

Drilled Shaft Inspection Workbook

Certified Inspector
Training Program

Drilled Shaft Inspection Certification Workbook

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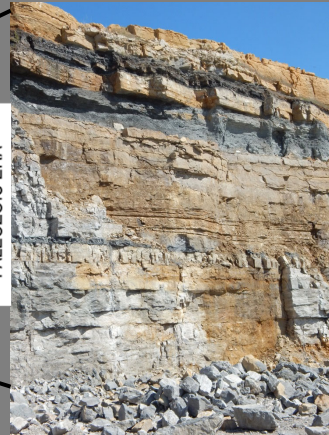
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Drilled Shaft CIT Class

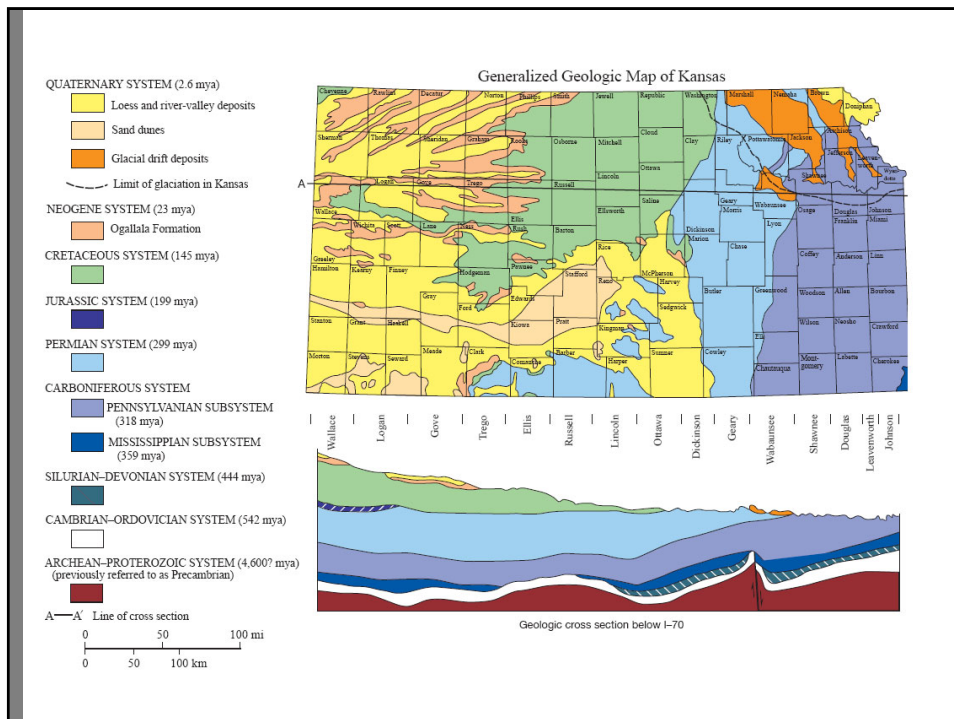
Kansas Geology 101

Member	Formation				
South Bend Ls. Mbr.	Stanton Limestone	Lansing Group	MISSOURIAN STAGE	UPPER PENN. SERIES	PENN. SUBSYST.
Rock Lake Shale Mbr.					
Stoner Limestone Mbr.					
Eudora Shale Member					
Captain Creek Ls. Mbr.	Vilas Shale				
Spring Hill Ls. Mbr.	Plattsburg Limestone				
Hickory Creek Sh. Mbr.					
Merriam Limestone Mbr.					



Kyle Halverson
Chief Geologist

1



2



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View from Mount Sunflower Elevation 4039

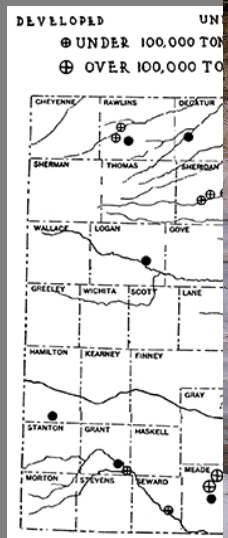


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Volcanic Ash Deposits



www.geographer-miller.com

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Ancient North American Sea 65 to 135 million years ago



9

Camel Rock Kiowa County



10

Arikaree Breaks Cheyenne CO.



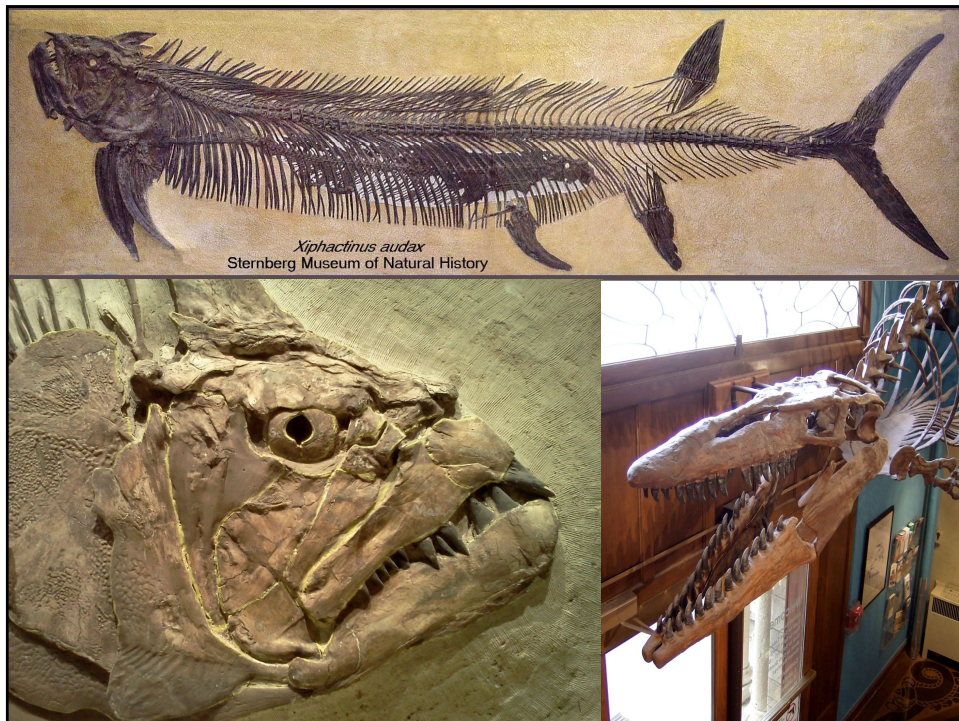
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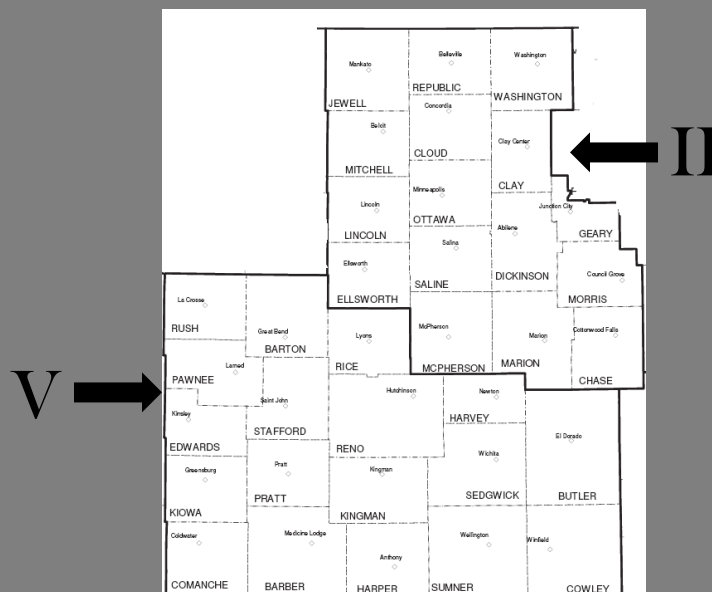
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What to expect in your district

- Districts 3 & 6- Weak limestones and shales, and thick deposits of sand and soil. Drilled shafts have been constructed in these districts when bedrock is close to the surface and of good quality. Most of the time the depth to bedrock and the poor quality of bedrock, limits drilled shaft construction.

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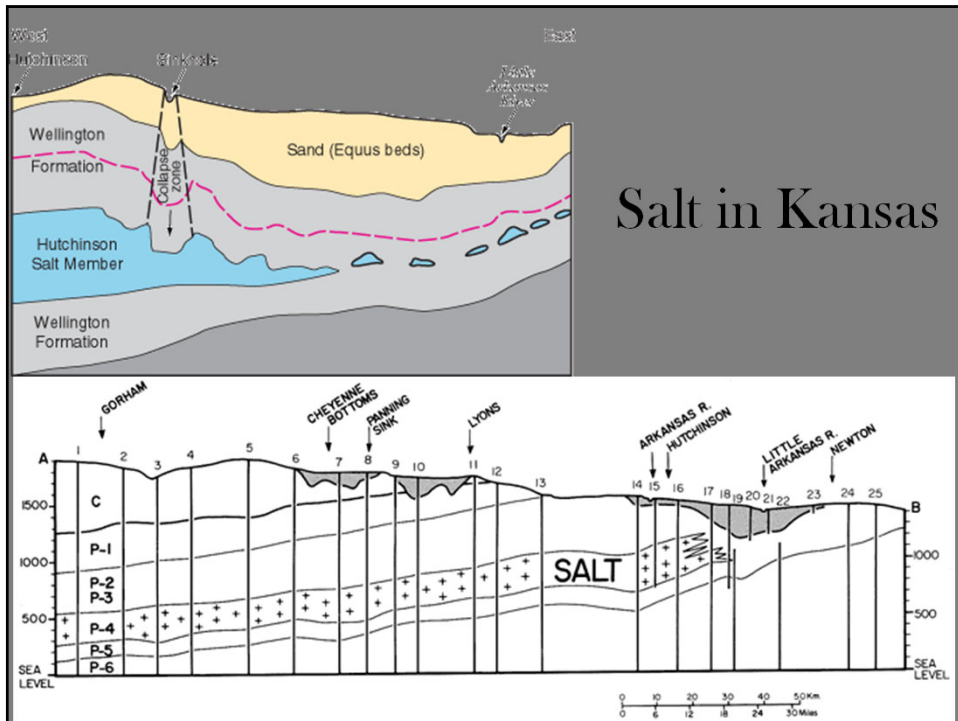
District II and V



