCDOT will process documentation and place individual into tracking system.
- Potential Batcher will contact local M&T representative and request a “Concrete Batcher On-Site Evaluation” be performed.

Q-Cast Training:

- Search dates and locations on web page.
- Register for the selected scheduled training date.

- Individual must notify instructor their request to obtain the NCDOT training.
- Successfully complete the course.
- Passing documentation must be sent to M&T (Shannon Burns).
- Q-Cast instructor will submit roster and test results to M&T (Shannon Burns) for verification.
- M&T will process documentation and place individual into tracking system.
- Potential Batcher will contact local M&T representative and request a “Concrete Batcher On-Site Evaluation” be performed.

PHASE TWO – Concrete Batch On-Site Evaluation:

- This form is to be completed after an individual successfully completes either the NCDOT Concrete Batch School, or Q-Cast Certification School.
- This activity is **REQUIRED** for certification. If this activity is not conducted, the individual is **NOT** certified.
- The evaluation is to be conducted by a representative from M&T.
- The evaluation is to be completed ASAP after completion of school.
- All information is to be completed on the form- do not leave anything blank.
- The completed form is to be sent to M&T (Sandra Williams).

ACTIVE CERTIFIED BATCH TECHNICIAN:

To remain an “Active” certified batch technician, the following must be performed:

- If the Technician is molding test specimens and/or performing acceptance test, he/she must keep their NCDOT Concrete Field Technician certification active.
- If the Technician is actively responsible for “Batching” operations (this includes performing moisture analysis on aggregate), the Technician is required to complete the “Concrete Batcher Yearly Assessment”.
- This assessment is to be completed once per year on all “Active” Batchers.
- This assessment is REQUIRED for certification. If this assessment is not conducted, the individual is NOT certified.
- The assessment is to be conducted by a representative from M&T.
- All information is to be completed on the form- do not leave anything blank.
- The completed form is to be sent to Shannon Burns (M&T).
- It is the responsibility of the Technician to contact the local M&T representative.

NCDOT Materials and Tests Unit
Standard Operating Procedure
Inspection of Reinforced Concrete Pipe
Effective July 1, 2018

Objectives:

The purpose of this SOP is to establish guidelines for the inspection, the acceptance and reporting of Reinforced Concrete Pipe. The guidelines are designed to insure all technicians/inspectors follow the same procedures and comply with all NCDOT, AASHTO and ASTM specifications. The technicians/inspectors will insure quality control techniques, quality control records, and testing equipment are being followed. The technician shall personally inspect each piece of pipe and place a "NCDOT Approved" stamp on each piece of pipe once it meets approval.

Concrete Pipe should meet Section 1032-6 of the NCDOT Standard Specifications, AASHTO M 170 and ASTM C 76 guidelines.

Materials Inspection and Acceptance:

It is mandatory for technicians/inspectors to follow these guidelines in order to establish, manage and monitor quality control, quality assurance and quality documentation. Following the proper inspection process will ensure effectiveness and efficiency in the quality systems of the NCDOT.

- Periodically review Reinforced Concrete Pipe guidelines.
- Periodically review ASTM C 76, AASHTO M 170 and NCDOT Standard Specifications Sub-Article 1032-6 to insure proper procedures are followed during the inspection
- Ensure all equipment required for testing the material and any safety equipment needed is in possession and serviceable before arrival.
- Verify that the facility is an approved NCDOT Producer with a NCDOT Annual Facility Inspection that is up to date.
- Verify that the facility has a current third party inspection with a copy of inspection and NCDOT Addendum available for inspection at the facility.
- Verify the facility technicians have all the required NCDOT certifications or approved alternatives required for the production of concrete pipe.
- Review the assigned NCDOT approved mix designs for the facility.

Safety Equipment List:

Safety Shoes with ANSI Z 41 rating
Hard Hat with ANSI Z89.1 rating
First Aid Kit
Fire Extinguisher
Safety Glasses
Gloves
Safety Vest
Ear Plugs
Sun Block (optional)
Lifting Belt (optional)
Dust Masks (optional)

Safety Concerns:

Pinch Points/Test Rack/Pipe Inspection
Heavy Equipment/Backing Incidents
Possible dusty conditions

Equipment Required for Product Inspection:

Concrete Pipe Inspection Field Worksheets
Tape Measure
0.01 Leaf Gauge
Micrometer
Calculator
Calipers (wall thickness)
Black Paint
Pencil or Pen
"NC Approved DOT" Stencil

M&T Inspector's Duties for Reinforced Concrete Pipe Inspection:

1. When arriving at the facility, inspectors should check into main office (if required).
2. Make contact with QC Technician to determine items to be inspected.
3. Concrete pipe will be accepted as a lot as described in the table below.

