

WV DOT Corridor H Deep Fill Boxes

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West Virginia

Known as the “Mountain State”

- Home to the WVU Mountaineers
- Population 1.8 Million
- The birthplace of Jerry West, Randy Moss, Don Knotts, Steve Harvey, Lou Holtz, Nick Saban, and America’s Sweethearts Mary Lou Retton and Jennifer Garner.

Actually the terrain is more Big Hills and Valleys than Mountains

- Not Level in a lot of places-Pump the Sunlight into the hollows
- Steep Rugged Terrain
- Hills Not as high as the Mountains of Colorado, Wyoming, and out West

John Denver- "Country Roads" (1971)

- Adopted as the WV State Anthem by 1972
- Opened New Mountaineer Field in 1980
- Great Song sang by everyone in celebration
- Not a Great Song for Transportation

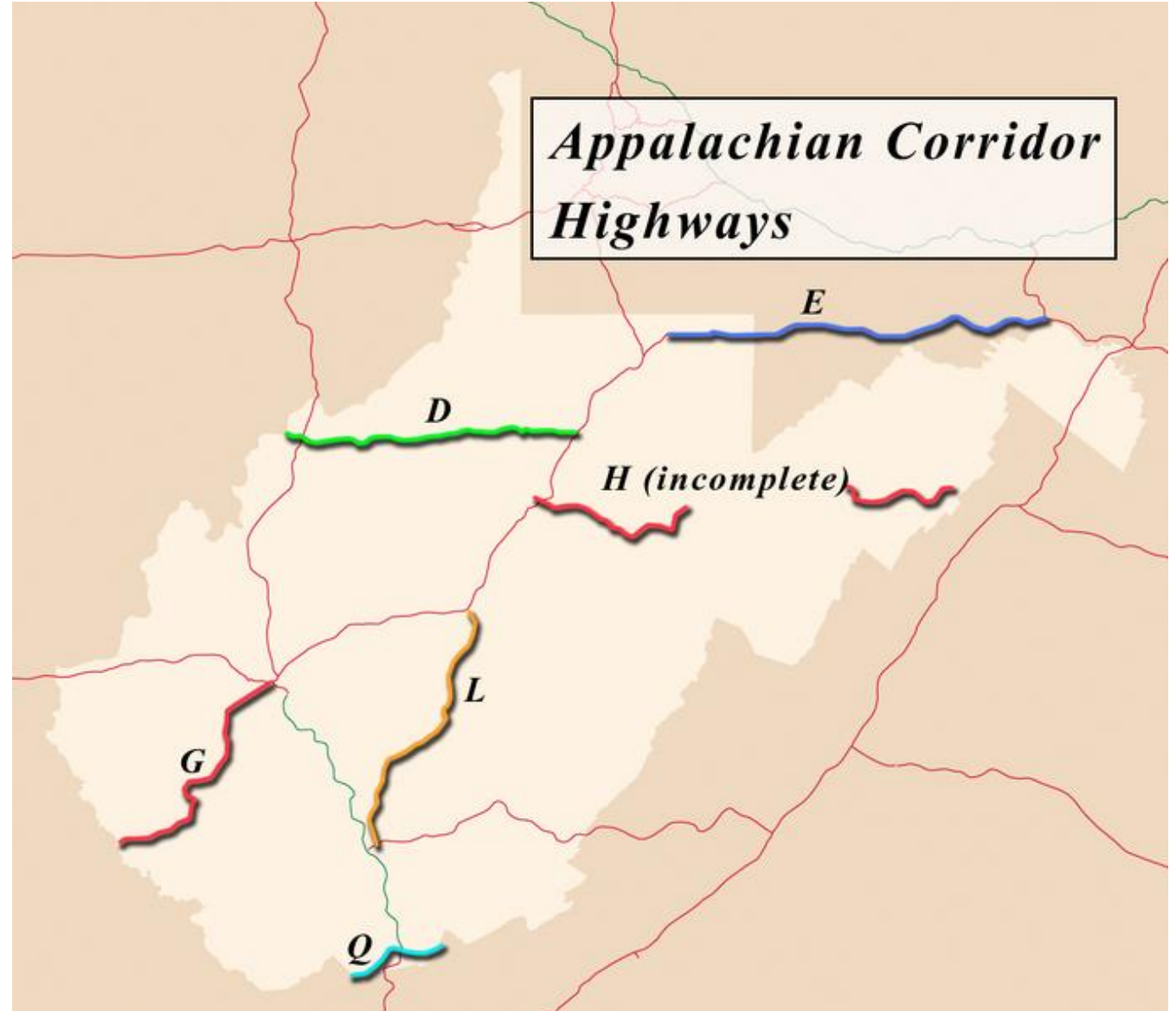


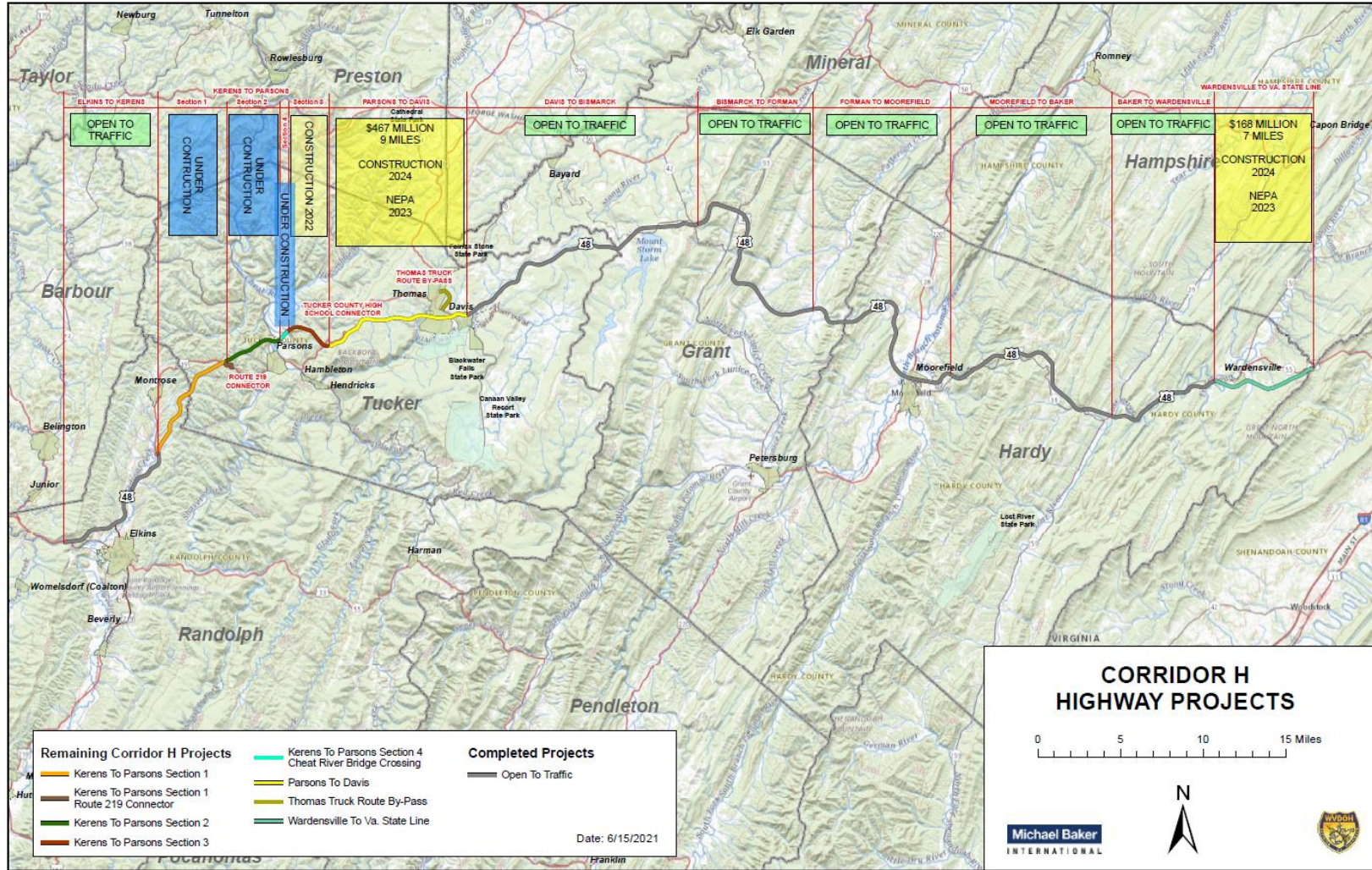
Background and Information for Corridor H—What is it?