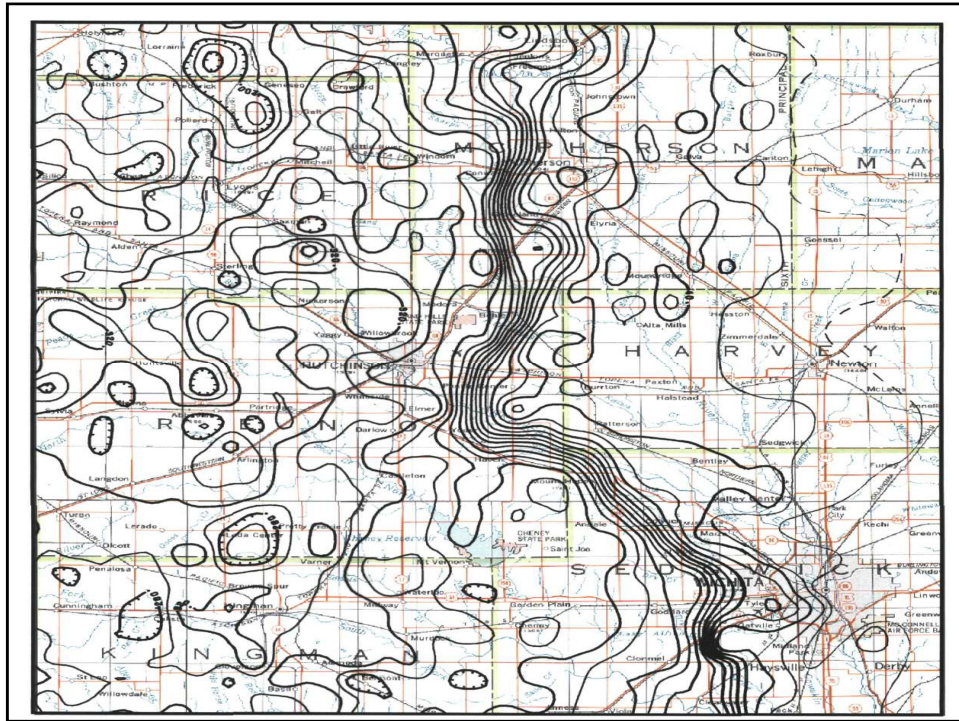
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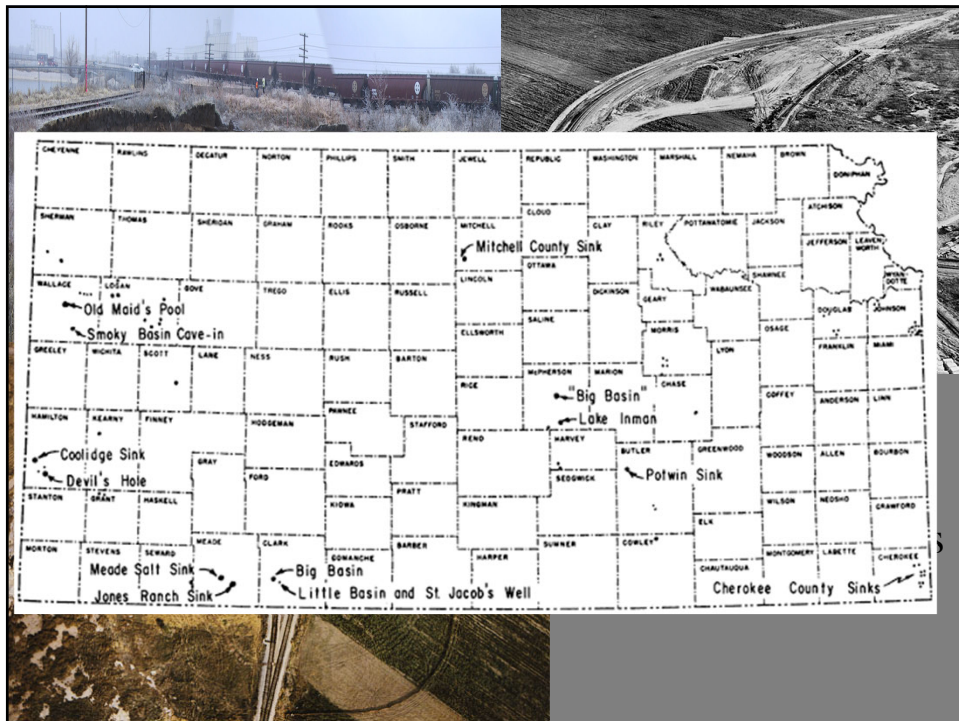
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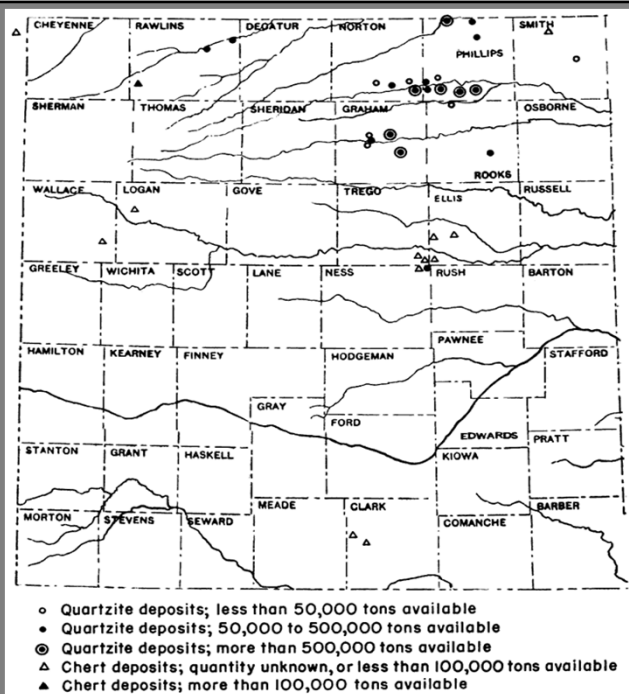
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Green Rock?

- District 2 has some unique deposits of Opaline Cemented Sandstone.
- The opal or chert cement is green.
- This material is commonly used for rip-rap on western Kansas lakes and as a concrete aggregate.

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Where you
can find the
Green Rock!



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26

Post Rock Quarry



27

Sand Dunes



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What to expect in your district.

- District 2- Limestones, shales, and sandstones. Eastern half is similar to District 1. Western half rock is of good quality but special considerations must be taken before a drilled shaft is constructed.

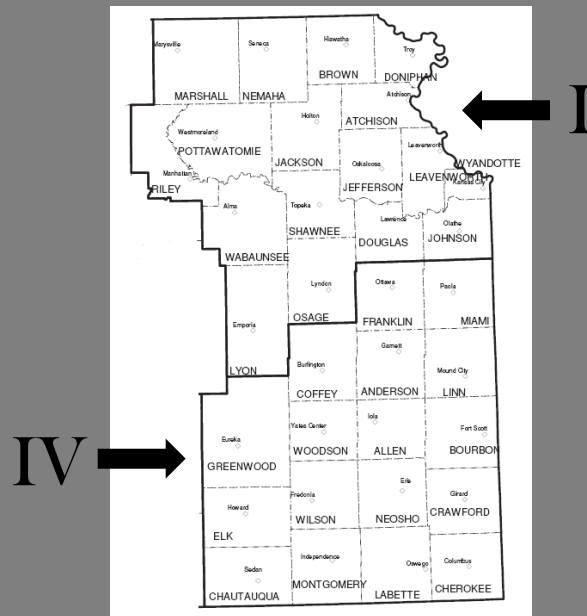
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What to expect in your district (D5)

- District 5- Limestone (east), shale, and thick layers of sand. Eastern part (Butler and Cowley Co.) is similar to District 4. Western part has weaker shales and lots of sand that can very deep (100ft +) Drilled shafts can be placed but depth to bedrock and foundation material must be considered.

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Districts I and IV



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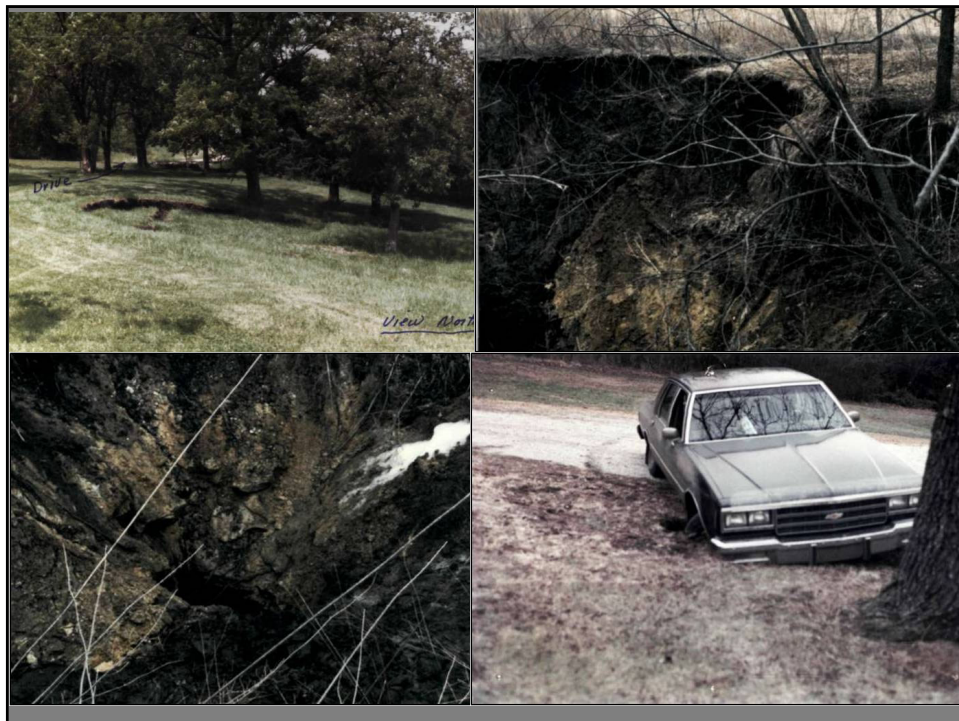
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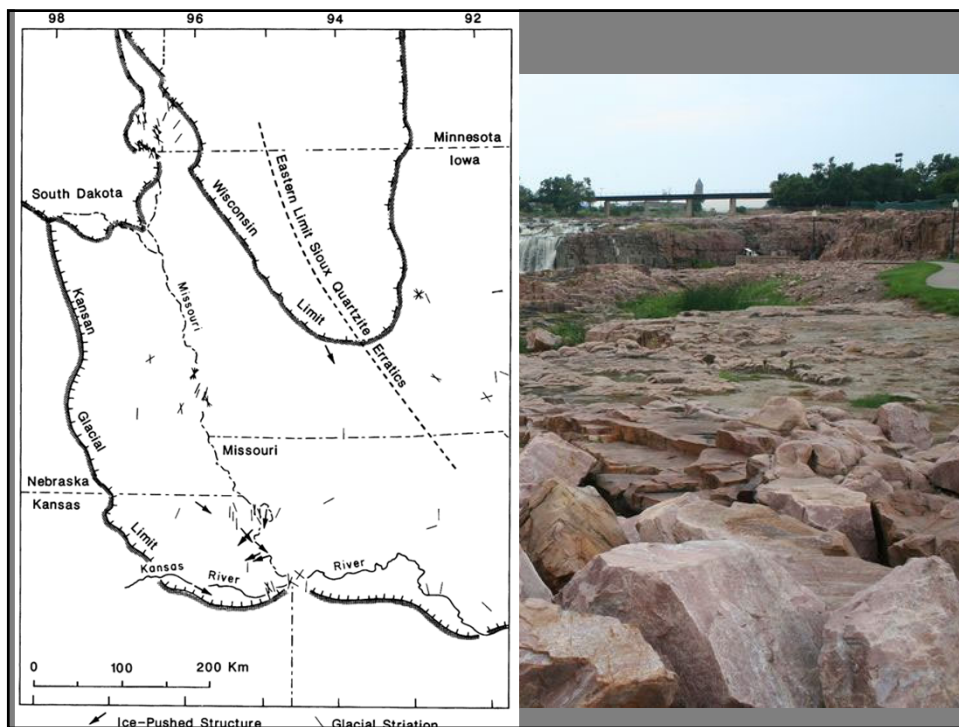
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What to expect in your district (D1 & D4).

- Districts 1 & 4- Limestones, shales, and sandstones. Lack of depth to bedrock and hardness of material make it nearly ideal for drilled shafts

41

Common Rock Types?

- What are the 3 main sedimentary rocks we have in Kansas?
- What variations can we have?

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Who you need to Contact

- District 1- John Barker
 - (785)291-3861
- Districts 2 & 3- Neil Croxton
 - (785)-263-4597
- District 4- Denny Martin
 - (620)431-1000
- Districts 5 & 6-Art Peterson
 - (316) 320-1721

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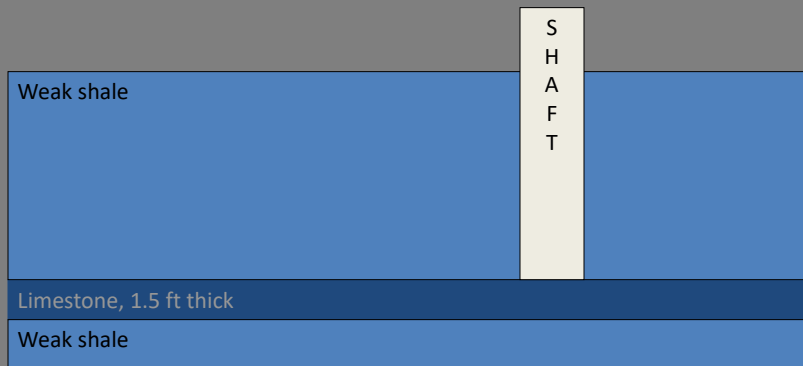
Why are tip elevations important?