Concrete Pipe Lot Sizes

Diameter	**Lot Size/Description**
12"	4000 LF per consecutive day's production (max 5 days)
15"	4000 LF per consecutive day's production (max 5 days)
18"	4000 LF per consecutive day's production (max 5 days)
24"	2000 LF per day's production
30"	4000 LF per consecutive day's production (max 5 days)
36"	4000 LF per consecutive day's production (max 5 days)
42"	2000 LF per day's production
48	2000 LF per consecutive day's production (max 5 days)
D>48	2000 LF per day's production

(Example: Producer has 2800 LF of 24” 3-B concrete pipe that was produced on 03/01/2013. Producer is asking that this material be stamped. The NCDOT inspector will randomly select two pieces of pipe to be tested. One pipe will represent 2000 LF and the other will represent 800 LF)

4. Technician will randomly select from stock the concrete pipe for testing.
5. Technician shall make a determination at this point if the pipe lot has excessive defects. Section 1032-6 (E) of the NCDOT Standard Specification states the rejection of more than 20% of any lot of pipe due to cracks, fractures, variations in alignment or other manufacturing defects will be cause for the rejection of the entire lot.
6. If concrete pipe is 48” or larger in diameter, the concrete pipe can be accepted on cylinders or three edge bearing. If concrete pipe is <less than 48” in diameter then a three edge bearing test must be performed.
7. Verify the pipe has been stenciled with the proper Alternate ID identification. Alternate ID will be the assigned State #, diameter of pipe, and year pipe was produced. Example: CP1-24-13. This information also shall be on the Manufacture’s Bill of Lading.
8. Verify the pipe has required AASHTO M 170 markings. This will consist of pipe class and specification designation, the date of manufacture and the name or trademark or manufacture. Markings shall be indented (scratched) or painted with waterproof paint.
9. Three-Edge Bearing Tests
    a. If pipe selected is <less than 48” then a three edge bearing test is required. This test will consist of D-Loading the pipe which is external loading of the pipe. The readings you will get are pounds per foot of length per foot of diameter

Three Edge Bearing Test Schedule

Diameter	**0.01” Load Test**	**Ultimate Load Test**
12”	Each Lot	1/Quarter (each 4 months)
15”	Each Lot	1/Quarter (each 4 months)
18”	Each Lot	1/Quarter (each 4 months)
24”	Each Lot	Each Lot
30”	Each Lot	1/Quarter (each 4 months)
36”	Each Lot	1/Quarter (each 4 months)
42”	Each Lot	Each Lot

    b. Three-Edge Bearing test rack must be calibrated annually or when a question of accuracy arises.

    c. Before placing pipe in rack a calculation must be done to determine lower bearing width. Example:(24” (Pipe Size) / 12 = 2” (lower bearing width)

    d. Refer to AASHTO M 170-4 to determine specification requirements of selected pipe.

Three Edge Bearing Loading

Classification	D-Load 0.01” crack	D-Load ultimate load
Class I	800	1200
Class II	1000	1500
Class III	1350	2000
Class IV	2000	3000
Class V	3000	3750

e. Example: If a class III pipe is selected.
D-Load required to produce an 0.01” crack 1350
D-Load required to produce the ultimate load 2000

f. Example: Calculations for a 30” Class III 8’ length pipe used to determine minimum readings required for acceptance in the test rack are as follows:

- 0.01” load = 1350 (D-Load) x 8’ (length of pipe) x 2.5’ (Diameter of pipe in decimal form) = 27000 lbs.
- Ultimate load = 2000 (D-load) x 8’ (length of pipe) x 2.5’ (Diameter of pipe in decimal form) = 40000 lbs.

g. The definition of a 0.01” crack is: “When the point of the measuring gage will, without forcing, penetrate 1/16” at close intervals throughout the specified distance of 1 FT.”

h. The definition of Ultimate Load is: “Maximum load pipe will support.”

i. Should the test pipe fail to meet the strength requirements, the manufacturer shall be allowed a retest two additional pipe for each pipe that failed, and the pipe shall be acceptable only when all of the retest specimens meet the strength requirements.

j. Failure of two consecutive lots of pipe to meet Three Edge Bearing Loading test requirements for either the 0.01” or Ultimate Load will result, as a minimum, in the lot size being reduced to 2000LF per day’s production with Three Edge Bearing Loading testing for both the 0.01” and Ultimate Load being conducted for each lot until such time as the Producer can demonstrate that meeting specifications can consistently be produced.

17. Concrete Cylinder Compression Tests

a. Pipe diameters 48” or larger may be strength tested by means of compression testing of concrete cylinders, in lieu of three-edge bearing testing, at the manufacturer’s discretion.

b. If concrete cylinders are to be used for acceptance. A minimum of four cylinders are to be made for each class, diameter and lot from that day’s production. A NCDOT Certified Field Concrete Technician representing the manufacturer must perform tests and make cylinders for acceptance.

c. NCDOT will witness cylinder breaks at the manufacture's facility. Compression machine must be calibrated annually or when a question of accuracy applies. Acceptance is the average of two cylinders. Specified concrete strength for acceptance is listed in AASHTO M 170-4 for the size, class and wall. Testing shall be conducted in accordance with ASTM C39.

d. Should the average of two cylinders fail to meet the strength requirements, the manufacturer shall be allowed to perform a three-edge bearing test on pipe.

