Cofferdam Design and Construction Overview – MDOT Perspective

By Anthony Pietrangelo, P.E.
MDOT Geotechnical Construction Support Engineer
March 17th, 2015

Presentation Overview

- Cofferdam Overview
- MDOT Specifications
- Contractor Submittal of Calculations and Drawings
- Basics of Design
  - Geotechnical
  - Structural
- Construction Procedures
- Soil Types and Effects on Construction and Design
- Common Issues in Design and Construction
- Guidance Documents and Forms
- Safety

General

- **Cofferdams**. Construct partial or total enclosure cofferdams that permit construction of the substructure, above the seal or subfooting, in the dry without damage to the work. 704.03.C
- **Pay Item Cofferdams Includes:**
  1) Designing
  2) Furnishing
  3) Installing
  4) Maintaining
  5) Removing or cut off

***** Includes steel sheet piling, bracing, tie-back, tie-back testing, walers and other related materials.

General

MDOT Specifications

- MDOT 2012 Standard Specifications for Construction section 704
  - SSC Subsection 104.02 – Working Drawings
  - MDOT Bridge Design Manual
  - *AASHTO Standard Specifications for Highway Bridges 17th Edition*
- Contract Plans
- Project specific Special Provisions included in Contract

MDOT 2012 Standard Specifications for Construction

- Specification Requirements
  - Subsection 104.02 – Plans and Working Drawings
    - Requirement for contractor to submit working drawings and calculations for cofferdams.
    - Where the combined depth of retained water and soil is **less** than **6 feet** the contractor is required to submit working drawings for cofferdams prepared by an engineer competent in geotechnical and structural engineering.
    - Where the combined depth of retained water and soil is **greater** than **6 feet** the contractor is required to submit working drawings for cofferdams prepared by a professional engineer, licensed in the State of Michigan competent in geotechnical and structural engineering. The working drawings and calculations must be sealed by the licensed engineer.

MDOT 2012 Standard Specifications for Construction

- Specification Requirements
  - Subsection 704 Steel Sheet Piling and Cofferdams
    - Provide new or used continuous interlocking steel sheet piling including connections in corner pieces. Used sheeting must be in good conditions.
    - Provide minimum nominal section modulus of at least 18.1 cubic inches per foot of wall when installed next to traffic or supporting traffic loads.
    - Both cold and hot rolled sheeting is permitted.
    - A copy of the cofferdam design and working drawings shall be provided and maintained at the job site as required by MIOSHA Construction Safety Standard
    - Vibratory hammers are permitted – see plan notes for exclusions
    - Do not pull up or redrive sheeting to match cut off elevation.

MDOT 2012 Standard Specifications for Construction

- Design in accordance with the *AASHTO Standard Specifications for Highway Bridges, 17th Edition.*
  - Sheet piling section modulus and embedment depth
  - Design criteria for bracing and bracing sections, connection and tie-back details, and deadman sections.
  - Assumptions and references for the design calculations
  - Any temporary loads for construction equipment, construction materials, traffic loading and any unbalanced hydrostatic pressure loading
  - Profile and Plan Views with cross sections
  - All located in Subsection 704.03.A

Contract Plans

- May Include:
  - Minimum section modulus
    - May call out specific type
      - Depth of sheeting may need to be reviewed if different section is being proposed.
  - Minimum Embedment Depths
  - Prohibit use of Vibratory Hammers
  - Only hot rolled sheeting is permitted.
  - Overall cofferdam dimensions.
  - Cut off elevations
  - Tremie thickness

Special Provisions

- Common items included in Special Provisions
  - Deflection Criteria, 2.0 inches maximum
  - Design based on Geotechnical Engineering Software including the following programs
    - SPW 911 by PileBuck International Inc.
    - SupportIT by GT Soft Ltd.
    - CivilTech Software Shoring Suite
    - Other software will be reviewed by the Department and requires approval prior to use.
    - Hand calculations for structural designs and details are acceptable.