- Strength of material at this location is best.
- May be supported by a thin unit.
 - At least 2 ft. thick.
 - Less than 2 ft. may cause a punch out

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Punch Out

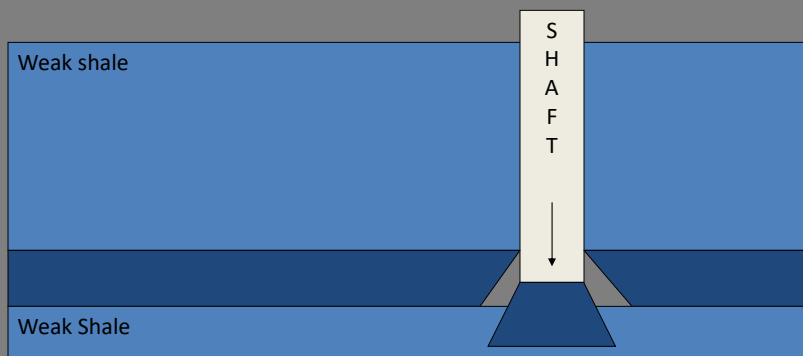
Drilled shaft on too thin of Limestone



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Punch Out In Weak Shale

- What can happen

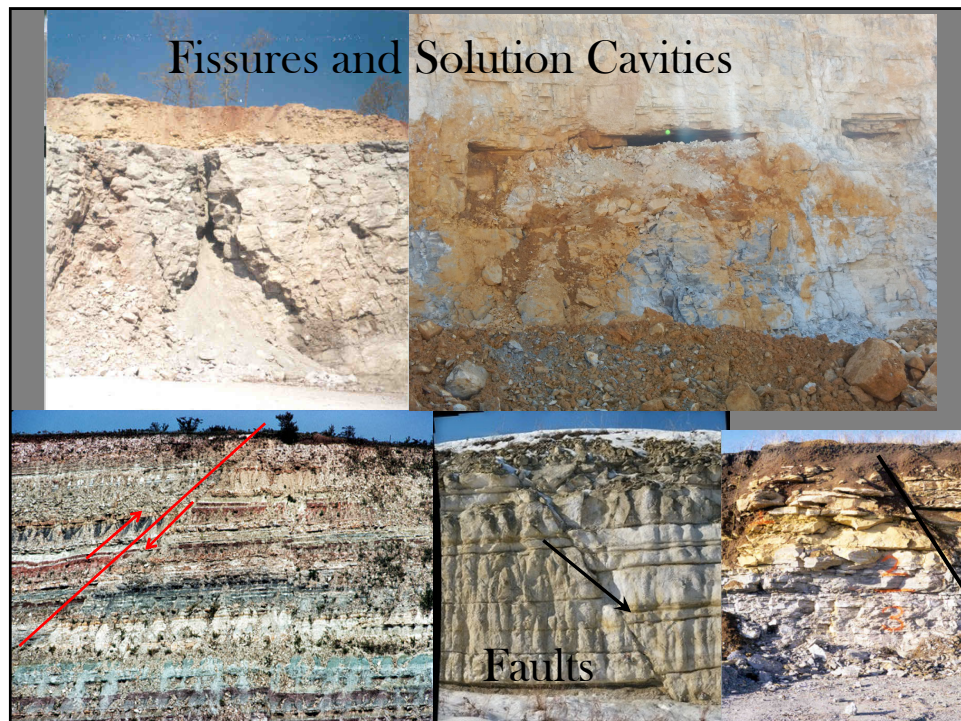


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GEOLOGIC PROBLEMS

1. Solution Cavities and Fissures
2. Limestones Underlain by Weak Shales
3. Bedding
4. Faulting

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The Geology Report and the Purpose for it

When in doubt.....

1

Sections of the Geology Report

- Introduction
 - Location of bridge
 - Local conditions
- Geology at Bridge Site
 - Soil Mantle
 - Bedrock
- Foundation Recommendations
 - Pile foundations
 - Drilled shaft foundations
 - Investigative Core Holes
- Hydrology

2

Introduction

- The content of this report provides geologic information pertaining to the design of a new bridge along existing 118th St that cross the proposed widening of I-70 northeast of the city of Bonner Springs in Wyandotte County. The new bridge is 520.6 ft long, 36.6 ft wide and will accommodate 2 lanes of traffic and a sidewalk.

3

Geology at Bridge Site -Soil Mantle

- What is the soil mantle composed of?
- How thick is the mantle material?
- Does the composition and thickness change over the length of the bridge?

4

Geology at Bridge Site -Soil Mantle

- The soil mantle is classified as all unconsolidated material above bedrock. The soil mantle encountered at the project site is comprised silty sandy clay. The soil observed was soft to firm, light brown to dark brown, and slightly moist to wet. The overall thickness of the soil mantle is 0 ft to 15.5 ft thick.

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Geology at Bridge Site -Bedrock

- What is the bedrock composed of?
- How thick is the bedrock material?
- Does the composition and thickness change over the length of the bridge?
- What is the foundation material?
- Any special conditions?

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Geology at Bridge Site-Bedrock

- **Stranger Formation**

- **Tonganoxie Sandstone Member**

- The Tonganoxie Sandstone Member is the upper most sequence of bedrock found across the bridge site. This member will be encountered over much of the project where it cuts through the Iatan Limestone and Weston Shale Members and lies disconformably on the Stanton Formation. This disconformity developed by the infilling of existing deep erosional channels during the deposition of the Tonganoxie Sandstone. The rock that was observed contained thick sequences of fine grained, cross-bedded sandstone with several thin, discontinuous, interbedded sandy shales. The sandstone is weathered in the upper most portions and transitions to unweathered through the majority of the unit. The basal portion of the Tonganoxie Sandstone, a discontinuous sequence of shales and conglomerate was observed in samples taken near Abutment #2. Well cemented sandstone and closely to very closely spaced horizontal fractures were also identified throughout the borings. The spacing of the fractures resulted in an average RQD of 63%. The rock ranged in competency from hard to very hard. The Unconfined Compression Strength (Qu) averaged 80.04 TSF, but varied from 1.875 to 245 TSF. The total thickness of this unit across the bridge site varied from 0 to 37.4 feet thick. The RMR classification for this unit is 77 which classify it as Good Rock. This rating was determined using the RMR system which uses strength, RQD, discontinuities, weathering, and a number of different factors to determine the classification.

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Bedrock Continued

- **Stanton Limestone Formation**

- **South Bend Limestone Member**

- The South Bend Limestone Member consisted of a 4.7 to a 5.2 feet thick limestone. This limestone contains a broad assemblage of fossils ranging from *Echinodermata* to *Bivalvia*. The "South Bend" may be locally missing or scoured and replaced by sandstone from the Tonganoxie Member. The South Bend observed in borings across the bridge site appeared unweathered, gray, well cemented, fossiliferous, closely to widely fractured, and very dense. The spacing of the fractures resulted in an average RQD of 94%. The Unconfined Compression Strength (Qu) averaged 230 TSF, and varied slightly from 206 to 258 TSF. The RMR classification for this unit is 84 which place it in the Very Good Rock category.

- **Rock Lake Shale Member**

- The Rock Lake Shale Member varied across the bridge site from 8.1 to 9.1 feet of hard to very hard, gray limy shale. This shale unit has an abundant amount of interbedded limestone stingers across the bridge site. The Rock Lake Member generally weathers to yellowish-gray, clayey shale, however the shale observed in borings at the bridge consisted of non-weathered, very closely to closely fractured rock. The spacing of the fractures resulted in an average RQD of 90%. The Unconfined Compression Strength (Qu) averaged 40 TSF, but varied from 10.65 to 70.5 TSF. The RMR classification for this unit is 64 which places it in the Good Rock Category

8

Bedrock Continued

■ **Stoner Limestone Member**

- The Stoner Limestone Member observed at the bridge site is gray to dark gray, well cemented, fossiliferous, very hard limestone. In areas where the Stoner is directly covered by soil mantle, the Stoner Member tends to weather severely and develop large vertical joints that may extend through the entire unit. However, the “Stoner” across the bridge site was non-weathered, and closely to widely fractured. This unit was observed in both cores holes, but the Stoner Limestone Member was not penetrated to the full extent in CH-2 near Abutment #2. The thickness of the Stoner was determined at Core Hole #1. The limestone unit was found to be 13.9 feet thick. The spacing of the fractures resulted in an average RQD of 95%. The rocks competency was very hard. The Unconfined Compression strength (Qu) averaged 145 TSF, but varied from 33.9 to 248 TSF. The RMR classification for this unit is 82 which classify it as Very Good Rock

■ **Eudora Shale Member**

- The Eudora Shale Member was observed in the core hole boring located near Abutment #1. This unit appeared dark gray to black, fissile, non-weathered, closely fractured and approximately 5.2 feet thick. The Eudora Shale was deposited in a deep water environment where a lack of oxygen caused the black to dark gray color. The Eudora Shale can be used to confirm the rock sequence in the stratigraphic column at this bridge site due to the unique black shale in this portion of the stratigraphic sequence. The RMR classification for this unit is 79 which classify it as Good Rock.

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Bedrock Continued

■ **Captain Creek Limestone Member**

- The Captain Creek Limestone Member consists of a very hard, gray, unweathered, well cemented limestone. This unit can have even to slightly uneven, thin to medium bedding. The Captain Creek Limestone typically is fossiliferous and fine to medium grained. The thickness for the Captain Creek Member at the bridge site is 4.2 feet thick. The RMR system which uses strength, RQD, discontinuities, weathering, and a number of different factors to determine the classification of the quality of rock places this unit in the Good Rock classification with a RMR of 79.

■ **Lansing Group**

■ **Vilas Shale Formation**

- The Vilas Shale Formation in the project area is made up of gray, limy, non-weathered, very closely fractured shale. This formation tends to be extremely limy and very well cemented with finely laminated beds, may contain beds of sandstone and fossiliferous sandy limestones. The Vilas Shale observed at the bridge location contained an abundant amount of interbedded limestone stringers and was considered very hard. An overall thickness of the “Vilas” was not determined. The RMR classification for the Vilas Shale Formation at this bridge site is 71 which classify it as Good Rock.

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Foundation Recommendations

-Pile foundations

- What material will the pile be founded in?
- What type of pile will be used?
- What are the pile tip elevations?

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Foundation Recommendations

-Pile foundations

- Steel H-Pile is recommended for the abutments of this bridge. The pile will penetrate the mantle and achieve the required resistance within the underlying sandstone of the Tonganoxie Member. The designed resistance is governed by the drivability of the pile. A Phi factor of 0.55 is given based on the geologic investigation performed and knowledge of the site. Pre-drilling will be required at the Abutment #2 for this bridge. The pre-drilled piling should be backfilled with commercial grade concrete to the top of bedrock. See the table below. Some variation in final pile tip elevations across the bridge site should be expected.

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Pile Foundations Abutment 1

The following table gives the top of bedrock elevation for the Tonganoxie Sandstone and the maximum anticipated pile tip elevation at each abutment.

Location	Station	Elevation Top of Bedrock	Pre-Drill Elevation	Pile Tip Elevation	
				HP 10 x 42	HP 12 x 53
Abutment 1	46+75.69	969.01	n/a	965.9	965.9
Abutment 2	51+95	988.46	987.46	986.0	986.0

LRFD Design Resistance and Phi Factor Information

	Pile HP 10x42	Pile HP-12x53
Rn (kN)	372	465
Rr (kN)	205	256
Phi Factor	0.55	0.55

Plan Note:

The following notes should be placed in the Construction Plans:

Piling:

Once sufficient resistance and penetration into the bedrock is achieved, driving should cease to avoid damage to the pile. Final pile tip elevations should be determined in the field based on force calculations.

All pre-drilled piling should be backfilled to the top of bedrock with commercial grade concrete."

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Foundation Recommendations -Drilled shaft foundations

- What material will the drilled shaft be founded in?
- How deep ?
- What are the Shaft tip elevations?
- Special situations! Shale

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PIERS 1-4 DRILLED SHAFT FOOTINGS

- Drilled Shafts are the recommended foundation element for the piers of this bridge. The base of the drilled shafts should be set into the competent South Bend Limestone Member for Pier #4 and Stoner Limestone Member for Piers #1, #2, and #3.
- Permanent casing is required for all piers. Casing should set a minimum of 1.0 ft into the top of rock, but not exceeding 3.0 ft. (See approximate elevations below.) All casing set should extend from proposed elevation into rock to approximately 1.0 ft above the excavated surface. If water is percolating through bedrock material at a high rate, wet pour techniques may be required. Allow no loose material within the footing when the footing is considered ready to pour.
- It should be noted that the drilled shafts are primarily end bearing and it is critical that the bottom socket be clean and relatively flat. The bottom of the rock socket should be placed no higher than the elevations provided below
- The table below gives the Nominal Geotechnical Resistance results from Shaft 6 and hand calculations. Three foot diameter shafts will meet the load requirement of 1418 kips per drilled shaft at the piers; however a shaft size of 4.0 ft will be recommended to match the preferred column sizes as requested by design.. The LRFD Factored Resistance was calculated using a phi factor of 0.55 for the skin friction and 0.45 for the end bearing at all locations. If larger drilled shafts are needed for the columns of the structure please contact the Topeka Regional Geology Office for additional recommendations.
- The following Drilled Shaft recommendations have taken into account the preliminary Strength I load of 1418 kips at the Piers, and the weight of the drilled shaft using 1.83 kips/ft for the recommended 4.0 diameter Drilled Shafts.

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Drilled Shaft Table

Location	Station	Dia. (ft)	Approximate Elevation at Bottom of Casing	Elevation Base of Drilled Shaft	Nominal Geotechnical Resistance kips	LRFD Factored Resistance kips	Footing Material
Pier #1	47+59	4	963.3	948.5	7104.36	3670.05	Stoner LS
Pier #2	48+72	4	957.0	948.5	5370.58	2723.13	Stoner LS
Pier #3	50+00	4	961.6	947.0	6344.22	3363.32	Stoner LS
Pier #4	51+13	4	979.0	964.4	9566.24	5044.05	South Bend LS

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Foundation Recommendations

-Drilled shaft foundations

INVESTIGATIVE CORE HOLE:

Standard Specification 703.3b

Investigative core holes will be required at the far right columns of Pier 1, Pier 2, and Abutment 2, and the center column of Pier 3.

Extract and maintain a core of the foundation material from 4 feet above the top of the plan tip elevation and 6 feet below the plan tip elevation. The contractor will maintain and protect the properly labeled (elevation and location) samples for review by the Regional Geologist. The location of the core hole will be a surveyed location with the same construction tolerance as that of the shaft construction.