- In 1965, Congress authorized the Appalachian Development Highway to connect Appalachia to the rest of the world with limited access four-lane highways. Some of those corridors have now become interstate highways. From Maine to Alabama, these roads have opened commerce to the people, businesses and mountains of Appalachia. They were designed for only one purpose – to open the region to more economic development opportunities.
- Corridor H is the final one yet to be completed in West Virginia. Stretching from I-79 at Weston, West Virginia, it runs to the Virginia border where it is designed to travel to I-81 near the junction with I-66 close to Front Royal, Virginia. When completed, the plan is it will be 157 miles long.

Corridor H, when completed will be US 48

- Corridor D became US 50
- Corridor E became I-68
- Corridor G became US 119
- Corridor L became US 19
- Corridor Q becomes US 460 (Primarily VDOT and KDOT)
- Corridor H has 15 miles in 2 separate sections (not under construction) and another 13.5 miles currently under construction so about 28.5 more miles left





Highways Construction in West Virginia?

Cost of building highways in the “Mountain State” is expensive

The terrain of the State of WV has large hills and valleys of varying widths to navigate

Lots of Bridges and Fills are needed to span the valleys

Every large hill we cut through is going to have material used for a fill somewhere

Every fill has drainage as an issue to accomodate

Corridor H in 2010

- Grant County, WV
Presently Buried under 300' of Fill
- LARGEST BOX CULVERT PROJECT EVER IN
WVDOT HISTORY
 - 267 box culverts due to “Clean Water Act”
regulations for maintaining the path of a
stream
 - 1500+ ft in Length
 - 10'x10' box culverts
- Also had to put baffles and “turtles rocks”
inside some box culverts for trout.