18. Visual/Walk Thru Inspection and "NCDOT Approved" stamp.

a. Repairs

- Repair materials and methods must be approved by the Engineer before their use.
- AASHTO M 170-13
  "Pipe may be repaired, if necessary, because of imperfections in manufacturing or damage during handling and will be acceptable if, in the opinion of the owner, the repaired pipe conforms to the requirements of this specification."

b. Technician will refer to AASHTO M 170-15. Causes of Rejection.

- Any fracture or crack that visibly passes through the wall of pipe.
- Any fracture or crack that is 0.01" wide or greater at the surface and 12" or longer regardless of position in the wall of the pipe.
- Offsets in form seam that would prevent adequate concrete cover over reinforcing steel.
- Delamination in the body of the pipe when viewed from the ends.
- Evidence of inadequate concrete cover for reinforcing steel.
- Any severe surface condition that affects the majority of the pipe section surface and could reduce the durability and service life of the pipe.
- Damaged or cracked ends where such damage would prevent making a satisfactory joint.

c. Technician shall personally inspect and accept each pipe. Technician must be able to visually look through pipe and inspect both ends of pipe.

d. Pipe will be accepted and individually stamped, by the NCDOT technician after all criteria meets specifications.

19. Reinforcement Check

a. Technician will randomly inspect reinforcement area and placement for concrete pipe at each visit. Refer to AASHTO M170-4 for specified areas for each class and wall thickness of concrete pipe.

b. Refer to AASHTO M 170-8 for reinforcement requirements for reinforced concrete pipe. Below is a list of some items from M 170-8 that will assist you in your inspection.

- If splices are not welded, the reinforcement shall be lapped not less than 20 diameters for deformed bars, and deformed cold-worked wire, and 40 diameters for plain bars and cold-drawn wire. In addition, where lapped cages of welded-wire fabric are used without welding, the lap shall contain a longitudinal wire.
- When splices are welded and are not lapped to the minimum requirements above pull tests of representative specimens shall develop at least 50 percent of the minimum specified strength of the steel, and there shall be a minimum lap of 2" for butt-welded splices in bars or wire, permitted only with helically wound cages, pull tests of representative specimens shall develop at least 75 percent of the minimum specified strength of the steel.

c. Basic Wire Calculations for Area:

Area =

$$\frac{(\text{Diameter of Wire in Inches})^2 \times (\text{\# of complete circumferential rolls}) \times (0.7854)}{\text{Length of Pipe in LF}}$$

20. Annual Samples

a. Cores for Absorption

- Absorption for concrete pipe shall not exceed 9 percent of the dry mass. Each sample shall have a minimum mass of 2.2 lbs. shall be free visible cracks (4" cores are normally used for this test). If absorption fails, the absorption sample shall be made on another sample from the same pipe.
- Concrete cores shall be taken for each diameter, class and wall annually, with additional samples taken for each diameter, class and wall after every 10,000 LF is produced and accepted.
- Cores shall be taken from pipe produced during the current year or the previous year if current year is not available.
- Samples will be sent to Materials and Tests Unit Physical Lab.

b. Reinforcement Sample

- Reinforcement wire and steel samples will be taken annually for each size, with additional samples taken for every 10,000 LF produced and accepted.
- Wire samples will be 30" with a minimum of three circumferential reinforcement wires.
- If wire reinforcement is welded at the lap, a representative sample shall be taken with the weld as part of sample. Sample shall be 30" with a minimum of three circumferential reinforcement wires.
- Reinforcing steel samples shall be two 30" bars for each diameter.
- All samples will be sent to Materials and Tests Physical Lab along with mill certs.

c. Cement Samples

- Cement samples shall be taken annually or if a questionable material is an issue.

d. Pozzolan

- Pozzolan samples shall be taken annually or if a questionable material is an issue.

e. Coarse Aggregate

- Coarse Aggregate samples shall be taken quarterly or if a questionable material is an issue.
- Material must come from the NCDOT's Approved List.

f. Fine Aggregate

- Fine Aggregate samples shall be taken quarterly or if a questionable material is an issue.
- Material must come from the NCDOT's Approved List.