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Issues with the Investigative Cores

- Location
- Logs
- Recovery
- Not notified

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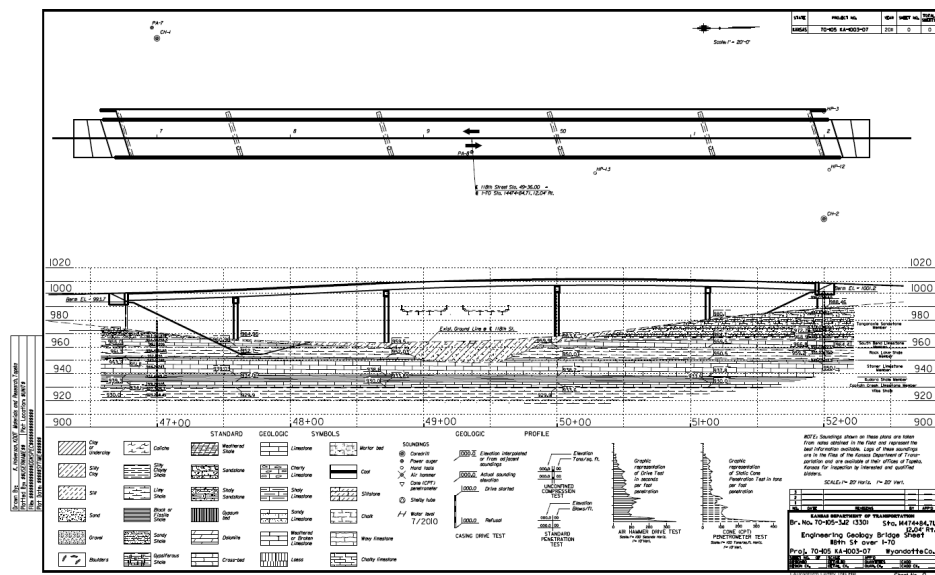
HYDROLOGY

- States if dewatering equipment will be needed
- Gives ground water elevations
- Also can State if casing will be used

The groundwater elevations noted at the site and along 118th St during our field work in July, 2010 was 962.8. Groundwater elevations were recorded 24 hours after borings were completed. A number of factors may influence groundwater elevations at the site. These factors include periods of above or below normal precipitation. Dewatering equipment may be necessary for excavation below these elevations.

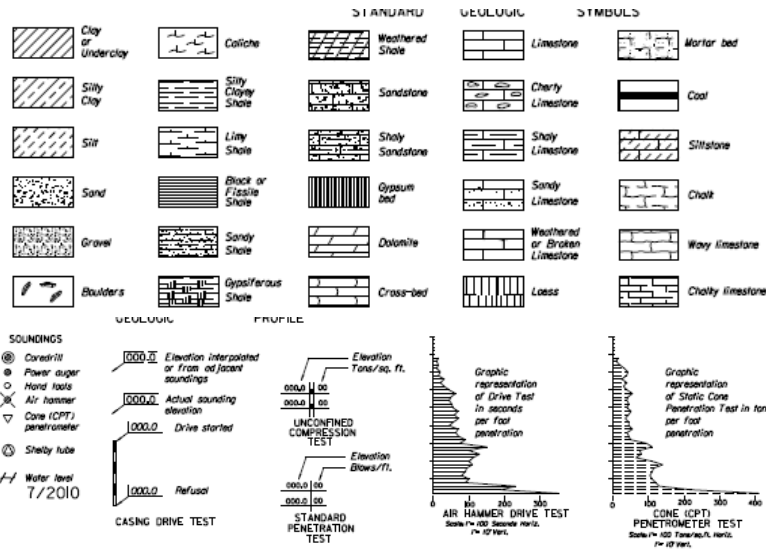
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Engineering Geology Sheet-
Some things you might like to know.



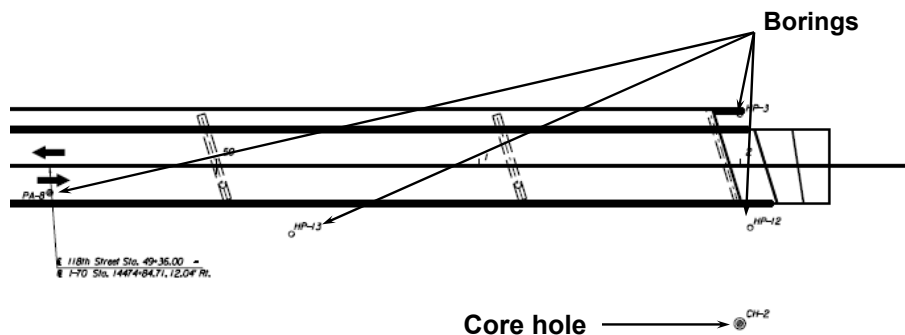
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Engineering Geology Sheet- Geology



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Engineering Geology Sheet- Shows the Geology Investigative holes



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Engineering Geology Sheet- Unconfined compression test

The diagram shows a vertical soil sample with two sets of data recorded along its length. The top set of data is for an Unconfined Compression Test, with values in Tons/sq. ft. The bottom set of data is for a Standard Penetration Test, with values in Blows/ft. The sample is divided into sections by horizontal lines, and the data is recorded in a table-like format.

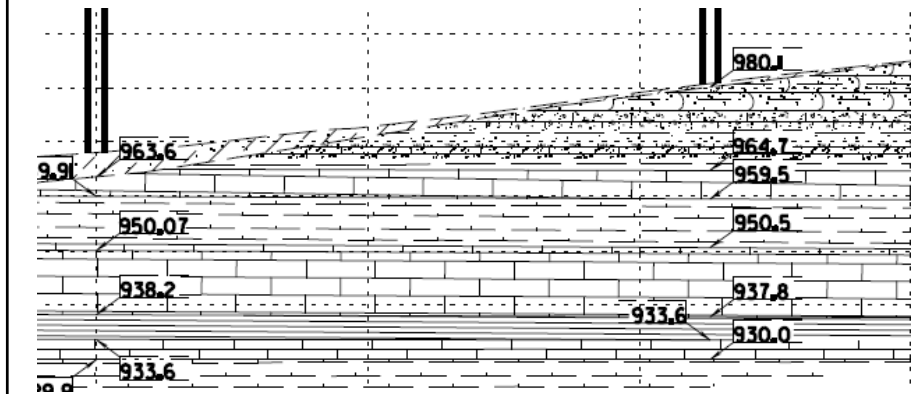
Test Type	Parameter	Value 1	Value 2
UNCONFINED COMPRESSION TEST	Elevation	967.0	187.7
	Tons/sq. ft.	964.5	258.5
		961.1	206
		956.4	10.65
		952.1	55
STANDARD PENETRATION TEST	Elevation	949.5	248
	Blows/ft.	944.2	243
		937.4	49.25
		931.2	505
		927.7	25.1
	923.2	41.45	

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[illegible]

24

Engineering Geology Sheet- Elevations



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When in doubt.....
You can find

- Site conditions- location, geology, and hydrology
- Foundations- Pile and drilled shaft elevations and locations
- Special instructions- Investigative core hole, construction recommendations

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The Purpose of a Subsurface Study?

- ◆ For design :

 - Must know subsurface materials

 - Must know engineering properties

 - Must know capability to support loads

- ◆ For construction:

 - Materials dictate rig and tool choices

 - Materials dictate construction method

 - Identifies potential problems

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Geology Investigations

- Once we have a set of Field Check Plans, we begin our foundation investigation.
- The investigation includes the following:
 - 1. Survey in the new structure.
 - 2. Power Auger all foundation element locations, if possible.
 - 3. Drill at least one core hole.

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GOALS OF THE SUBSURFACE STUDY

To gather data about the site:

- Geologic formations
- Soil & Rock units
- Material engineering properties
- Groundwater conditions
- Ground surface elevation
- Localized conditions

**THE BORING
LOG**

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THE EXPLORATION

A variety of subsurface exploration methods can be employed.

Most common include:

- Standard Penetration Test Borings (Split-spoon)
- Undisturbed Sampling (Shelby tube)
- Rock Coring

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GEOLOGY CORES

- Drilled Shaft Foundations are investigated by obtaining Core Samples.
- Samples of the cores are sent in for testing. An unconfined compression test is conducted.
- The test results and visual inspection of the core, provide guides as to where the bottom of the rock socket should be placed.

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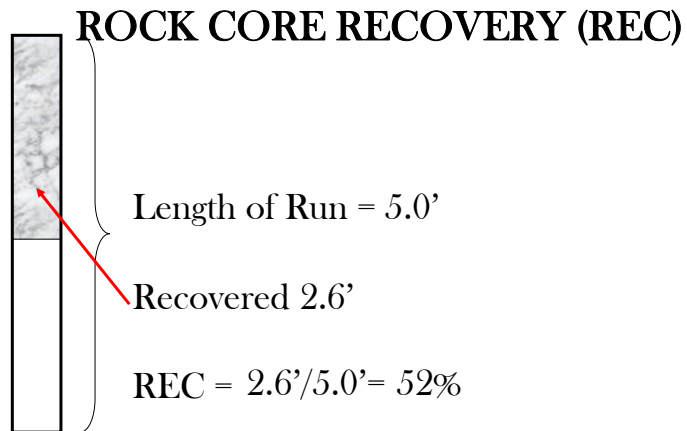
Rock Core Recovery

- Rock Core Recovery (REC)
 - Defined as the length of core recovered divided by the length of core run and is expressed and reported as a percentage.
 - % REC = $\frac{\text{Length of Core Recovered}}{\text{Length of Core Run}} \times 100$

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Rock Core Recovery Example

Sample



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Rock Quality Designation

- Rock Quality Designation (RQD)
 - Defined as the sum of all recovered pieces of rock core greater than 4" in length by the length of core run and is expressed as a percentage.
 - $\% RQD = \frac{\text{Sum of Pieces} > 4"}{\text{Length of Core Run}} \times 100$

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RQD-Rock Quality

RQD-Rock Quality	
RQD (%)	Description of Rock Quality
0-25	Very Poor
25-50	Poor
50-75	Fair
75-90	Good
90-100	Excellent

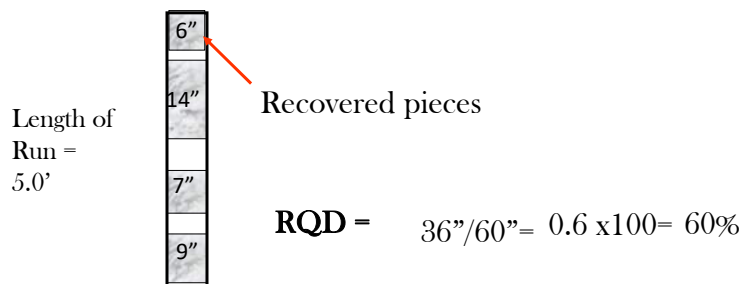
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Sample Problems

RQD is defined as the sum of all recovered pieces of rock core greater than 4" (100 mm) in length divided by the length of core run and is expressed and reported as a percentage.

$$\% \text{ RQD} = \frac{\text{Sum of Pieces} > 4" (100 \text{ mm})}{\text{Length of Core Run}} \times 100$$

Sample



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Sample Problems FAQ

Can REC be greater than 100%?

YES

Can RQD be greater than REC?

NO

Can RQD be greater than 100%?

NO

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How fast will that shale degrade?

- We are often requiring drilled shafts founded in shales to be poured as quickly as possible. In the Geology Report you will find the time limit from completion of the excavation to the placement of concrete. Here is the main reason why!!!
- What other change usually occurs when the shafts are founded in shale?

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Shale Samples

- Four Shale Core Samples
- 1. Scranton Shale Formation
- 2. Lane-Bonner Springs Shale
- 3.&4. Two samples of the Cherokee Shale
- 5. Vilas Shale
- Samples covered in water for 24 hours and this is the result:

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The End

Questions?

Topics

- Design
- Specifications
 - Concrete Mix Design
 - Casing Requirements
- Plans and Details
- Osterberg Cell

PL - 3

3

Design - 1

Why do we use drilled shafts?

- The footing would have short piles
- The water table is high
- A spread footing would be uneconomical because rock is deep
- Concerns about pile driving vibrations, or noise

DES - 4

4

Design - 2

What types of loads do we design for?

