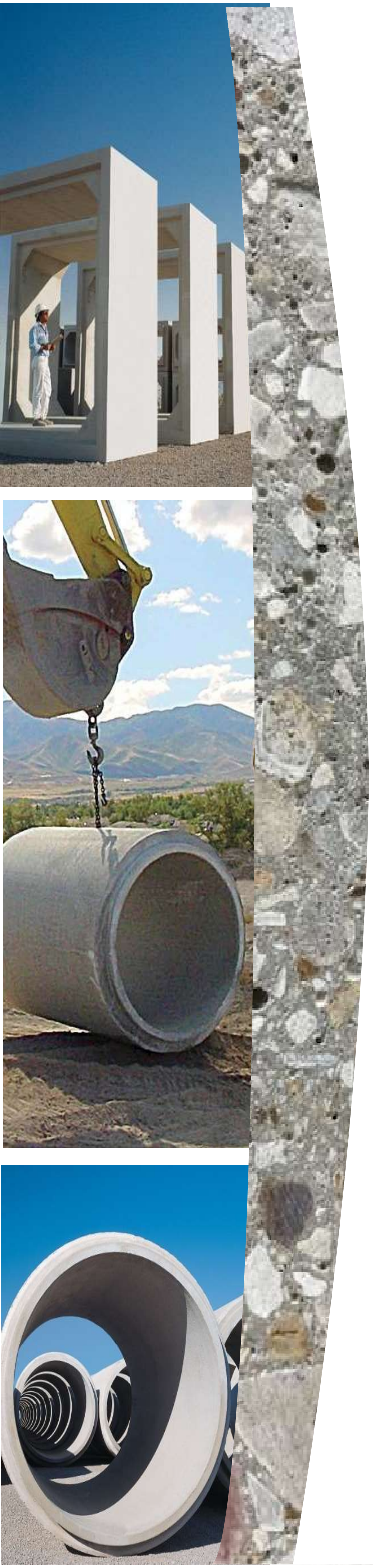
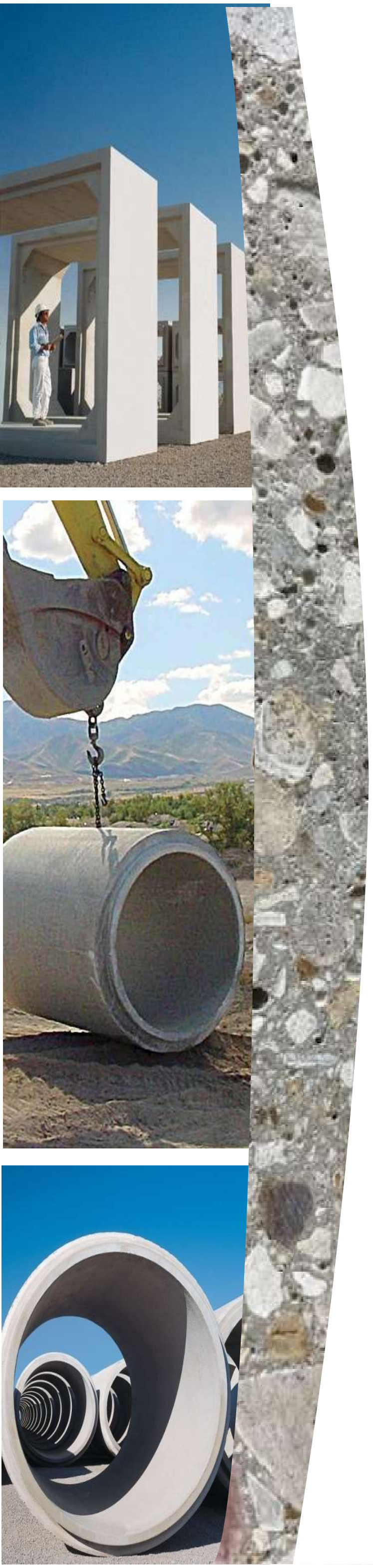


Introduction
to
Self Consolidating Concrete

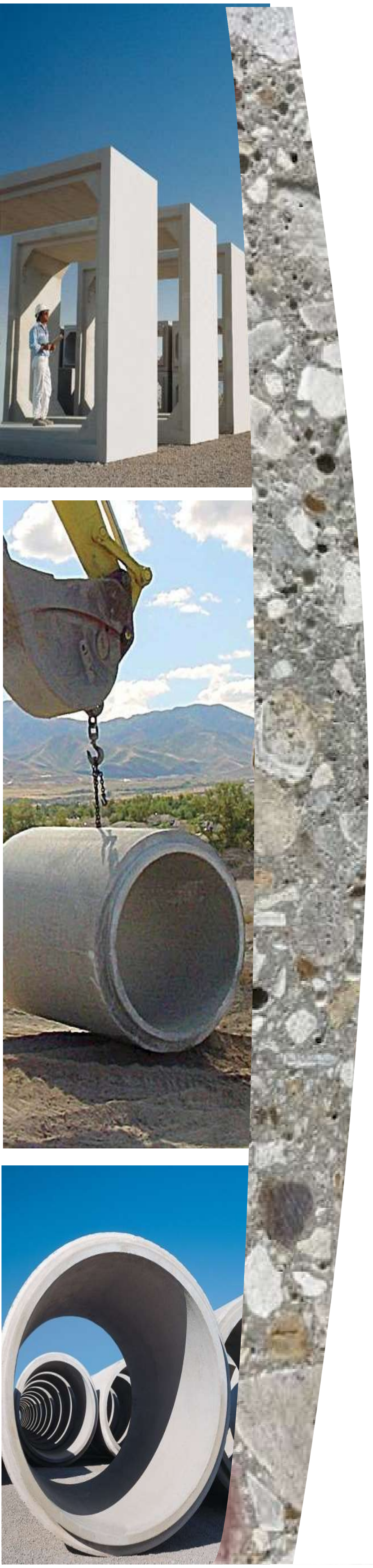
Vartan Babakhanian, PE, FACI

Rinker MATERIALS®
A QUIKRETE® COMPANY



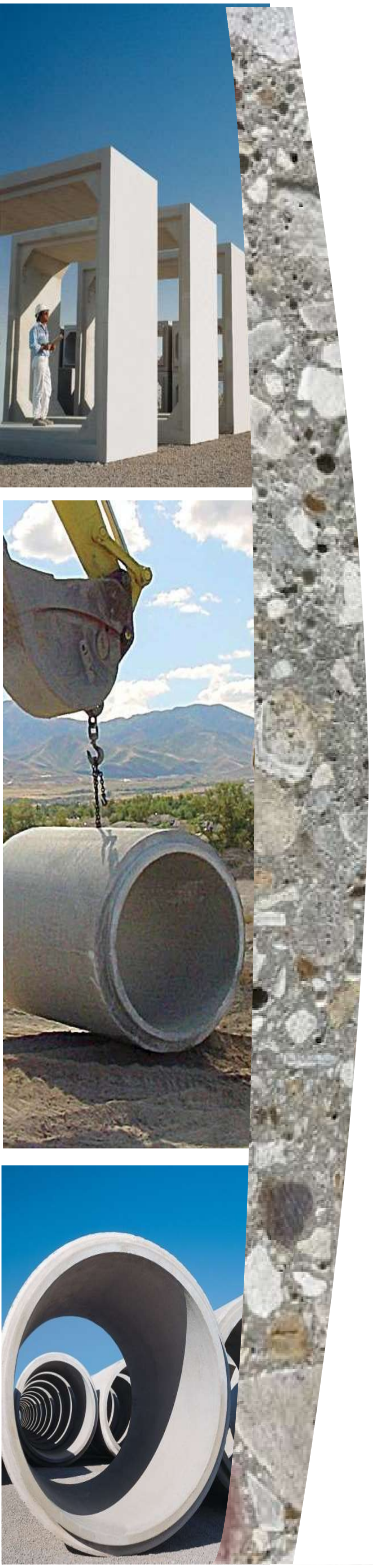
What is Our Main Objective?

- Quality Control / Quality Assurance
- Consistent Concrete
- Quality Concrete
- Cost Savings
- SCC Concrete



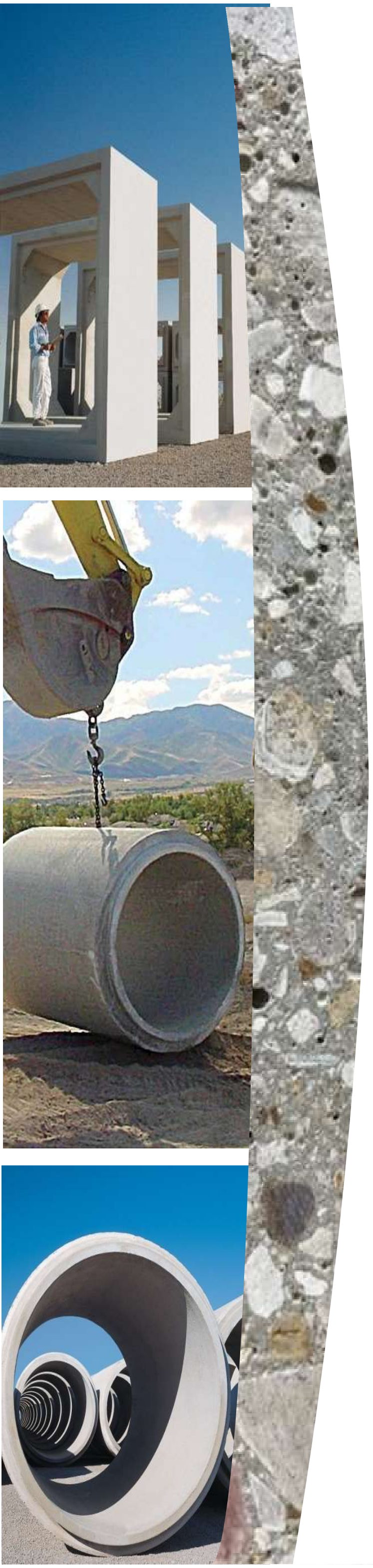
Essential Items for Quality Control

- How do we control our batches?
- How do we control our aggregate moistures?
- How do we manage our aggregate stockpiles?
- When do we load our bins?
- How often do we load our bins?
- How do we get our aggregate sample for moisture?

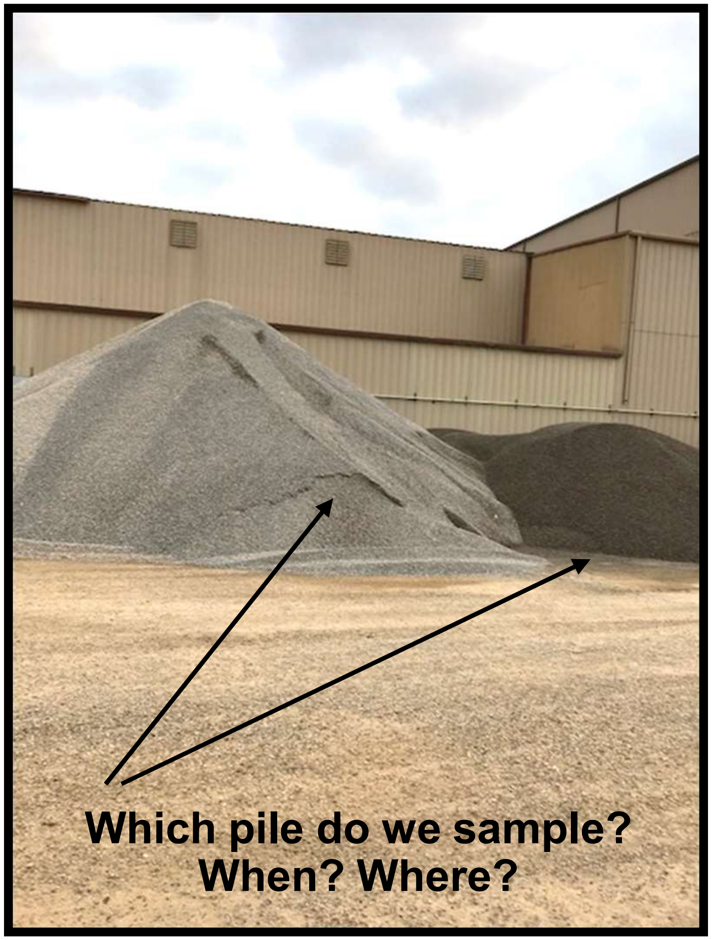


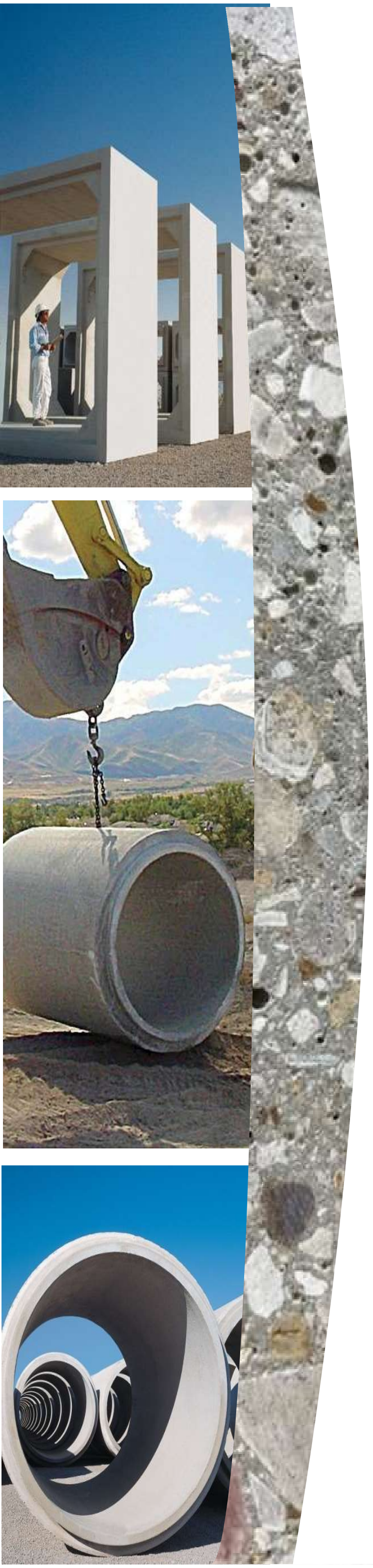
What is Essential for Mix Development?

- Understanding Key Materials Properties
- Concrete Batch Control



How Do We Store Our Aggregates?

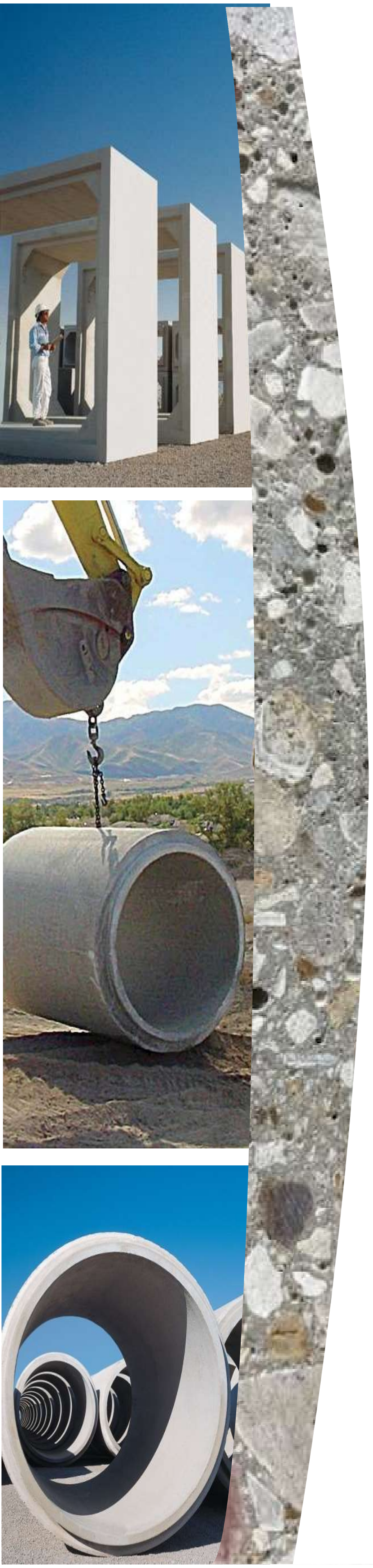




What Can We Do On Rainy Days?

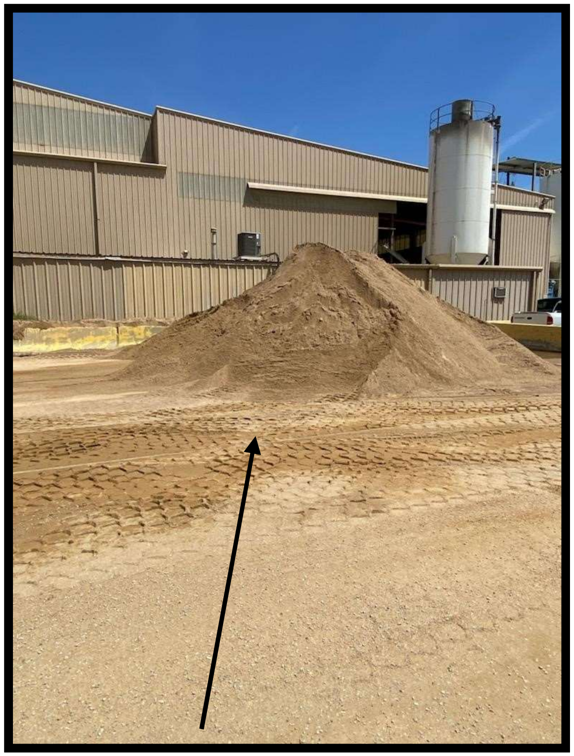
- What can we do about the excess water?

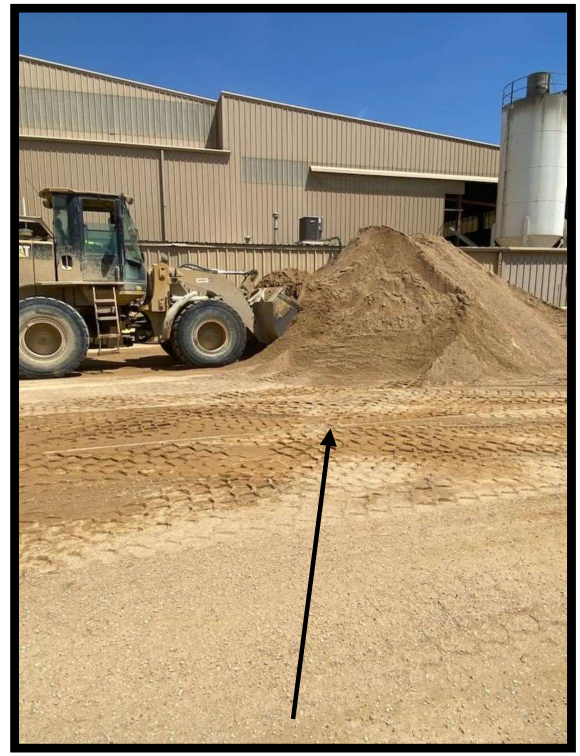
- Suggestion – fix the drainage…



How Do We Store the Aggregates?

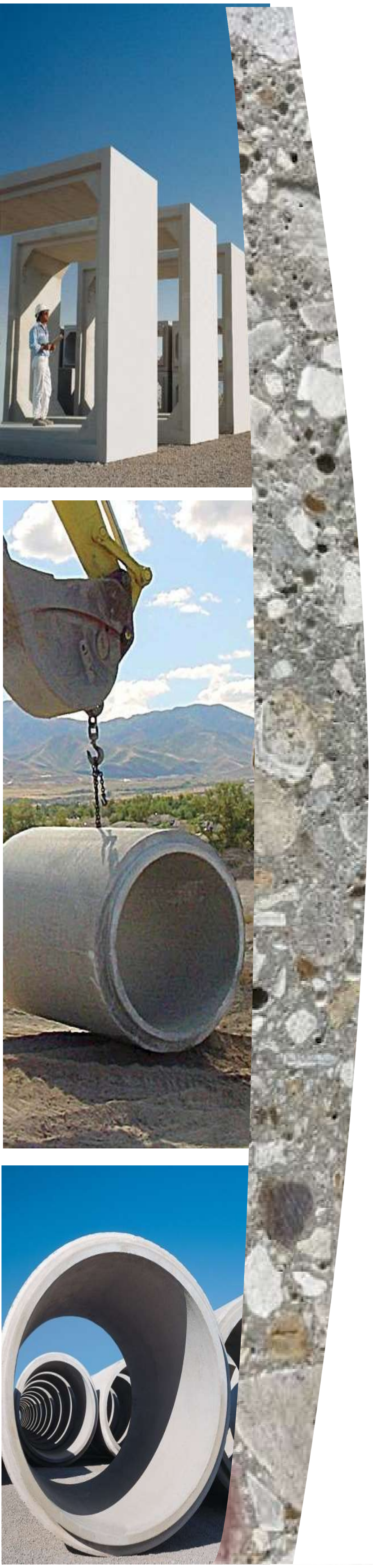
Proper material storage. Perhaps two storages for each material.



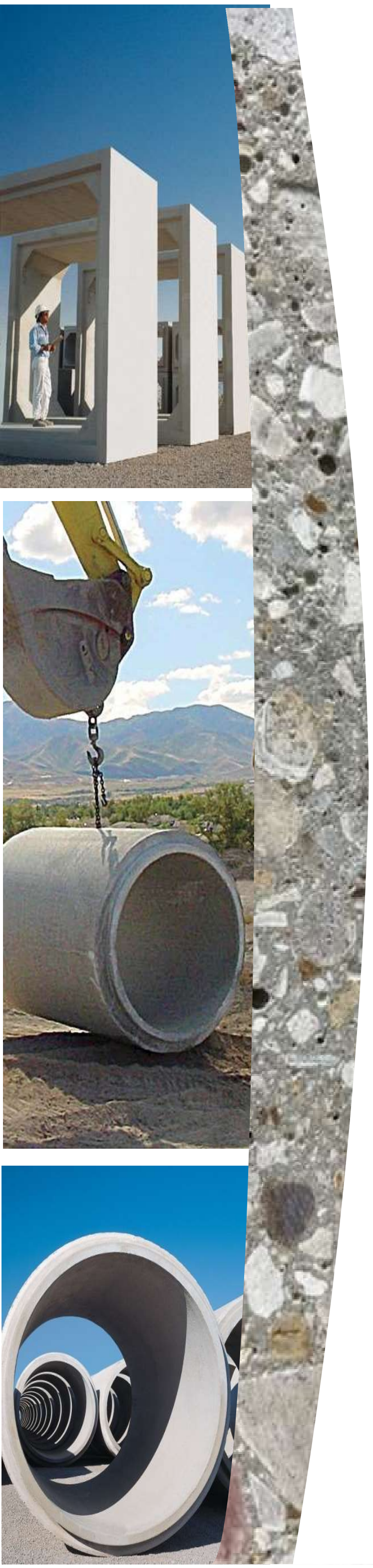


Do you mix & push all your aggregate up with a loader?

How Do We Fill Our Bins & When?



Proper stockpile storage with drainage for materials & two storage for each material.



Fine Aggregates

Lab # Suggested Gradation Date April 10, 2001
Sample Description Natural Sand Project
Source River

FINE AGGREGATE SIEVE ANALYSIS & FINENESS MODULES

Sieve Size	Cumulative Weight Retained		% Retained By Weight	% Passing By Weight	ASTM C33 Specification
3/8"			0		0
1/4"	Optional		1.0		
#4			3.0		0-5
#8			6.0		0-20
#10	Optional		14.0		
#16			27.0		15-50
#20	Optional		40.0		
#30			55.0		40-75
#40	Optional		68.0		
#50			82.0		70-90
#80	Optional		90.0		
#100			96.0		90-98
#200	TX DOT		98..0		97-100
Pan					

Total % Retained = 269.0
Sample Weight =

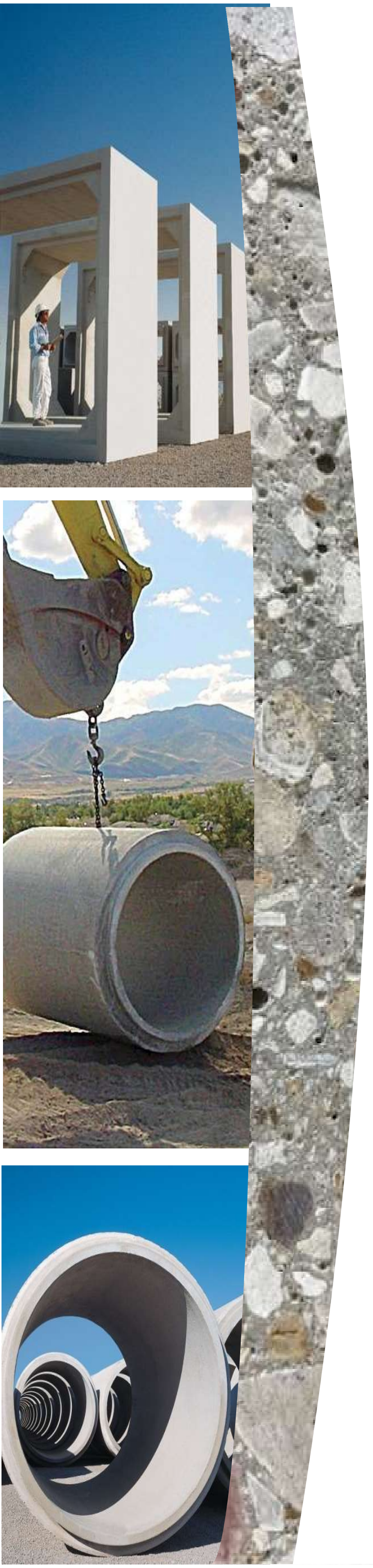
Fineness Modulus, F.M. = The total of the % retained column divided by 100

F.M. = Specification, ASTM = 2.31 to 3.1 $= \frac{269}{100} = 2.69$

-#200 Wash

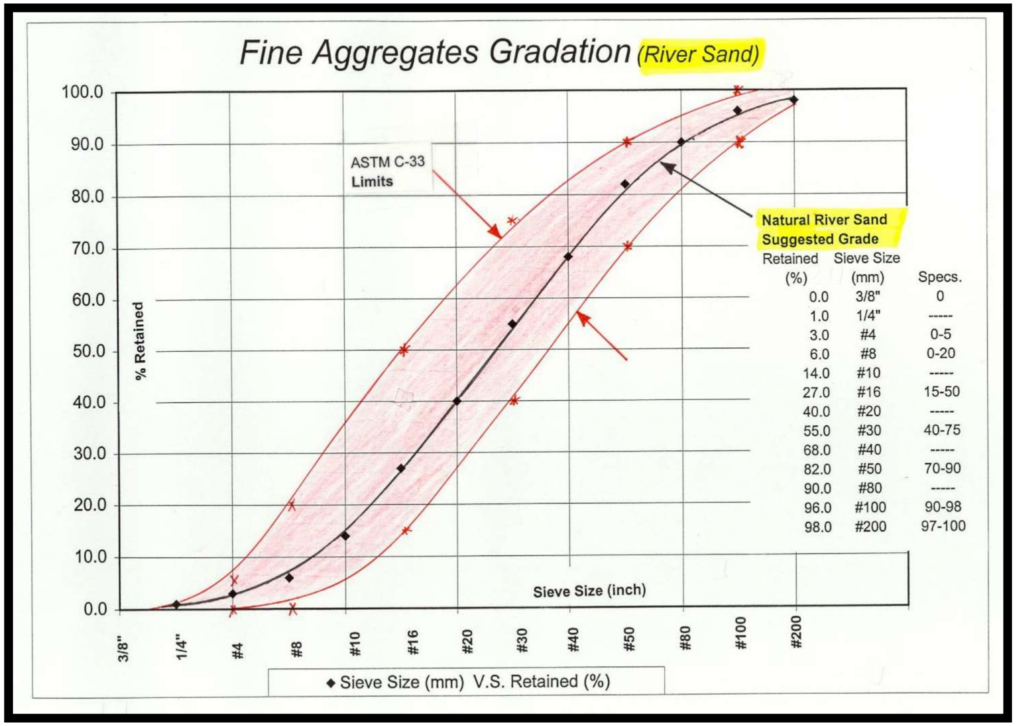
Wt. of Sample Before Washing, B =
Wt. of Sample After Washing C =
B-C = Wt. Of -#200 lost =
% of -#200 lost =

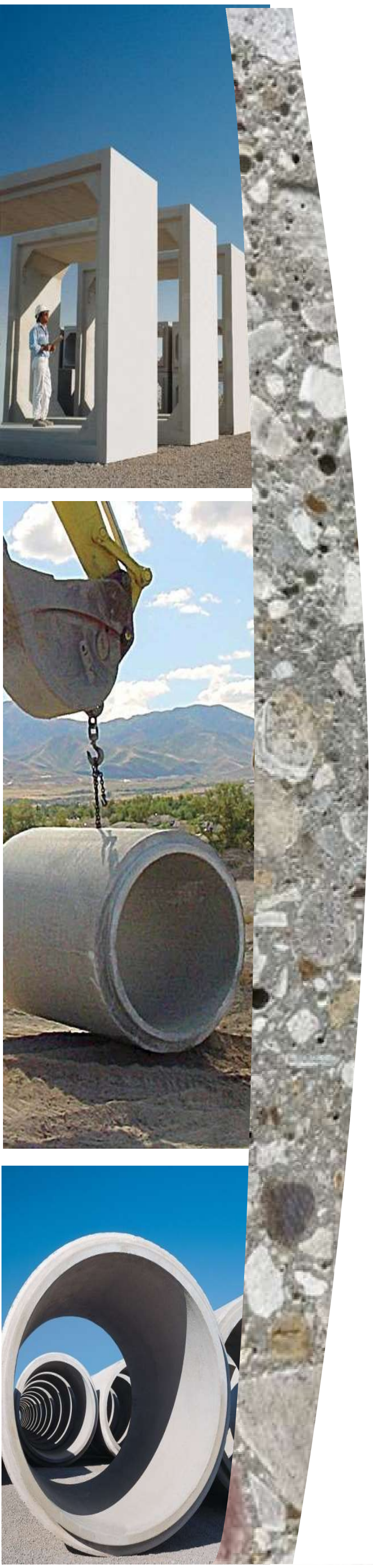
Tested By
Checked By



Fine Aggregates

- Verify specs





Coarse Aggregates

Lab # ______ **Suggested Gradation** Date April 10, 2001

Sample Description ______ ASTM #67 (3/4"-#4) Project ______________

Source ______ Any ______

COARSE AGGREGATE SIEVE ANALYSIS

Sieve Size	Cumulative Weight Retained	% Retained By Weight	% Passing By Weight	ASTM C33 Specs - % Retained: Size 467 (1-1/2" - #4)	Size 57 (1" - #4)	Size 67 (3/4" - #4)
2"				0		
1-3/4"						
1-1/2"				0-5	0	
1-1/4"		**Good Grade**				
1"		**0**			0-5	**0**
3/4"		**7**		30-65		**0-10**
1/2"	Optional	32			40-75	
3/8"		**60**		70-90		**45-80**
1/4"	Optional	85				
#4		**92**		95-100	90-100	**90-100**
#8		**96**			95-100	**95-100**
#10						
#16	Optional	98				
Pan						

There are several aggregate gradings specified in ASTM C-33.