Standards:

NCDOT Standard Specs 1032-6

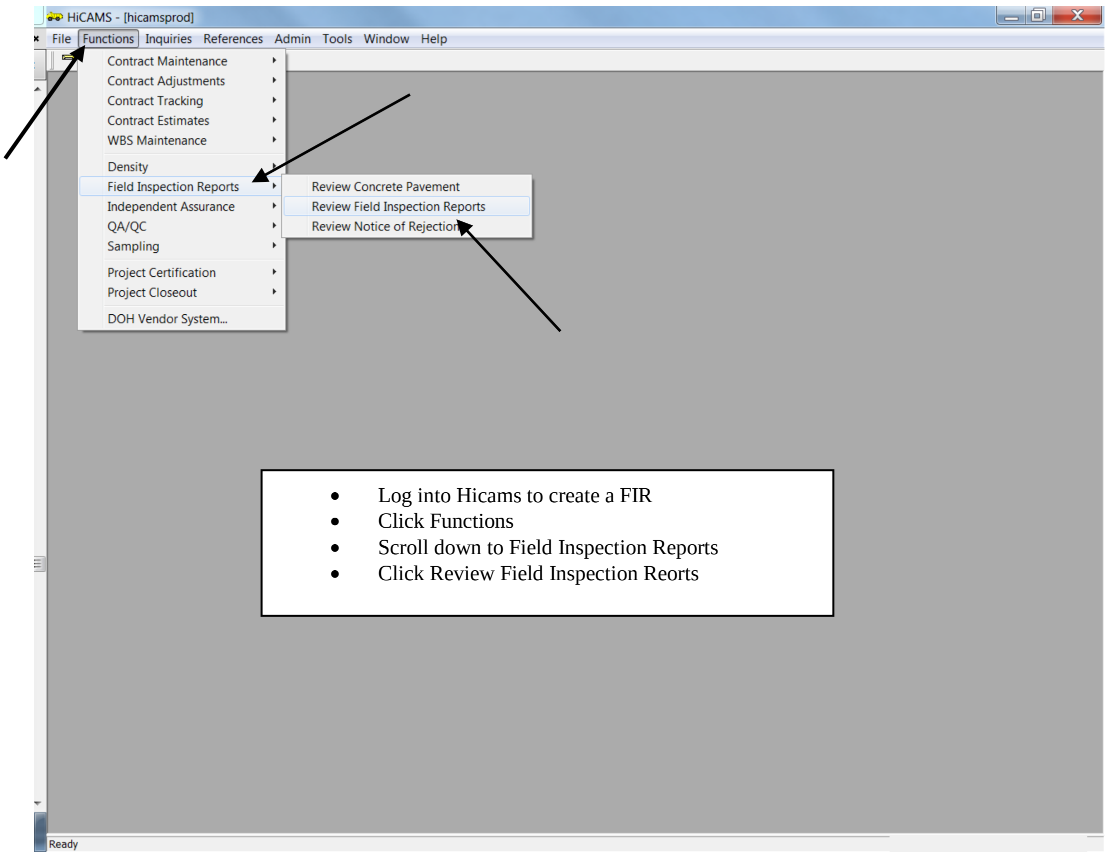
AASHTO M170