Axial loads



Lateral loads



Bending



DES - 5

5

Design Loads

Axial loads

Self weight of the Bridge and everything the bridge holds up against gravity

End Bearing Limestone 25-30 tsf Shale 10-15 tsf

Skin Friction Limestone up to 27 tsf Shale up to 11 tsf

Lateral & Bending loads

Flowing Water, Wind, Braking Forces, Moment from Structure, and Seismic

Are counteracted by Soil Mantle and Ultimately Fixity at the Rock Socket

DES - 6

6

Specification - 1

SECTION 703 – Drilled Shafts

- 703.1 Description
- 703.2 Materials
- 703.3 Construction Requirements
- 703.4 Measurement and Payment

PL - 7

7

Specification - 2

- 703.1 Description

BID ITEMS

Drilled Shaft (*) (**)

Permanent Casing (*) (Set Price)

Sonic Test (Drilled Shaft) (Set Price)

Core Hole (Investigative)

* Size

** Cased (If Contract Documents specify the case method)

UNITS

Linear Foot

Linear Foot

Each

Linear Foot

PL - 8

8

Specification - 3

- 703.2 Materials
 - a. Concrete
 - b. Grout/Flowable Fill
 - c. Granular Backfill Material
 - d. Reinforcing Steel
 - e. Casing
 - f. Pipe for Sonic Testing

PL - 9

9

Specification - 4

- 703.3 Construction Requirements
 - a. General
 - b. Investigative Core Hole
 - c. Excavating the Drilled Shaft
 - d. Placing Reinforcing Steel and Sonic Testing Pipes
 - e. Final Inspection and Access

PL - 10

10

Specification - 5

- 703.3 Construction Requirements cont.
 - f. Placing Drilled Shaft Concrete
 - Errata R15
 - g. Raising Temporary Casing
 - h. Curing
 - i. Sonic Testing
 - j. Backfill

PL - 11

11

ERRATA R15 - 1

SECTION 703.3f

- R15 modified 703.3f and can be found on OnBase

PL - 12

12

ERRATA R15 - 2

The change in the errata is to delete subsection 703.3f from Method C to end of 703.3f and replace with the following:

Method C (Figure 3): Use tremie tube, with a sealed gate separating ground water and concrete, to place concrete in the shaft.

Fully charge the tremie tube and hopper, then raise the tremie tube by 1 tremie diameter and seal the discharge end of the Tremie tube with the fresh concrete.

(3) For both Dry and Wet Pours. When the concrete reaches the top of the shaft continue placing concrete (over-pump) to expel any excess water, debris, or unsound concrete. If the casing extends above the planned shaft elevation, the excess material must be expelled by providing an outlet in the casing above the planned elevation of the shaft. Do not bail the excess material out of the shaft. On all wet pours regardless of the method used, the Engineer will make a set of cylinders (in addition to normal concrete cylinder sampling requirements) from the top of the shaft after completing over-pumping. This set of cylinders will be used to verify a compressive strength of 1800 psi before proceeding with subsequent substructure (i.e. columns, abutments, etc.) construction.

Prior to constructing the portion of the substructure that attaches to the drilled shaft, thoroughly clean the top of the drilled shaft to facilitate the bond at the cold joint.

PL - 13

13

Specification - 6

- 703.4 Measurement and Payment
 - a. Drilled Shafts
 - b. Permanent Casing
 - c. Sonic Test (Drilled Shaft)
(Set Price)
 - d. Payment

PL - 14

14

Mix Design - 1

- Where does the mix come from?

The Contractor requests a mix design from Materials and Research, using their choice of pre-qualified materials, or designs one according to Section 401 or Appendix A.

Ultimately the contractor is responsible for the concrete mix, regardless of who aids in creating it.

DES - 15

15

Drilled Shaft Mix design

- ▣ Optimized Gradation for workability and strength.

1102 - AGGREGATES FOR CONCRETE NOT PLACED ON GRADE

TABLE 1102-3: ALLOWABLE GRADING FOR MIXED AGGREGATES FOR CONCRETE												
Type	Usage	Percent Retained - Square Mesh Sieves										
		1 ½"	1"	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100
MA-3	Optimized All Concrete		0	2-12	Note ¹	Note ¹	Note ¹	Note ¹	Note ²	Note ²	Note ²	95-100
MA-4	Optimized All Concrete	0	2-12	Note ¹	Note ¹	Note ¹	Note ¹	Note ¹	Note ²	Note ²	Note ²	95-100
MA-5	Optimized Drilled Shafts		0	2-12	8 min	22-34		55-65		75 min		95-100
MA-6	Optimized for Bridge Overlays		0	0	2-12	Note ¹	Note ¹	Note ¹	Note ²	Note ²	Note ²	95-100
MA-7	Contractor Design KDOT Approved	Proposed Grading that does not correspond to other limits in this table but meet the requirements for concrete in DIVISION 400.										98-100

¹Retain a maximum of 22% (24% for MA-6) and a minimum of 6% of the material on each individual sieve.

²Retain a maximum of 15% and a minimum of 6% of the material on each individual sieve.

DES - 16

16

Mix Design - 2

What are we looking for in a mix?

- 703.2.a Drilled Shafts – Materials – Concrete

Must be in compliance with Section 401 (General Concrete), Section 402 (Structural Concrete) and Section 1102 (Aggregates for Concrete Not Placed On Grade)

- 9" slump is the target (+/- one inch)

703.2.f Slump

- (1) Designate a slump for each concrete mix design that is required for satisfactory placement of the concrete application. Reject concrete with a slump that limits the workability or placement of the concrete.
- (2) If the designated slump is 3 inches or less, the tolerance is $\pm 3/4$ inch, or limited by the maximum allowable slump for the individual type of construction.
- (3) If the designated slump is greater than 3 inches the tolerance is $\pm 25\%$ of the designated slump.
- (4) For drilled shafts the target slump just prior to being pumped into the drilled shaft is 9 inches. If the slump is less than 8 inches, redoes the concrete with admixtures as permitted in subsection 401.3i.
- (5) Do not designate a slump in excess of 5 inches for all other structural concrete.

DES - 17

17

Mix Design - 3

- Trial mix

The concrete specification requires that a trial batch be produced and tested, unless a positive history exists. This is the time a **slump loss analysis** should be done. This includes a **slump loss test**.

DES - 18

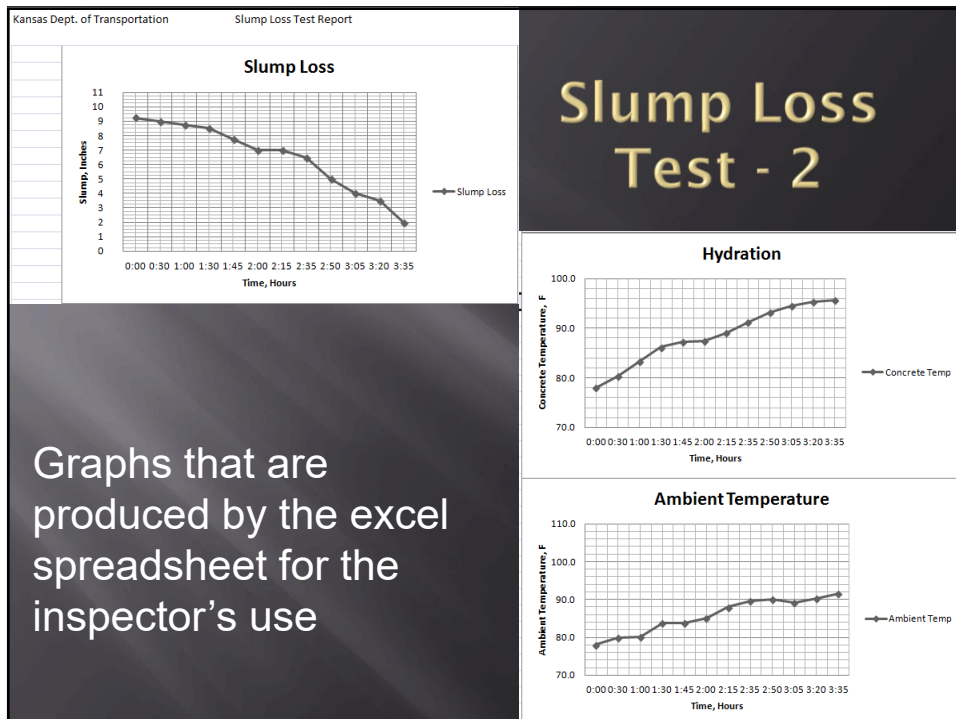
18

Slump Loss Test - 1

Kansas Dept. of Transportation			Slump Loss Test Report				
Time	Elapsed Time	Slump from In-Place (in.)	Slump from Mixer Truck (in.)	% Air (If Entrained)	Concrete Temp	Ambient Temp	Date of Test:
11:15 AM	0:00	9 1/4	-	-	78.1	78.1	Time Test Started 11:15 AM
11:45 AM	0:30	9	-	-	80.4	80.0	
12:15 PM	1:00	8 3/4	-	-	83.3	80.2	
12:45 PM	1:30	8 1/2	-	-	86.2	83.8	Contract Number
1:00 PM	1:45	7 3/4	-	-	87.3	83.8	
1:15 PM	2:00	7	-	-	87.4	85.1	
1:30 PM	2:15	7	-	-	89.1	88.0	Project Number 67 C-4270-01
1:50 PM	2:35	6 1/2	-	-	91.2	89.6	
2:05 PM	2:50	5	-	-	93.2	90.0	
2:20 PM	3:05	4	-	-	94.5	89.2	Ready Mix Plant: O'Brien Ready Mix Parson's
2:35 PM	3:20	3 1/2	-	-	95.4	90.3	
2:50 PM	3:35	2	-	-	95.6	91.5	
							Inspector:
Notes: 3 Yds Concrete Batched at 10:25 AM, simulated drive/delivery time 40 minutes, at 11:10 AM Super Plasticizer was added at a rate of 42.67 oz per Yd and 40 revolutions were applied to the Truck.							

DES - 19

19



20

Casing - 1

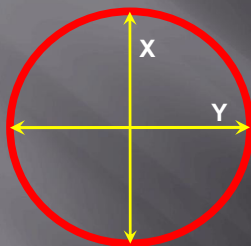
- ▣ Permanent, Must be Water Tight
 - Thick walled
 - CMP (14 gage minimum)
- ▣ Temporary
 - Immediately after the concrete is placed the Temp. Casing can be raised the depth of embedment plus 6 inches.
 - Temp. Casing cannot be removed for 24 hours AND a Compressive Strength of 1800 psi OR 72 hours have passed.

PL - 21

21

Casing - 2

703.2.e



IF $X = Y$
Casing is "Round"



IF $X > Y$ or $Y > X$
Casing is "Out of Round"

IF the difference $(X-Y)$ is less than or equal to 1", the casing is acceptable.

22

Casing - 3

703.2.e



String line (chord) – End to end

If “Z” is less than or equal to 2”:
Casing is **acceptable**

23

Casing - 4

- ▣ Make sure the minimum rock socket length is provided
 - Do not try to make the hole dry by advancing the casing (This is a case were deeper is not better, set the bottom of the casings were the plans show them)
 - It is always better to pour the shaft using wet pour methods than to try to make a wet hole dry

PL - 24

24

General Notes - 1

SUMMARY OF QUANTITIES														
Item	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13	Class 14
Location	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL
Abstract No. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Par. No. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Par. No. 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Par. No. 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Abstract No. 2	195	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	195	0	0	0	0	0	0	0	0	0	0	0	0	0
Supernote	195	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	195	0	0	0	0	0	0	0	0	0	0	0	0	0

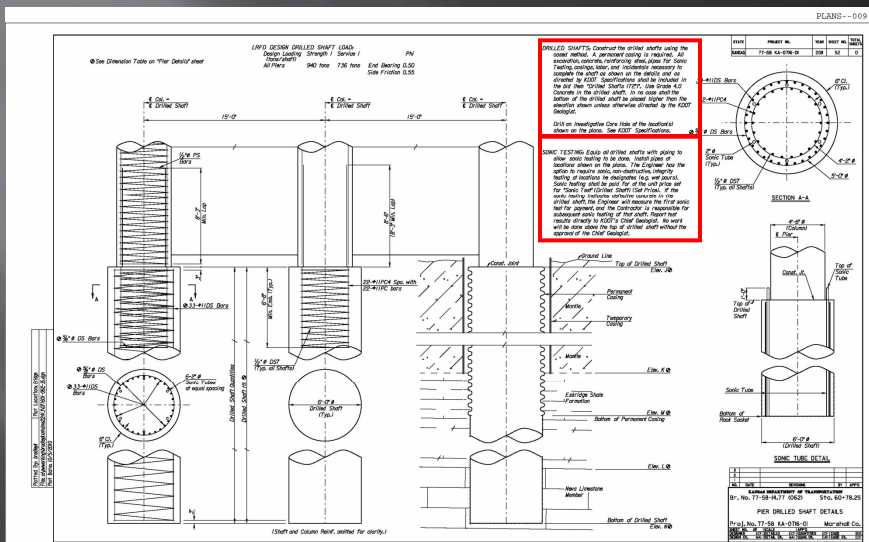
SUMMARY OF STEEL QUANTITIES														
Item	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13	Class 14
Location	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL	CU TBL
Abstract No. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Par. No. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Par. No. 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Par. No. 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Abstract No. 2	195	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	195	0	0	0	0	0	0	0	0	0	0	0	0	0
Supernote	195	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	195	0	0	0	0	0	0	0	0	0	0	0	0	0

GENERAL NOTES														
1. EXAMINATION: Complete the examination of the documents as shown on the Bridge Examination sheet prior to driving the abutment piling or connecting with the abutment framing connection.														
2. BRIDGE EXCAVATION: Excavation (Class 2) and deepening the Excavation (Class 3) of the abutment piling shall be done in accordance with the Bridge Examination sheet prior to driving the abutment piling or connecting with the abutment framing connection.														
3. BACKFILL COMPACTION: Compact backfill of the abutments.														
4. REMOVAL OF EXISTING STRUCTURE: Removal of existing structure is required in the old and existing of existing structure. The removal of the existing structure shall be done in accordance with the Bridge Examination sheet prior to driving the abutment piling or connecting with the abutment framing connection.														
5. EXISTING CONCRETE: Place the existing concrete on the old and existing of existing structure. The existing concrete shall be done in accordance with the Bridge Examination sheet prior to driving the abutment piling or connecting with the abutment framing connection.														
6. BRIDGE CONSTRUCTION: Construct the bridge structure in accordance with the Bridge Examination sheet prior to driving the abutment piling or connecting with the abutment framing connection.														