Special Provisions Continued

- Include a minimum Live load surcharge of 360 psf.
  - Construction equipment loaded must be accounted for and may increase the live load surcharge.
    - i.e. Crain Loads applied directly behind sheeting.
- Sheeting adjacent to existing spread footings shall be designed using a uniform surcharge equal to the applied footing pressure.
- Bottom stability (piping and heave) and overall (global) stability evaluated for all stages of construction. Minimum factors of safety are included in SP.

Design/Submittals: Contractor's Responsibility

- Submit proposed design to Construction Engineer 10 working days before starting work. (Standard Specs.)
- Special Provisions may require longer review cycle times.
- Multiple review cycles may be needed.
- Show sheet piling, section modulus, embedment depth, water level and bracing details.
- Excavation profile.
- Make sure cofferdam design are constructible.
- Work begins after Engineer's acceptance.

Design/Submittals: Engineer's Responsibility

- Engineer shall check the following:
  - Section modulus of sheet piling
  - Method of excavation, "dry" vs. "wet"
    - Hydrostatic forces
  - Construction staging and sequence.
    - Supporting Calculations for ever step in the excavation process.
    - Clearly define each construction sequence
    - Provide room for waler installation
  - Excavation Profile
  - Toe Embedment of the sheet piling
  - Bracing-If required
    - Structural Calculations
    - Connection Details
  - Two or more rows of Bracing require Apparent Earth Pressure Model used to calculate earth loads.

Design/Submittals: Engineer's Responsibility

- Battered Pile vs Sheet Piling Conflict
  - If cofferdam is widened, Tremie design must be revisited by contractors Design Engineer.
    - Tremie is a designed element from Bridge Design Engineer
    - Consult MDOT Bridge Design Manual on Bending Stress analysis
- Driveabilty Analysis
  - Soil Profile
    - Sands vs Clays
    - Cobbles / Boulders
  - Vibratory hammer may not be as critical as Impact hammer
  - Sheeting must be able to with stand impact driving stresses.
- Other External Loads
  - Surcharge Loads
  - Soil surcharges (i.e. sloping backfill)