-#200 Wash

Wt. of Sample Before Washing, B = ______________

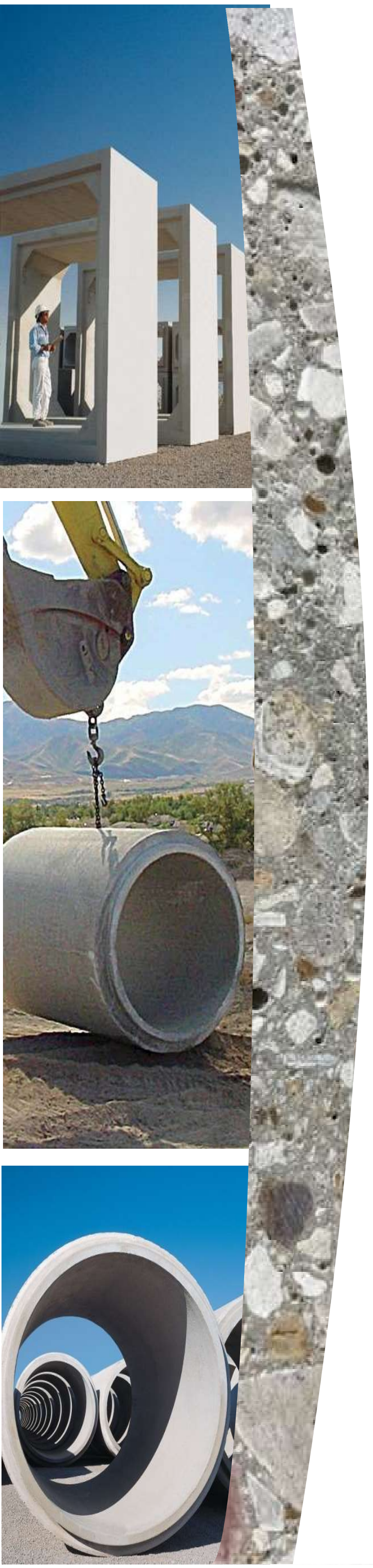
Wt. of Sample After Washing C = ______________

B-C = Wt. Of -#200 lost = ______________

% of -#200 lost = ______________

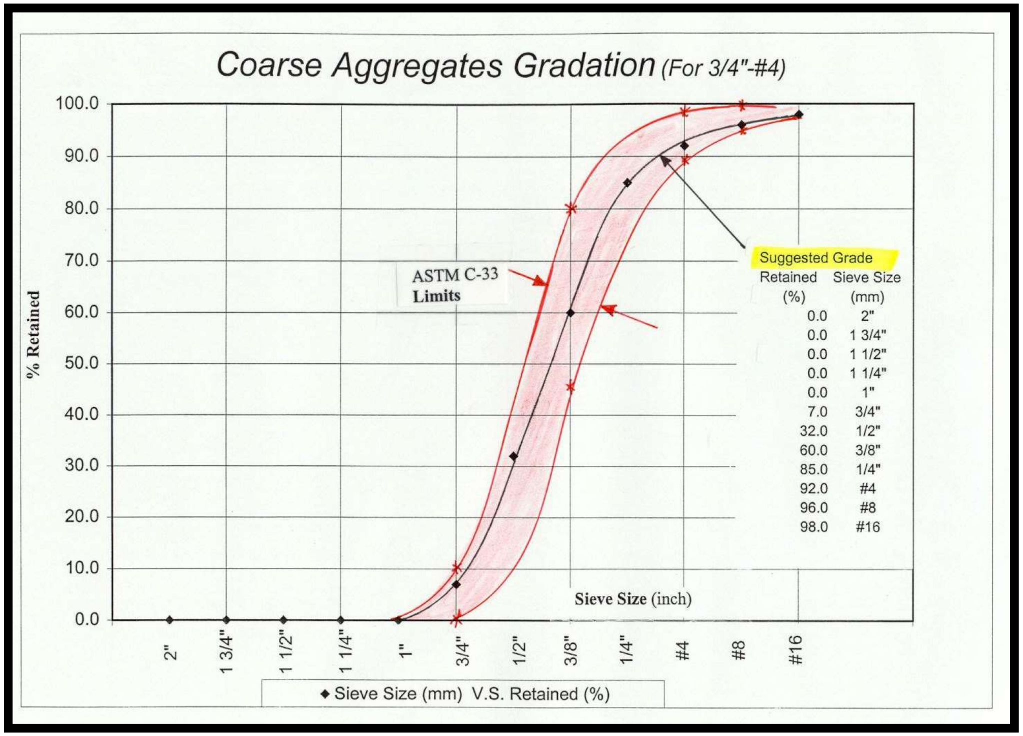
Tested By ______________

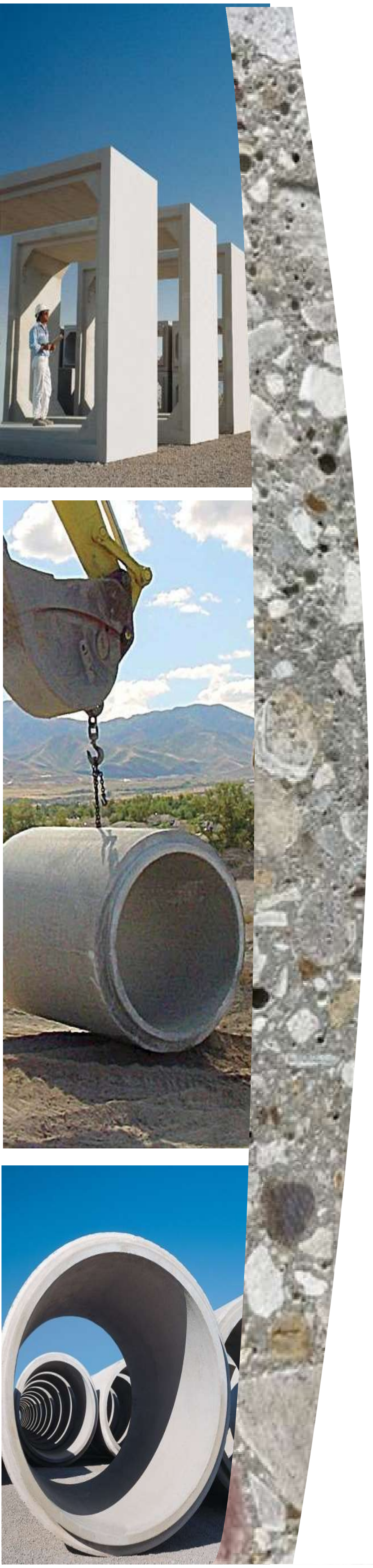
Checked By ______________



Coarse Aggregates

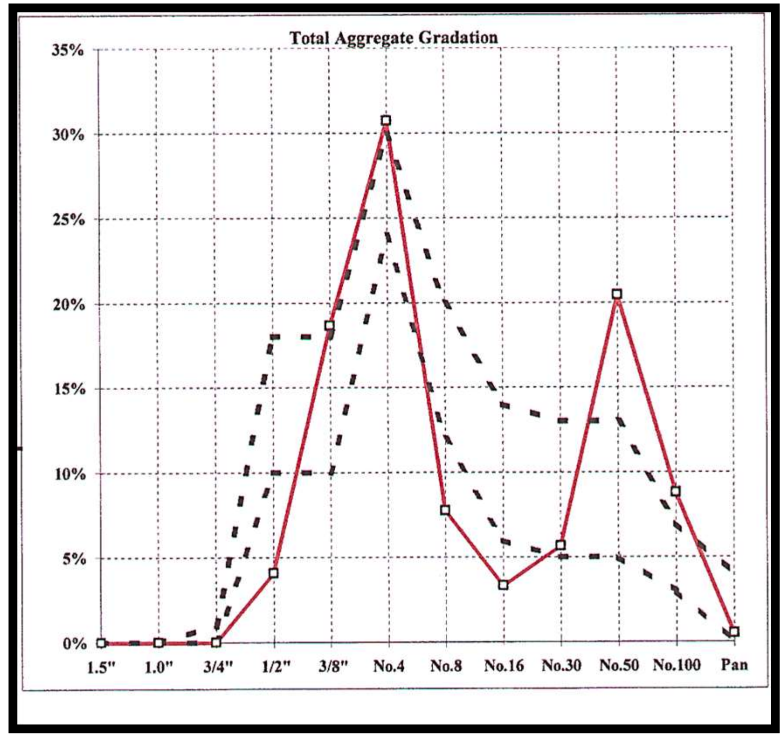
- Verify specs

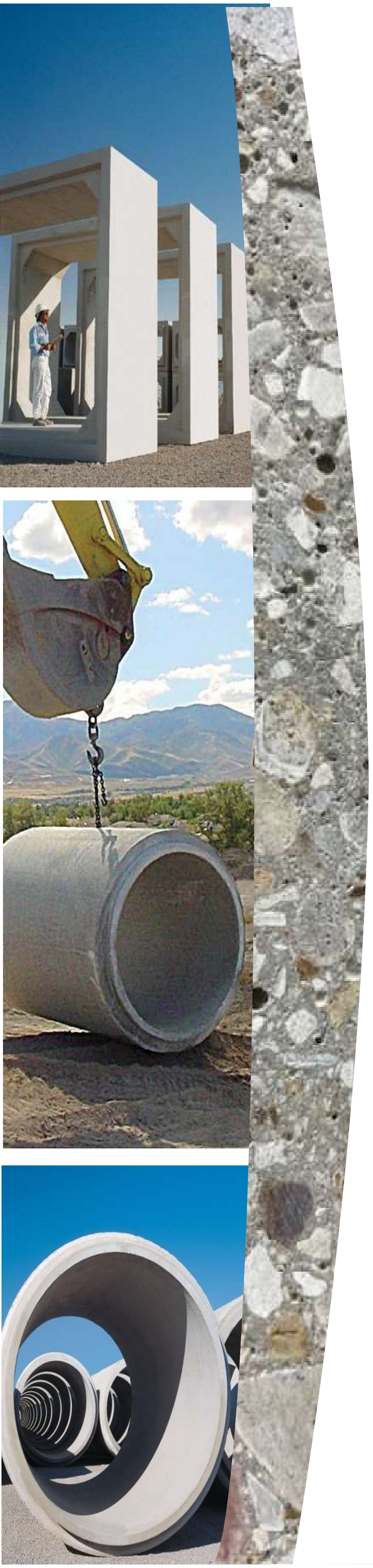




Aggregates Gradation

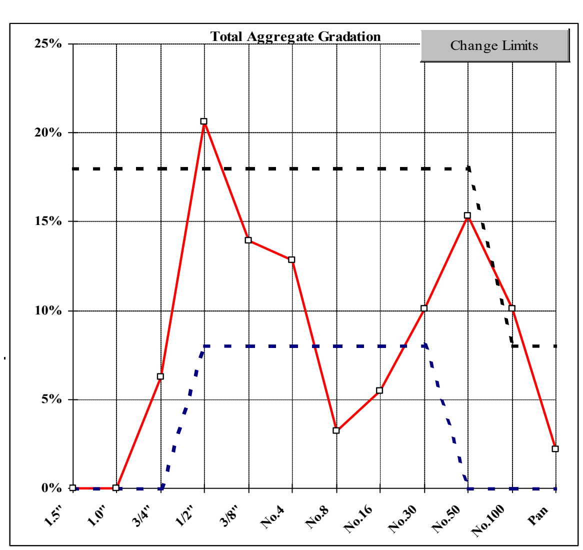
- Many coarse aggregates available in North America are Gap Graded, and thus have low volumes of No. 8 and No. 16 sieve size particles
- The optimized grading curve for SCC is much tighter than for conventional concrete
- Optimizing mix packing density is critical for many SCC mixes, so it is may be necessary to blend aggregate sources

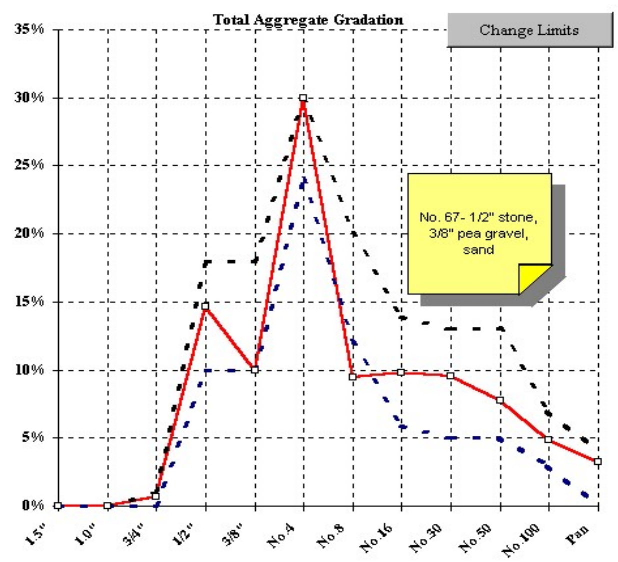




Aggregate Grading

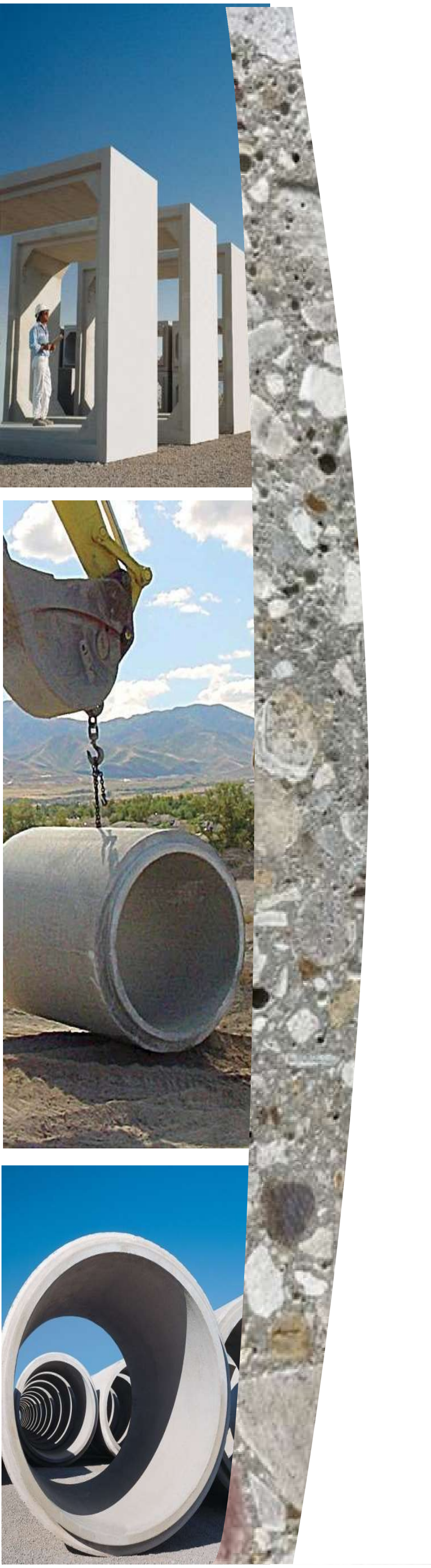
- An example of a typical #57 blend, indicating a Gap Graded Aggregate

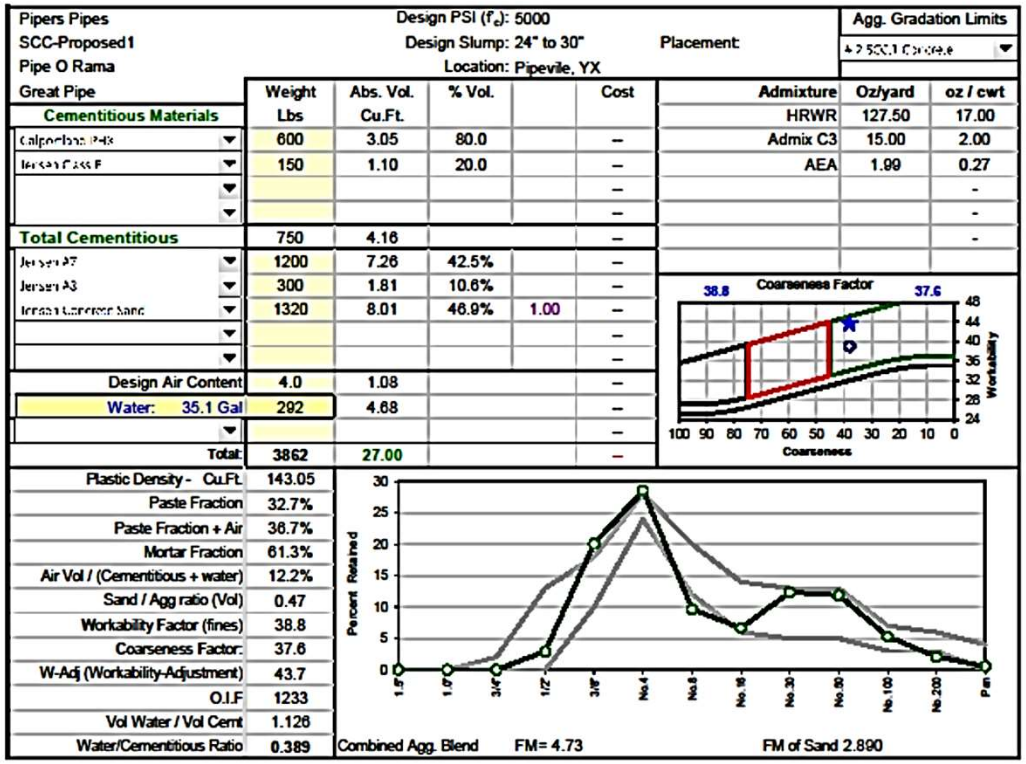




An optimized SCC aggregate gradation with blended aggregates.

Optimize Aggregate Gradation





Pipers Pipes
SCC-Proposed1
Pipe O Rama
Great Pipe

Design PSI (f'_c): 5000
Design Slump: 24" to 30"
Location: Pipevile, YX

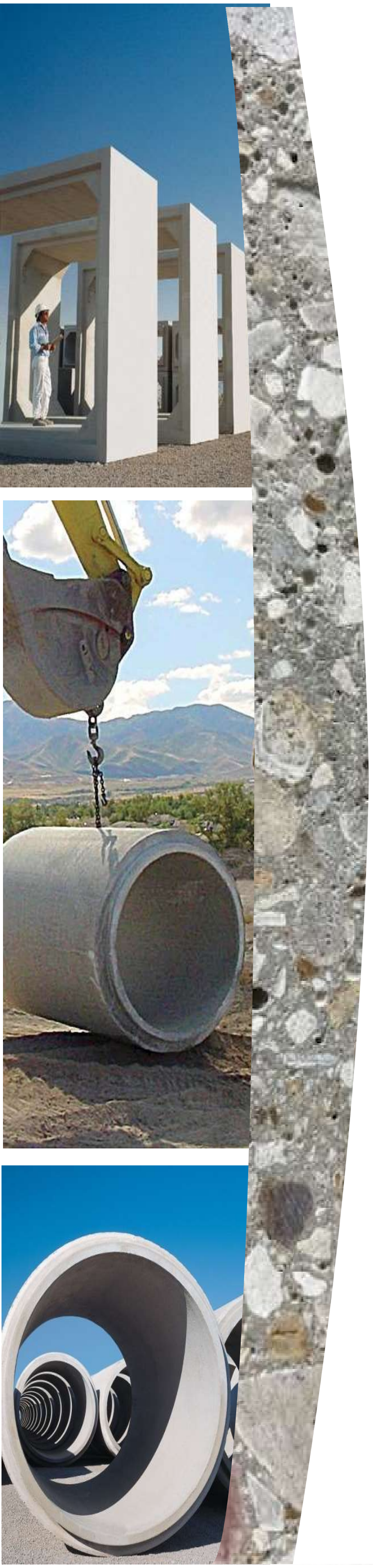
Placement

Agg. Gradation Limits

Cementitious Materials	Weight Lbs	Abs. Vol. Cu.Ft.	% Vol.		Cost
[illegible]	600	3.05	80.0		–
[illegible]	150	1.10	20.0		–
					–
					–
Total Cementitious	750	4.16			–
Jersen A7	1200	7.26	42.5%		–
Jersen A3	300	1.81	10.6%		–
[illegible]	1320	8.01	46.9%	1.00	–
					–
					–
Design Air Content	4.0	1.08			–
Water: 35.1 Gal	292	4.68			–
					–
Total:	3862	27.00			–

Admixture	Oz/yard	oz / cwt
HRWR	127.50	17.00
Admix C3	15.00	2.00
AEA	1.99	0.27
		-
		-
		-

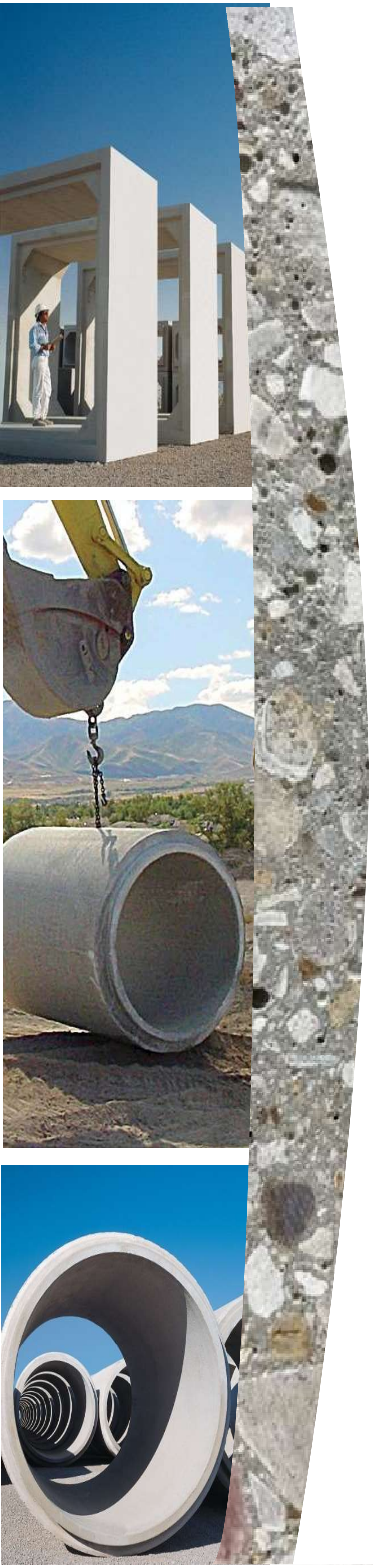
Plastic Density - Cu.Ft.	143.05
Paste Fraction	32.7%
Paste Fraction + Air	36.7%
Mortar Fraction	61.3%
Air Vol / (Cementitious + water)	12.2%
Sand / Agg ratio (Vol)	0.47
Workability Factor (fines)	38.8
Coarseness Factor:	37.6
W-Adj (Workability-Adjustment)	43.7
O.I.F	1233
Vol Water / Vol Cemt	1.126
Water/Cementitious Ratio	0.389

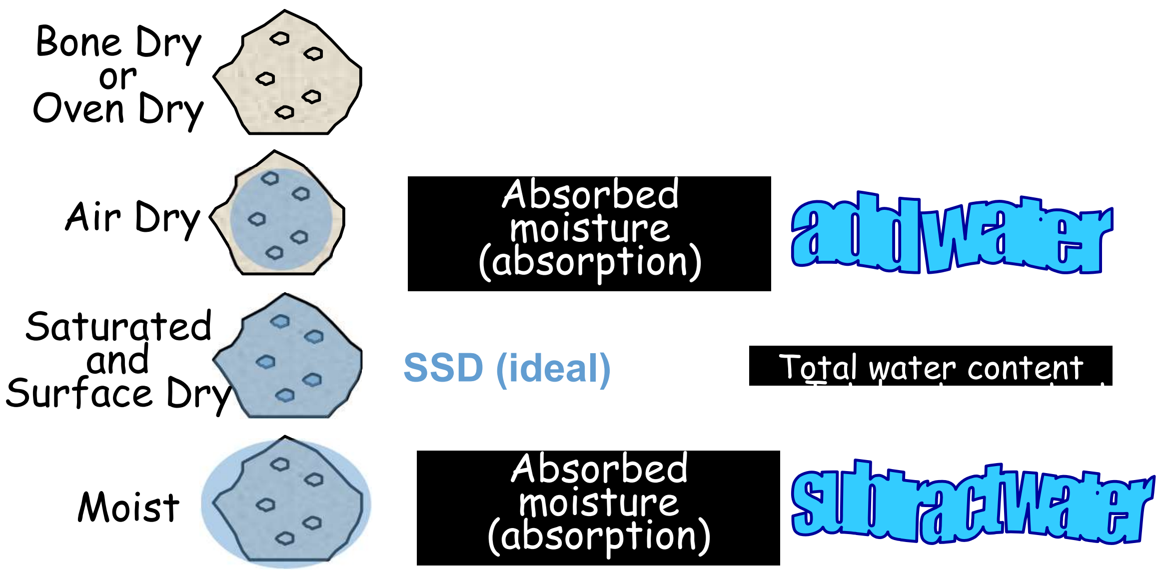


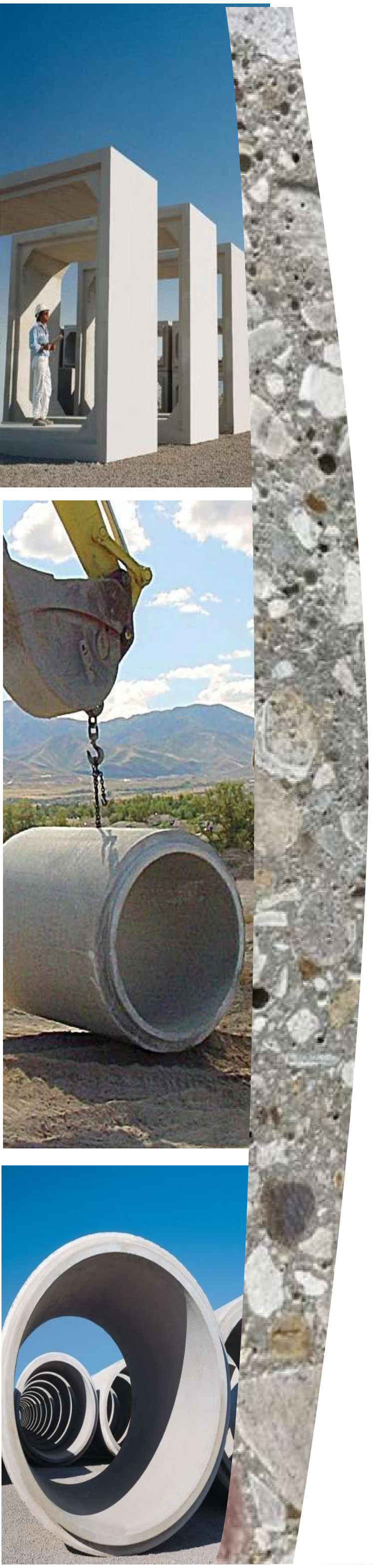
Aggregates, Cement, and Fly Ash – What to Check