PL - 25

25

General Notes - 2



PL - 26

26

General Notes - 3

DRILLED SHAFTS: Construct the drilled shafts using the cased method. A permanent casing is required. All excavation, concrete, reinforcing steel pipes for Sonic Testing, casings, labor, and incidentals necessary to complete the shaft as shown on the details and as directed by KDOT Specifications shall be included in the bid item "Drilled Shafts (XX)(Cased)". Use Grade 4.0 Concrete in the drilled shaft. In no case shall the bottom of the drilled shaft be placed higher than the elevation shown unless otherwise directed by the KDOT Geologist.

Drill an Investigative Core Hole at the locations shown on the plans. See KDOT Specifications.

If the location of the top of the shaft is such that the casing cannot be overtopped to remove concrete impurities provide extra casing length to over-pour the concrete in the shaft and chip back to the plan elevation of the top of the shaft.

If the permanent casing is to be corrugated metal pipe (CMP) then it will be galvanized.

SONIC TESTING: Equip all drilled shafts with piping to allow sonic testing to be done. Install pipes at locations shown on the plans. All wet pours will be tested. Also, the Engineer has the option to require sonic, non-destructive, integrity testing at any location of concern. Sonic testing shall be paid for at the unit price set for "Sonic Test" (Drilled Shaft) (Set Price). If the sonic testing indicates defective concrete in the shaft, the Engineer will measure the first sonic test for payment, and the Contractor is responsible for subsequent sonic testing of that shaft. Report test results directly to KDOT's Chief Geologist. No work will be done above the top of drilled shaft without the approval of the Chief Geologist.

<i>Drilled Shaft (72") (Cased)</i>	<i>Drilled Shaft (36")</i>	<i>Permanent Casing (36") (Set Price)</i>	<i>Sonic Test (Drilled Shaft) (Set Price)</i>	<i>Core Hole (Investigative)</i>
<i>Lin. Ft.</i>	<i>Lin. Ft.</i>	<i>Lin. Ft.</i>	<i>Each</i>	<i>Lin. Ft.</i>
129.0				50.0
97.5				32.1
138.0				53.1
	131.8			26.8
364.5	131.8			162.0
364.5	131.8	1	1	162.0

PL - 27

27

Other Notes

- **DRILLED SHAFT BACKFILL:** Backfilling the annular space between the temporary casing and the permanent casing, as defined in the KDOT Specifications, is not required at this location.

- **FOUNDATION ROCK INVESTIGATION:** Drill at least one 1 1/2 - 2 inch diameter hole at each drilled shaft location to penetrate the bedrock a minimum of 4 feet below the base of the shaft. If a cavity or otherwise incompetent zone is detected in the bedrock below the shaft, revise the shaft to ensure a competent shaft. Drill the test holes in the presence of the Engineer. The work required for investigation shall be subsidiary to the excavation. Payment for lowering or repairing the shafts will be in accordance with KDOT Specifications.

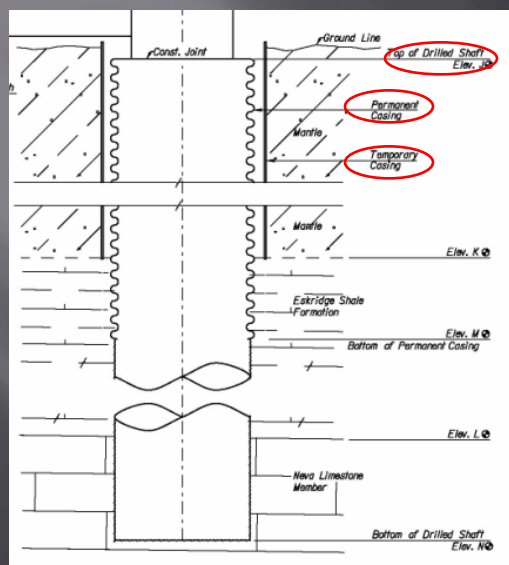
PL - 28

28

[illegible]

PL - 33

Drilled Shaft Details - 3

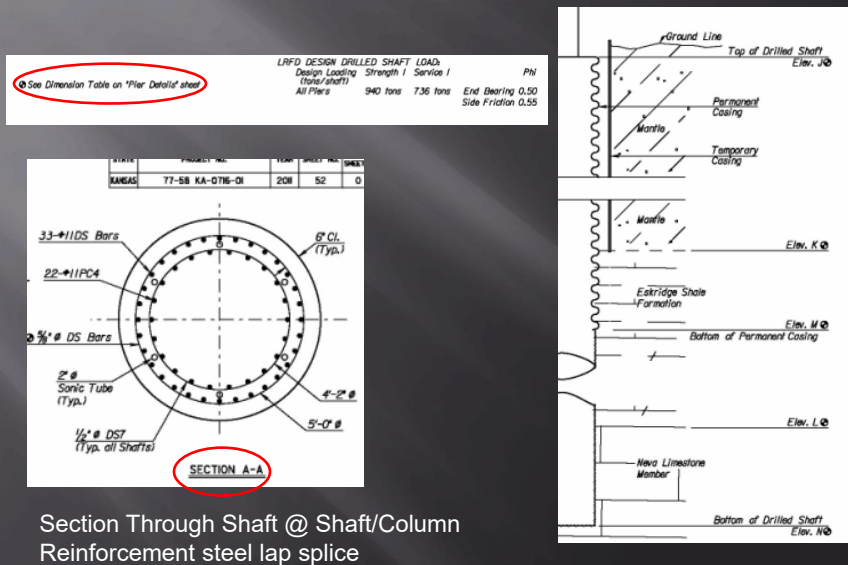


Elev.	Pier #1	Pier #2	Pier #3
A	1141.40	1143.84	1147.28
B	1141.54	1143.98	1147.42
C	1141.68	1144.13	1147.57
D	1141.54	1143.98	1147.42
E	1141.40	1143.84	1147.28
F	1135.40	1137.84	1141.28
G	1134.40	1136.84	1140.28
H	1108.90	1096.34	1099.78
J	1107.90	1095.34	1108.78
K	1077.00	1077.70	1085.00
L	1069.60	1066.70	1064.30
M	1074.1±	1074.7±	1082.0±
N	1064.90	1062.84	1062.78

PL - 34

65

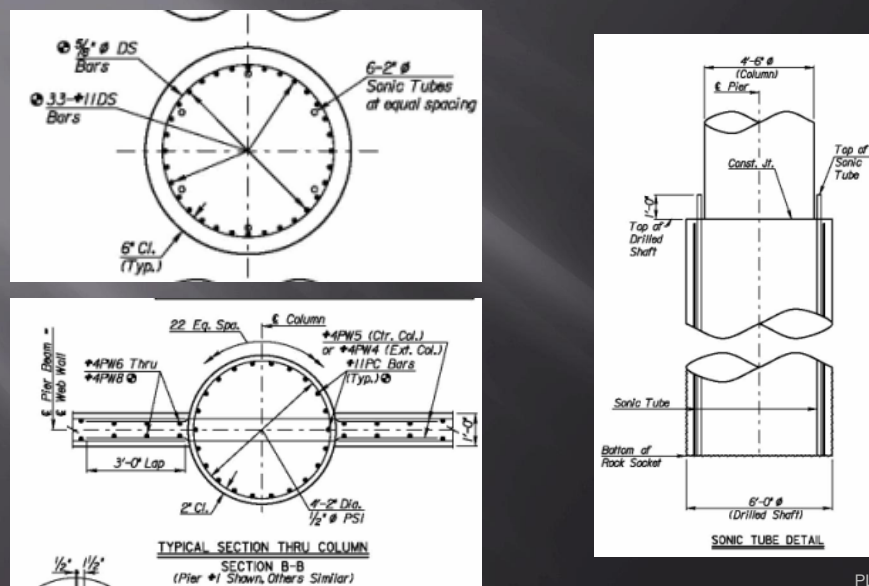
Drilled Shaft Details - 4



PL - 35

35

Pier to Drilled Shaft Details



PL - 36

36

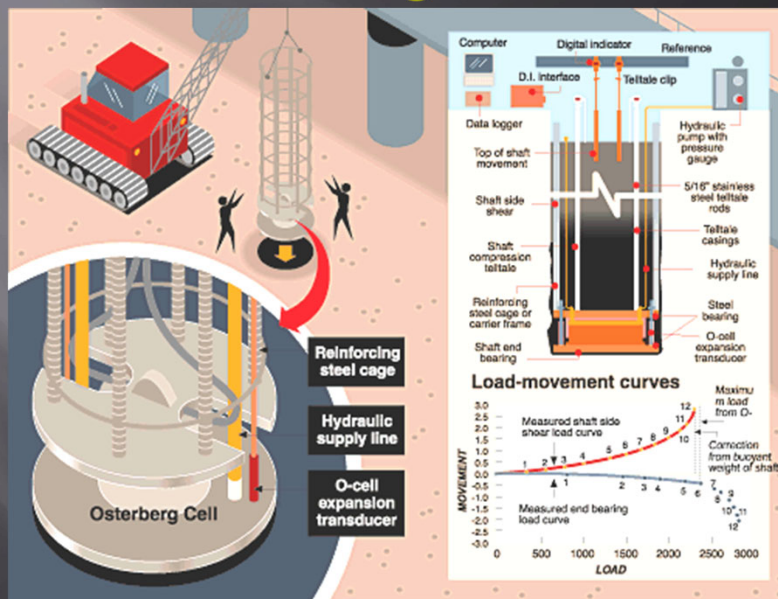
Drilling Equipment



PL-37

37

Osterberg Cell - 1



PL - 38

38

Osterberg Cell - 2



PL - 39

39

Osterberg Cell - 3



PL - 40

40

What do O-cell tests provide other than Headaches for the contractor?

- ▣ Test shafts very similar to the production shafts. Gives the contractor a heads up on the construction practices needed at the site.
- ▣ Gives real skin friction and end bearing values
- ▣ Hopefully gives you the same capacity data you calculated (or more).
- ▣ Lets you have the most economical shaft for the structure.
- ▣ Not cheap!

PL - 41

41

Questions?

PL - 42

42

DRILLED SHAFT EQUIPMENT

BY
KYLE HALVERSON
CHIEF GEOLOGIST

1

Drilled shaft Rigs have been available since the early 1900's and were powered by horses!



2

This Beck Rig is from Texas in the 1950's. Notice the large gear drive system.