You never know what might end up on top of the cofferdam

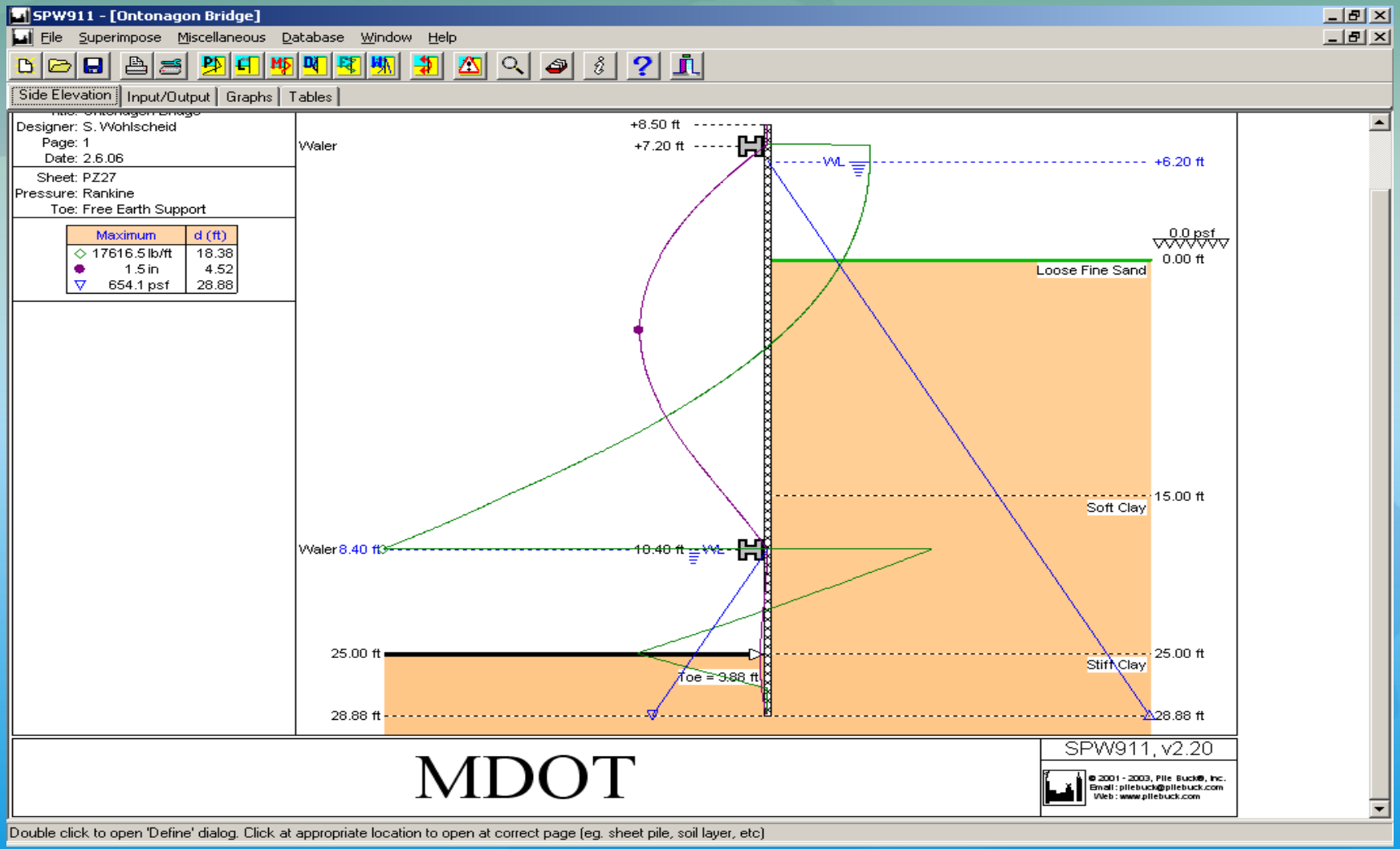
Construction Sequencing

Staging Details of Cofferdams

- Layout of cofferdams shall match maintaining traffic staging details, and structure removal limits
- Minimum lane width, barrier, and bar splices shall be accounted for in layout.
- Coordinate with culvert manufacture to find out all culvert section dimensions.
- Stream diversion plan shall be included if required.

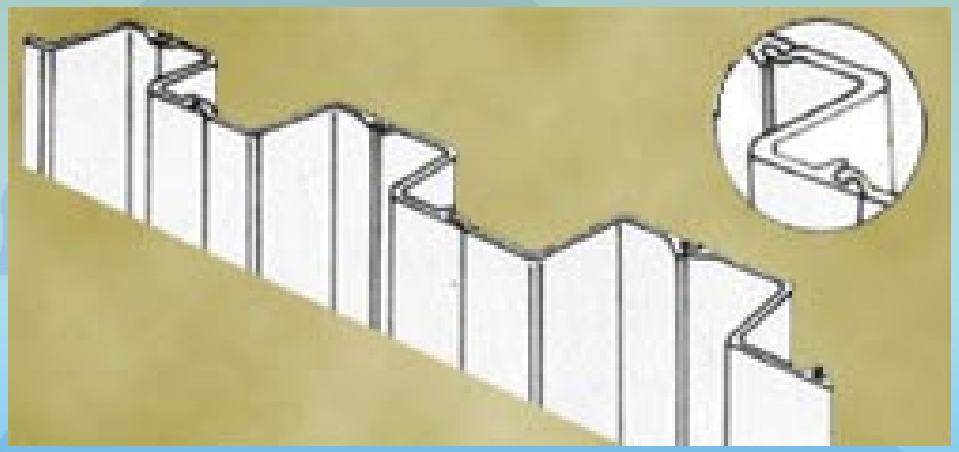
Staging Details

Design Program-SPW911



Sheet Piles

- Hot Rolled vs. Cold Rolled
- Hartman Reduction Factor
- Straight, Arch-Web, Deep-Web, & Z-Sections