- **Moisture Content of Aggregates** – More often for higher slump flows & when weather changes occur
- **Gradation and Void Content of Aggregates**
- **Cement & Fly Ash Fineness** – Blaine or % Passing #325 sieve
- **Slump or Flow VSI, and T20** – Sharp changes are an indication that something has changed in the yield and/or viscosity of the mixture and is usually attributed to changes in water content

Moisture Content & Absorption







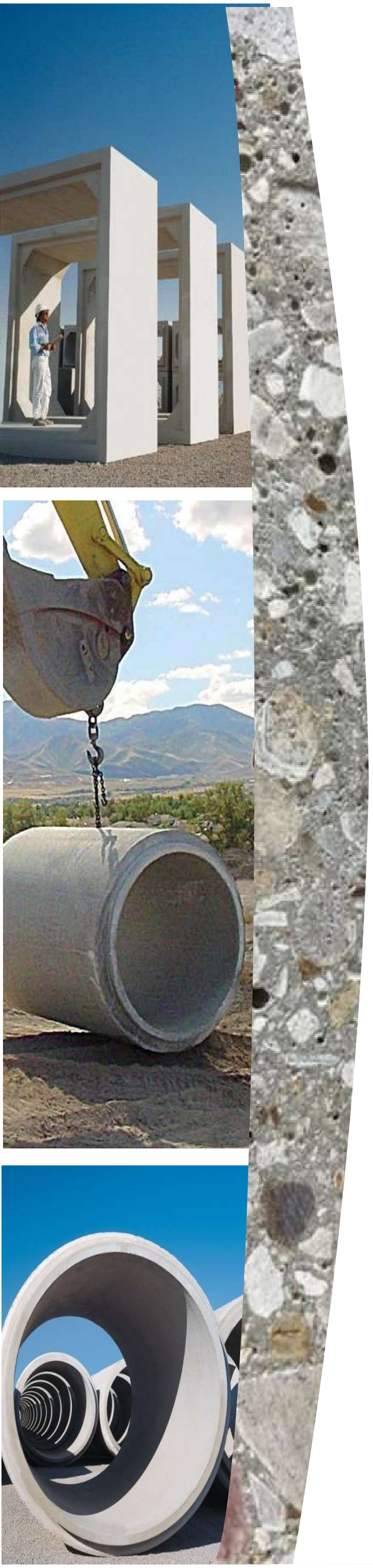
How will Moisture Effect Slump & Slump Impact on Consolidation Effort

2" Slump

5" Slump

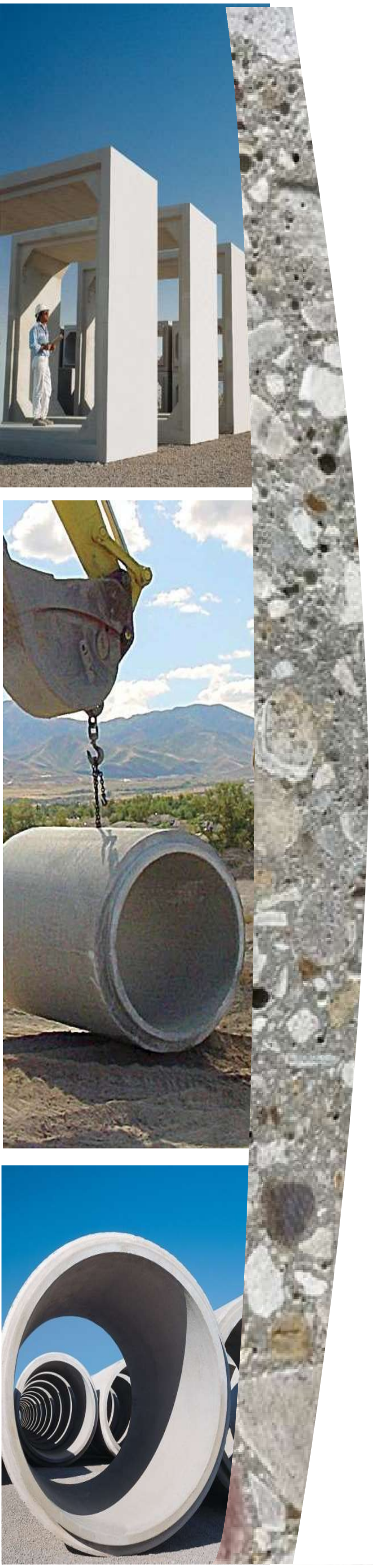
7" Slump

10" + Slump



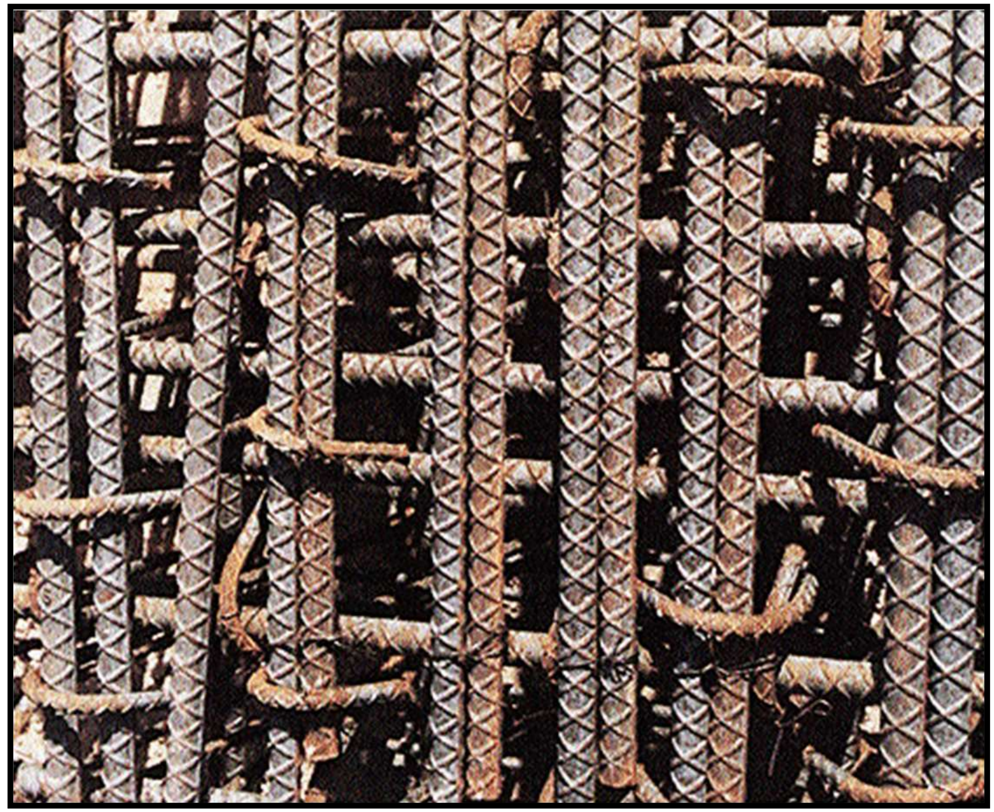
Internal Vibration

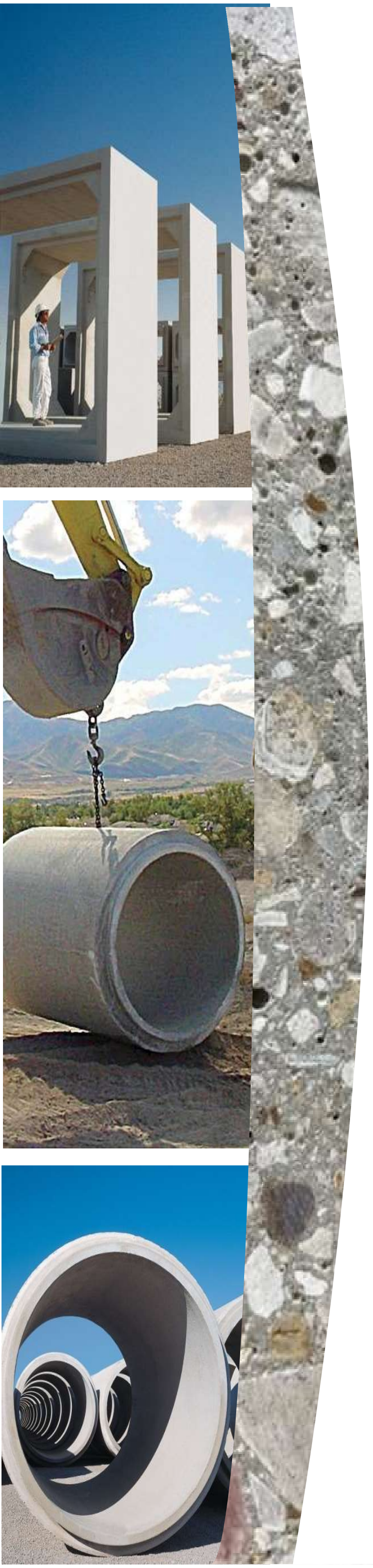
- Let's think about our choices
- Physical Labor
- Equipment
- Time
- Cost



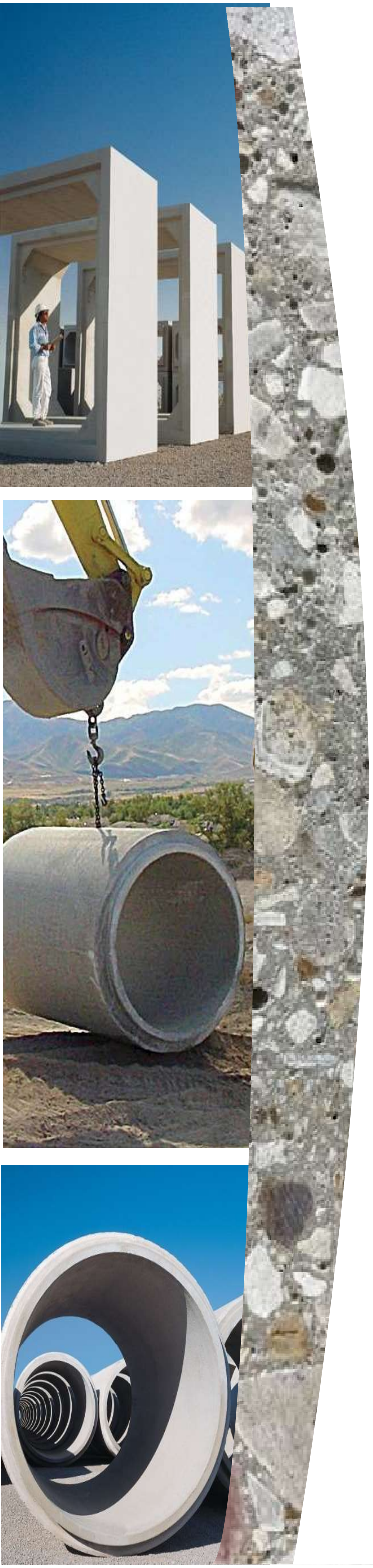
Concrete Mix Design?

- Slump?
- Flow?
- Consolidation Effort!
- Cost Saving!
- Surface Finish!

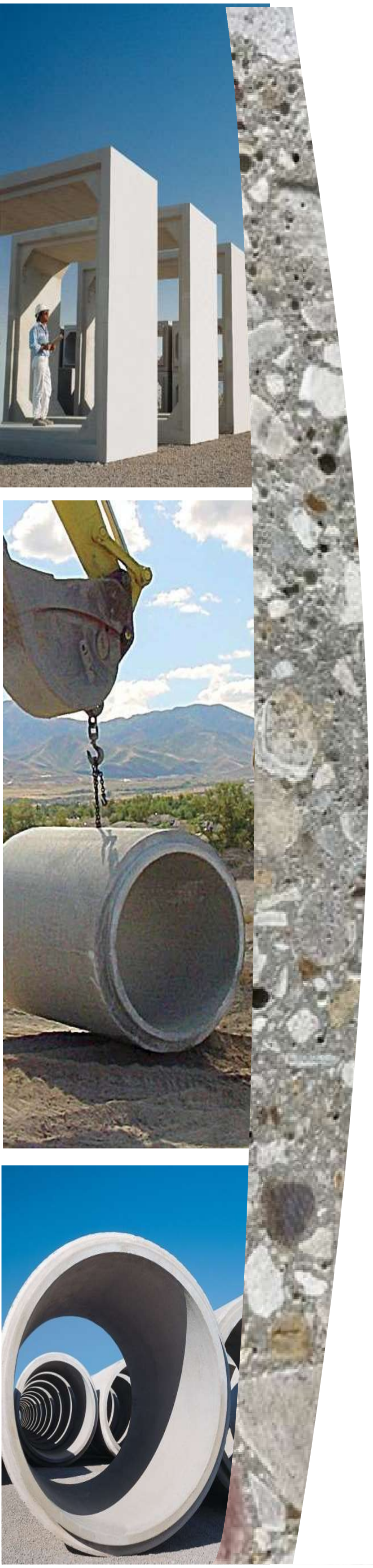




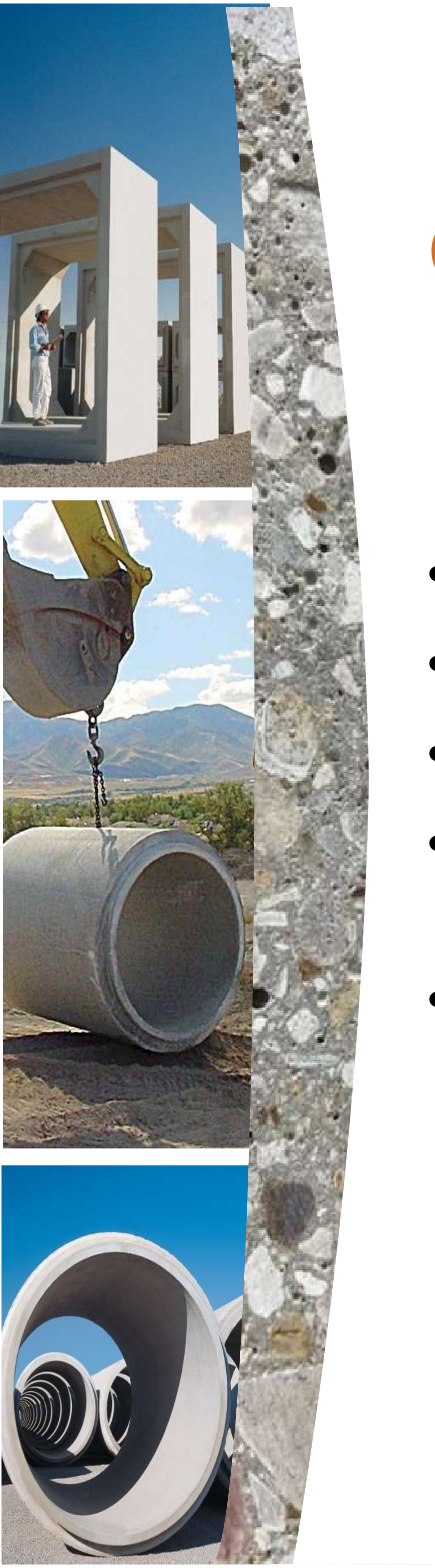
Will Concrete Slump or Flow Affect the Finished Product?



Concrete Slump, Consolidation Effort & Surface Finish



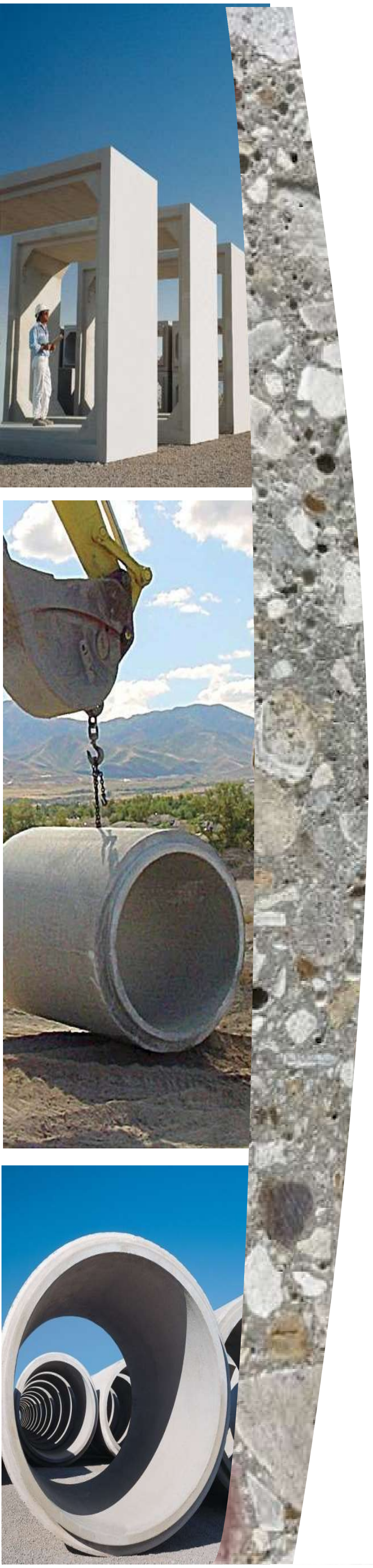

Any
Questions

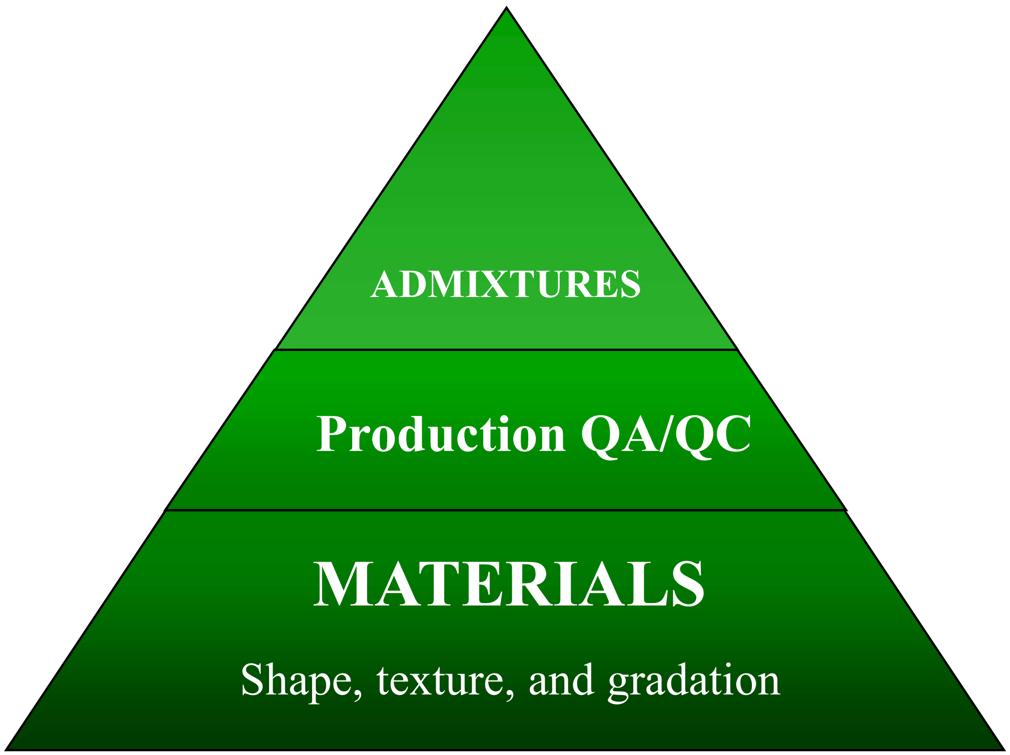


Developing Self Consolidating Concrete

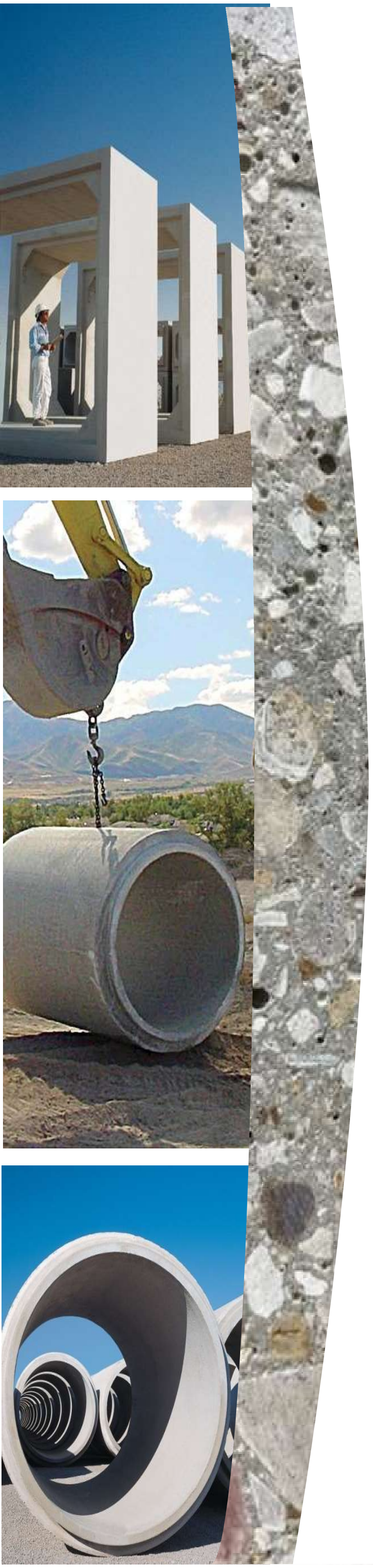
- What is SCC
- Terminology
- Applications for SCC
- How are SCC mixes developed
- What are the testing methods

SCC Technology and Practice – SCC Mixes



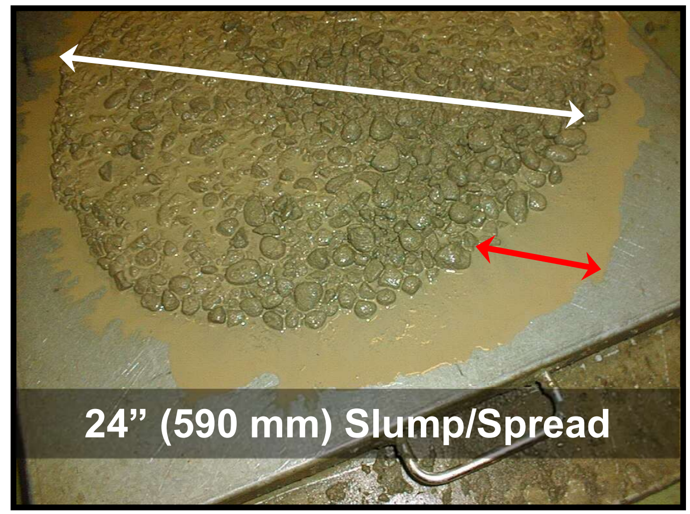


Mixture Proportioning Process

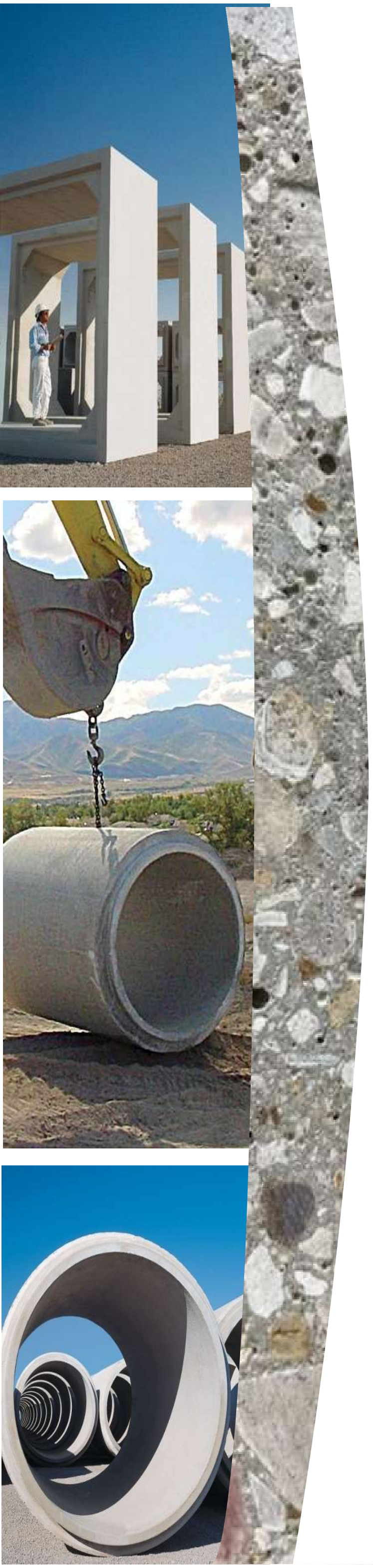


What is SCC?

- SCC is more than flowable concrete
- It is a highly engineered fluid with unique Rheological properties



This is not SCC. You cannot just add water or admix and get SCC.



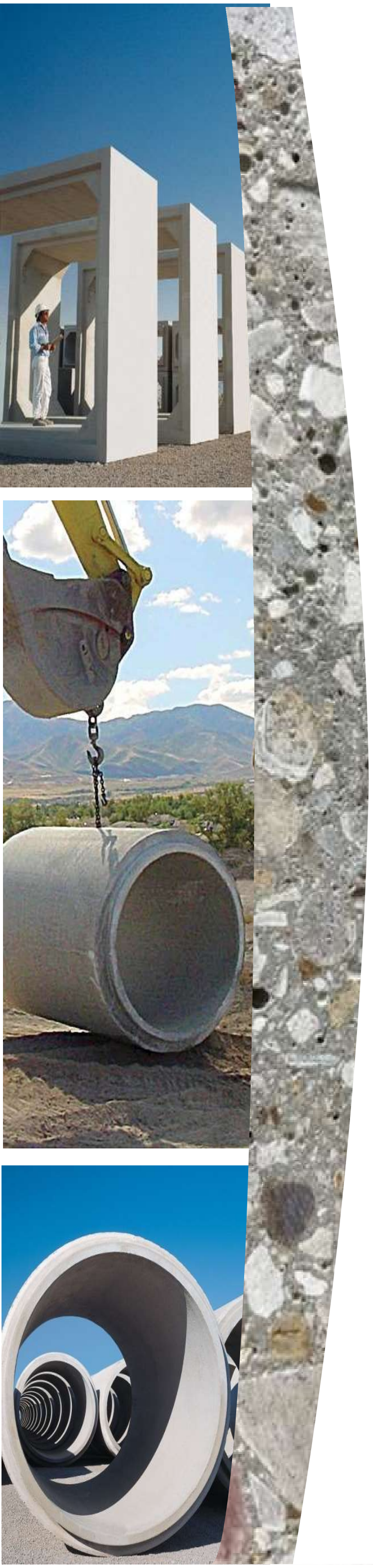
What is SCC? What Is It Designed For?

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.

Will it work for you?

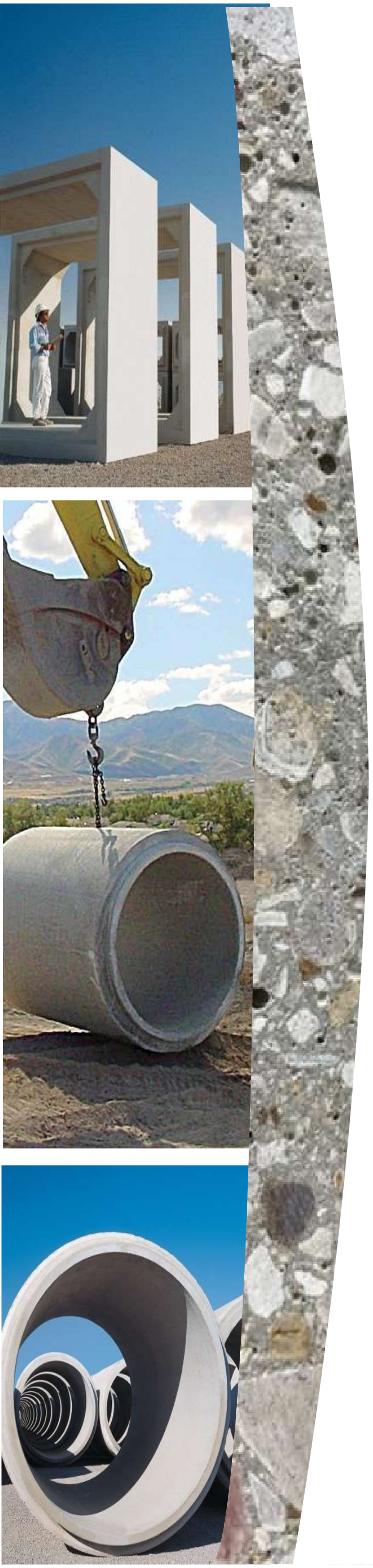
For your production and form?