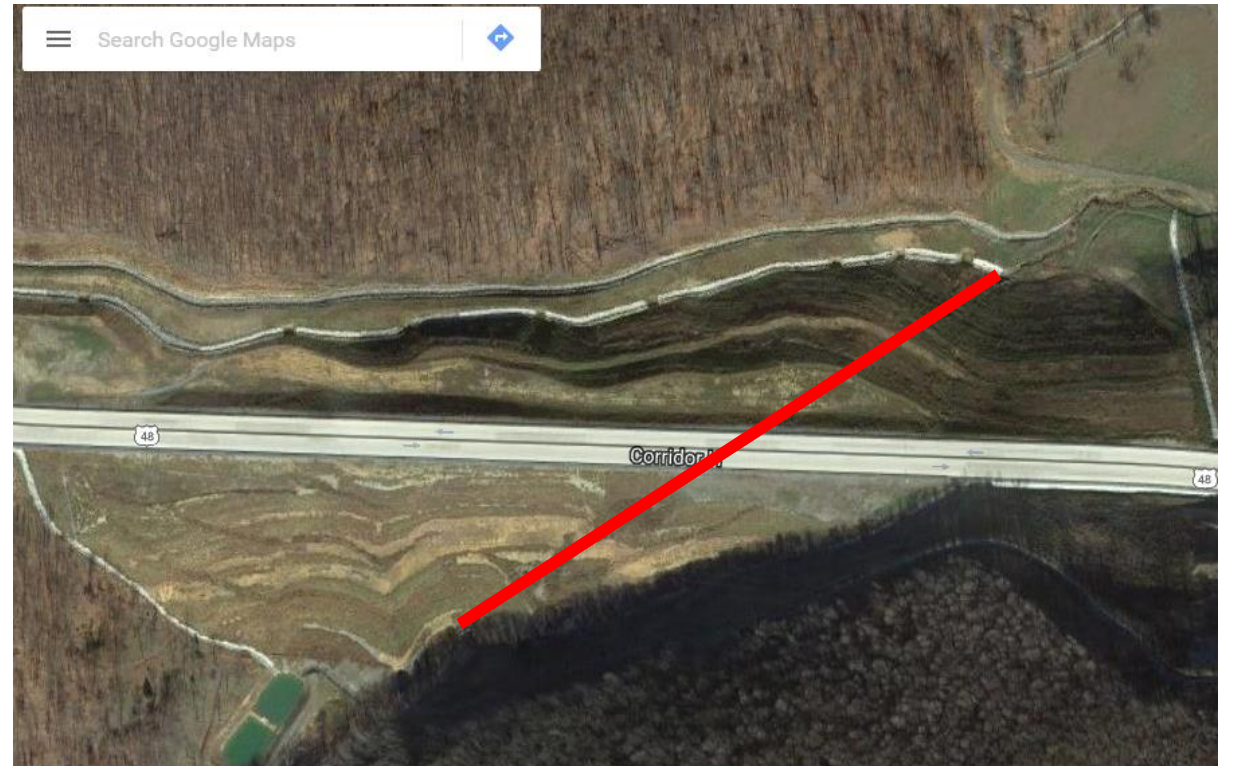
Corridor H

Due to a reported Native Trout Species, baffles and natural rock had to be placed inside the box culvert waterway



Corridor H Today

Red Line
indicates the
approximate
path of the box
culvert under
the finished
highway system.



Corridor H

Assembly was one section at a time and took over 60 installation days

All Box Culverts on this section were made with SCC (Self Consolidating Concrete).



Box Culvert fabrications/ inspection like all precast in WV DOT is controlled by WV DOT Specs & Materials Procedures

- In 2010, All Box Culverts were “wet cast”
 - Took over 60 days to set in place the 267 box culverts.
 - Took over 4 months to fabricate the 267 box culverts due to only fabricating at most 2 units a day.
 - Trial fitting at that time was an option.
 - At the beginning when the box culverts were put together in the field there were blowouts because the forms were not aligned and set up properly to make the “spigot” and “bell” ends match.
 - This caused delays and also scrapping damaged box culverts.
- Today, Box Culverts can be either “wet cast” or “dry cast”. Both types are accepted and have benefits and advantages.

BACKGROUND and INFO

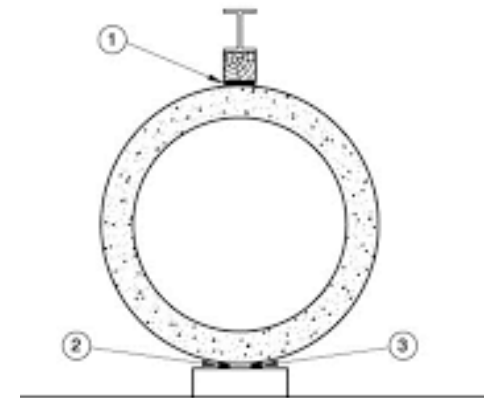
- PRECAST Concrete-Concrete cast at an WVDOH Approved Fabricator into a form and cured under a more controlled environment and transported to the field for installation. Examples are Inlets, Manholes, Junction Boxes, BOX CULVERTS, 3 Sided Bridge Units, Pipe, and Lagging as examples.
- Wet Cast Concrete-Concrete that must either be vibrated to flow so as to fabricate in a form or is Self Consolidating Concrete (Minimal Vibration and Free Flowing). This Concrete is the most commonly used material in precast for the WVDOH. This concrete will set in the form until it reaches a strength able to be released and stripped (typically 60-75% of shipping strength depending upon the 28 day shipping strength).
- Dry Cast Concrete-Concrete that is < 1 Slump where the concrete is formed and vibrated into its final form and allowed to moist cure. The Dry Cast Concrete is just that---Dry, as it in its final shape after vibration in the form and the form is removed and moisture via a curing room & steam is added to cure. Cures overnight and gains a moving strength to be moved out of curing room when compressive strength reaches 2000 psi.

BACKGROUND and INFO (Continued)

- Three Edge Bearing Test-Test used on Reinforced Concrete Pipe (Round and Elliptical) referenced in ASTM C 76 where a pipe based on size and class is loaded with an applied load at the top and supported at the bottom on 2 narrow edges. This test has 2 loading bench marks with the 0.01 inch crack load and the Ultimate Load (Failure).