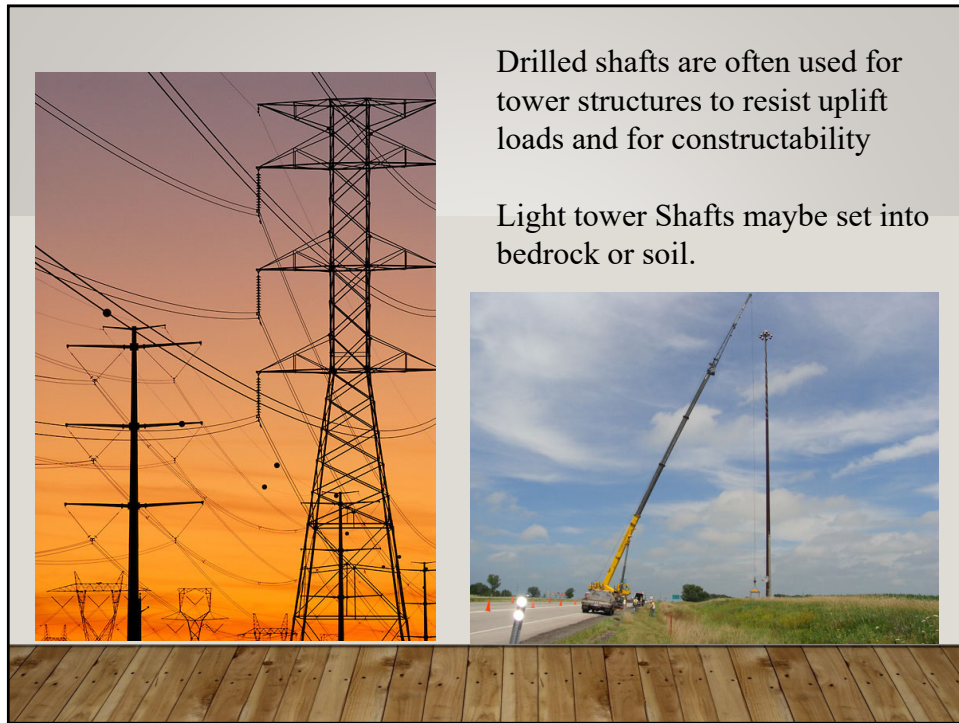


3

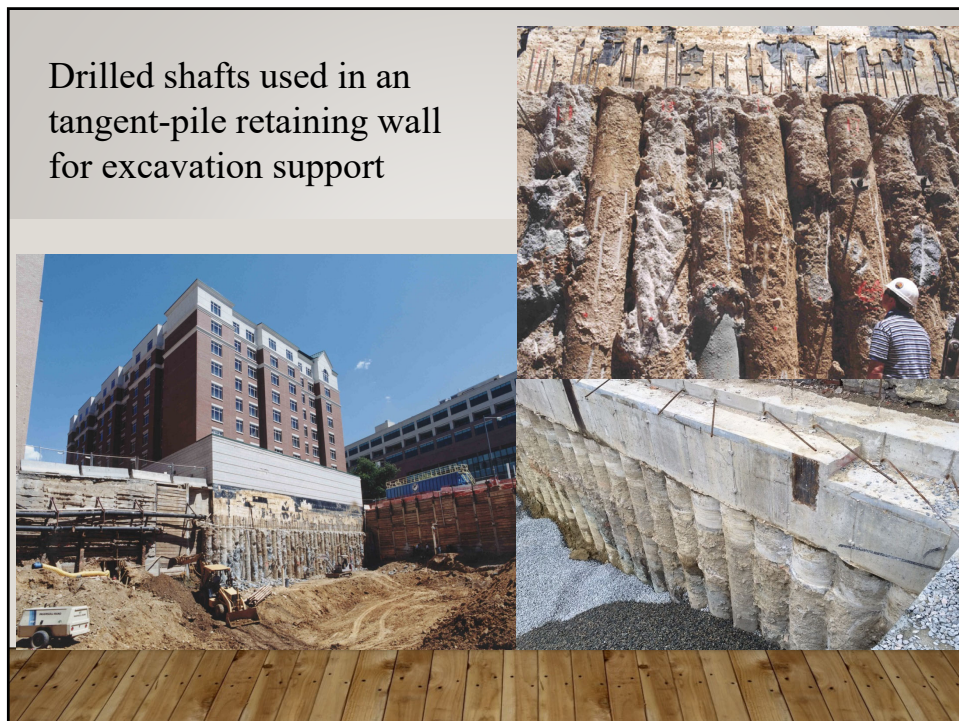
Drilled shafts are foundation of choice for shallow rock, large axial, and lateral loads associated with bridges. Kansas Bridges are founded only in rock! (Shale, Limestone, Sandstone)



4



5



6

Smaller diameter drilled shafts are used for residential structures, landslide repair, and other applications. Many times these small augers are mounted on the back of tractors



7

DRILLED SHAFTS: POTENTIAL DISADVANTAGES

- CONSTRUCTION MAY BE DIFFICULT OR MORE COSTLY IN DIFFICULT GROUND (E.G., GROUNDWATER PROBLEMS, SQUEEZING CLAY, COBBLES, AND BOULDERS)
- LACK OF REDUNDANCY COMPARED TO PILE GROUP
- NOT SUITABLE IN V. SOFT - SOFT CLAYS
- QUALITY IS SENSITIVE TO CONSTRUCTION PROCEDURES
- REQUIRES ENGINEERS TO BE FAMILIAR WITH CONSTRUCTIBILITY ISSUES

8

Basic elements of a drilled shaft rig



9

DRILLED SHAFT RIGS

- Crane Mounted
- Truck Mounted
- Crawler Mounted
- Carrier Mounted

10

light-medium duty rig
Watson 2000, crawler mounted
capacity: 82 ft. depth, 5 ft. dia



11

medium-heavy duty rig
Watson 3000, carrier mounted
up to 118 ft. deep, 7.9 ft. diameter
torque: 136 kN-m
crowd: 225 kN



12

The *Lo-Drill*, a low-clearance rig



13

Crane attachment, mounted on a bridge platform that can drill to 328 ft. with torque of 340 kN-m



14

US VS. EUROPEAN RIGS

- US Rigs tend to be mechanical driven
- European Rigs are mostly Hydraulically driven.
- European Rigs can drill and advance casing at the same time
- European Rigs are becoming much more popular.

15

SOILMEC SR-90

Can be configured with dual rotary heads to install casing while drilling inside the casing with an auger



16

The Leffer Oscillator
installs casing by oscillation
soil is excavated from inside as
casing is advanced

7 ft. diameter shafts, 69-121 ft. deep



17

Clamshell hammer grab
tool

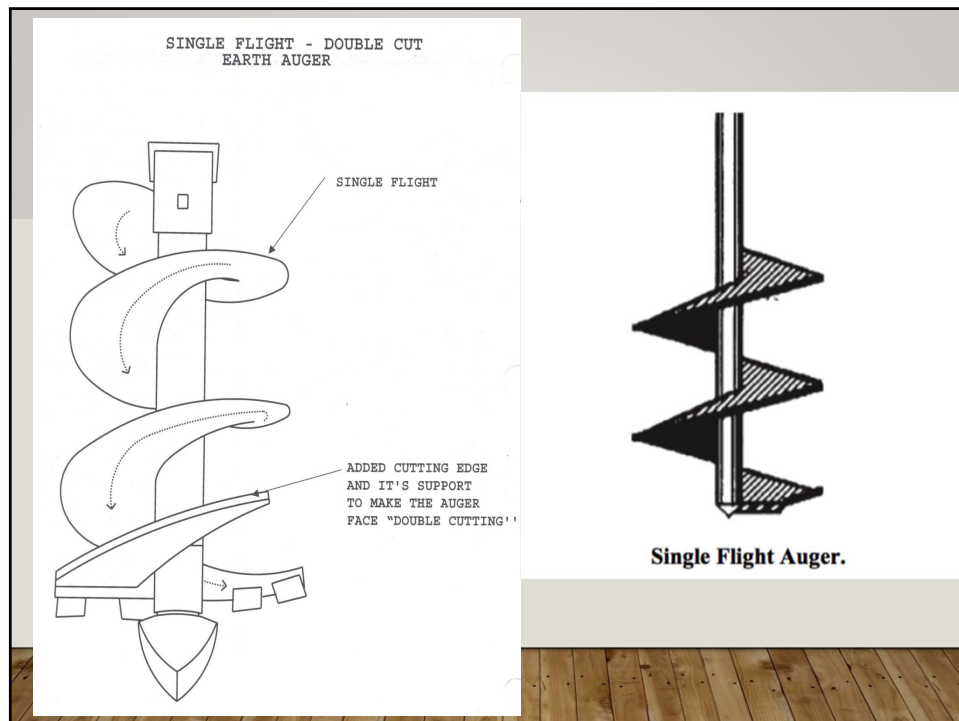


18

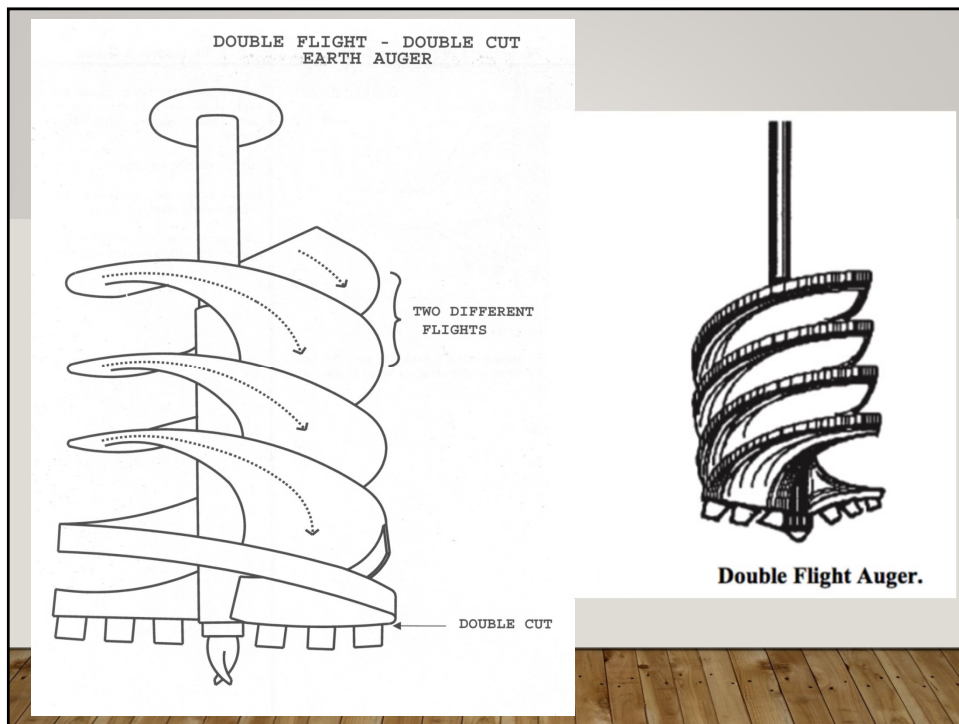
AUGERS

- Two Main Types: Soil and Rock
- Augers can be single cut or double cut
- Single flighted or double flighted.
- Auger can have adjustable diameters.

19



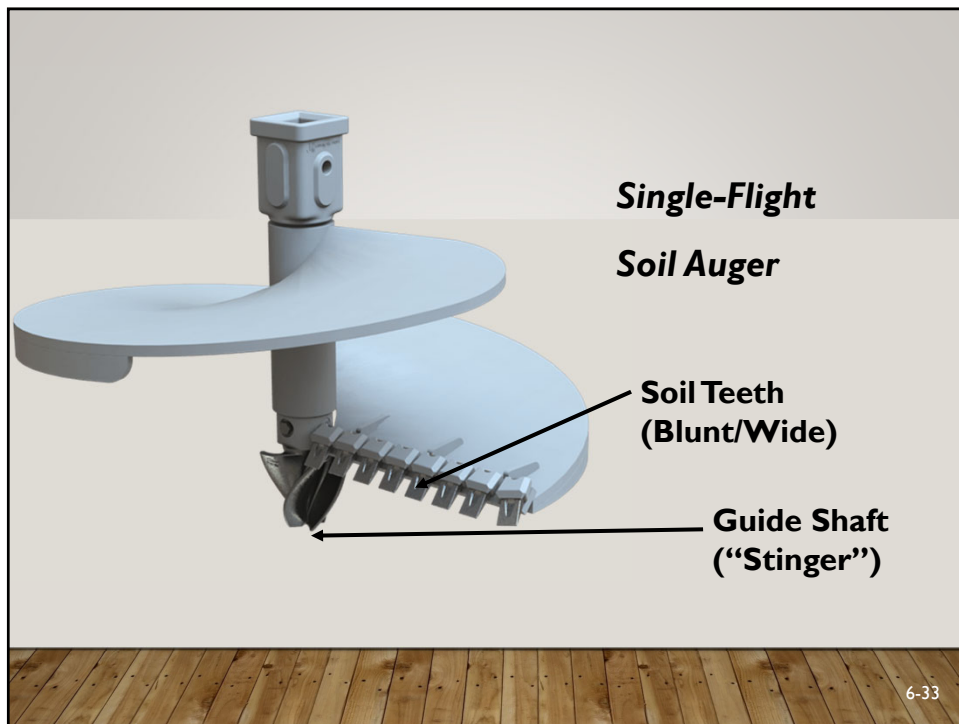
20



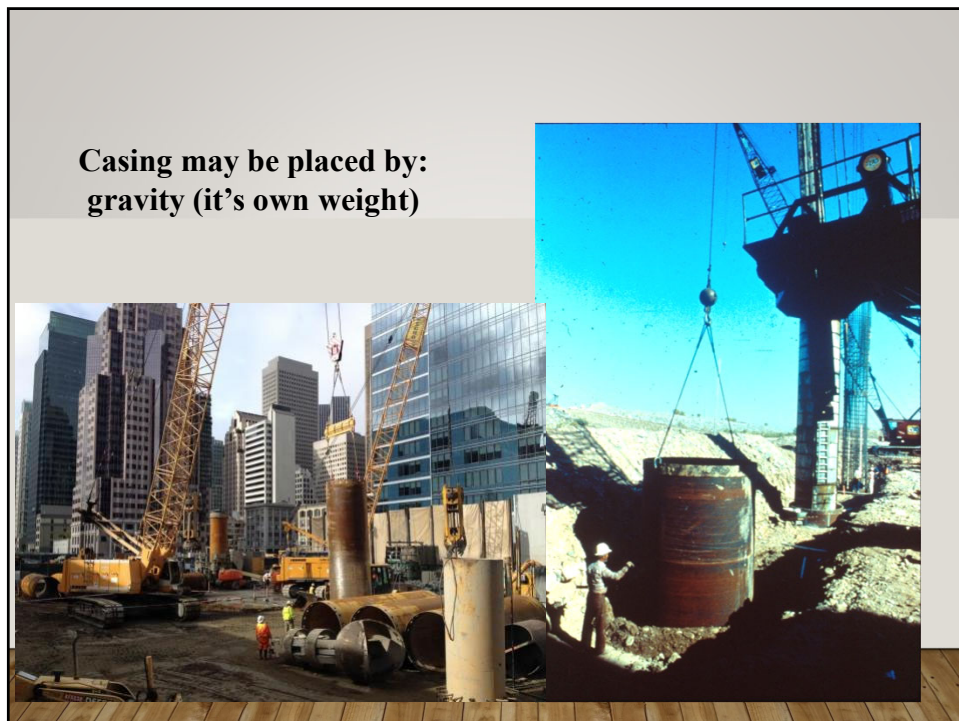
21



22



23



24



“twister” fits into slots in casing, allowing drill rig to apply torque and crowd

25

Vibratory Hammer
Make sure hammer has two clamps
One is for sheet pile installation!