ACI 237



Another Example of SCC Flow

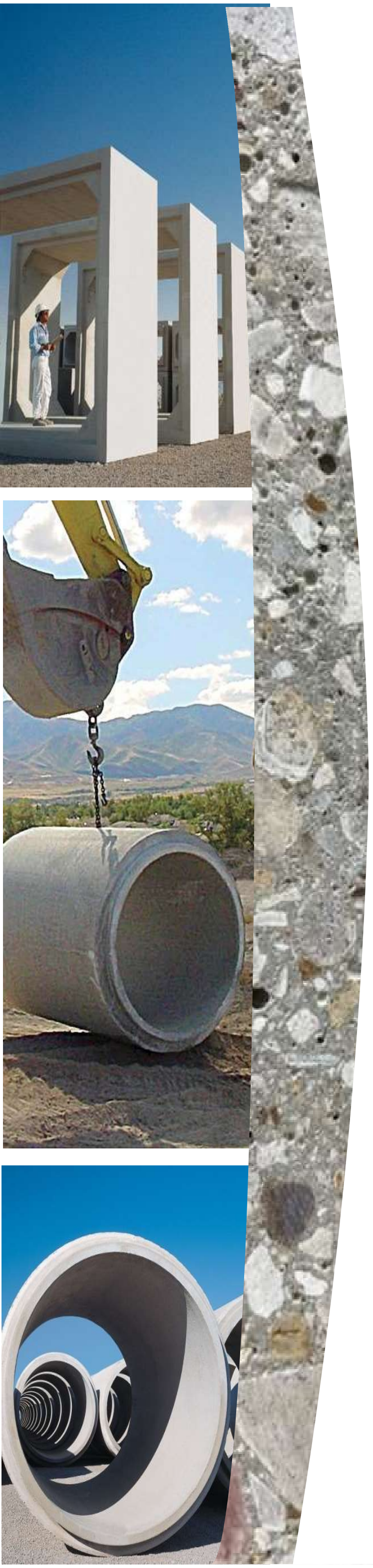
And Another…



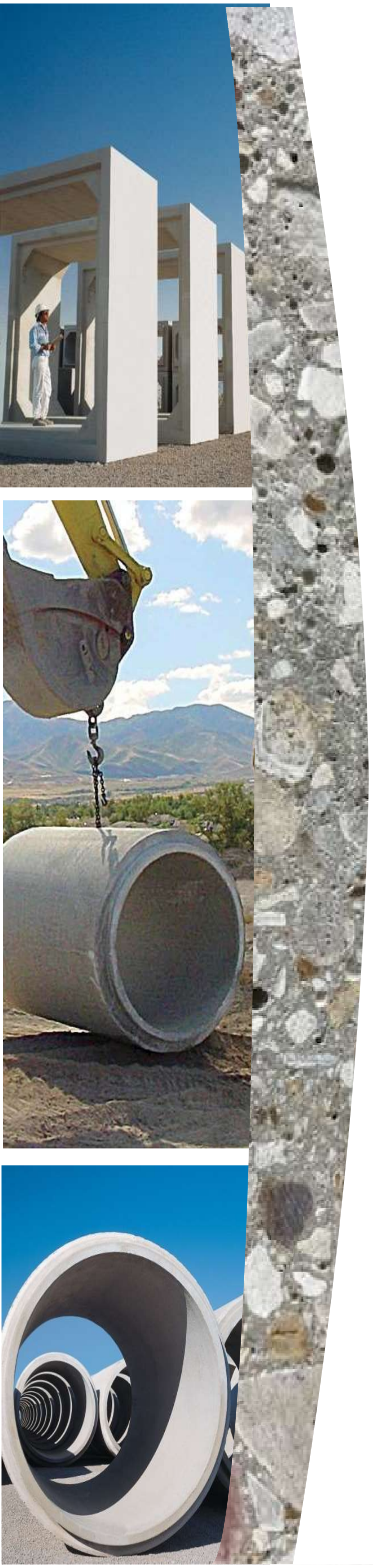
How Does SCC Work?

SCC fills the formwork without vibration and with a significant reduction in labor

What this means is that SCC is *much* more than flowable concrete

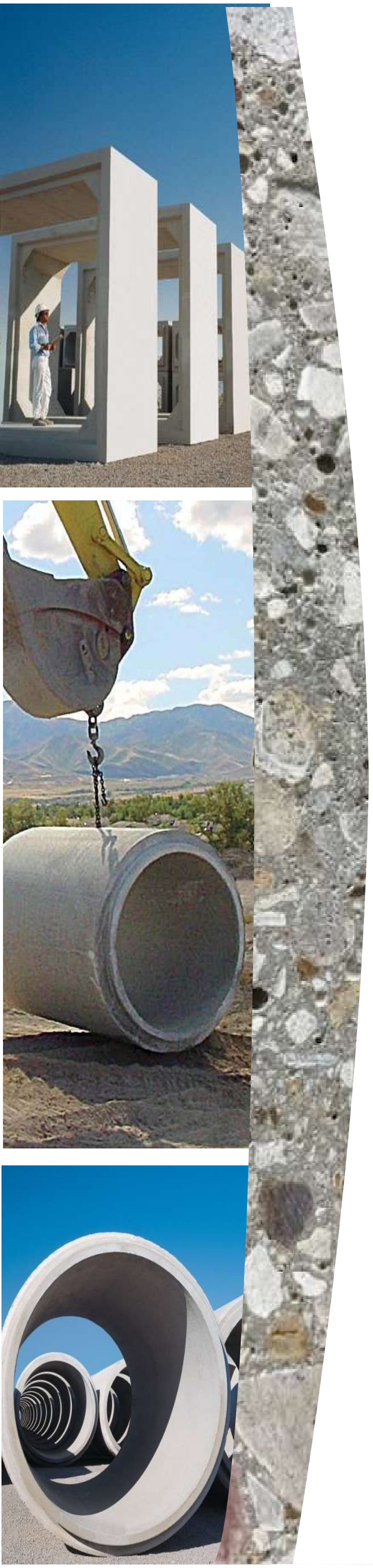


SCC – Flowing Concrete



SCC Terminology

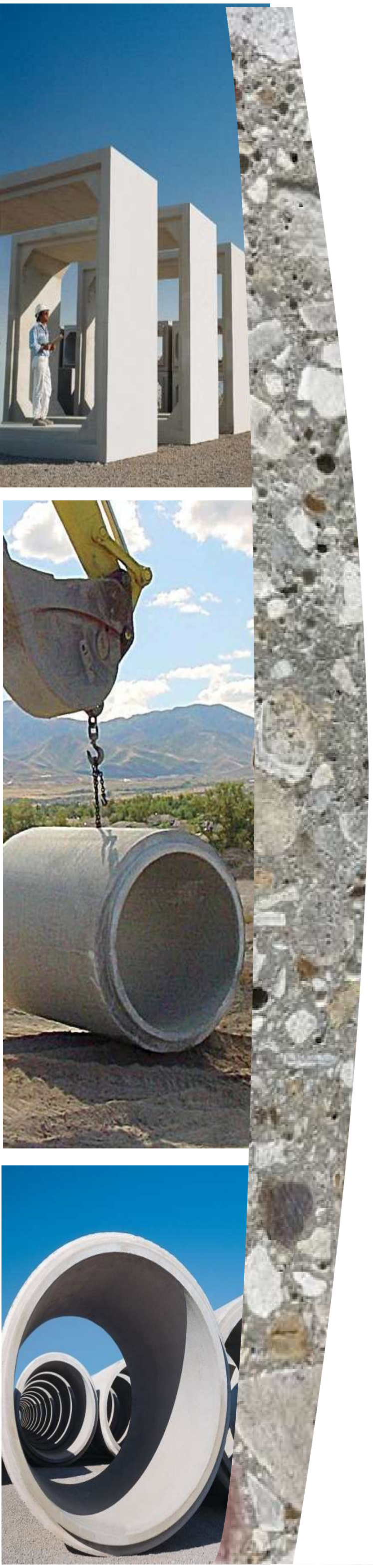
- Rheology
- Viscosity
- Thixotropy
- And more…



Rheology

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.

Cement and Concrete Terminology, ACI Publication SP-19

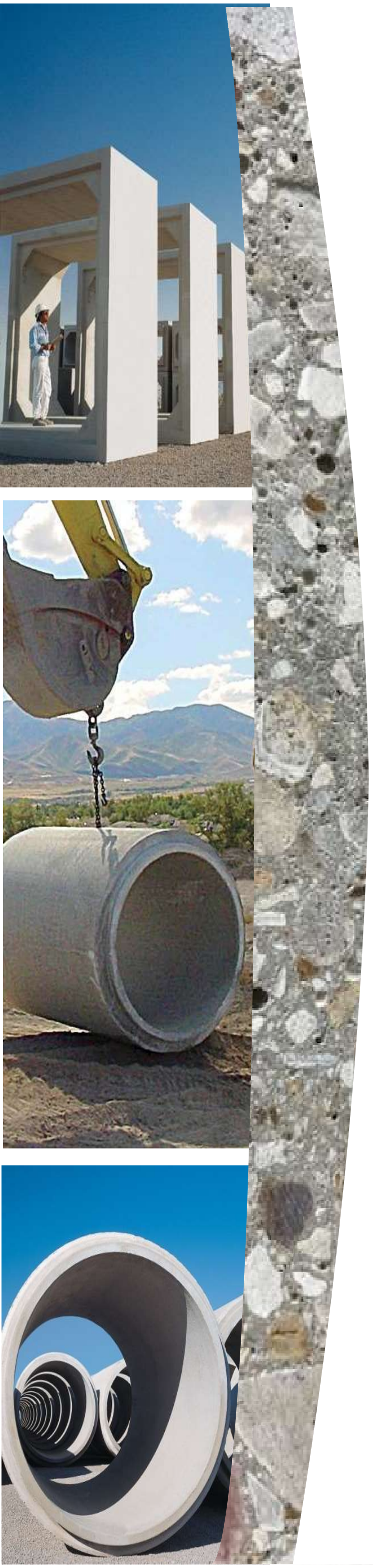


Viscosity

The property of a material which resists change in the shape or arrangement of its elements during flow, and the measure there of Cement and Concrete Terminology.

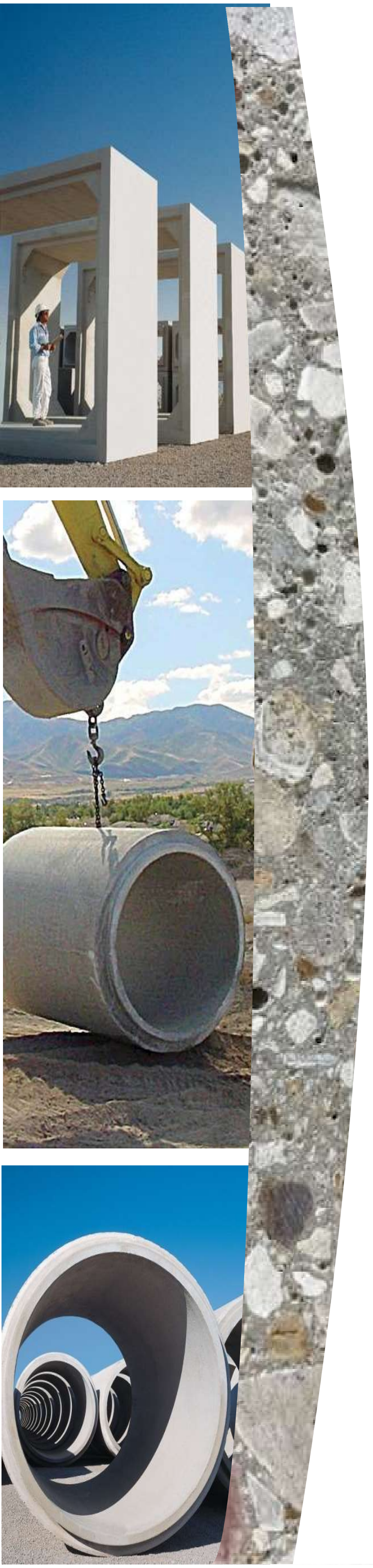
Honey is more viscous than water

ACI Publication SP-19



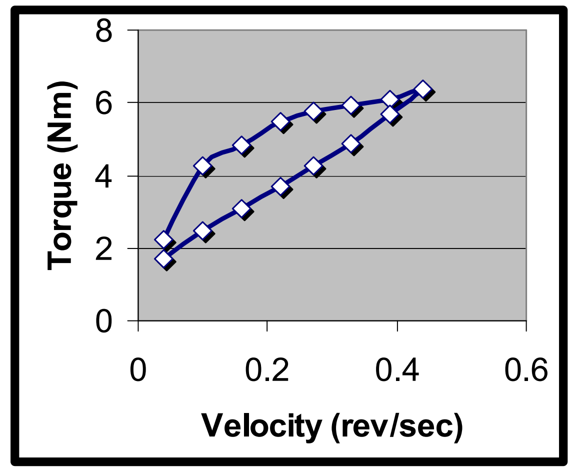
Thixotropy

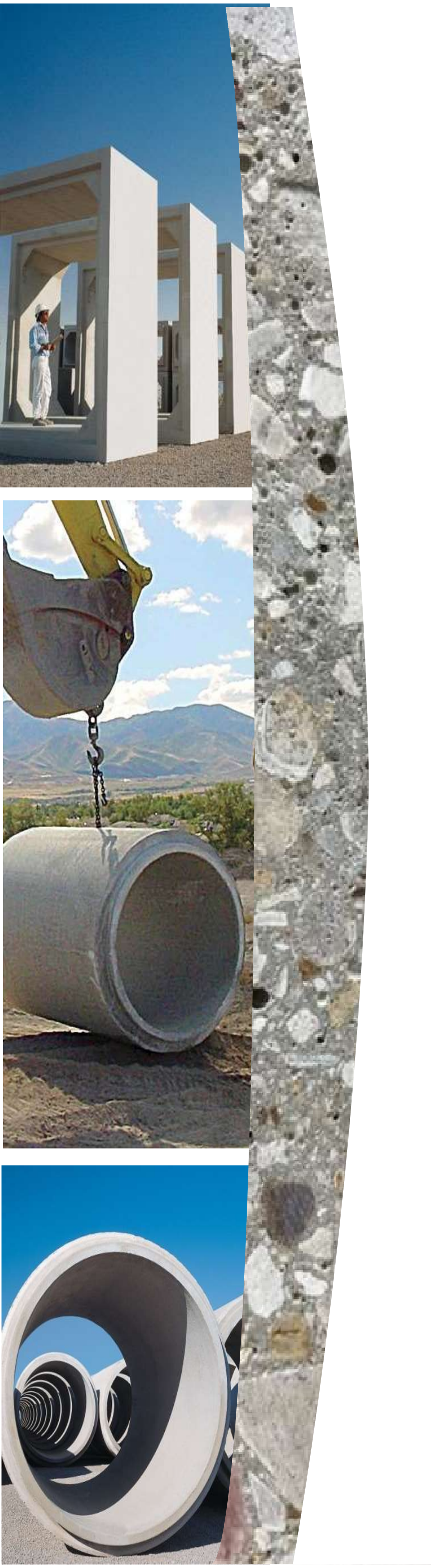
- The tendency of a material to act as a semi-solid (gel) at rest, and a fluid while in motion.
- A material is said to have thixotropic properties when it exhibits a decrease in viscosity with time when the material is subjected to a constant shearing stress.



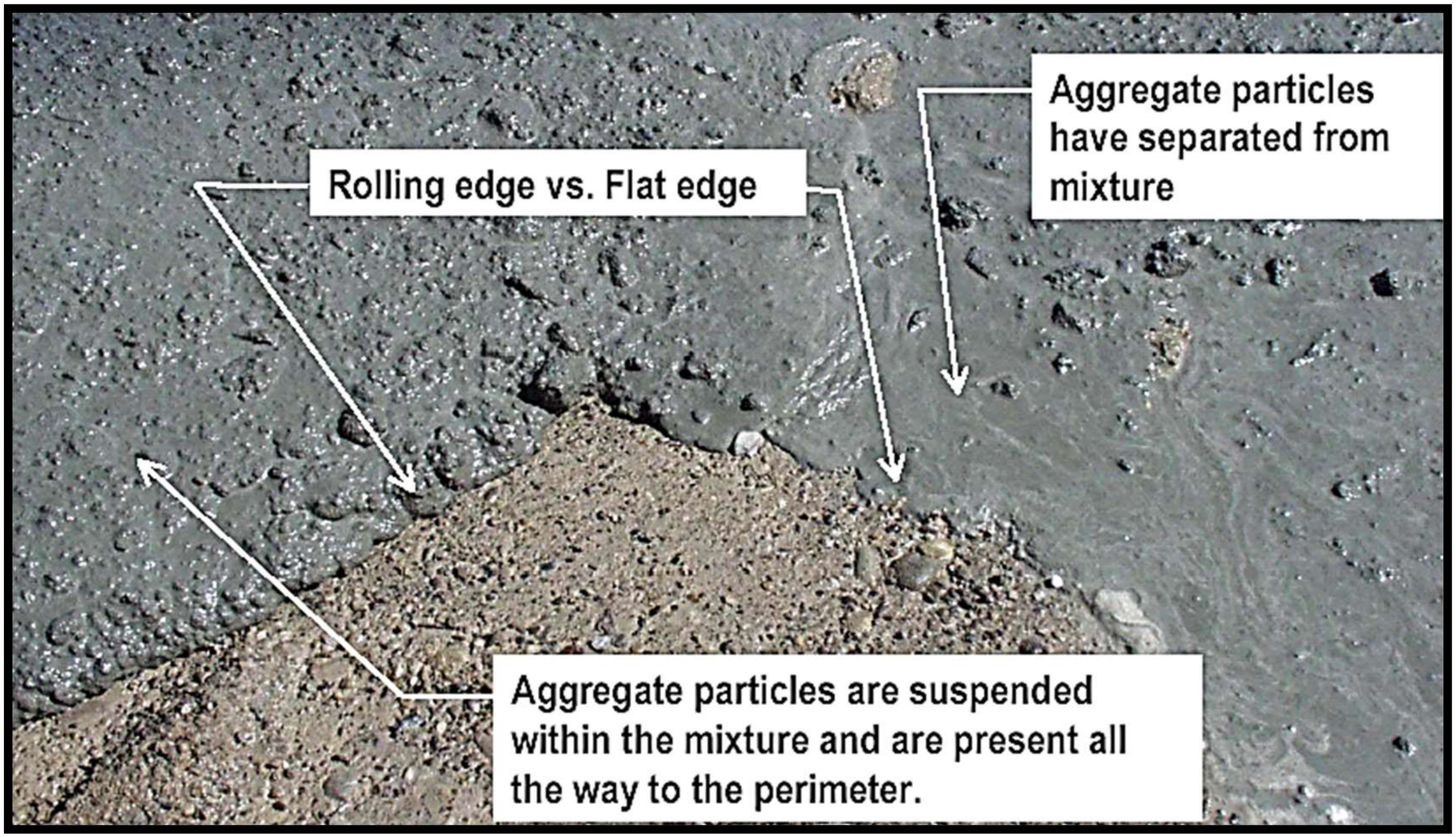
Rheology

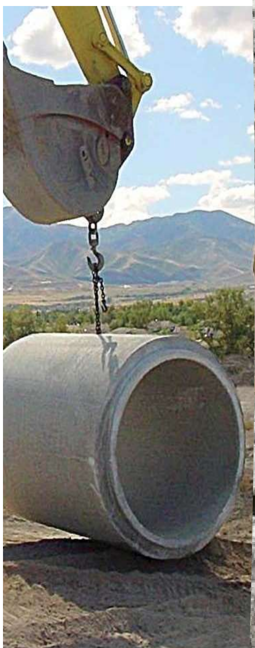
- Targets for SCC Mixes
- Static YIELD STRESS (t_0)
    - Low enough that concrete will flow under own weight
- VISCOSITY (m)
    - Low enough to allow flow
    - High enough to prevent segregation





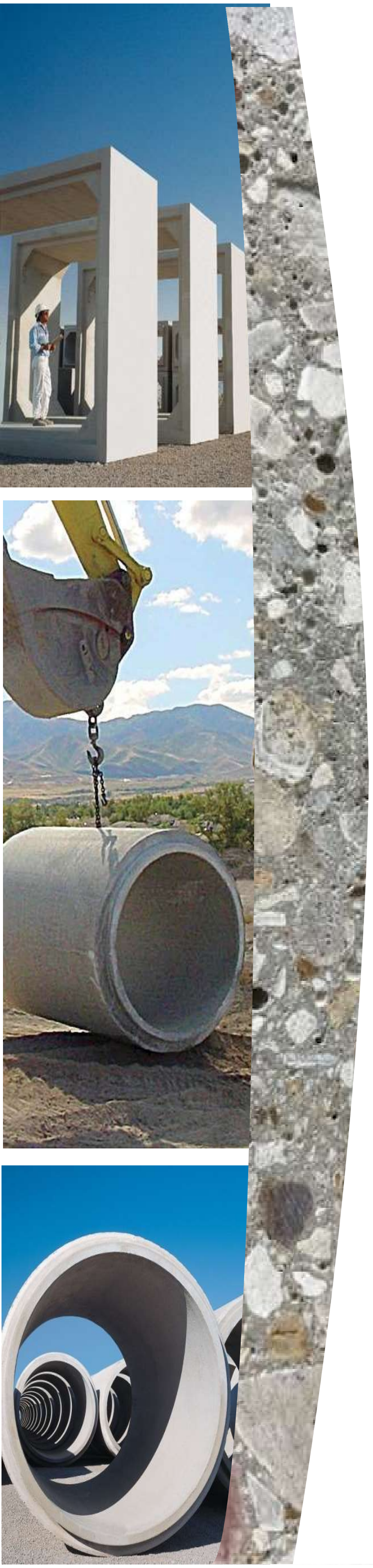
SCC: Rheology and Stability

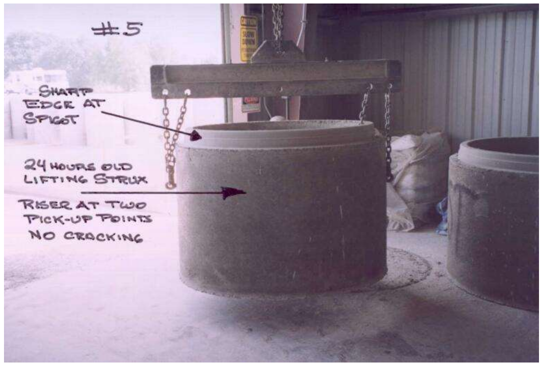


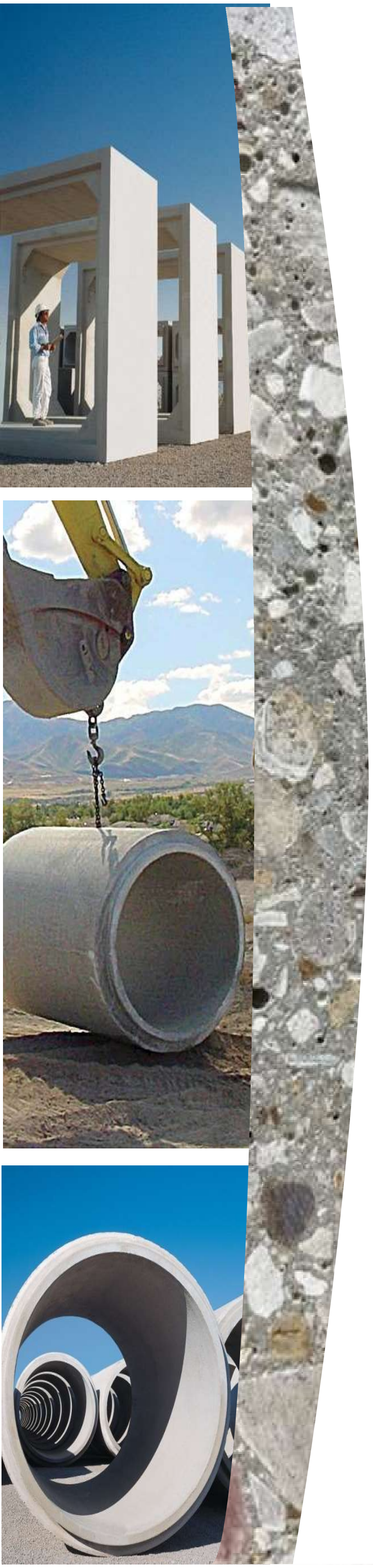

Where Can SCC Be Used?

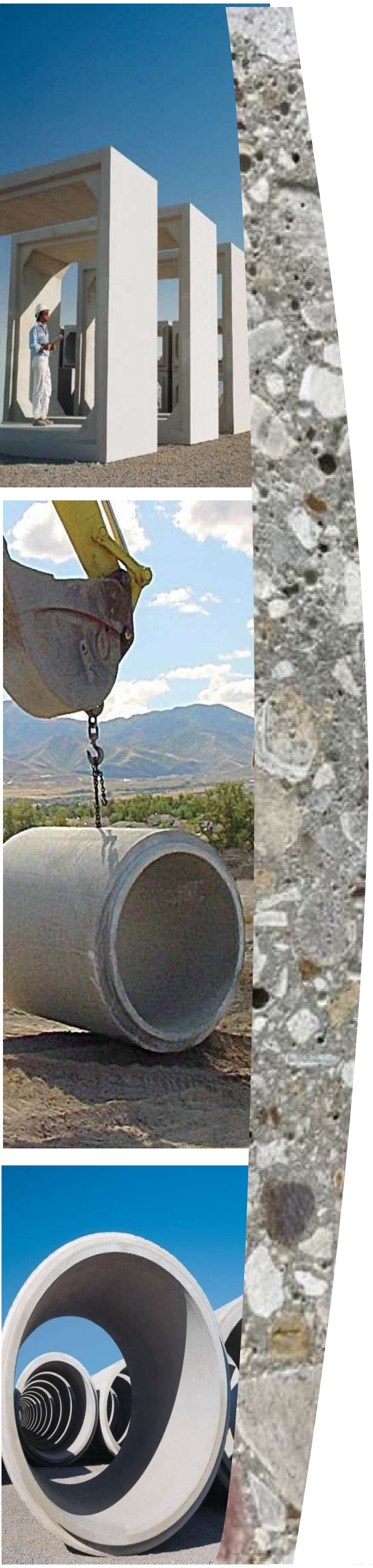

Where Can SCC Be Used?