THREE - EDGE BEARING TEST



BACKGROUND and INFO (Continued)

- MP 604.02.40-Inspection and Acceptance Procedures for Precast Concrete Products. This is known as the “Precast MP” within the WVDOH not to be confused with the “Prestressed MP” which is MP 603.10.40. The Precast MP deals with Box Culverts, 3 sided bridge units, manholes, inlets, junction boxes, etc.
- MP 714.03.30-Quality Assurance of Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe. This is known as the “Reinforced Concrete Pipe” MP within the WVDOH.
 - NOTE: Some RCP is wet cast but most is dry cast.

Situation Arises that leads to Dry Cast Concrete in Box Culverts

- Materials gets a call from a Fabricator that primarily produces RCP saying they have a box culvert job coming up.
- Materials response is we need to see your mix design and that is when it is discovered they want to do dry cast box culverts.
- Problem is the Specs and MPs written for WVDOT in 2020 didn't really allow Dry Cast for box culverts.
 - The 714.7 Spec (Governing Spec for Precast Reinforced Concrete Box Culverts) says "shall conform to ASTM C1577". ASTM C1577 doesn't say anything about the concrete material having to be "wet cast" or "dry cast".

Note ASTM C1577 is an update using LRFD methods and replaced AASHTO M259 and M273.
- Specs and MP 604.02.40 (Section 4.5) October 2021 and before used to say that "Unless otherwise stated, Plastic Concrete must have an air content of 7 +/- 2%"
 - Notice the use of the word "plastic" which means it is still "wet".
 - Notice the requirement of an air content.

PROBLEM: Can't really test air on a daily basis on every 7 cubic yard with Dry Cast. AASHTO T196 and AASHTO T152 don't work with dry cast.

What did this mean?

- NO DRYCAST for all practical purposes in precast concrete. Only Traditional Concrete or SCC (Self Consolidating Concrete) could be used as the material for precast.
- MCS&T is bound from our end by the Specs and MPs. MCS&T can't make changes and exceptions when not supported by the Specs and MPs. Otherwise the Specs, MPs, and Publications are all worthless because there's no enforcement or accountability.

Corridor H Project is a Design Build.

- Project calls and says, we have a schedule to meet? We want to talk about what we can do. Can we look into allowing dry cast material for box culverts?
- Since it is a Design Build, there are exceptions. The Engineer Of Record (EOR) is permitted to allow and accept changes from the Specs, but it is the EOR's decision. The EOR's decision and responsibility. So before the EOR makes a formal decision, says to MCS&T 'to look into it, do some research, and see if this is okay. Otherwise our schedule is way off and subsequently the cost goes way up.'
 - Reason in part being is a fabricator can make 8 box culverts a day with dry cast concrete in a single form. They can make 1-2 a day in 1-2 forms with wet cast concrete meaning going to take 4 times as long to fabricate. This puts everything in a delayed mode cause there's not 8 forms for wet cast concrete at fabricator to make 8 boxes a day.
 - Alternative to box culverts is dry cast RCP but RCP molds aren't available for the job and the cost goes up. This would be a lot of thick walled RCP, likely Special Design and not standard. This type of RCP isn't typically 3 edge tested but tested with cylinder breaks cause the amount of steel is a significant increase. Also getting the steel would have been an issue too at that time due to shortages in 2020.

FIRST THING-----This Situation Poses the Questions Why allow Dry Cast Concrete for use in Reinforced Concrete Pipe but Not for Box Culverts? What's the big difference?



RCP



Elliptical RCP



Box Culvert

NOTE: WVDOH had just approved 640 ft of 60 inch Class 5 (9500 DLoad) RCP with a wall thickness of 13inch for a project in another area

Situation Poses the Questions Why allow Dry Cast Concrete for use in Reinforced Concrete Pipe but Not for Box Culverts? What's the big difference? (Continued)