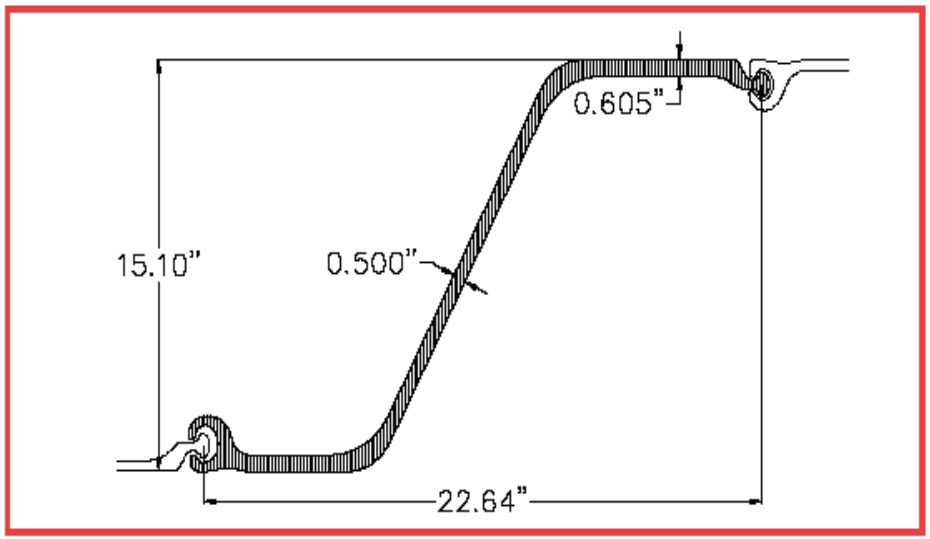
Cold Rolled

- Produced from a coil by cold rolling the coil into a sheet pile shape.
- “Loose” interlock compared to hot rolled.
- Uniform thickness.
- Thickness limited to ½” based on coil thickness.
- Residual stresses in bends due to rolling process.

Cold Rolled

Hot Rolled Section

- PZ-35 Section Example
- Ball and Socket Interlock
- Better interlock
- More points of contact.
- Joints are less likely to leak than cold rolled
- Easier to install
  - Less Friction
  - Alignment
- Generally specified in permanent applications



Dimensions and Properties

US Standard

	Weight in Pounds		Moment of Inertia, in⁴		Section Modulus, in³		Surface Area sq ft per lin. ft of bar	
Nominal Width, in.	Per Lin. ft of bar	Per sq ft of bar	Single Section	Per Lin. ft of wall	Single Section	Per Lin. ft of wall	Total Area	Nominal Coating Area
22.64	66.0	35.0	697.0	369.4	92.3	48.9	5.83	5.33

Hot Rolled vs. Cold Rolled

- Effective vs. Nominal Section Modulus
- Hot Rolled and Cold Rolled Nominal Section Modulus.
- Contractor’s Engineer should check availability of Sheet Piling before specifying.
- Hartman Reduction Factor-Illinois DOT
- 83% Lower Bending Failure Stress

Construction Procedures

- Bracing Methods
- Sheeting Installation Methods
- Inspector to Verify Cofferdam Construction Matches Cofferdam Submittal
- Excavations Methods
- Tremie Seal/Pour

Bracing

- Struts
- Walers
- Tie Backs
- Bracing Rings

Internal Bracing

- Use of Walers and Struts to internally transmit load
- Tremie may also used as a brace point once minimum strengths are achieved.

Strut and Wale Bracing

Bracing Rings

Waling

- Waling transmits forces from the sheet piling internally from side to side or into the anchor assembly. The wailing assembly may composed of struts (HP or W sections), channels, tie rods and connection bolts.
- Walers could also be used as a driving template to keep sheeting lines straight.
- Walers should be in contact with the steel sheet piling.
  - Gaps will need to be filled in with a structural detail

Structural and Connection Details

- Weld details and call outs
- Properly size walers and struts
- Correct end support conditions
  - Fixed – Fixed
  - Pinned – Pinned
  - Free end
- Continuous Walers
  - Splice detail
  - Negative Moments
- Structural Detail for when waler is not in contact with sheet pile
- Most common failure mechanism is connection details/failures

This is what is being built!

This is what is being built!