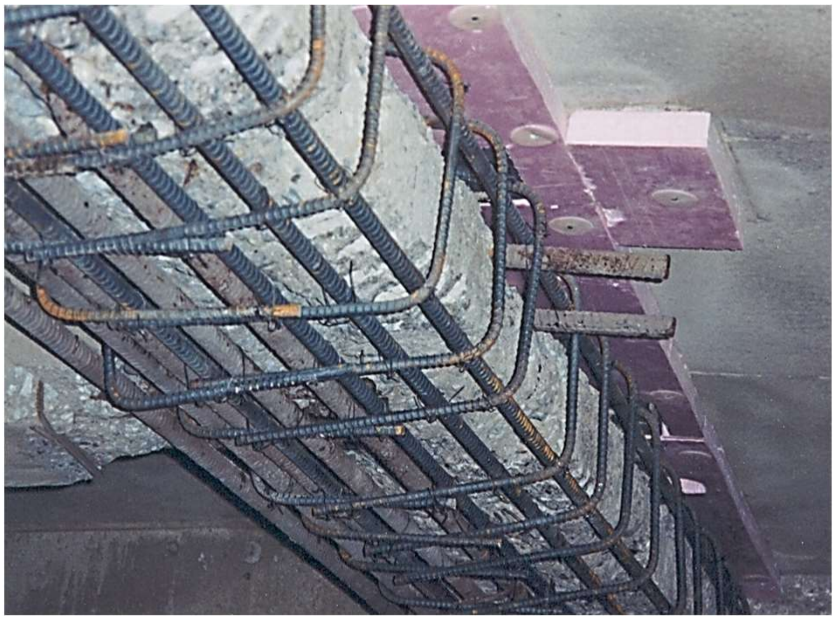


Application for SCC: Repair

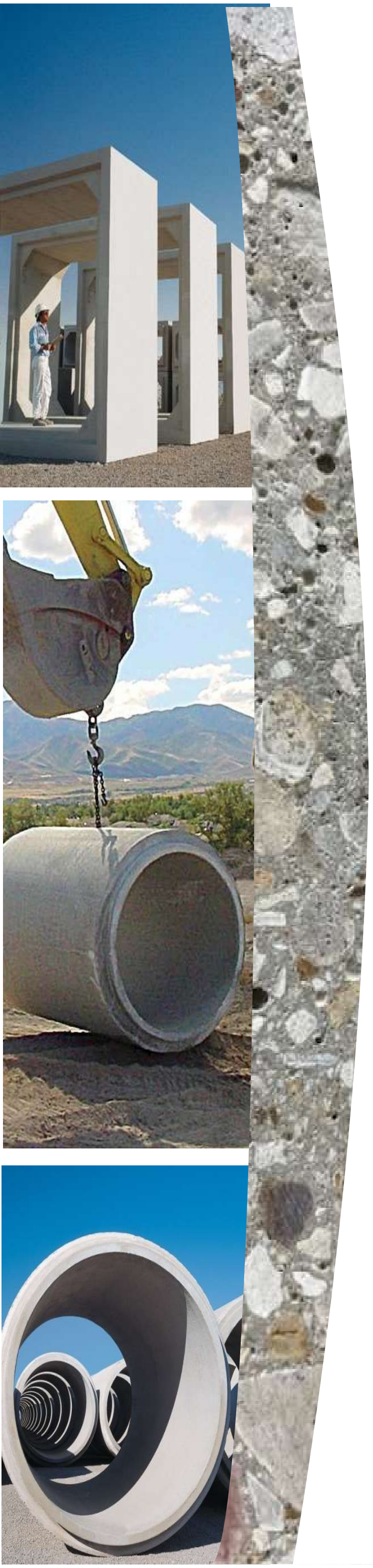


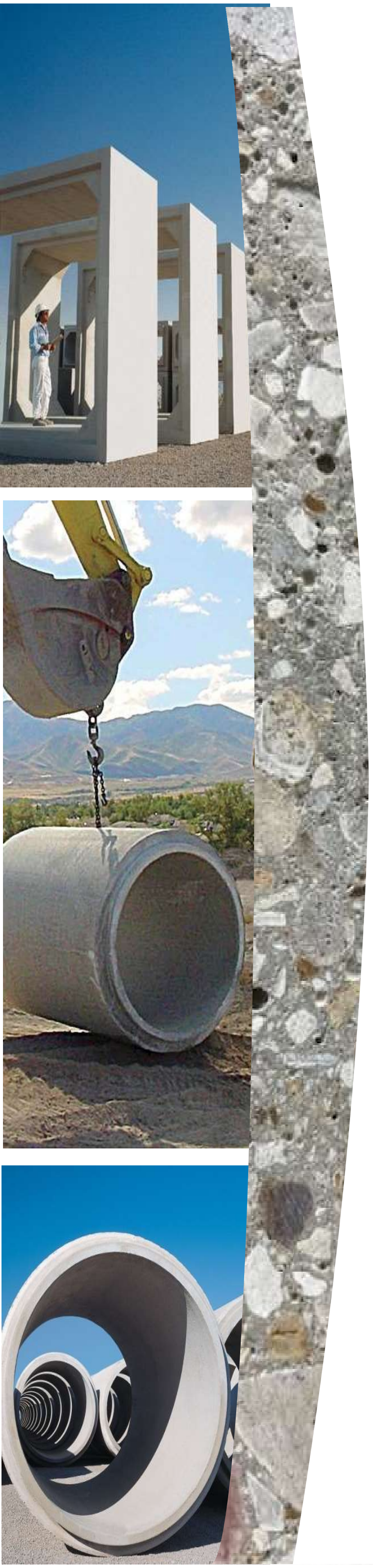


Parking Garage



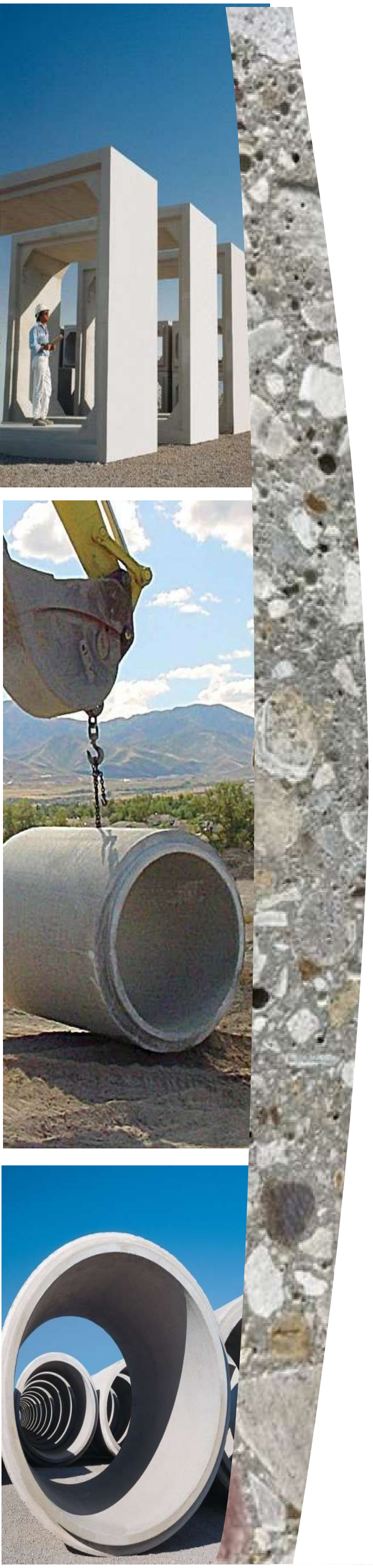
Application for SCC: Precast



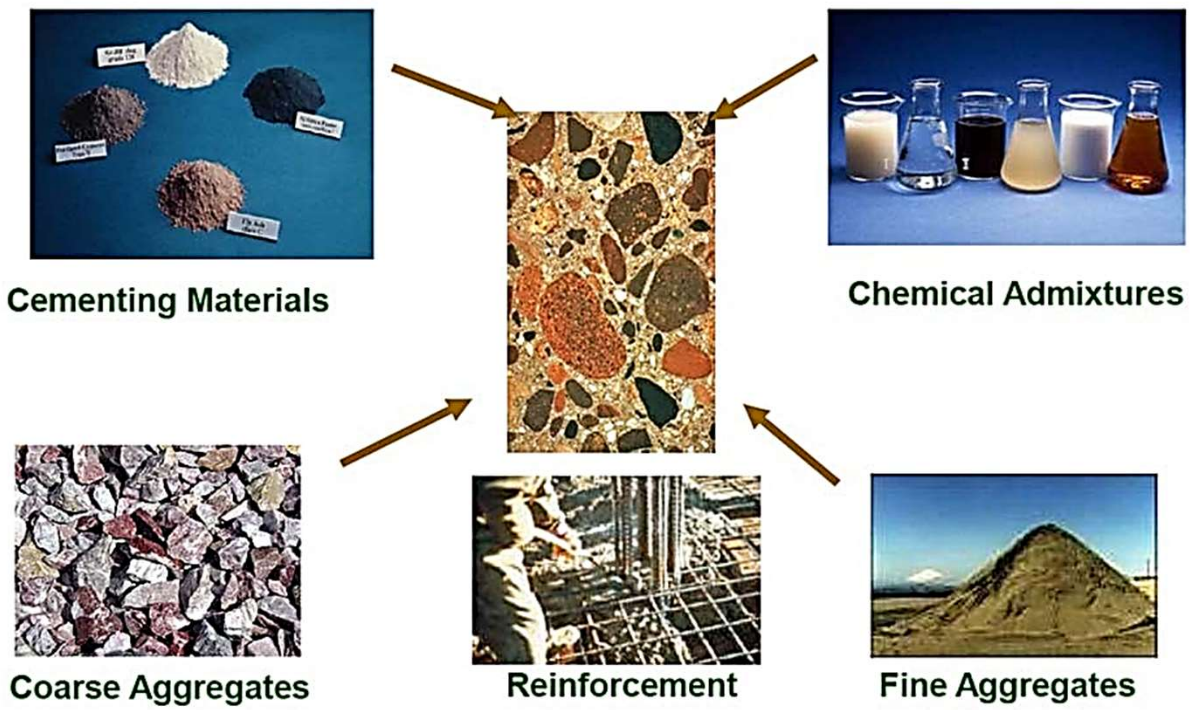


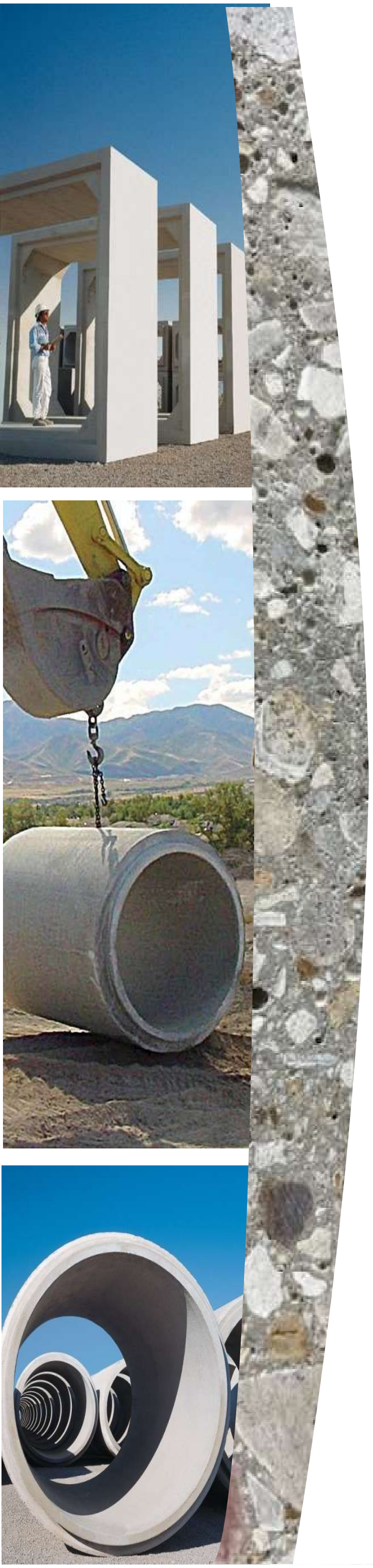
SCC Mix Development

- Understanding Key Properties



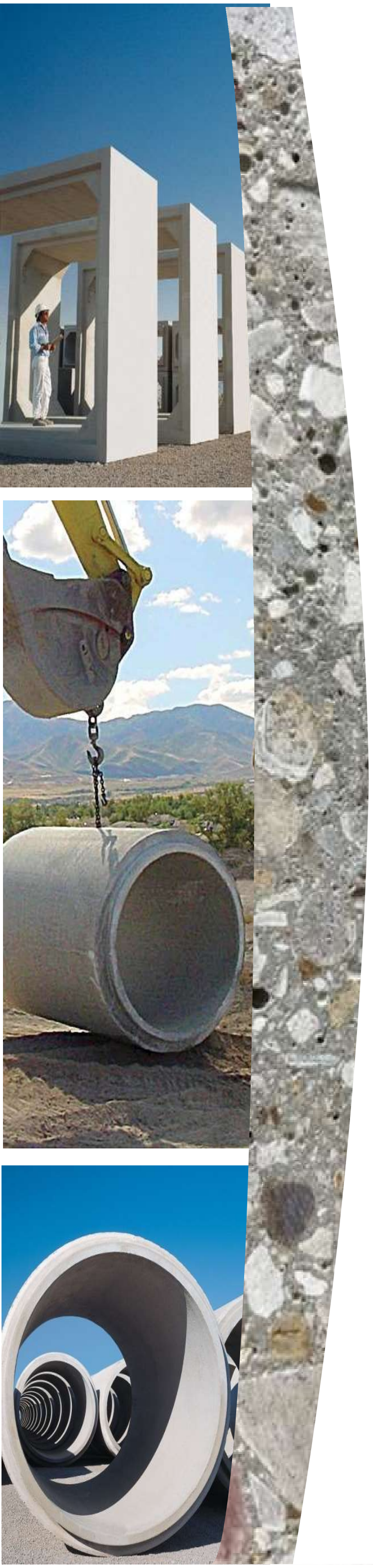
Many Ways to Make SCC





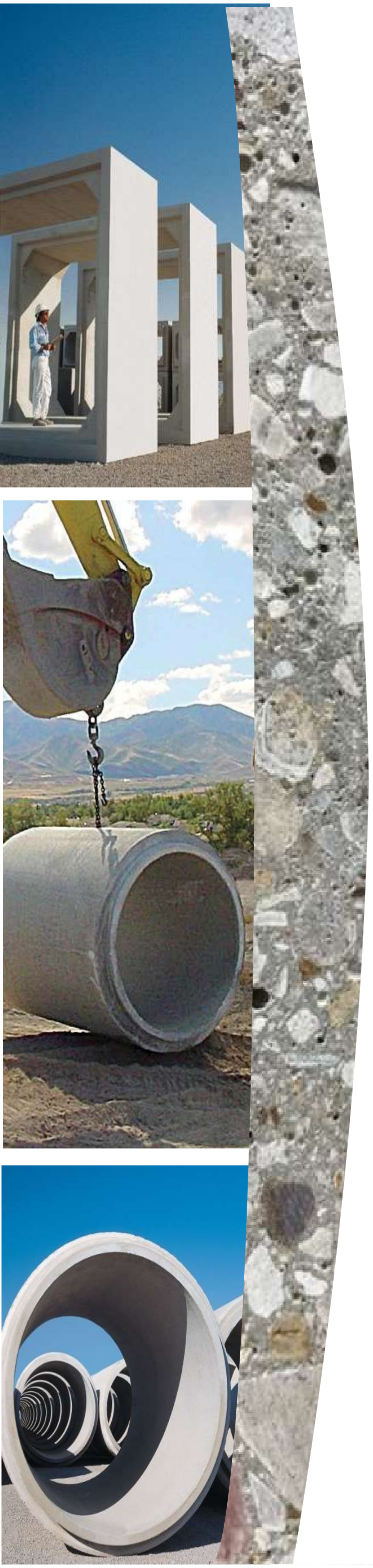
Key Plastic Properties of SCC: Filling Ability

- The ability of the concrete to flow freely under its own weight, and to completely fill formwork of any dimension and shape without leaving voids
- Filling ability is impacted by:
  - Spread-Slump Flow
  - Viscosity (T20/T500)
  - Aggregate Shape
  - Aggregate Ratio
  - Placing Methods
  - Size and Configuration of the Forms

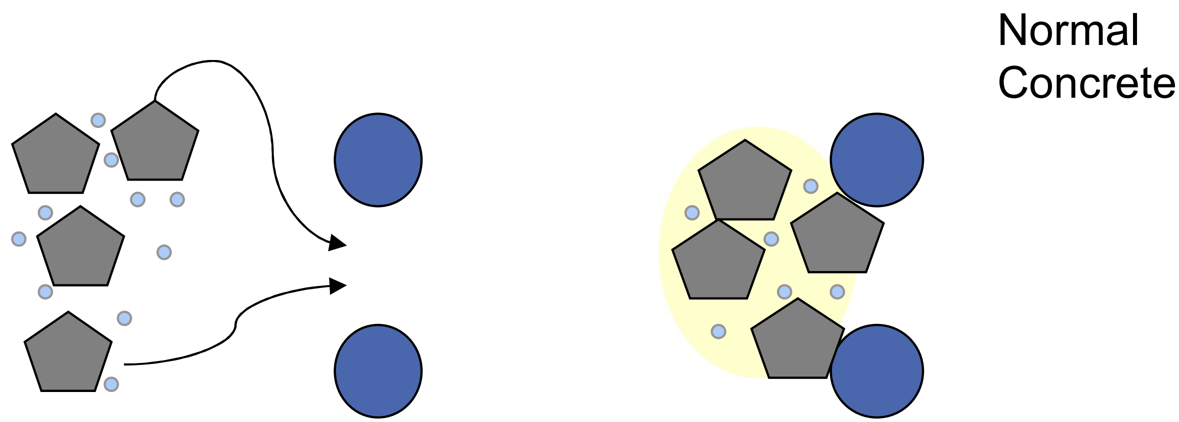


Key Plastic Properties of SCC: Passing Ability

- The ability of concrete to flow freely in and around dense reinforcement without blocking

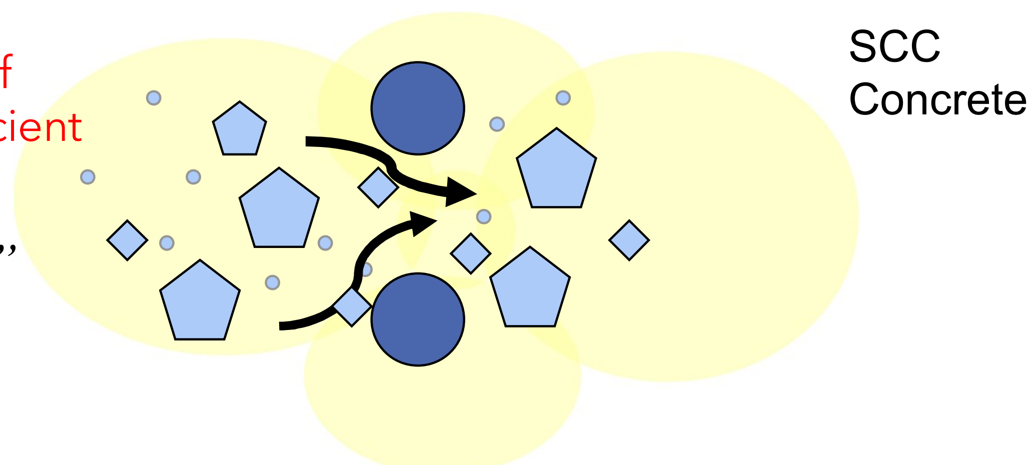


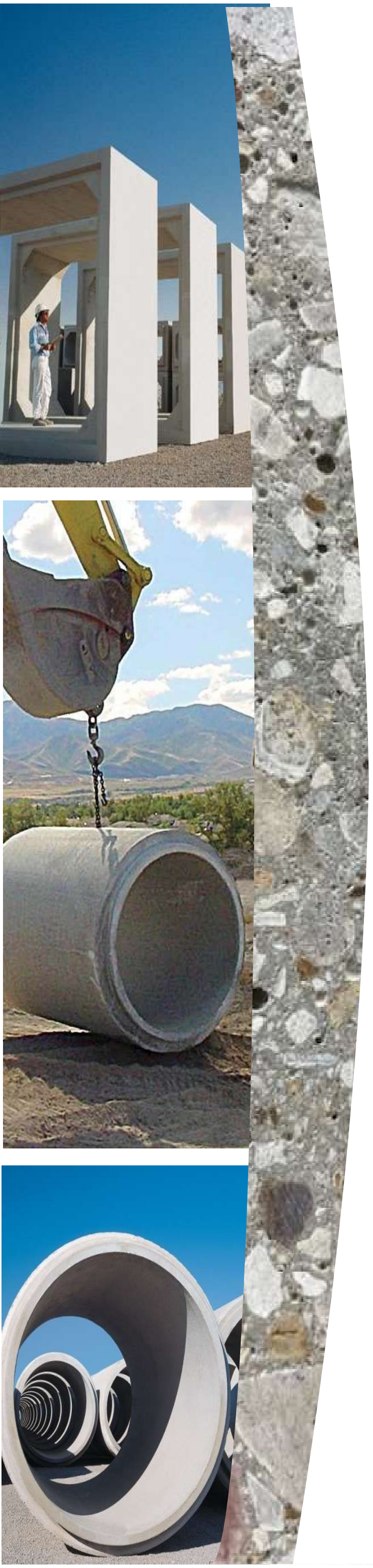
What is Blocking?



Size, volume, & blend of aggregate require sufficient volume of paste to flow

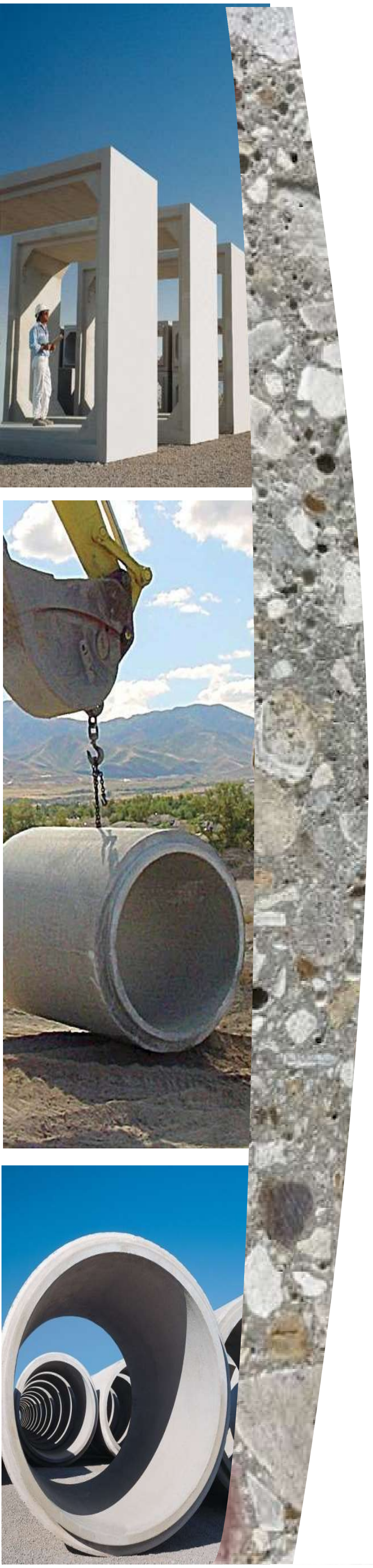
"Passing ability"





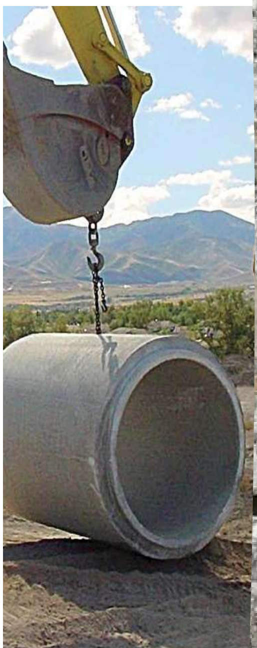
Key Plastic of SCC: Passing Ability

- Passing Ability is impacted by:
  - Spread-Slump Flow
  - Viscosity (T20/T500)
  - Aggregate
    - Specific gravity
    - Shape
    - Ratio
    - Size
  - Placing Methods
  - Form or Rebar Spacing



Key Plastic Properties of SCC

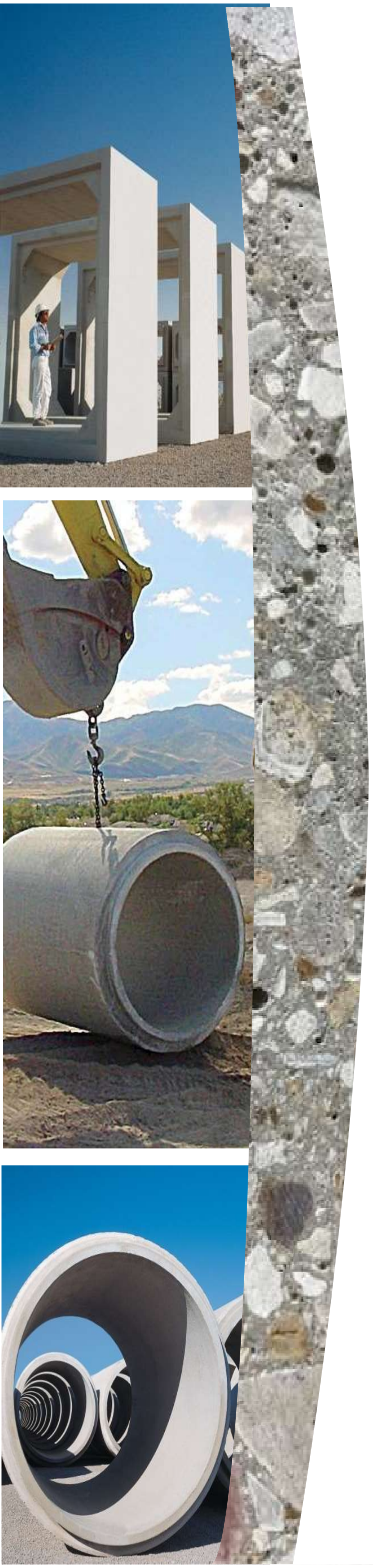
- **Resistance to Segregation**
  - During placement and while flowing, the concrete should retain its stability.
  - There should be no separation of aggregate from paste or water from solids and no tendency for coarse aggregate to sink downwards through the fresh concrete mass under gravity.
  - Resistance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



Key Plastic Properties of SCC

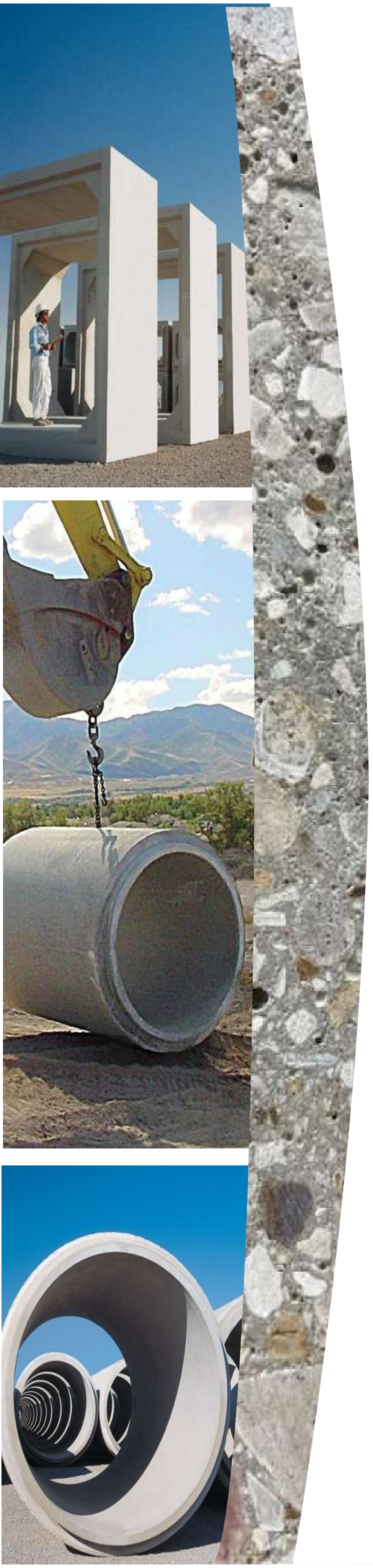
- **Dynamic Stability**
  - The characteristic of fresh concrete that ensures uniform distribution of solid particles and air voids as the concrete is being transported and placed

- **Static Stability**
  - The characteristic of fresh concrete that ensures uniform distribution of solid particles and air voids once all the placement operations are complete and until the onset of setting



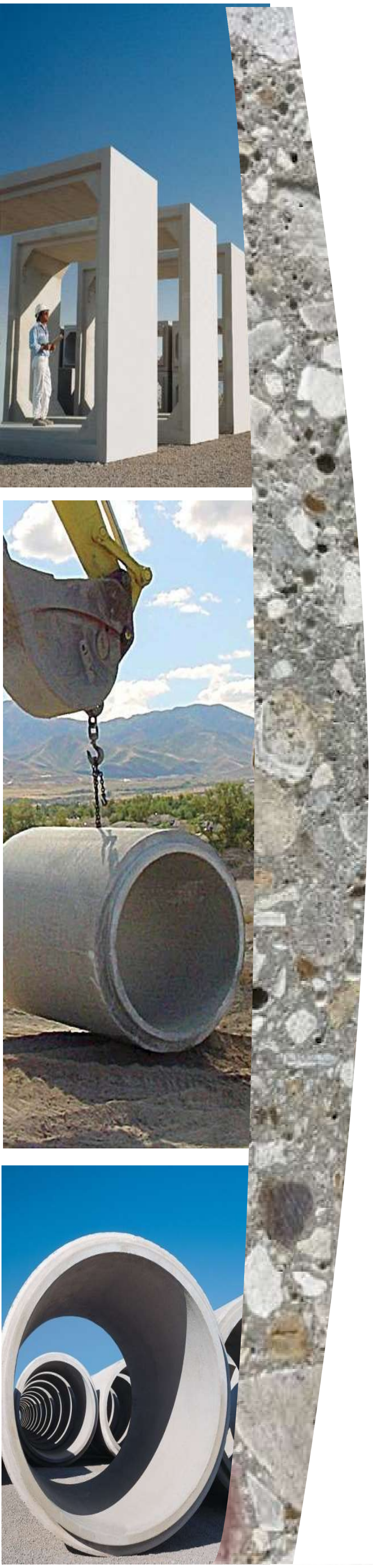
Key Plastic Properties of SCC

- Stability is Impacted by:
  - Slump Flow- Spread
  - Viscosity (T20/T500)
  - Aggregate Size
  - Aggregate Ratio
  - Aggregate Specific Gravity
  - Powder Content
  - Air Content
  - Paste Content
  - Mortar Content
  - Transportation and Placing Methods
  - Admixture Content
  - Water Content