- Simple answer is the Specs & MPs don't permit it!!!!
- A deeper dig is the primary concern for box culverts was dry cast doesn't have the proven freeze thaw resistance due to lack of entrained air in Dry Cast. Still it has been allowed in RCP with dry cast
 - Dry cast RCP it has been shown to have complete resilience to freeze thaw degradation.
 - Box Culverts are about always buried deeper (less freeze thaw impact) than pipe too especially in WV.
- Also RC Pipe (Round and Elliptical) is typically three edge tested in most sections and that is really the primary difference from the inspection side.
- Also no approved fabricator **at that point** has wanted to or been able to use dry cast concrete for box culverts so no one has pressed the issue. The equipment necessary to fabricate with dry cast is specialized and expensive (no "mon & pop operations").
- The ACPA (American Concrete Pipe Association) also informed WVDOH-MCS&T that Dry Cast Box Culverts are allowed in other states and by other State's DOTs.

What Are Other State DOTs Doing with Box Culverts and Dry Cast to perhaps go an On Site Investigation?

- ODOT (Ohio) allows dry cast for box culverts but not had any projects as of 2021 have ever been done. They have a propensity to use thicker walled RCP. They don't have many mountains in OH like WV. The Box Culverts (larger) have been wet cast. This is due to size limitations of dry cast facilities with handling forms.
- MDSHA (Maryland) does NOT allow dry cast for box culverts
- PENNDOT does NOT allow dry cast for box culverts
- VDOT allows dry cast for box culvert and has for 30 years. There's not a great record keeping of which projects are which (wet cast vs dry cast). Same climate and usage. Went to 2 different sites but they were not very accessible to show complete information. Got to see them but it was totally dark and visual pictures were a no go even with a flash light. Both sites were in a city and were a storm runoff system.
- KYDOT allows dry cast but there's not been that many to do an onsite investigations. KYDOT has allowed it over 20 years with good results based on conversations.
- TXDOT allows dry cast for box culverts for over 40 years but that is 1250 miles away. Also TX doesn't have the climate WV does so it is not as helpful. TX does have freezing but not the number of freeze thaw cycles. TX doesn't bury at the depth WV would bury at either.
- MODOT allows dry cast box culverts
- ILDOT allows dry cast box culverts
- INDOT allows dry cast box culverts. Drivable distance (closer than IL and MO) and they've allowed them in State DOT for over 30 years. Was able to find 7 different sites in close proximity to one another SO INDIANA WAS THE BEST STATE FOR ONSITE VISITS.

*******At this years ACPA, I have learned that AZ, MN, and CANADA (Toronto) use DRY CAST Box Culverts and WI is in the process of allowing**

Sites Visited for Inspection in Indiana

Box Size	Length	Location	Address
8x5	180' (+/-)	under US 52 (Brookville Rd, from I-465 to Post Road)	8402 Brookville Road, Indianapolis, IN 46239
7x4	90' (+/-)	under State Road 46	5950 SR 46, Greensburg, IN 47240
8x4	150' (+/-)	under State Road 9 (at intersection of SR46 & SR9)	2550 North Old State Road 9, Columbus, IN 47203
twin 10x5	350' (+/-)	under Stop 11 Road (east of US 31)	1614 E Stop 11 Rd, Indianapolis, IN 46227
5x3	250' (+/-)	under US 421 (Michigan Rd, from I-465 north to 106th St.)	10495 North Michigan Road, Carmel, IN 46032
12x9	300' (+/-)	under I-65 (north of SR 32 - exit #140)	under I-65 north of exit #140
10x5	100' (+/-)	under Garoffolo Blvd (north of SR 32)	under Garoffolo Blvd (north of SR 32)
twin - 6x3	250' (+/-)	under 86th Street (east of Zionsville Road)	5400 West 86th Street, Indianapolis, IN 46278

- These sites are 20 years or older
- As pictures will show they've held up really well. Don't see scour, spalls, cracking, exposure of reinforcement, etc.