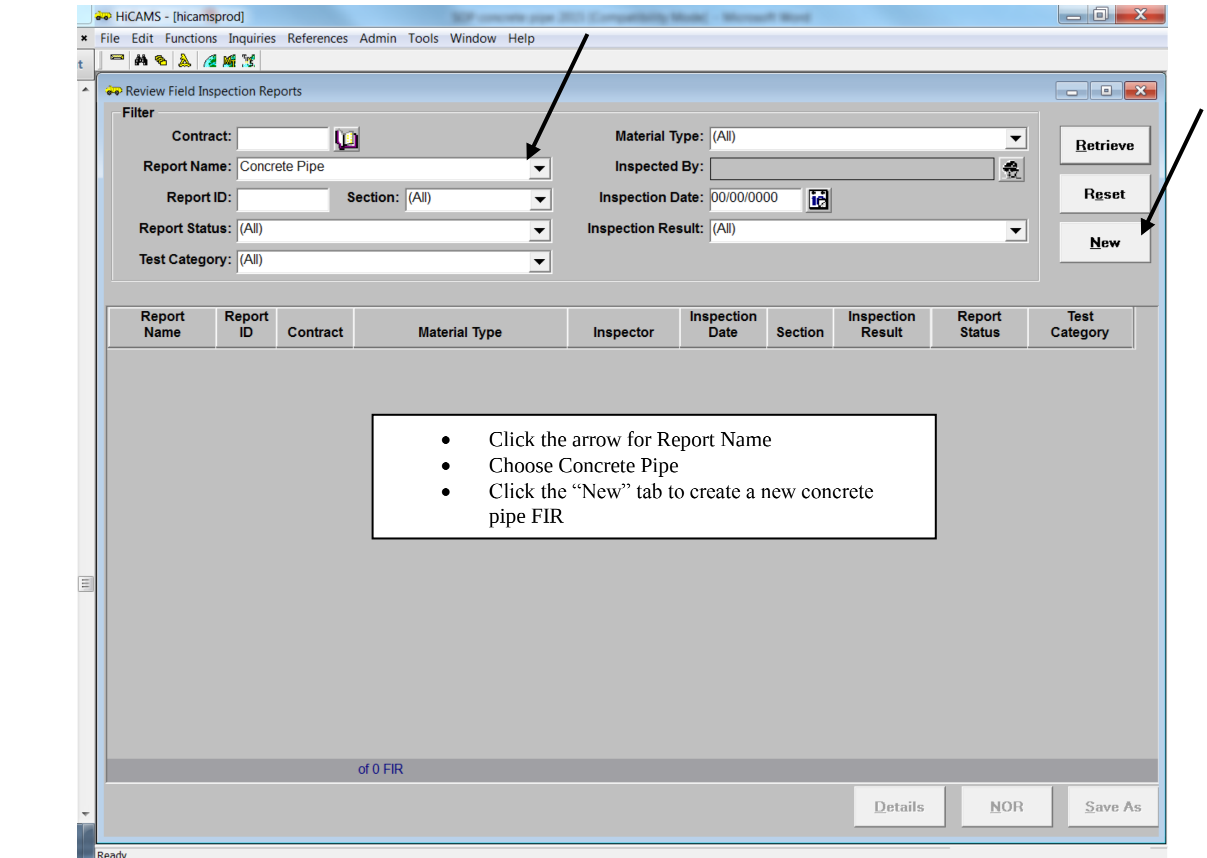
ASTM C76

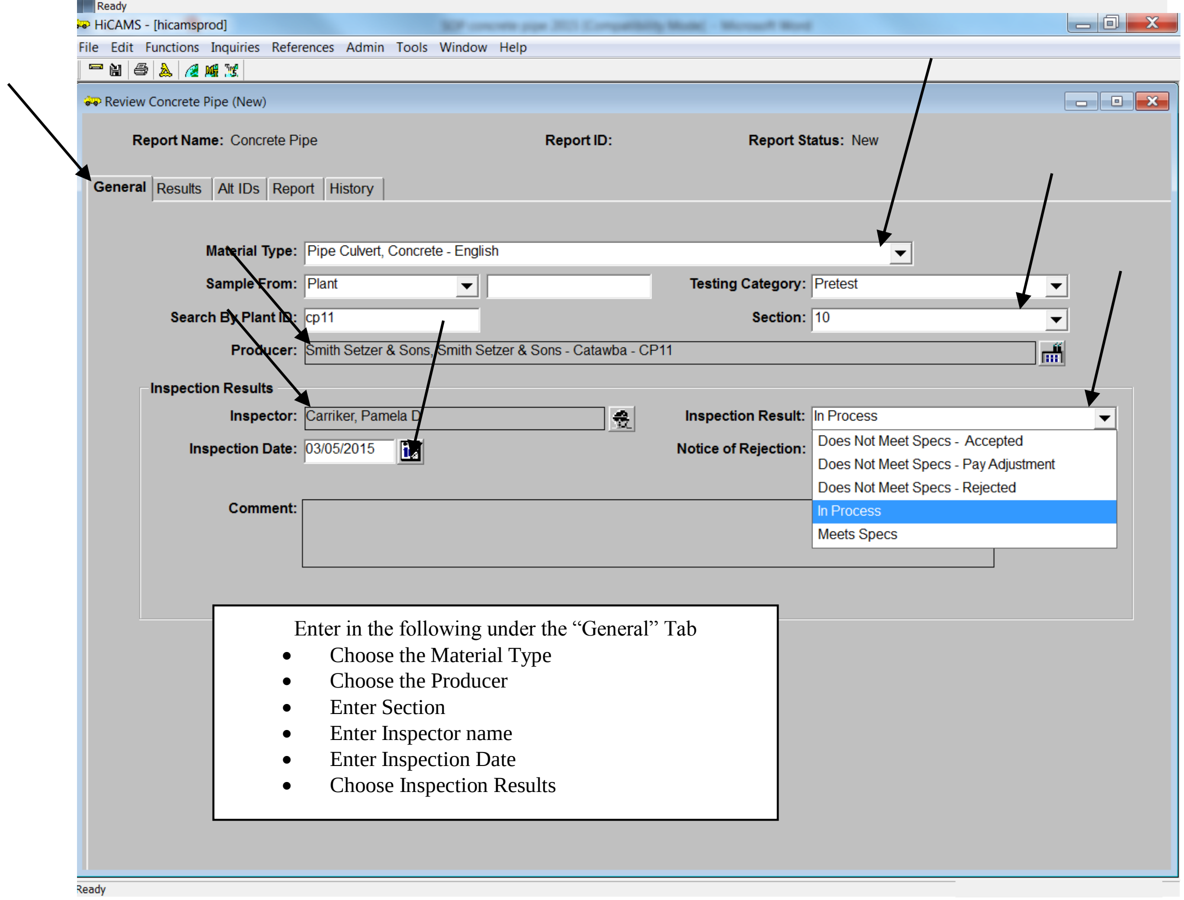