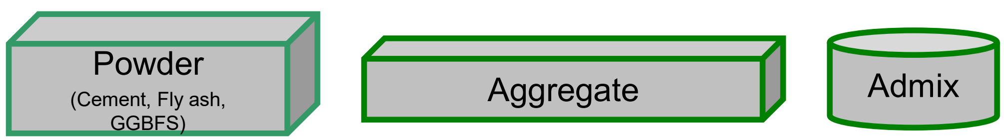
SCC Mix Proportioning

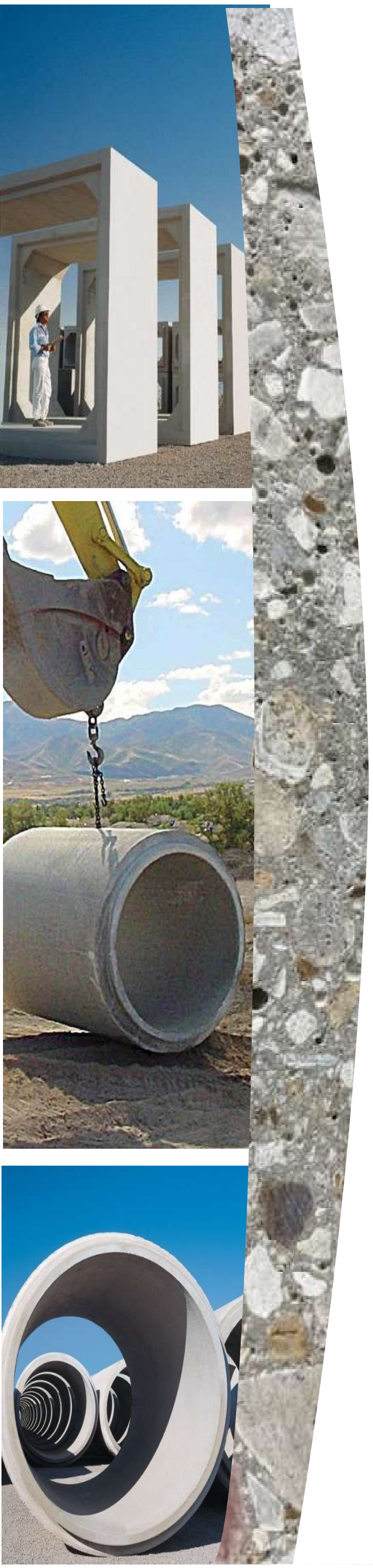
- Developing SCC consists of material combinations and relationships of:
  - Cementitious Materials **(Optimize)**
  - Sand / Aggregates **(Optimize)**
  - Admixtures **(Optimize)**
  - Water **(Optimize)**



SCC Mix Design Approaches

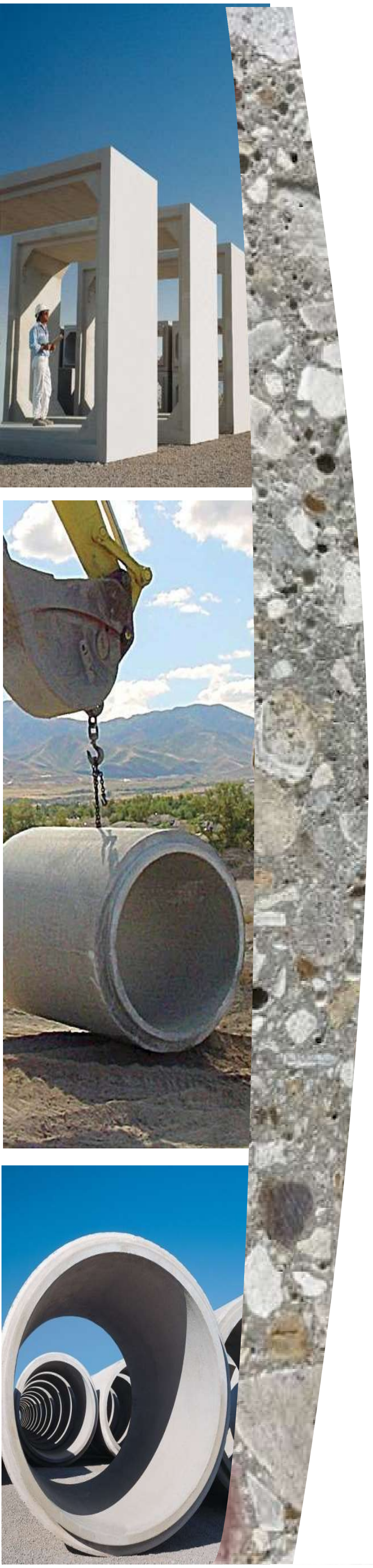
- **High Powder Content** and high-range water-reducing (HRWR) Admixture
- **Lower Powder Content**, HRWR Admixture, and Viscosity Modifying Admixture (VMA)
- **Moderate Powder Content**, HRWR Admixture, w/wo Moderate VMA addition





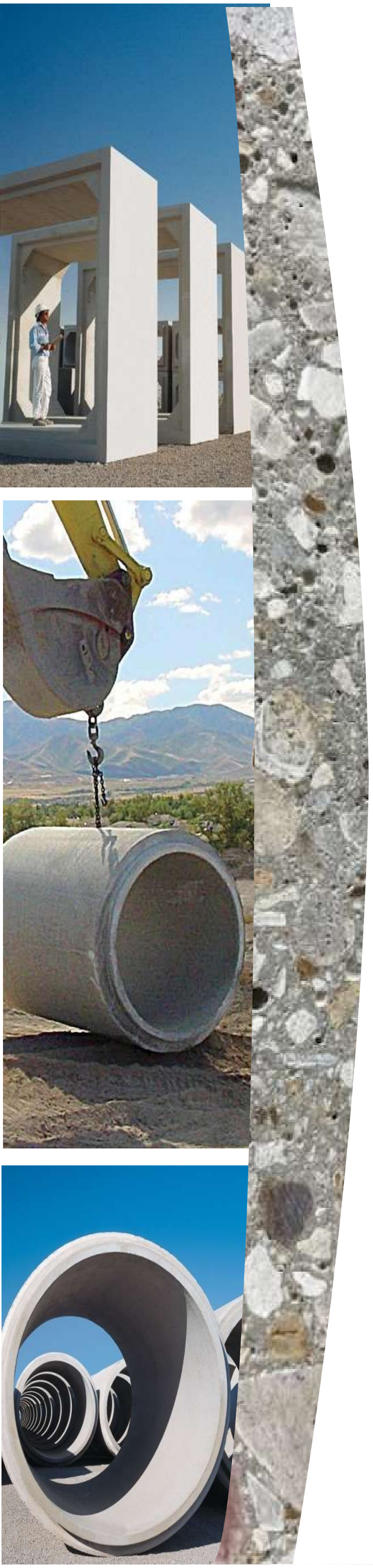
Were To Start

<table>
<tr><th></th><th>Slump Flow (in)
<22</th><th>Slump 22-26 (in)
22-26</th><th>Slump Flow (in)
>26</th></tr>
<tr><td>Powder Content (lbs./Yard^3)</td><td>< 650</td><td>650 - 750</td><td>750 +</td></tr>
<tr><td colspan="2">Absolute volume of coarse aggregate</td><td colspan="2">28-32% (total mix volume)</td></tr>
<tr><td colspan="2">Paste Fraction (calculated on volume)</td><td colspan="2">34-40% (total mix volume)</td></tr>
<tr><td colspan="2">Mortar Fraction (calculated on volume)</td><td colspan="2">60-70% (total mix volume)</td></tr>
<tr><td colspan="2">Typical w/cm</td><td colspan="2">0.32 – 0.45</td></tr>
<tr><td colspan="2">Typical cement (powder content)</td><td colspan="2">650-800 pounds
Depends on Strength ?</td></tr>
</table>



To Design SCC

- 3 Things you need to determine
  1. Paste Volume (Workability)
  2. Paste Composition (Strength)
  3. Aggregate Blend (Minimize Segregation & Blocking) **(Optimize combined gradation)**



SCC Technology and Practice – *SCC Proportioning*

Higher percentage of Paste and Mortar

SCC

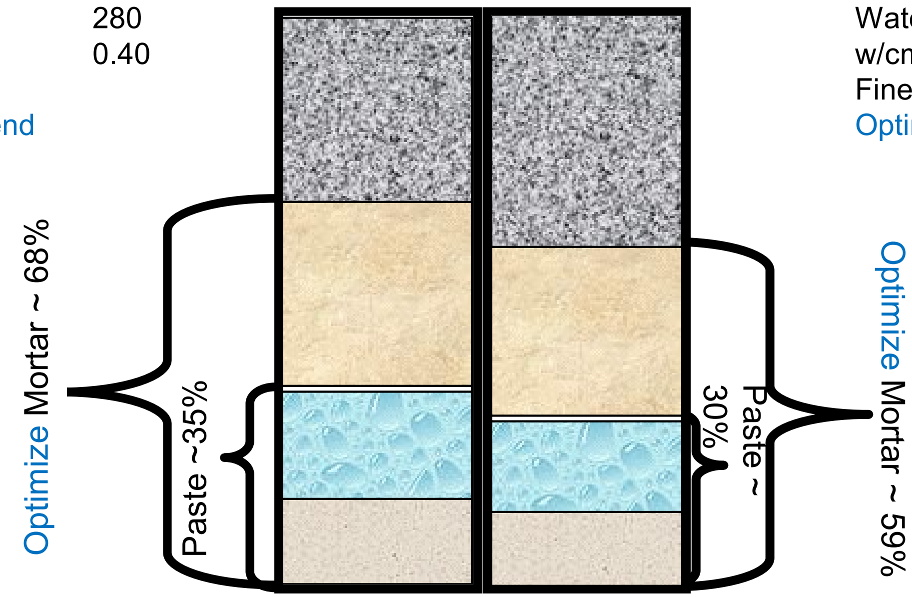
Paste	35%
Cement	700
Water	280
w/cmt	0.40
Fine/total agg	0.50

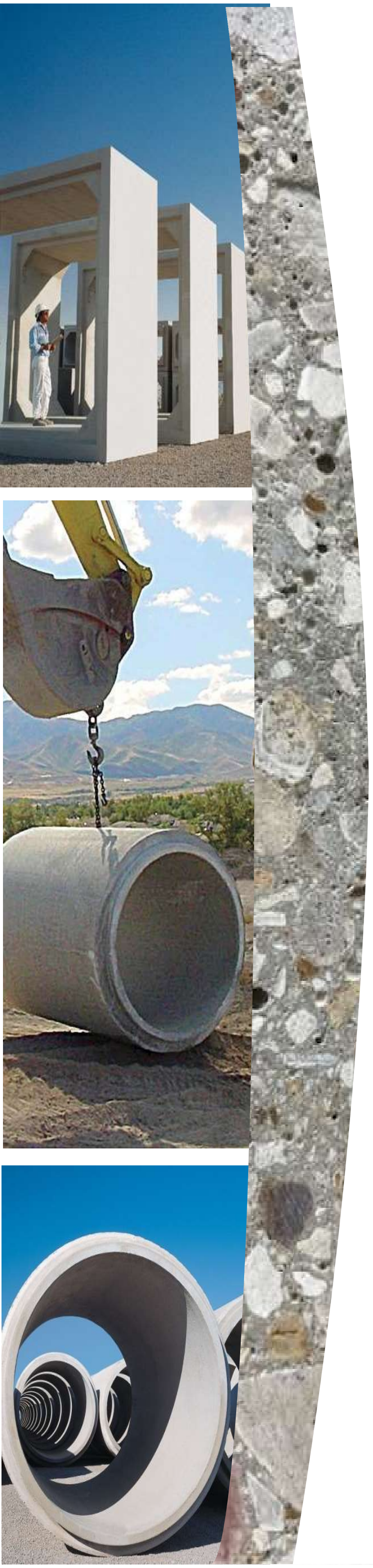
Optimize aggregates, blend

Conventional

Paste	30%
Cement	650
Water	260
w/cmt	0.40
Fine/total agg	0.42

Optimize aggregates, blend

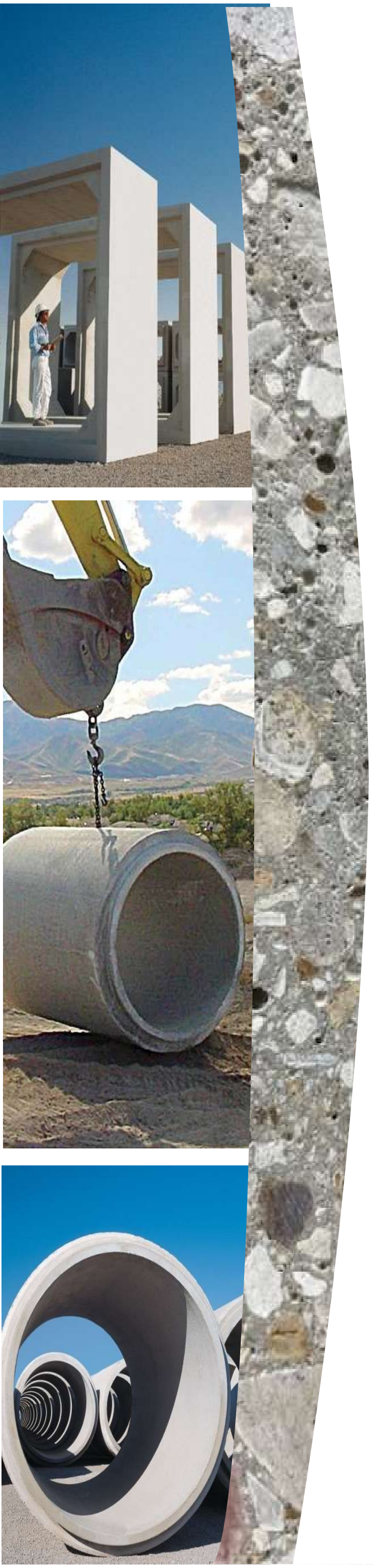




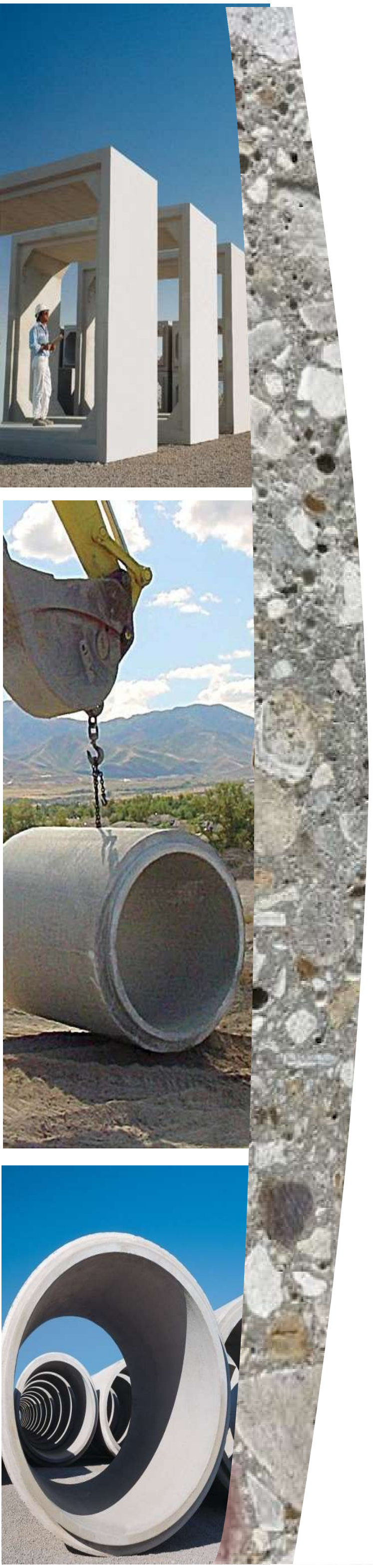
SCC Proportioning Steps

- Determine required **slump flow - Spread**
- Select **coarse aggregate size**
- Determine the required **air content**
- Estimate the required **powder content**
- Estimate the required **water content**
- Calculate **coarse and fine aggregate amounts** after Powder, Water and Air contents are determined
- Calculate **paste and mortar volume**
- Adjust **coarse and fine aggregate** weights based on paste and mortar volumes
- Select **admixture types, dosage and sequence**
- Batch **Trial Mixture** – Do the testing then adjust and batch again

SCC Mixture Success

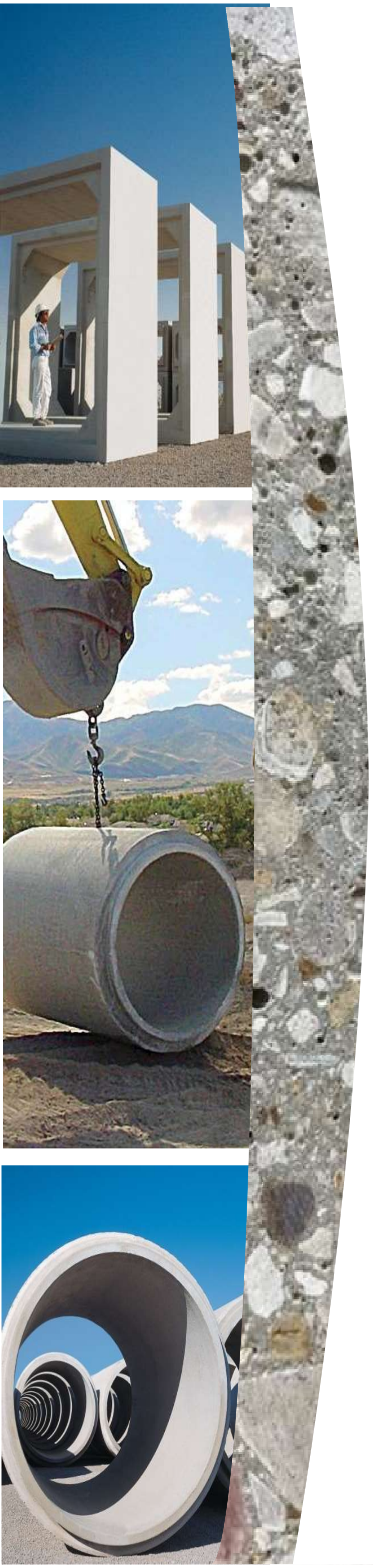


- **We must use locally available materials to be cost effective**
- **Quality of the ingredients can vary dramatically, and we need tighter QC**
- **One mix design *does not* fit all**



SCC Admixture Usage

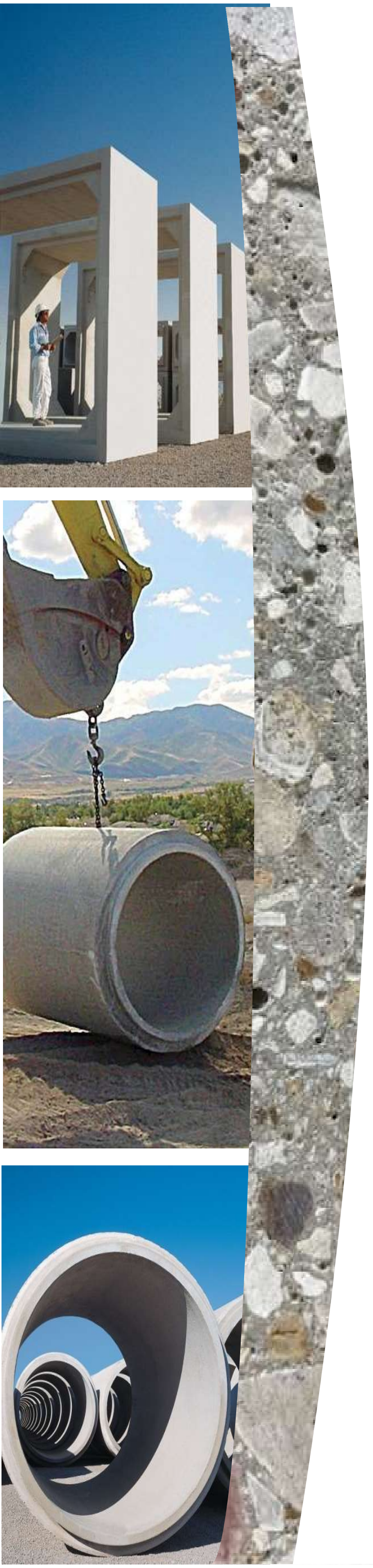
- **SCC Polycarboxylate Superplasticizers**
  - Excellent flowability with improved stability compared to superplasticizers for conventional concrete. Increased mix forgiveness.
- **Viscosity Modifying Agents**
  - For difficult aggregates (Optimize) and production conditions such as low cementitious 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
- Common admixtures such as AEA, retarders/HS and accelerators also work with SCC



Viscosity Modifiers & Admixtures

1. **Optimize your aggregate content and gradation**
2. **Optimize your cementitious**
3. **Optimize admixtures**
4. **Optimize VMA** **If you need to use**
   - VMA, Acts as a 'thickening' agent
   - Protects against segregation
   - Dispense VMA directly into mix
   - No effect on set times or air content
   - Provides flexibility of water contents

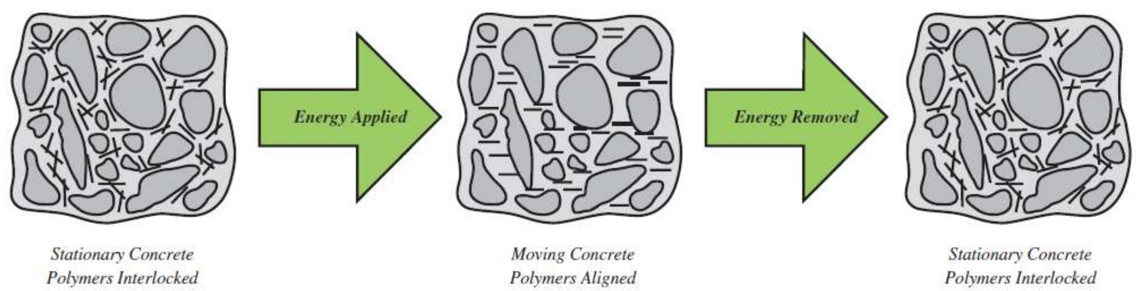
- **1 - 4 Optimize the flowability**



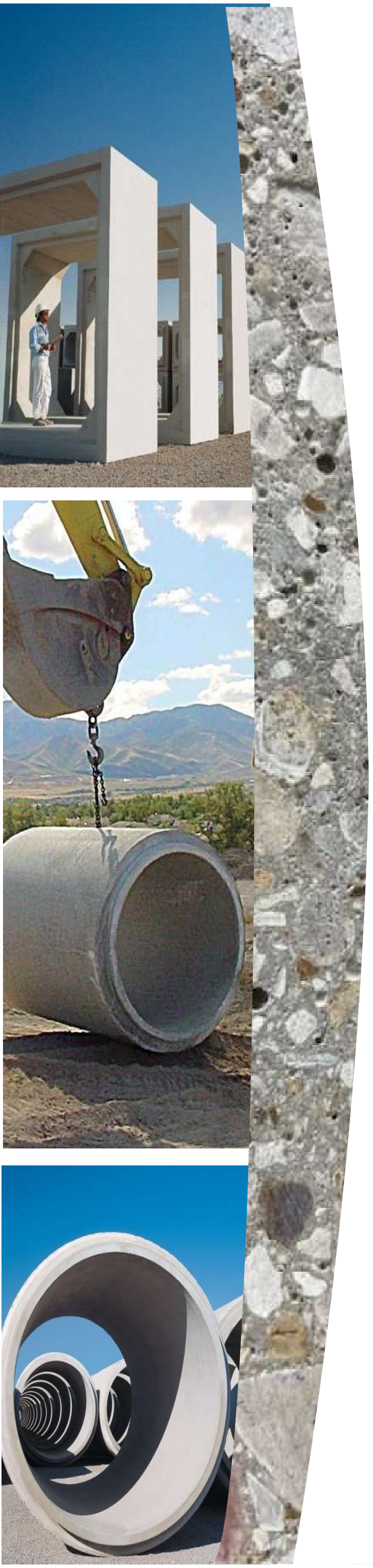
Viscosity Modifiers…

First optimize your aggregate content and gradation

What They Do

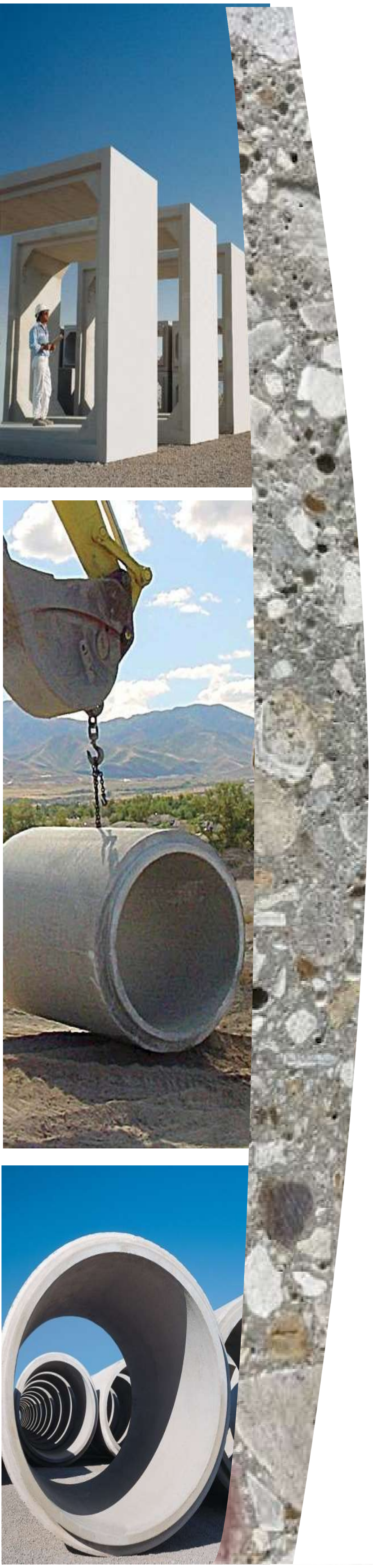


Large polymer structure of VMA align in the direct of the applied energy (flow) and allow paste to lubricate coarse, angular sand particles reducing internal friction



Characteristics

Performance Attributes	Plastic Concrete Benefits	Hardened Concrete Benefits
Rheology modifier acting as a *lubricant*: • Concrete flows more readily at low shear rates, without vibration (SCC, paving, truck discharge, poorly shaped aggregates) • Improve extrusion and surface texture (creamier with more body than V-MA)	• Mix 'lubricity' • Cohesive without being 'sticky' • Less clumping and lumps • Improved surface finishes • Even flows from the mixer – up the belts – out of the hopper and into the machinery • Less sticking in the chutes • Wide window of water flexibility • No effect on water contents • Generates more paste – potentially reduce cement content • Able to use less than optimum sand and stone – especially if added cement is used to enable	• Moisture retention aids curing • Higher strengths through better curing, lower air contents • Less cracking due to moisture retention • Better surface finish, swipe/webbing • More paste on surface, generally less bugholes • Crisper edges • Pallets and headers remove easier • Fewer defects

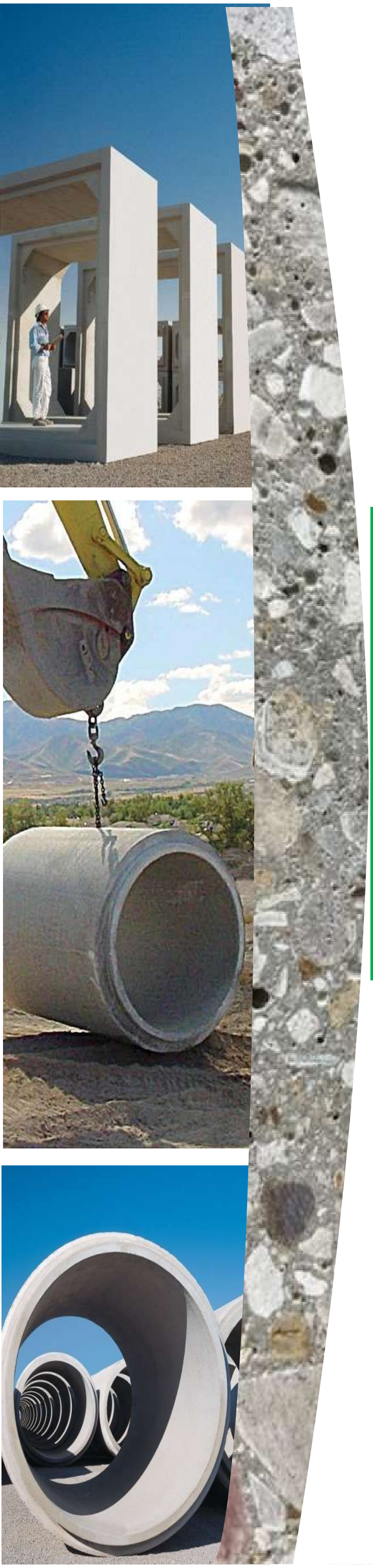


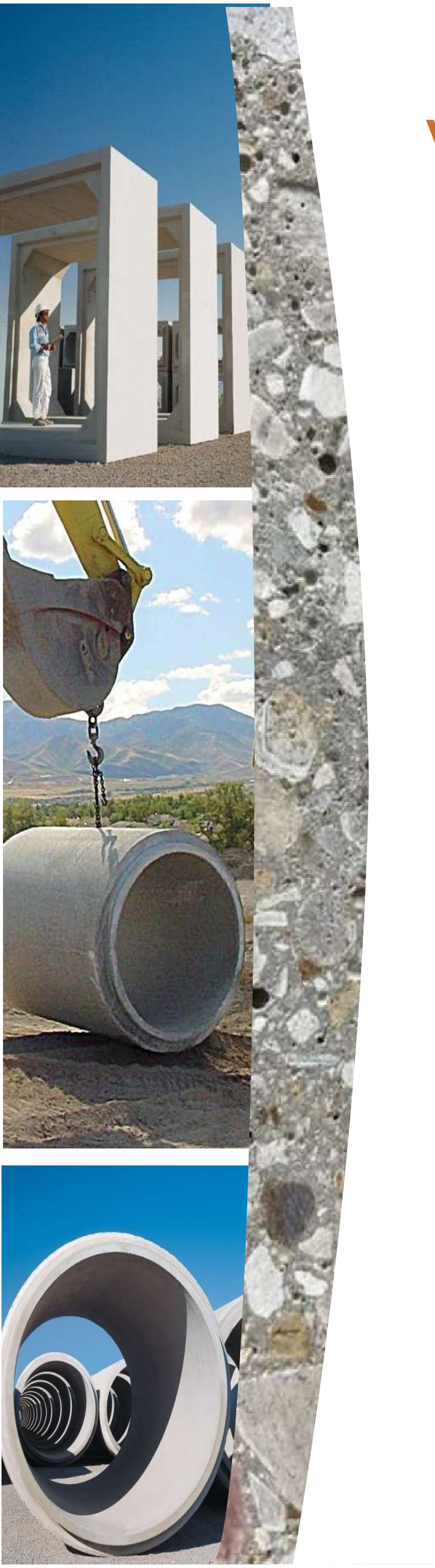
Test Methods to Evaluate SCC in Fresh State