Site Visits

- 5x3 Under US 421



- Probably Needs a wingwall
- Chlorides and weathering due to exposure but still holding up

- Twin 6x3 under 86th Street



- This is full of STICKY mud and not easy to get pics
- Notice the date of 1996 (that was 25 years ago at time)
- No Spalls, Cracks, etc

Site Visits (Continued)

7x4 under State Route 46



- Not getting weathering issues and delamination or spalls even on the ends where algae and run off from the highway above
- Inside Walls look good
- Also note taking pictures inside was difficult due to my height, weight, age, and flexibility as well as lighting conditions. I used a flash light to check ALL places that were accessible though

Site Visits (Continued)

Under Garoffolo Blvd



- Standing water but not seeing spalls or cracks or delamination.
- Mastic sealer is used in the joints



Dry Cast Box Culvert Fabrication

Again dry cast concrete is different than wet cast concrete in initial stages

- Wet cast concrete has a slump (Traditional) or a flow (SCC). It is workable with external energy (vibration) or flowable.
- Dry cast concrete is vibrated in the form as it is cast and can be in the final shape upon form removal in the curing room with moisture (steam) added



Dry Cast Box Culvert Fabrication (Continued)

Dry Cast can be worked with in the green state and finished just like wet cast concrete

Batch plants and automation allow for very consistent batches



- Finish and clean up the joint area in the green state.
- If a skew or segmented piece is needed the technician can literally measure on the full size box culvert and cut it out while in a green state.

Dry Cast Box Culvert Fabrication (Continued)

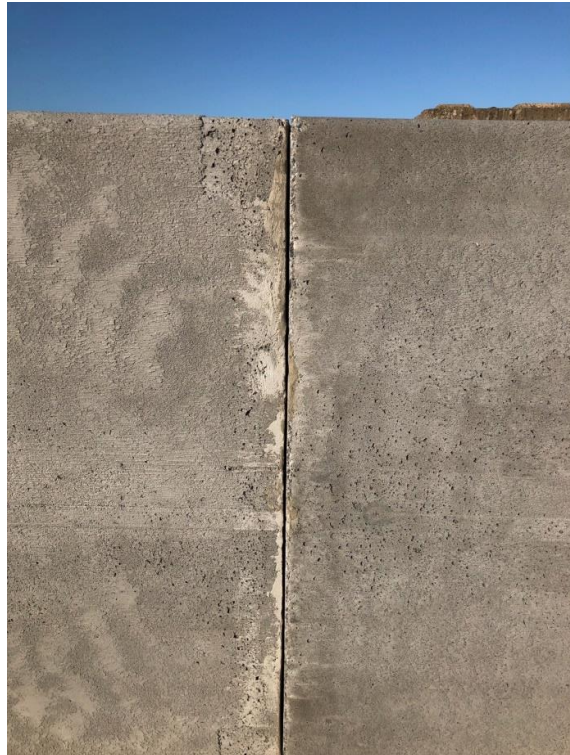
Dry cast can be worked for making skews and segmented pieces

- Cut the reinforcement and bend it at the angle of the skew and can be formed up to make a joint and new concrete added with a bonding agent
- If it is a segmented piece cut the reinforcement and bend. It is then formed up and new concrete added with a bonding agent to add the joint to fit with another box culvert



Dry Cast Box Culvert Fabrication (Continued)

Finished Products demonstrate a consistent trial fit with minimal gap



Summary of Findings:

- Material Similarities to RCP which is dry cast. RC Pipe has been used in WV for decades and there hasn't been massive failures.
- Neighboring States VA, OH, KY, and IN all allow Dry Cast Box Culverts, so there is proven usage there based on conversations with other DOTs.
- Sites Visits No noticeable delaminations, cracking, spalls (above the "thumb rule"), nor exposed steel reinforcement in IN which shows it is a good product with good track record.
- Dry Cast Box Culvert Fabrication Plant visit demonstrated how consistent and versatile the fabrication process is with skews and segmented pieces.

Conclusion to the EOR for Design Build

- Dry cast concrete can be used for Box Culverts
- Changes to the MP 604.02.40 are needed for long term use and allowance on other projects in the future

MP 604.02.40 Changes to Differentiate between Wet Cast and Dry Cast

- First change was to define dry cast concrete. It is a separate type of concrete and the first concern was for form removal criteria. The following was added.

Form removal limitations do not apply to elements fabricated with dry cast concrete. Dry cast concrete is defined as concrete with a slump less than 1-inch.

The reason for this is wet cast concrete is cured in the form where as dry cast is shaped in the form and cured via steam in the curing room.