Installation Methods: Impact Hammer vs. Vibratory Hammer

Installation Methods/Soil Types:

Driving Steel Sheet Piling, Vibratory vs. Impact Hammer

- Designers typically add notes indicating if vibratory hammers are not permitted.
- Method used based on soil type and nearby structures.
- Contractors prefer Vibratory Hammer for sandy soils.
- Cohesive soil responds better to a Impact Hammer.
- Driveability analysis may need to be performed for Impact Driven sheeting.
  - Size sheeting accordingly

Excavation/Soil Types

- Wet vs. Dry Excavation
- Cohesive vs. Granular
- Excavation Done Before Driving Piles
- Equipment Used
  - Clam Shell-Crane
  - Excavator
  - Soundings


2 1:35PM

Tremie Seal

- Required Thickness
  - Based on uplift resistance to sheet piling/piles and weight of concrete mass to resist hydrostatic forces.
  - Allowable skin friction can not be greater then pull out resistance of sheet piling and piles.
    - MDOT Bridge Design Manual also list allowable bond stresses.
  - Bending Stress Calculation of unreinforced concrete
    - Generally controls if foundation piles are used.
- Required Strength Before Dewatering(706.03.H.3)
- Grade T Concrete
- Before Pouring Tremie, Verify All Soil Has Been Cleaned Out of Sheet Piling.
  - Pockets of sheet piling should be checked
- Tremie Tube Shall be Kept Embedded into Tremie Concrete.

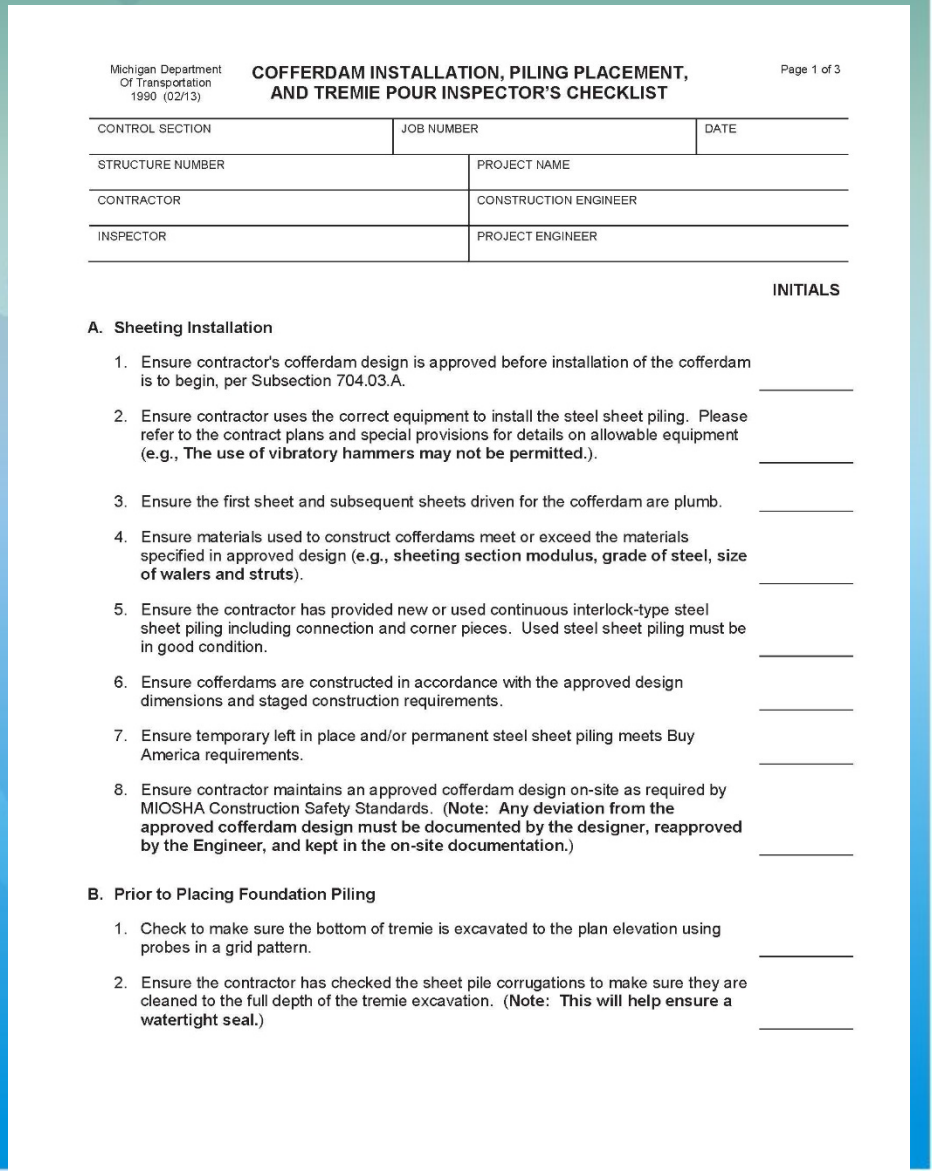
Tremie Pour in the “Wet”