ASTM C39

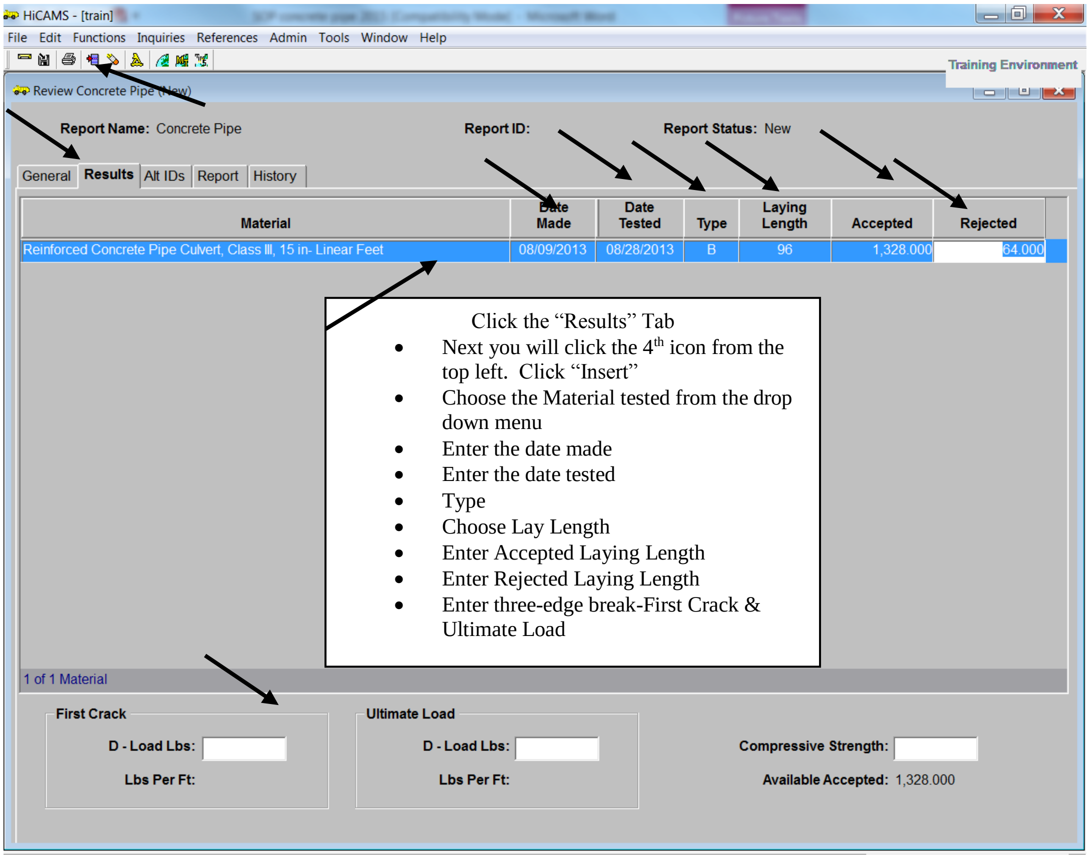
Sample Prep and Submittal:

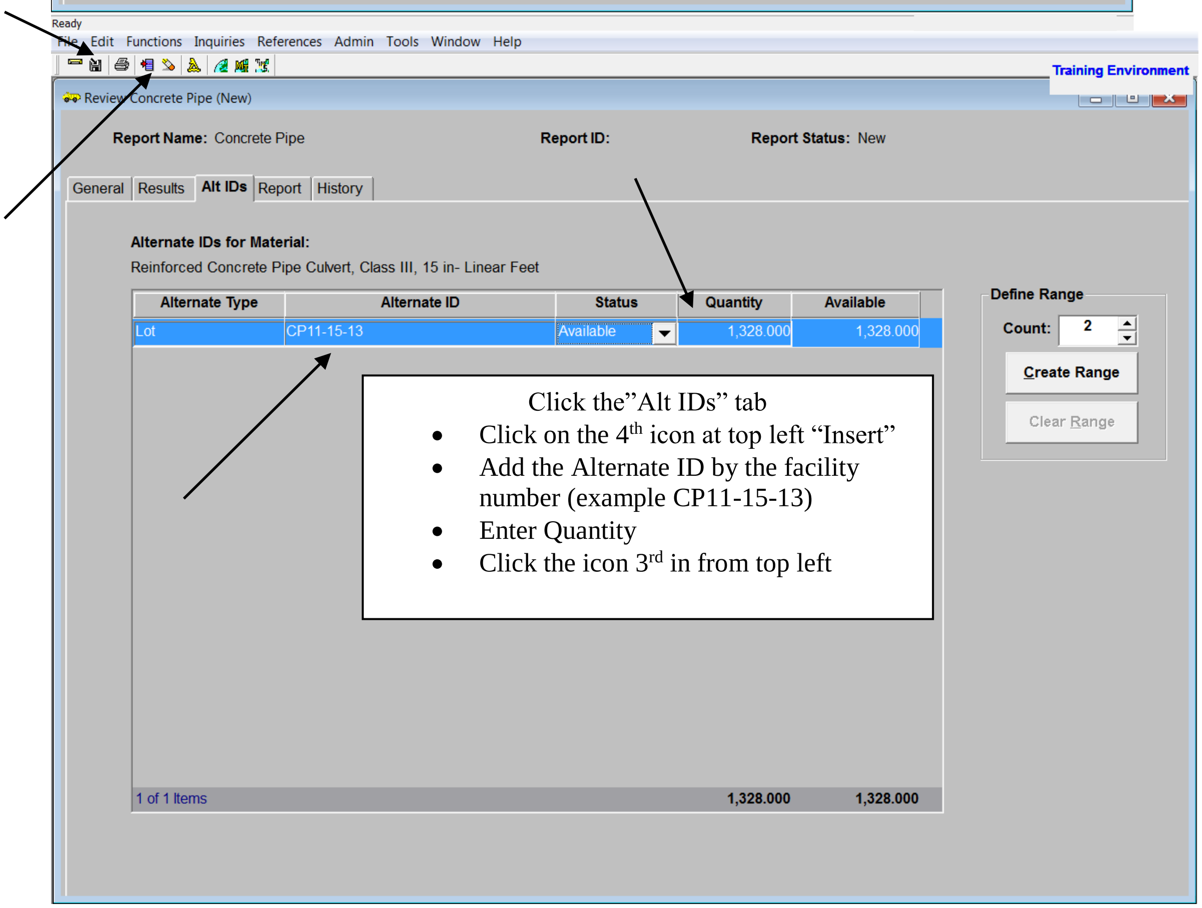
All inspections must be entered into Hicams under Field Inspection Report (FIR) within two working days.




HiCAMS - [hicamsprod]
Review Field Inspection Reports
Filter
Contract:
Report Name: Concrete Pipe
Report ID:
Section: (All)
Report Status: (All)
Test Category: (All)
Material Type: (All)
Inspected By:
Inspection Date: 00/00/0000
Inspection Result: (All)
Retrieve
Reset
New
Report Name
Report ID
Contract
Material Type
Inspector
Inspection Date
Section
Inspection Result
Report Status
Test Category
• Click the arrow for Report Name
• Choose Concrete Pipe
• Click the "New" tab to create a new concrete pipe FIR
of 0 FIR
Details
NOR
Save As
Ready


HiCAMS - [hicamsprod]
Review Concrete Pipe (New)
Report Name: Concrete Pipe
Report ID:
Report Status: New
General
Results
Alt IDs
Report
History
Material Type: Pipe Culvert, Concrete - English
Sample From: Plant
Testing Category: Pretest
Search By Plant ID: cp11
Section: 10
Producer: Smith Setzer & Sons, Smith Setzer & Sons - Catawba - CP11
Inspection Results
Inspector: Carriker, Pamela D
Inspection Result: In Process
Inspection Date: 03/05/2015
Notice of Rejection:
Does Not Meet Specs - Accepted
Does Not Meet Specs - Pay Adjustment
Does Not Meet Specs - Rejected
In Process
Meets Specs
Comment:
Enter in the following under the "General" Tab
• Choose the Material Type
• Choose the Producer
• Enter Section
• Enter Inspector name
• Enter Inspection Date
• Choose Inspection Results
Ready


HiCAMS - [train]
File Edit Functions Inquiries References Admin Tools Window Help
Training Environment
Review Concrete Pipe (New)
Report Name: Concrete Pipe
Report ID:
Report Status: New
General Results Alt IDs Report History
Material | Date Made | Date Tested | Type | Laying Length | Accepted | Rejected
Reinforced Concrete Pipe Culvert, Class III, 15 in- Linear Feet | 08/09/2013 | 08/28/2013 | B | 96 | 1,328.000 | 64.000
Click the "Results" Tab
Next you will click the 4th icon from the top left. Click "Insert"
Choose the Material tested from the drop down menu
Enter the date made
Enter the date tested
Type
Choose Lay Length
Enter Accepted Laying Length
Enter Rejected Laying Length
Enter three-edge break-First Crack & Ultimate Load
1 of 1 Material
First Crack
D - Load Lbs:
Lbs Per Ft:
Ultimate Load
D - Load Lbs:
Lbs Per Ft:
Compressive Strength:
Available Accepted: 1,328.000