- **Workability**: **ASTM C-1611**: “Standard Test Method for Slump Flow of Self-Consolidating Concrete”
- **Stability: ASTM C-1610** Column Segregation Test
- **Segregation: ASTM C-1712** Rapid Assessment Test for SCC Segregation
- **Passing Ability: ASTM C-1621** J-Ring

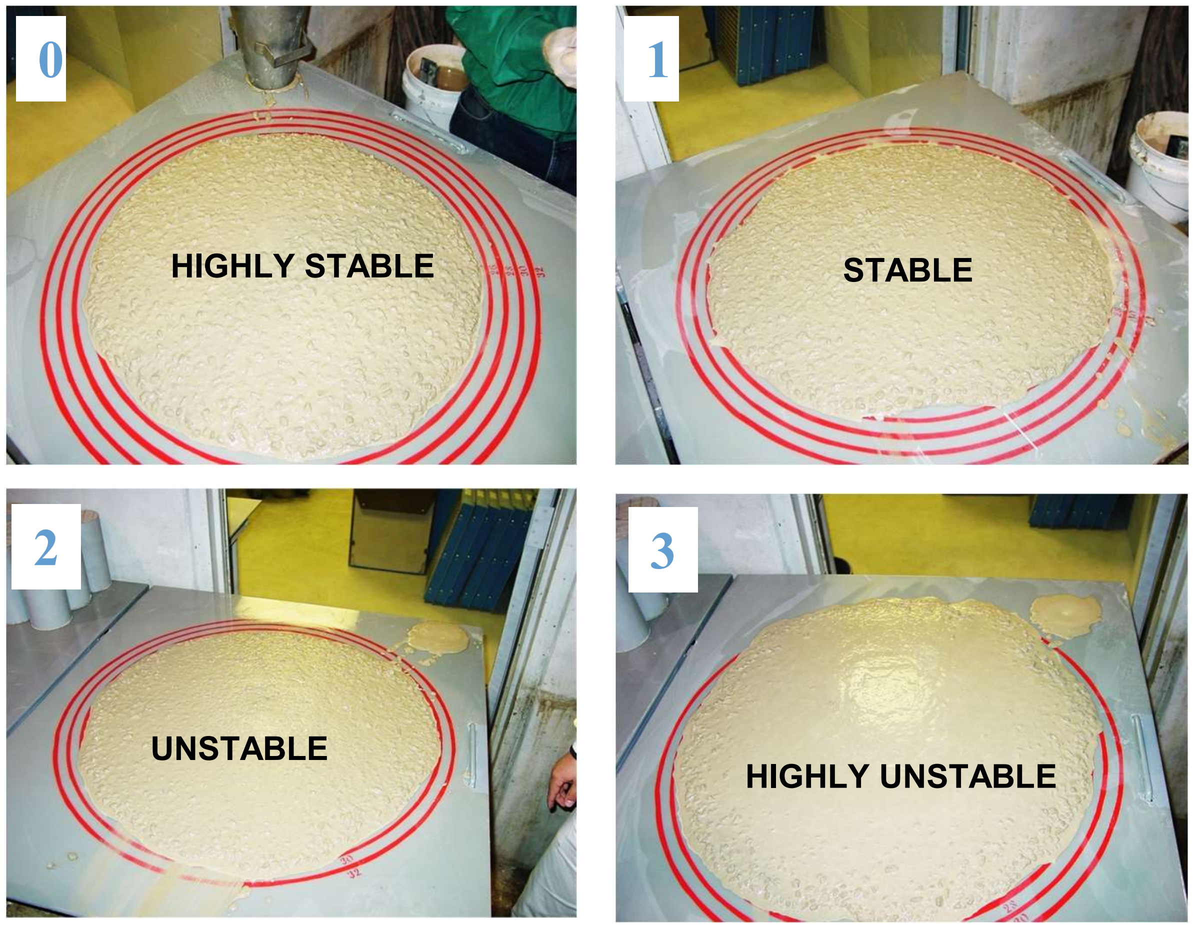
INTERNATIONAL

ASTM C-1611 Slump Flow





Visual Stability Index C-1611



ASTM

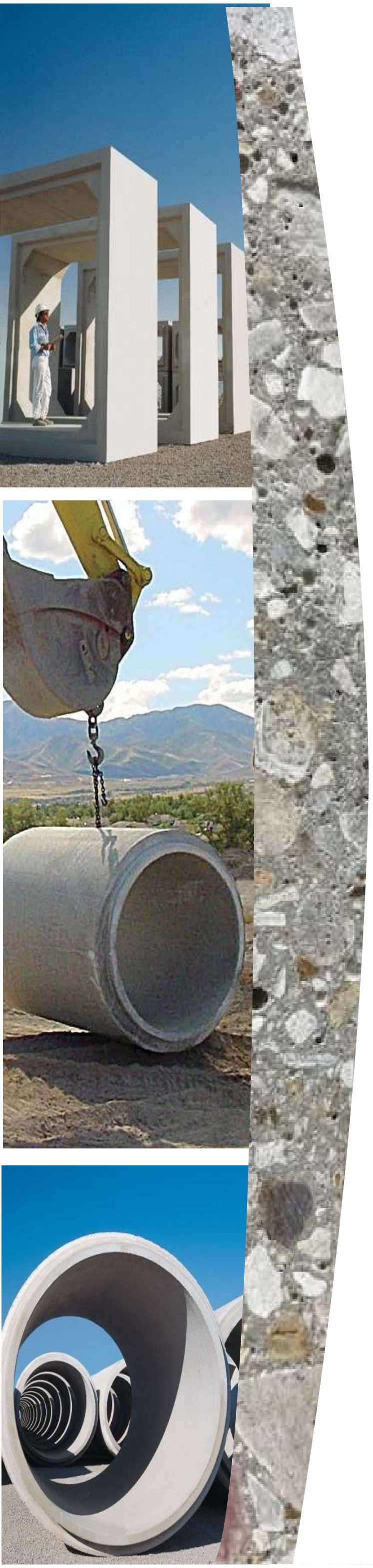
C-1610

C-1611

C-1621

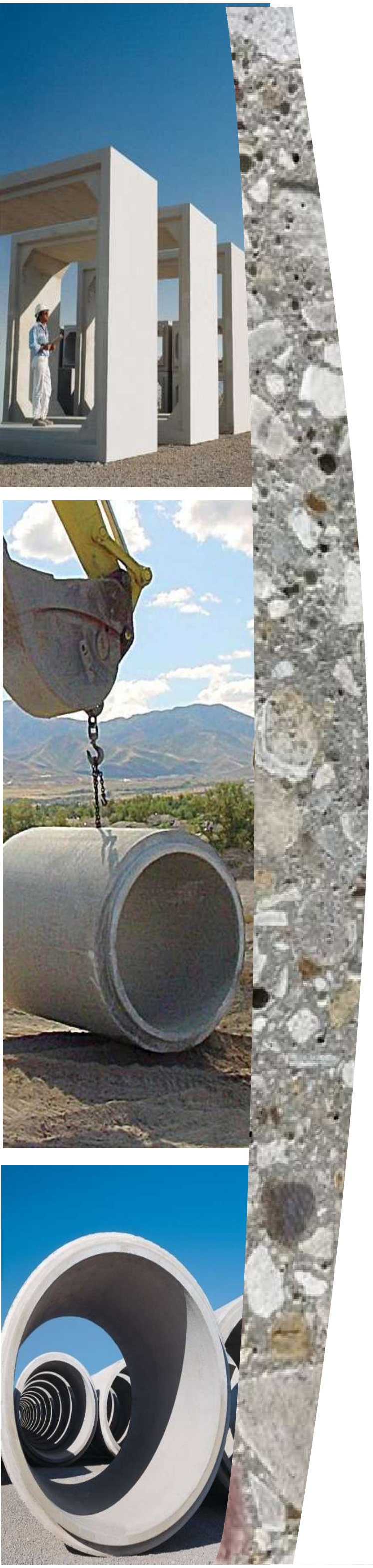
C-1712

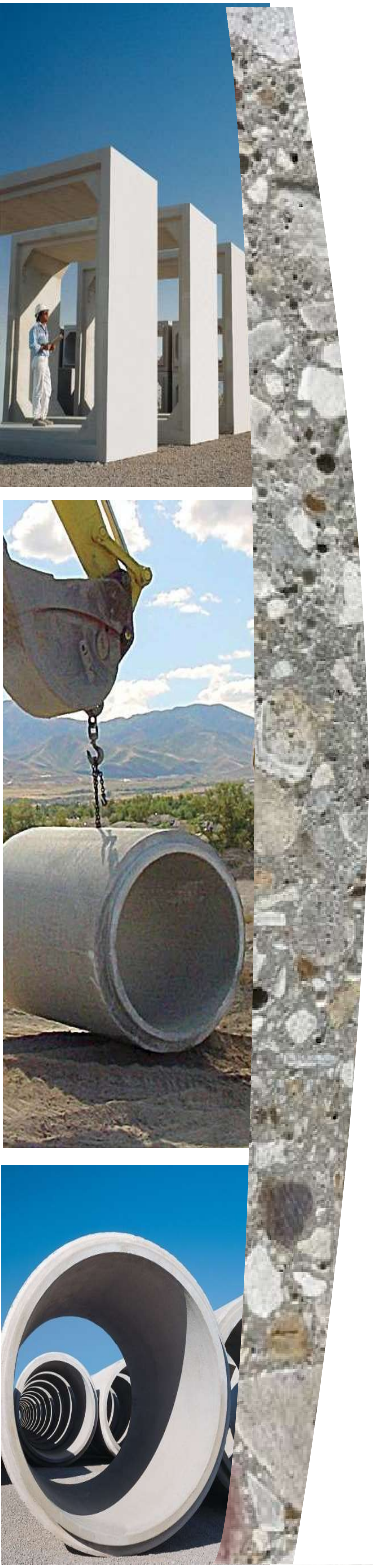
C-1758



Slump - Flow Test (Bleed and Segregation)

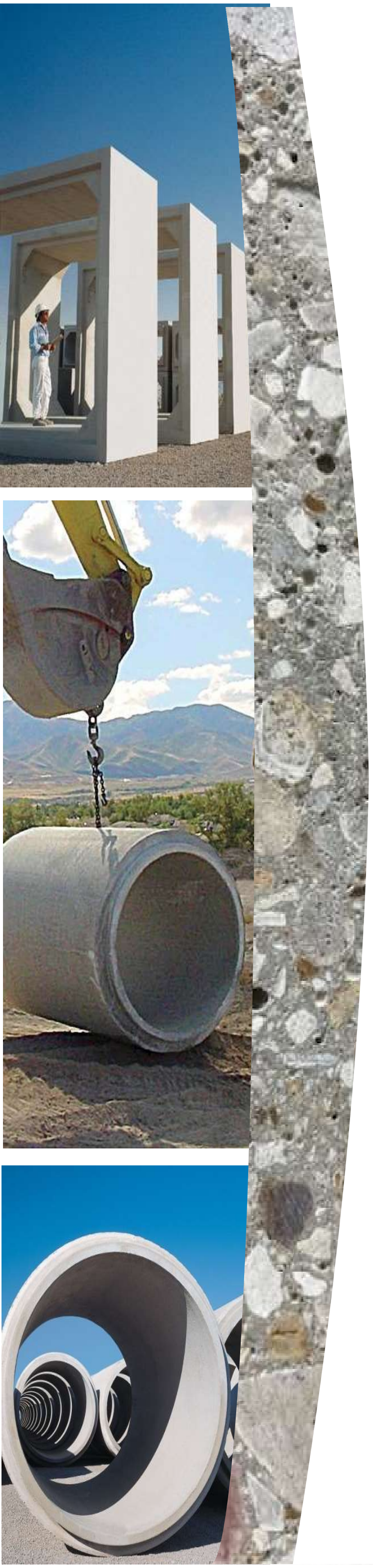
Slump - Flow





SCC Flow Characteristics ASTM C-1621

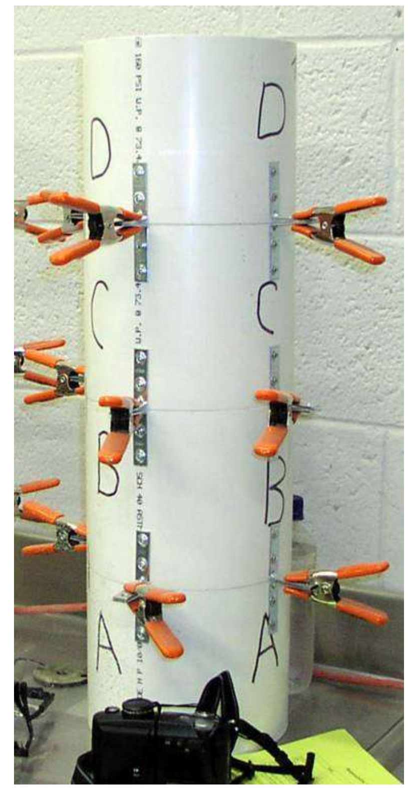
- J-Ring test (passing ability), Comparison of J-Ring flow and Slump flow tests
- **Optimize aggregate size & gradation for your application**

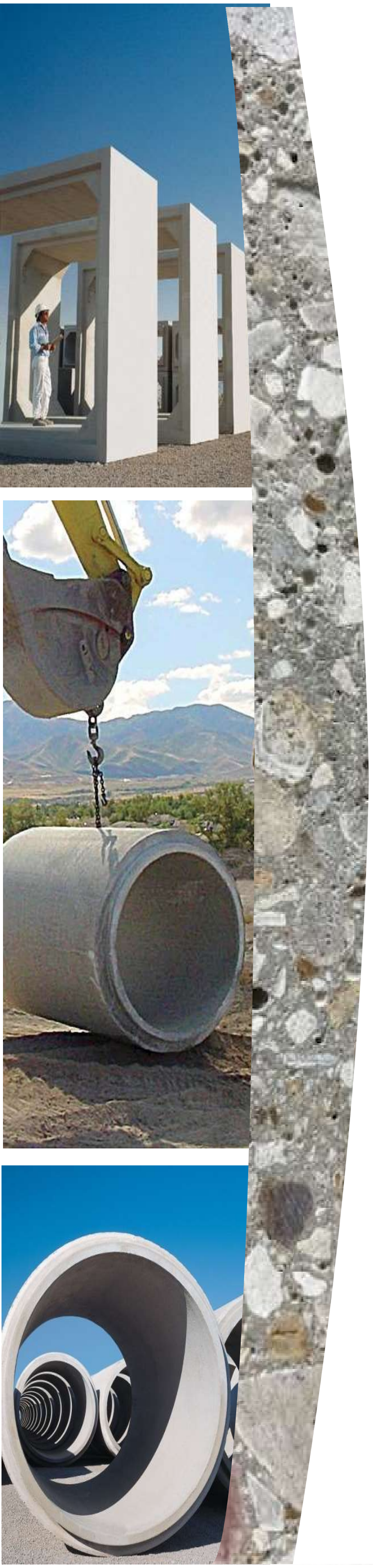


Column Segregation Test ASTM C-1610

Column Segregation Test ASTM C1610

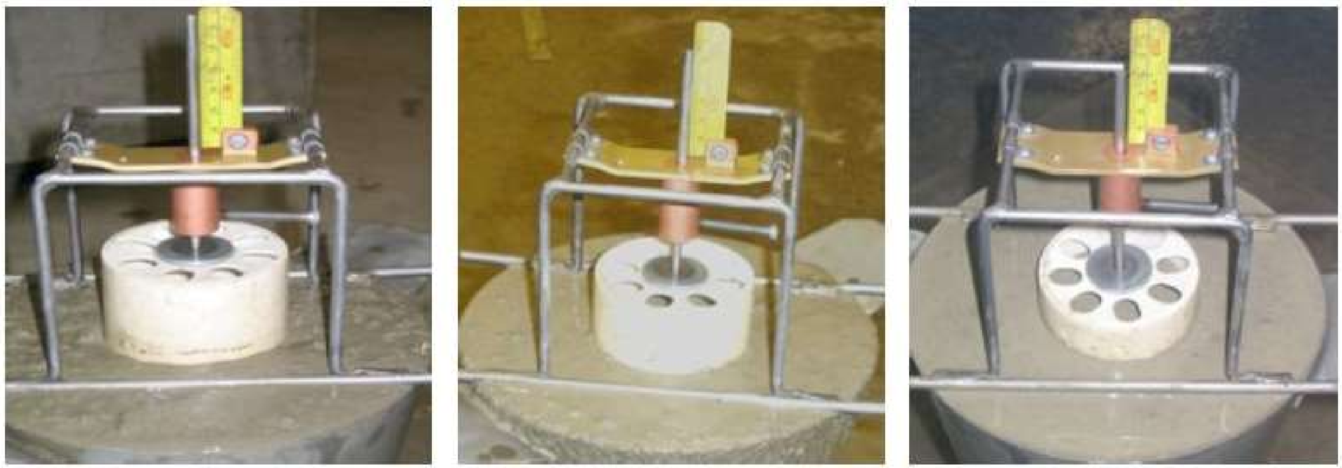
Verify your segregation aggregate gradation and **moisture**



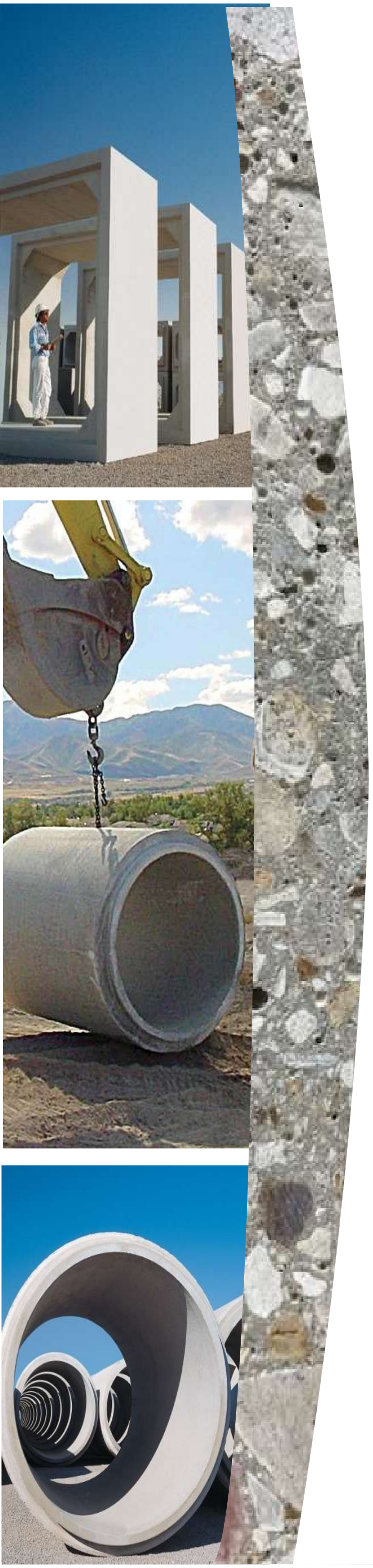


Rapid Assessment Method for SCC Segregation ASTM C-1712

Penetration Depth (PD) and Different Stability Levels



Highly Stable	Stable	Unstable
(PD ≤10 mm)	(10 mm < PD ≤ 25 mm)	(Pd > 25 mm)



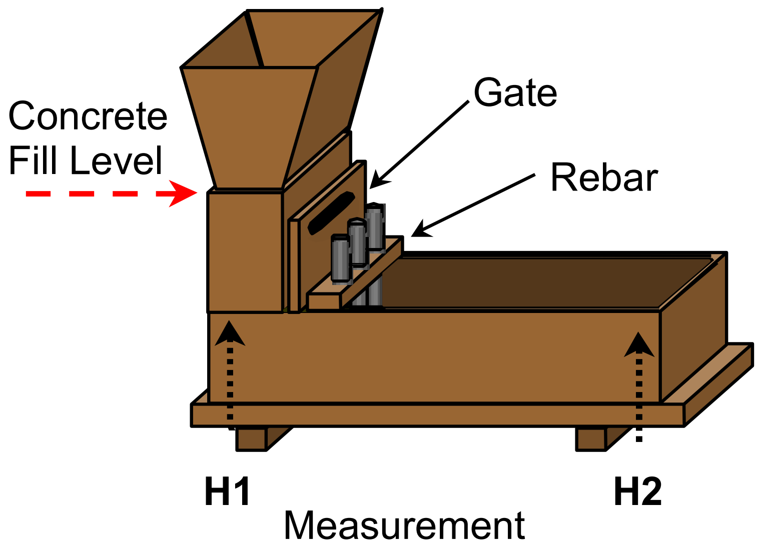
L Box Test

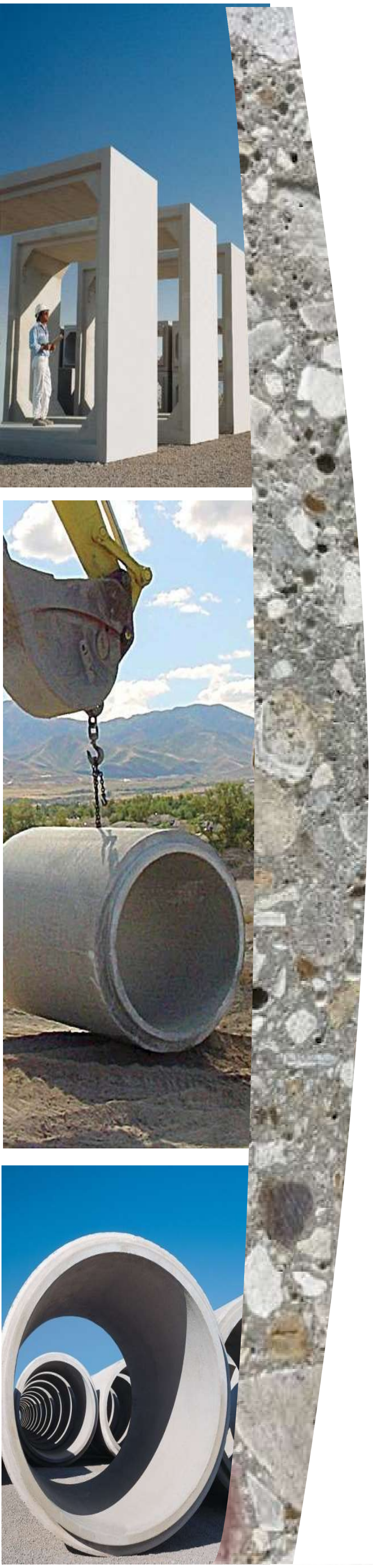
Test for passing ability indicated by the difference in concrete height between H1 and H2

Blocking ratio = H2/H1

BR = 1.0 is Excellent

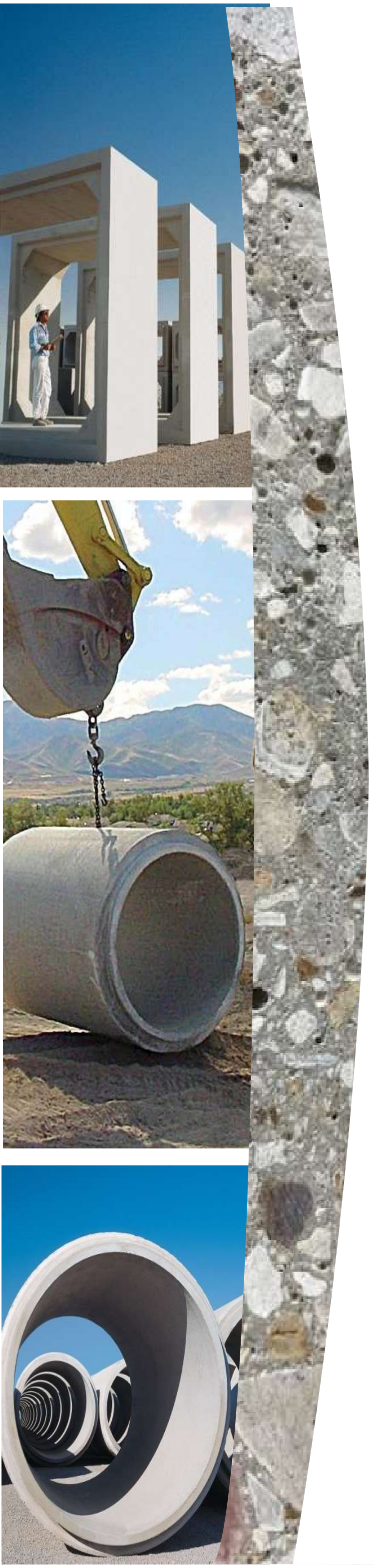
BR = 0.9 Acceptable





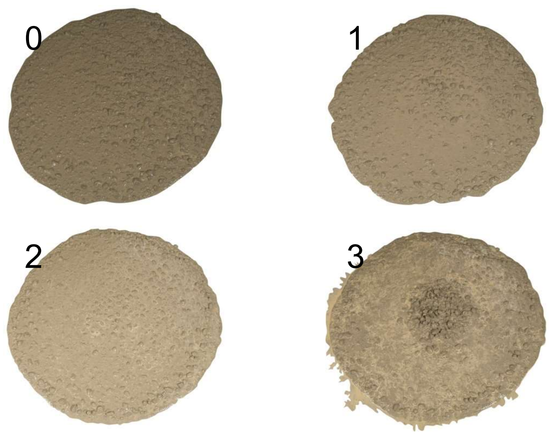
U Box Test

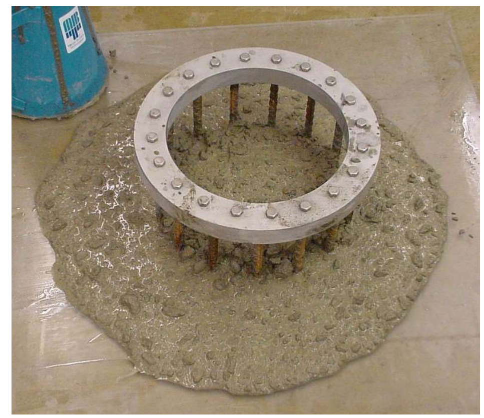
Concrete must reach **at least 12” (30 cm)** height after passing through rebar