Removal of sediments after tremie pour.

Guidance Documents
- MDOT Form 1990

- **MDOT Form 1990**, *Cofferdam Installation, Piling Placement, and Tremie Pour Inspector's Checklist.*

- Form is available on the MDOT forms website.
- Developed to prevent reoccurring geo-construction issues.
- Highlights sections already included in the 2012 Spec Book



Michigan Department Of Transportation 1990 (02/13)

COFFERDAM INSTALLATION, PILING PLACEMENT, AND TREMIE POUR INSPECTOR'S CHECKLIST

Page 1 of 3

CONTROL SECTION	JOB NUMBER	DATE
STRUCTURE NUMBER	PROJECT NAME	
CONTRACTOR	CONSTRUCTION ENGINEER	
INSPECTOR	PROJECT ENGINEER	

INITIALS

A. Sheeting Installation

1. Ensure contractor's cofferdam design is approved before installation of the cofferdam is to begin, per Subsection 704.03.A. _____
2. Ensure contractor uses the correct equipment to install the steel sheet piling. Please refer to the contract plans and special provisions for details on allowable equipment (**e.g., The use of vibratory hammers may not be permitted.**). _____
3. Ensure the first sheet and subsequent sheets driven for the cofferdam are plumb. _____
4. Ensure materials used to construct cofferdams meet or exceed the materials specified in approved design (**e.g., sheeting section modulus, grade of steel, size of walers and struts**). _____
5. Ensure the contractor has provided new or used continuous interlock-type steel sheet piling including connection and corner pieces. Used steel sheet piling must be in good condition. _____
6. Ensure cofferdams are constructed in accordance with the approved design dimensions and staged construction requirements. _____
7. Ensure temporary left in place and/or permanent steel sheet piling meets Buy America requirements. _____
8. Ensure contractor maintains an approved cofferdam design on-site as required by MIOSHA Construction Safety Standards. (**Note: Any deviation from the approved cofferdam design must be documented by the designer, reapproved by the Engineer, and kept in the on-site documentation.**) _____

B. Prior to Placing Foundation Piling

1. Check to make sure the bottom of tremie is excavated to the plan elevation using probes in a grid pattern. _____
2. Ensure the contractor has checked the sheet pile corrugations to make sure they are cleaned to the full depth of the tremie excavation. (**Note: This will help ensure a watertight seal.**) _____

Safety

- Limited Access
- Wet excavations/conditions
- Deep Excavations
- Adequate Walkways, Rails, and Ladders
- Flotation Devices
- MIOSHA-Part 9. Excavation, Trenching, and Shoring-Excavations >5 ft
- MIOSHA requires sealed cofferdam design be maintained on site

How safe is this?


29 1:06 PM

Closing Thoughts

- Cofferdams should be designed and detailed so contractor and MDOT inspector can easily construct cofferdam and all required components.
- All construction stages clearly defined
- Structural members and connection details should be clearly detailed and understood.
- Cofferdams are contractor's temporary works and can be revised as field conditions dictate.
  - However, changes must be reviewed and approved by design engineer, working drawings revised and resealed, reviewed and approved by MDOT.

Summary of Presentation

- MDOT Specifications
- Basics of Design
- Construction Procedures
- Soil Types and Effects on Construction and Design
- Safety

Questions?