Ready
File Edit Functions Inquiries References Admin Tools Window Help
Training Environment
Review Concrete Pipe (New)
Report Name: Concrete Pipe
Report ID:
Report Status: New
General Results Alt IDs Report History
Alternate IDs for Material:
Reinforced Concrete Pipe Culvert, Class III, 15 in- Linear Feet
Alternate Type | Alternate ID | Status | Quantity | Available
Lot | CP11-15-13 | Available | 1,328.000 | 1,328.000
Define Range
Count: 2
Create Range
Clear Range
Click the" Alt IDs" tab
Click on the 4th icon at top left "Insert"
Add the Alternate ID by the facility number (example CP11-15-13)
Enter Quantity
Click the icon 3rd in from top left
1 of 1 Items
1,328.000
1,328.000

<u>Documentation Submittal:</u>

- The FIR will be reviewed and authorized within two working days after being completed.
- The M&T technician will file a hard copy of the " Concrete Pipe Field Worksheets" which is filled out during inspection.

North Carolina Department of Transportation
Materials & Tests Unit
Precast Concrete Plant Inspection Checklist Addendum - 2018

Date Of Inspection:		NCDOT Facility Number:	PC
Facility Company Name:			
Facility Address:			

The following are tasks to be performed during the plant inspection for a precast concrete producer seeking NCDOT Certification.

Aggregates

A1.	Pass	Fail	Aggregates are listed on approved list maintained by the Department.
A2.	Pass	Fail	Aggregates stockpiled at plant are confirmed by Department's approved concrete mix designs.
A3.	Pass	Fail	Aggregate stockpiles maintained above Saturated Surface Dry (SSD) condition.
Comments:			

Cement and Fly Ash

A4.	Pass	Fail	Proper Bill of Lading meeting Department criteria and certifications as outlined in Department's Specifications received.
A.5	Pass	Fail	Verify cement and fly ash source with Department approved concrete mix design.
Comments:			

Water

A6.	Pass	Fail	Water source has been sampled and tested by producer within the last 12 months. The water analysis report is on site and meets the requirements as stated in Section 1024-4, Table 1024-2.
A7.	Pass	Fail	Water source has been sampled and tested by M&T Technician within the last 12 months. This report is on site and states the sample "Meets Specification".
Comments: Producers Water Analysis Report Date: _____________ M&T's Water Analysis Report Date: ________________			

Mix Proportions

A8.	Pass	Fail	Department approved concrete mix designs are on hand and match materials on site.
A9.	Pass	Fail	Concrete mix design proportions adjusted for moisture content according to Department procedures.
Comments:			

Moisture Content

A10.	Pass	Fail	Percent total moisture for each aggregate is determined by Department's Certified Batcher during inspection. **Documentation must be accessible and on-site.**
A11.	Pass	Fail	Moisture equipment, including moisture probes, checked for accuracy and proper working operation.
A12.	Pass	Fail	Review moisture calculations and w/c calculated for each batch.
Comments:			

Routine Duties

A13.	Pass	Fail	Daily checks on cement received and used. **Does the BOL and Certifications match what is called for in the mix design?**
A14.	Pass	Fail	Constant testing and checking moisture contents of aggregates. **Initial moistures will be performed at startup of each day, a second moisture will be performed if production is greater than four hours. Additional checks may be needed if weather conditions dictate [rain, wind, high temps, etc].**
A15.	Pass	Fail	Daily report prepared and batch weight tickets kept on site.
Comments:			

Certifications

A16.	Pass	Fail	All personnel have current/active Department certifications for their job responsibility, and documentation is on site. (List Below) • NCDOT Concrete Field Technician
A17.	Pass	Fail	All personnel have current/active Department certifications for their job responsibility, and documentation is on site. (List Below) • NCDOT Concrete Batch Technician
A18.	Pass	Fail	Plant has been approved and displays current Department Plant Certification
Comments:			

Equipment

A19.	Pass	Fail	All equipment used in the batching operations has been calibrated within the last 12 months. Scales and dispensing devices must be calibrated by a third party entity or the manufacturer (in-house calibration is not acceptable).
A20.	Pass	Fail	All equipment used in the quality control sampling and testing has been calibrated within the last 12 months if applicable and is in good working order. Scales, compression machines, three edge bearing machine, etc., must be calibrated by a third party entity or the manufacturer (in-house calibration is not acceptable).
Comments:			

Personnel

Any personnel involved in the QC testing of the product must have a current NCDOT Field Testing Technician certification. Any personnel involved in the batching operations at the plant must have a current NCDOT Batch Technician Certification. List all Field Testing, and Batch Technicians below:

NCDOT CONCRETE FIELD TECHNICIAN (PCT)

Name	Title	NCDOT Certification Number - PCT	NCDOT Certification Expiration Date

NCDOT CONCRETE BATCH TECHNICIAN (PCB)

Name	Title	NCDOT Certification Number - PCB	NCDOT Certification Expiration Date