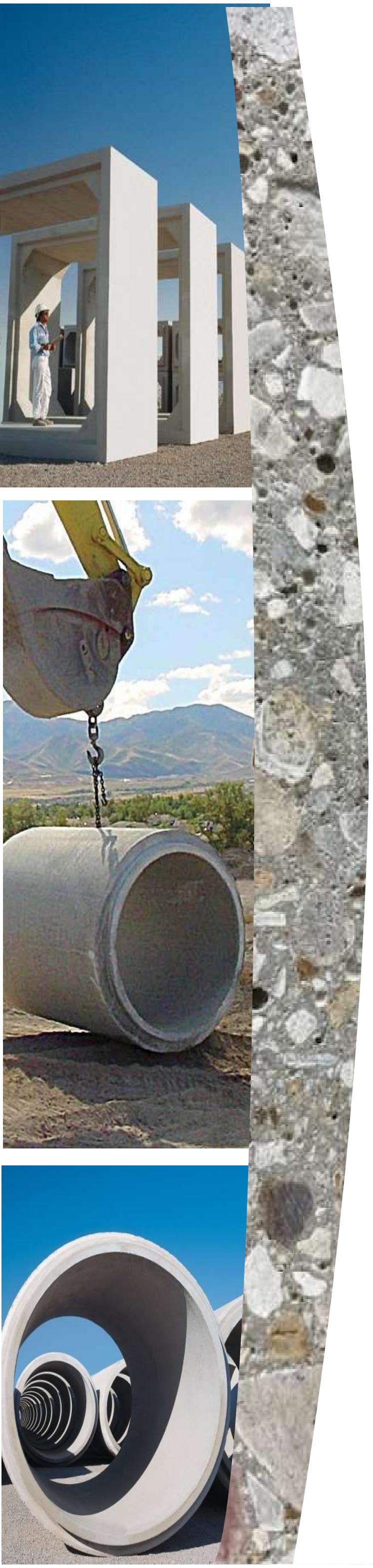


V Funnel Test

Slump Flow, VSI, J-Ring





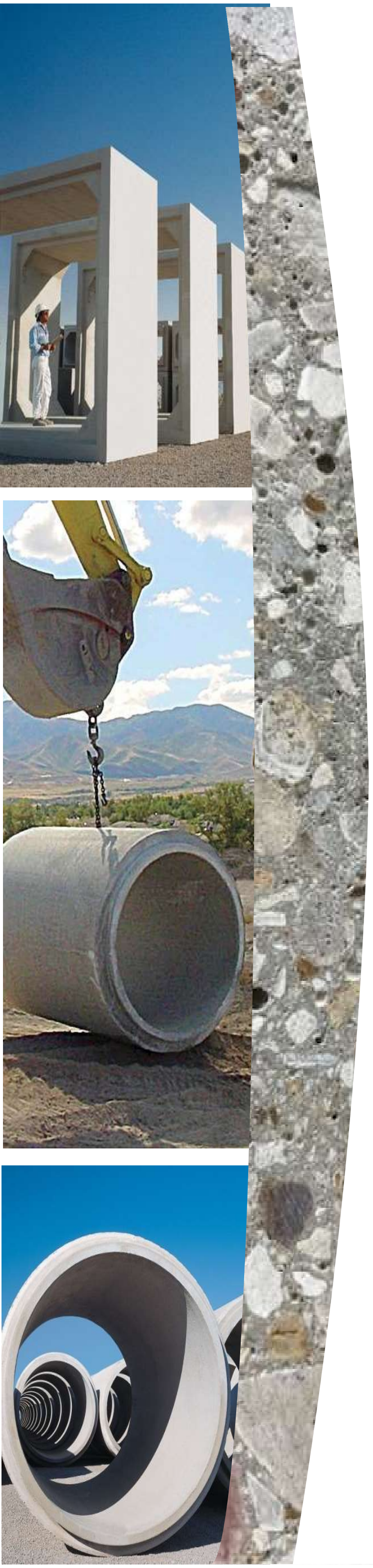


Guidelines (SCC Design Considerations)

- Use high quality, clean, well-graded aggregates (gap-graded/very angular materials can create problems)
- Ensure the SCC mix has sufficient flow and stability through the use of fines, supplementary materials, air, high range water reducers and/or viscosity modification
- Ensure proper moisture control **(+0.5%** error on aggregate moisture results - an additional 2 gallons of water/yd3 and can result in segregation)
- Rough rule of thumb: paste volume % = 10 + slump flow

SCC Plastics Properties

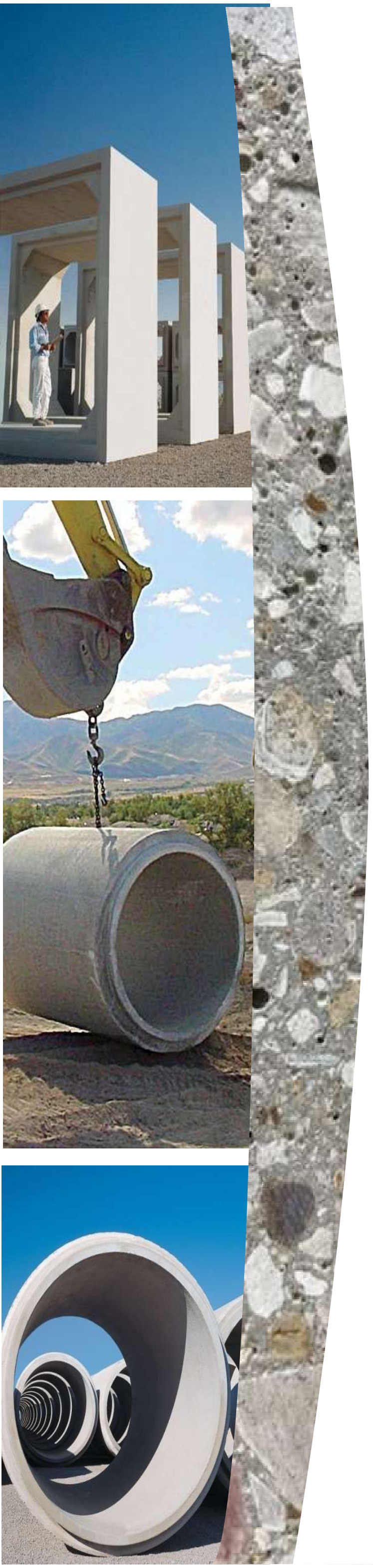
- Two main plastic properties of SCC that govern flow:
  - **Fluidity** – Ease in which concrete deforms and moves (measured by yield stress, shear stress or force required to initiate flow)
  - **Stability** – Ability to resist separation during transport (dynamic stability -with energy) and after placement (static stability -w/o energy) (measured by viscosity)
- **Fluidity and Stability** can be adjusted independently

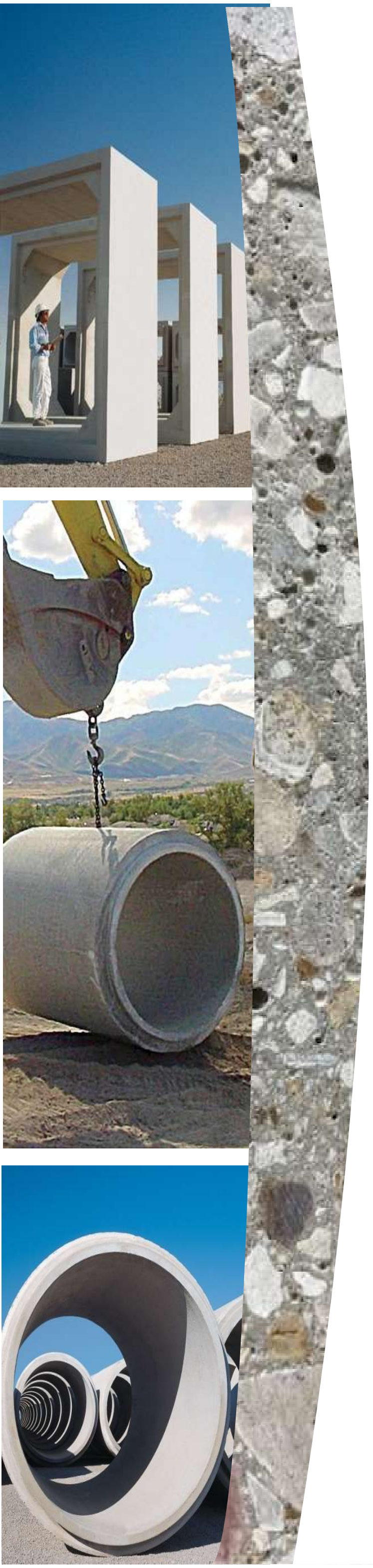


'Unofficial' Finger Test

SCC Testing for Trial Batches

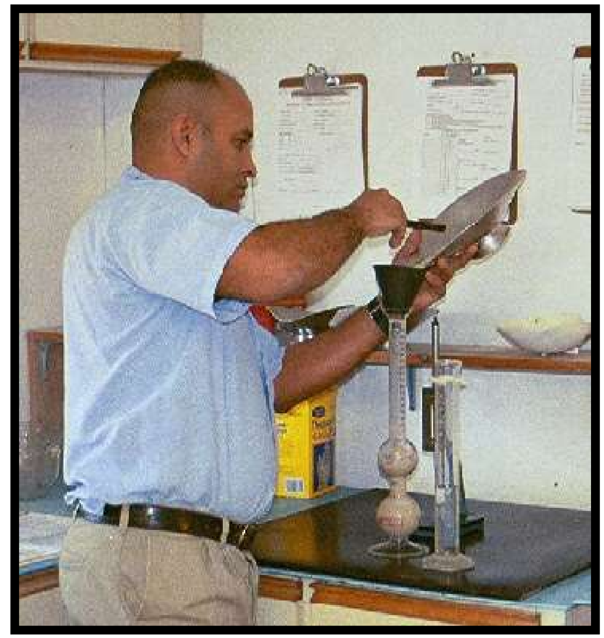
29"+- 3" Flow, 10,000 psi @ 28-Days

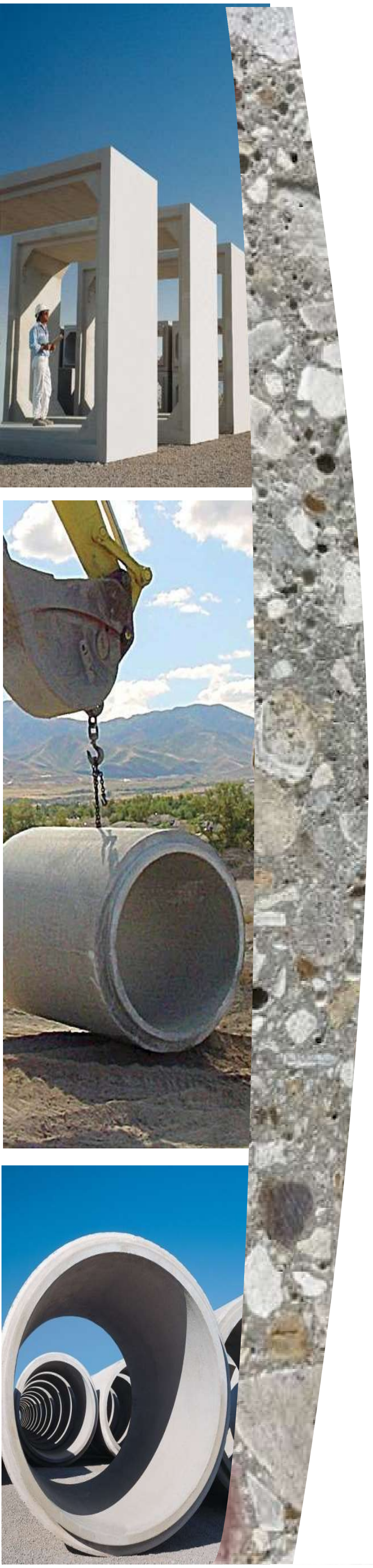




Chapman Flask - Moisture Determination

- Fill Chapman flask to 200 ml mark with water
- 500.0-gram sample of damp aggregate
- Add aggregate sample to flask
- Agitate flask with sample to remove entrapped air
- obtain reading from flask
- Using SSD specific gravity of sand look up **free moisture** on chart





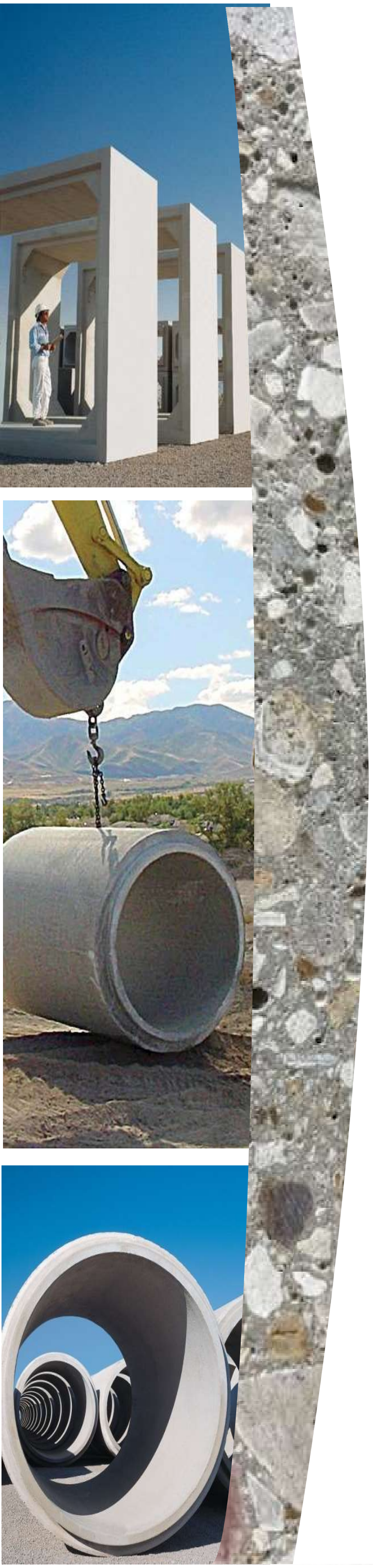
Fine Aggregate Gradation

- Fineness Modulus (FM) should be between 2.3 and 3.1
- FM is empirical # determined by dividing the sum of percent retained on a standard series of sieves by 100
(No. 4, 8, 16, 30, 50, 100)
- Coarser fine aggregate has a higher FM

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

ASTM C 33 Grading for Fine Agg

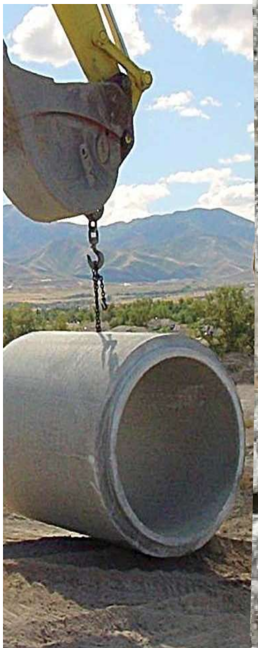
Segregation



Paste Layer No VMA
Some Segregation

Aggregate at top
No Segregation

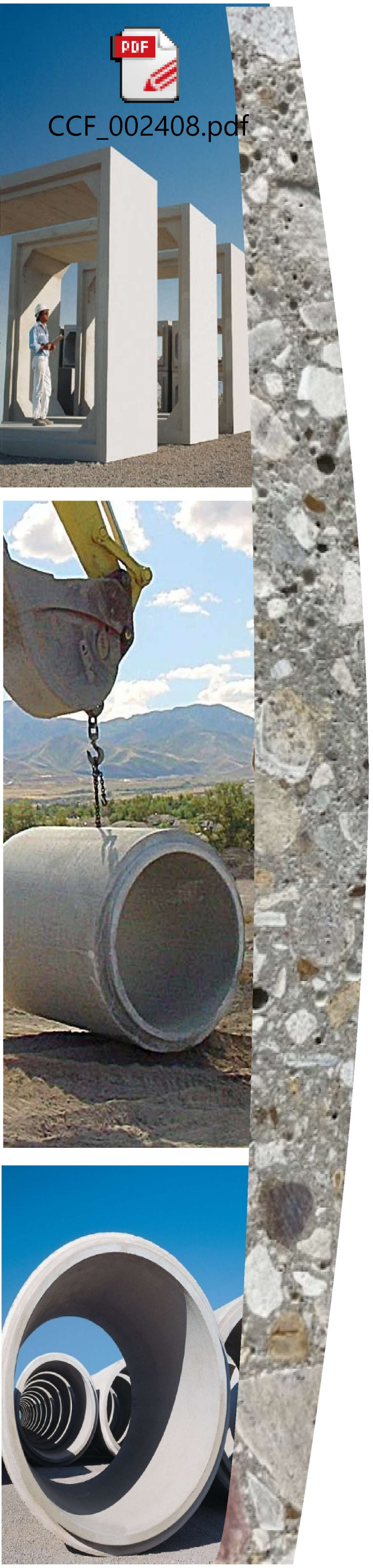
No VMA
Aggregate at top
No Segregation

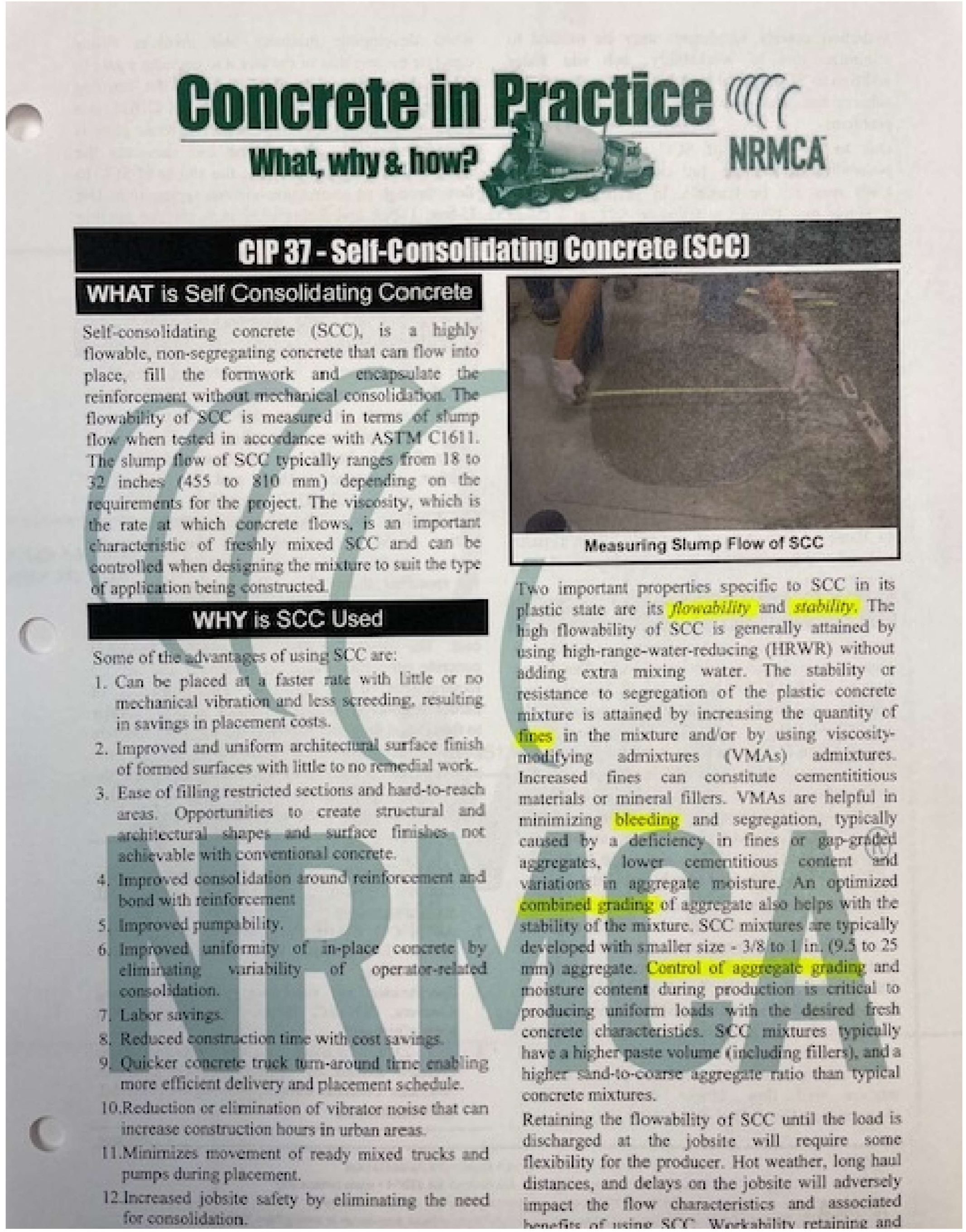


SCC Sources of Information

- **ACI**
  - Committee 237 – Self Consolidating Concrete
  - Committee 211H; Proportioning
- **PCI**
  - Guidelines for SCC
- **ASTM**
  - Test methods
- Other Resources
  - European, French, Japanese Guidelines
  - PCA Bibliography for SCC
- **NRMCA**
  - RILEM Proceedings (International SCC conferences)
  - ACBM Proceedings (1st North American SCC Conference)

NRMCA, What, Why & How?





Concrete in Practice
What, why & how?
NRMCA

CIP 37 - Self-Consolidating Concrete (SCC)

WHAT is Self Consolidating Concrete

Self-consolidating concrete (SCC), is a highly flowable, non-segregating concrete that can flow into place, fill the formwork and encapsulate the reinforcement without mechanical consolidation. The flowability of SCC is measured in terms of slump flow when tested in accordance with ASTM C1611. The slump flow of SCC typically ranges from 18 to 32 inches (455 to 810 mm) depending on the requirements for the project. The viscosity, which is the rate at which concrete flows, is an important characteristic of freshly mixed SCC and can be controlled when designing the mixture to suit the type of application being constructed.

WHY is SCC Used

Some of the advantages of using SCC are:

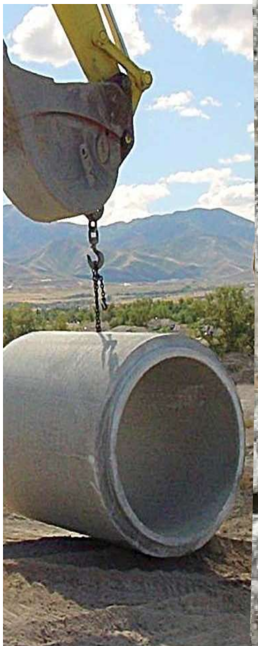
1. Can be placed at a faster rate with little or no mechanical vibration and less screeding, resulting in savings in placement costs.
2. Improved and uniform architectural surface finish of formed surfaces with little to no remedial work.
3. Ease of filling restricted sections and hard-to-reach areas. Opportunities to create structural and architectural shapes and surface finishes not achievable with conventional concrete.
4. Improved consolidation around reinforcement and bond with reinforcement
5. Improved pumpability.
6. Improved uniformity of in-place concrete by eliminating variability of operator-related consolidation.
7. Labor savings.
8. Reduced construction time with cost savings.
9. Quicker concrete truck turn-around time enabling more efficient delivery and placement schedule.
10. Reduction or elimination of vibrator noise that can increase construction hours in urban areas.
11. Minimizes movement of ready mixed trucks and pumps during placement.
12. Increased jobsite safety by eliminating the need for consolidation.

Measuring Slump Flow of SCC

Two important properties specific to SCC in its plastic state are its *flowability* and *stability*. The high flowability of SCC is generally attained by using high-range-water-reducing (HRWR) without adding extra mixing water. The stability or resistance to segregation of the plastic concrete mixture is attained by increasing the quantity of fines in the mixture and/or by using viscosity-modifying admixtures (VMAs) admixtures. Increased fines can constitute cementititious materials or mineral fillers. VMAs are helpful in minimizing bleeding and segregation, typically caused by a deficiency in fines or gap-graded aggregates, lower cementitious content and variations in aggregate moisture. An optimized combined grading of aggregate also helps with the stability of the mixture. SCC mixtures are typically developed with smaller size - 3/8 to 1 in. (9.5 to 25 mm) aggregate. Control of aggregate grading and moisture content during production is critical to producing uniform loads with the desired fresh concrete characteristics. SCC mixtures typically have a higher paste volume (including fillers), and a higher sand-to-coarse aggregate ratio than typical concrete mixtures.

Retaining the flowability of SCC until the load is discharged at the jobsite will require some flexibility for the producer. Hot weather, long haul distances, and delays on the jobsite will adversely impact the flow characteristics and associated benefits of using SCC. Workability retaining and

NRMCA, What, Why & How?



hydration control admixtures may be needed to minimize loss of workability. Job site water addition to SCC should be minimized as it may not achieve the same flowability and causes stability problems.

Due to the fluidity of SCC mixtures and the possibility of spillage, full capacity truck mixer loads may not be feasible. In such situations a producer may choose to transport SCC at a lower flowability and adjust the mixture with HRWR admixtures at the job site. Care should be taken to maintain the stability of the mixture and minimize blocking during pumping and placement of SCC through restricted spaces. Conservative formwork design may consider full head pressure and there is guidance on this aspect. Alternatively, SCC may have to be placed in lifts in taller elements. As with conventional concrete freefall of SCC should be minimized to prevent segregation and surface defects. Once the concrete is in place it should not display segregation or bleeding/settlement.

For design considerations, hardened concrete properties of SCC mixtures are essentially similar to those of conventional concrete. Higher paste volume may impact some volume change characteristics.

HOW to Evaluate and Test SCC

Several test procedures have been standardized to measure the plastic properties of SCC. The slump flow test, ASTM C1611, uses the traditional slump cone inverted, and is a field test that measures the unconfined flow of SCC. The slump flow is the spread of the concrete after it stops flowing. Slump flow can range from 18 to 32 inches (455 to 810 mm). The dynamic stability is a qualitative observation of the resistance to segregation of SCC in the slump flow test and is recorded as the visual stability index (VSI). VSI values range from 0 for *highly stable* to 3 for unacceptable stability.

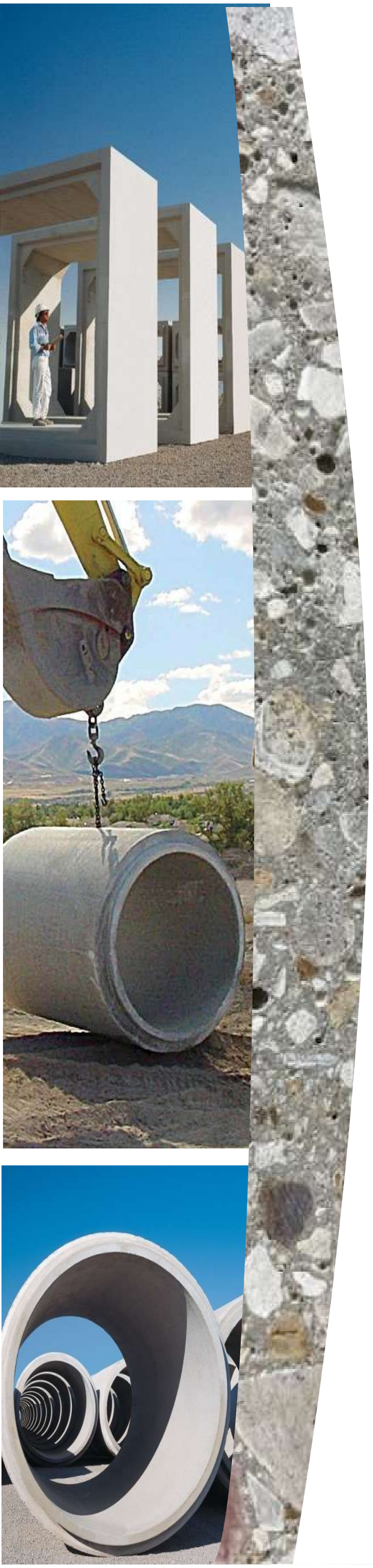
During the slump flow test the viscosity of the SCC mixture can be evaluated by measuring the time in seconds for the concrete to reach a slump flow of 20 inches (500 mm) after the slump cone is lifted. This is referred to as the T_{20} (T_{50}) value and varies between 2 and 10 seconds for SCC. A more viscous mixture will have a higher T_{20} (T_{50}) value that is more appropriate placements with congested reinforcement or in deep sections. A less viscous mixture will flow longer distances without obstructions. The U-Box and L-Box tests are used when developing mixtures and involves filling concrete on one side of the box and opening a gate to allow the concrete to flow through the opening containing rebar. The J-ring test, ASTM C1621, is a variation to the slump flow, where a rebar cage is placed around the slump cone and measures the relative slump flow to evaluate the ability of SCC to flow through an obstruction without segregation. The U-box, L-box and J-ring tests measure the *passing ability* of concrete in congested reinforcement. Other tests for evaluating the potential for static segregation are the column segregation test, ASTM C1610 and a penetration test, ASTM C1712.

HOW to Order and Specify SCC

The type of member being constructed should be considered when ordering or specifying SCC. Ready mixed concrete producers develop SCC mixtures based on performance and applications. The required slump flow is based on the type and shape of member, placement method, and the amount of reinforcement. ACI 237R provides guidance on specifications, materials, mixtures, construction and testing of SCC. It recommends slump flow for various conditions. ASTM C94 provides tolerances for specified slump flow. The lowest slump flow required for placement should be specified so that SCC used has the required stability and at the lowest cost. The design professional specifies hardened concrete properties based on structural and service requirements of the structure. The properties of hardened concrete and test methods used are similar to those used for conventional concrete. SCC concrete mixtures are developed and submitted by the producer for approval by the designer when the specification requirements of SCC in its freshly mixed and hardened state are clearly defined.

References

1. ACI 237R, *Self-Consolidating Concrete*, American Concrete Institute, Farmington Hills, MI, www.concrete.org
2. ASTM C94, C1610, C1611, C1621, C1712, C1758, ASTM International, West Conshohocken, PA, www.astm.org
3. *Specification and Guidelines for Self-Compacting Concrete*, EFNARC, Surrey, UK, February 2002, www.efnarc.org/
4. ACI 237T, *TechNote: Factors Affecting Form Pressure Exerted by Self-Consolidating Concrete*, American Concrete Institute, Farmington Hills, MI, www.concrete.org



Thank You

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