MP 604.02.40 Changes to Differentiate between Wet Cast and Dry Cast (Continued)

- Second Change was to define the 28 day shipping strength and a stripping strength as stated in a new section

For dry cast mixes, the 28-day strength shall be confirmed by a set of compressive strength cylinders. A minimum of one set of compressive strength cylinders per day shall be fabricated and tested to verify a minimum 2,000 psi stripping and handling is achieved. A minimum of one set of compressive strength cylinders shall be fabricated from every 14 yards of concrete, or fraction thereof, with a minimum of one set per day per mix design. The cylinders are to be fabricated in the molds on the vibration table in accordance with ASTM C497. For dry cast mixes, slump testing is not required, and concrete temperature testing shall be performed on the first batch of concrete each day and every time that cylinders are fabricated.

The every 14 yds test rate was put in after the fabricator had shown through multiple weeks of fabrication the consistency & strength of the mix. It started at every 7 yds but was changed to 14 yds. ASTM C497 is the Standard for how the dry cast cylinders are made.

MP 604.02.40 Changes to Differentiate between Wet Cast and Dry Cast (Continued)

- Third Change was to add language for the frequency of absorption testing and the limit

For precast products fabricated with dry cast mixes, absorption tests are to be conducted in accordance with ASTM C642, and tests should be conducted should be conducted on a weekly basis for each mix design used. The maximum allowable absorption shall be 9%.

This is similar to RCP. Absorption has to be tested with dry cast.

- Fourth change was to waive the air requirement for dry cast with a simple statement

For dry cast concrete, the air content test requirement is waived.

No way to regularly test for air in dry cast.

MP 604.02.40 Changes to Differentiate between Wet Cast and Dry Cast (Continued)

- Fifth and Final addition was to put in the size limits for wall thickness based on equipment was added

Precast products fabricated with dry cast concrete shall be limited to a maximum wall thickness of 12 inches when single sided vibration is used and 18 inches when double sided vibration is used .

Size limits on wall thickness for quality are controlled by vibration. 2 other DOTs have this in their specs.

MP 604.02.40 Changes to NOTE for Dry Cast

- The changes in the MP with dry cast aren't just for Box Culverts
- Approved Fabricators could make dry cast inlets and dry cast manholes as well if they wanted to
- Also the changes are balanced to not favor Dry Cast over Wet Cast or Wet Cast over Dry Cast. The top goal is to always have a QUALITY product regardless of the Concrete Type.

Dry Cast Box Culvert Facts on the project

- So far on the project there have been 62-2x4, 317-3x4 (6", 7", and 8" wall thickness), 99-2x3, 78-4x5, and 93-4x6 box culverts fabricated, shipped, and installed on the jobsite so far.

NOTE: This is about 5192 ft or almost a mile of box culvert. This is not a single run in one network. These are multiple runs in different networks. Most of these box culverts have been buried between 50 and 100 ft. The deepest depths for burial is 150 ft of cover.

- The dry cast fabricator produces about 7 to 9 box culverts a day. Compared to most wet cast fabricators that generally produce 1 or 2 box culverts a day. Dry cast has a better daily production factor.

DRY CAST Box Culverts in the Field



What has been the dry cast take away?

- So far so good with WVDOT. There hasn't been any fabrication issues or complaints. Fabrication has been monitored. Product has been good.
- Other state DOTs and SHAs should likely explore the use of Dry Cast Box Culverts

Wet Cast vs Dry Cast in Box Culverts (WV DOT experiences)

- Wet cast concrete can give you a higher concrete strengths and making cylinders is much easier. Wet cast finish is better.
- Wet cast does have always have the option of air entrainment in the mix
- Wet cast allows for more rectangular box culverts (18x6, 20x5) vs the square box culverts.
- Dry Cast gives a more consistent product with better more consistent trial fits and the production factor is higher. As an example, one fabricator said they could go up to 12x12 for WV DOT and make 5 per day. Another fabricator said they had done as large as 6x8 and only 3 per day. This is obviously based on facility limitations.
- Dry Cast allows versatility for making skews and shorter length box culverts by just raking the material away before it goes in for curing with steam being added. Also dry cast requires less man power for finishing before it goes into cure.

THANK YOU

QUESTIONS??