26



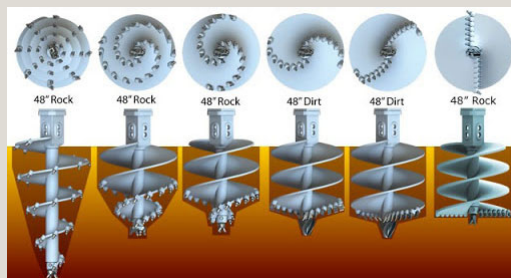
27

ROCK AUGERS



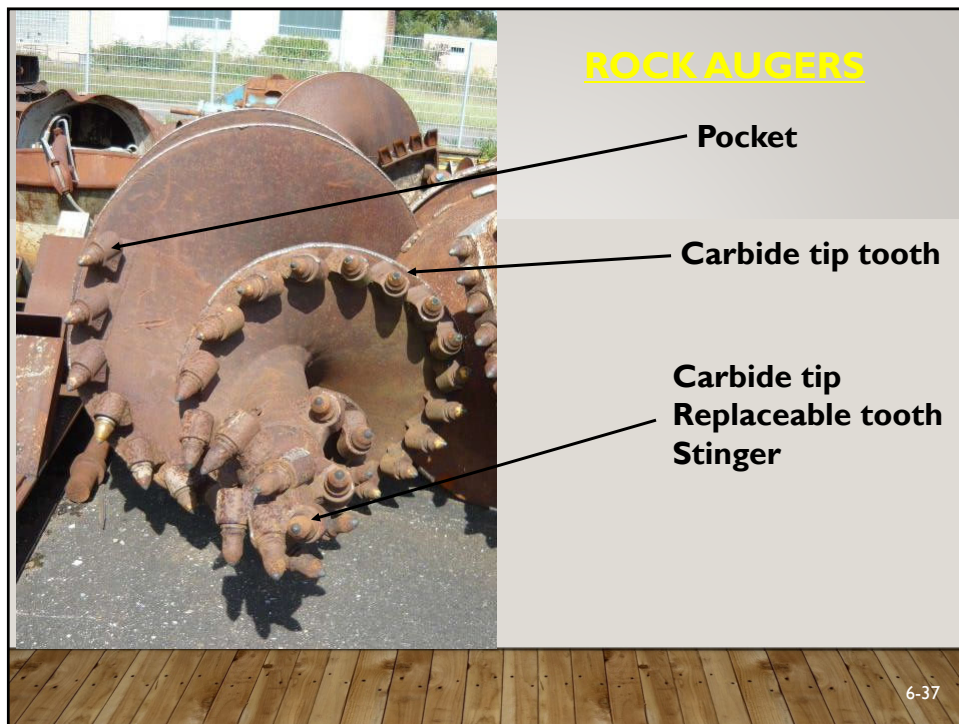
Rock augers are generally used in soft to hard rock formations.

- Tapered Geometry
- Conical (Bullet) Carbide Teeth



6-36

28



29



30



31

ROCK
CORE
BARREL



32



END VIEW OF CORE BARREL

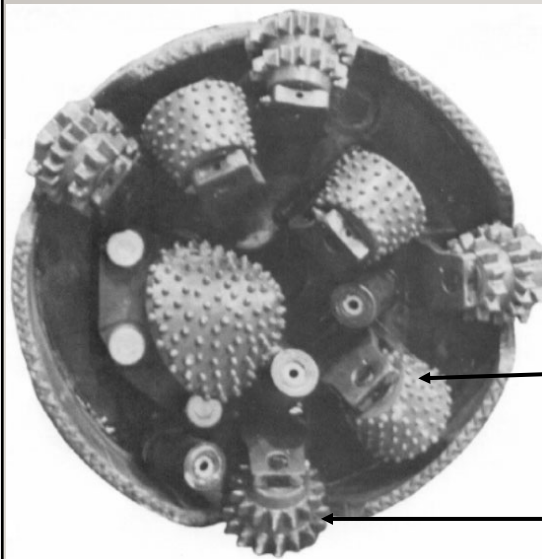
33



ADDITION
OF ROLLER
CONE BITS
FOR HARD
BEDROCK

34

ROCK BITS



This is typical of rock bits designed for drilling in hard to very hard rock.

→ Circulating bit

→ Replaceable Roller Bits

6-41

35

Down hole Hammer Bit for very hard rock



6-42

36

CLEAN OUT BUCKET



37

CLEANOUT BUCKET IN OPERATION



38

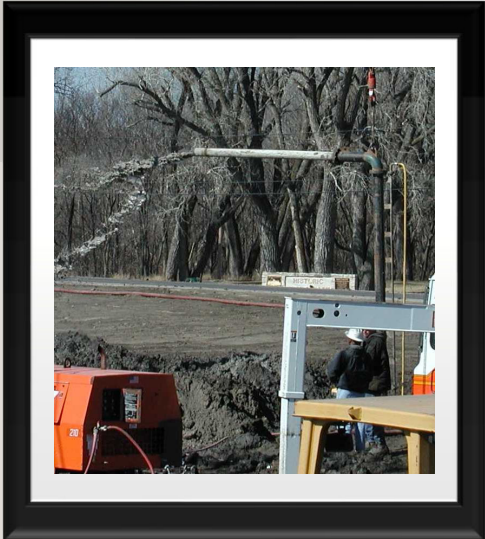


CLEANOUT TOOL

**Final cleaning
down-the-hole
pump**

6-52

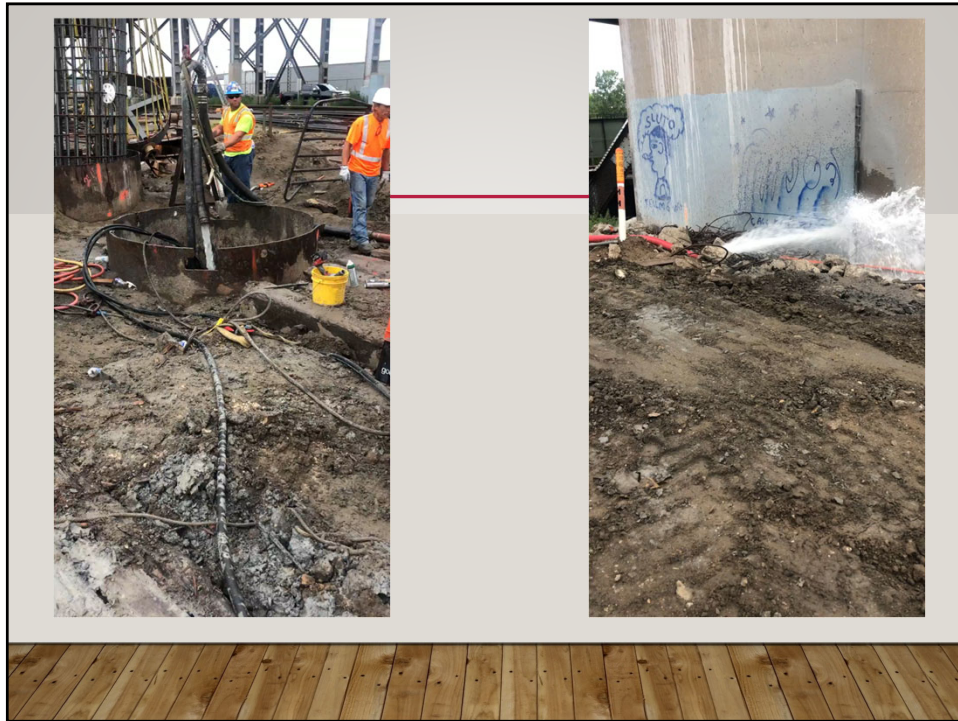
39



AIR LIFT



40

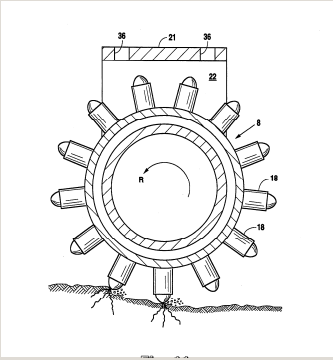
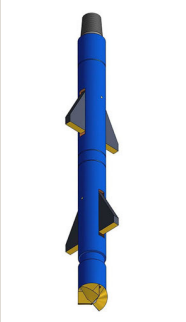


41



Overreaming Bucket

- To roughen the Sides of the Drilled Shaft
- Used when an Increase in Skin Friction is Req.

6-58

42

WHAT WILL THE INSPECTOR NEED AT THIS POINT?

- Weighted Tape
- Field Book
- Bridge Foundation Geology Report



43

WHAT SHOULD THE INSPECTOR NOTE ABOUT THE CONTRACTOR'S EQUIPMENT?

- Tool and Casing Diameters
- Casing Lengths
- Casing Cleanliness

44



Good Luck!



DRILLED SHAFT EXCAVATION AND CLEANING

1

DRILLED SHAFT EXCAVATION

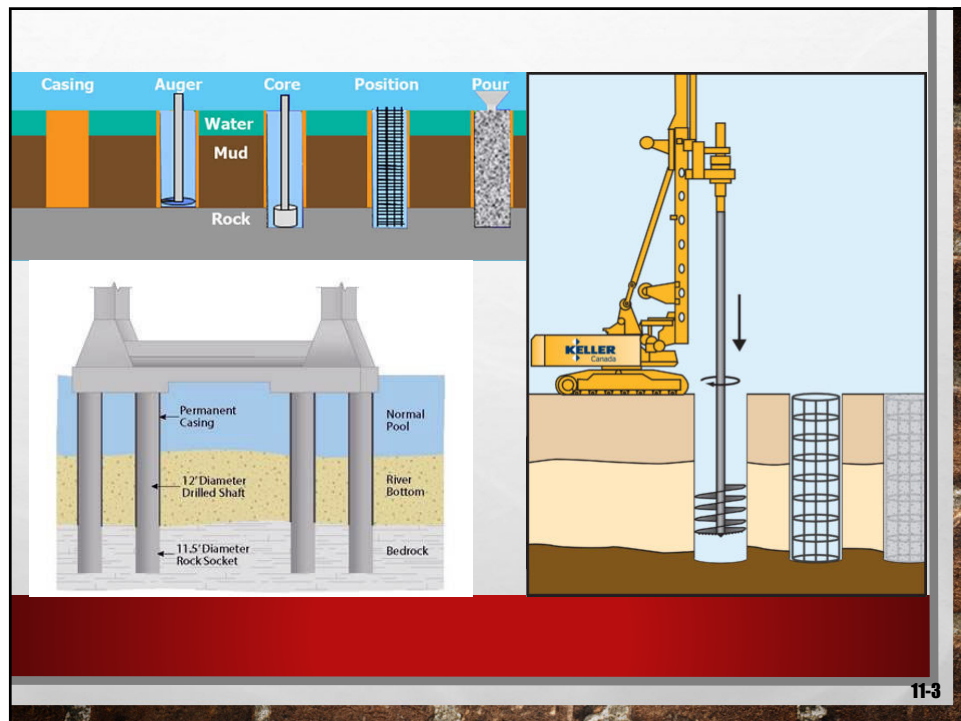
- **SURVEY IN LOCATION**
- **AUGER SOIL MANTLE**
- **SET TEMPORARY CASING OR THICK-WALLED PERMANENT CASING**
- **DRILL ROCK SOCKET**
- **CLEAN ROCK SOCKET**
- **INSTALL CMP PERMANENT CASING**

2

TRIAL DRILLED SHAFT

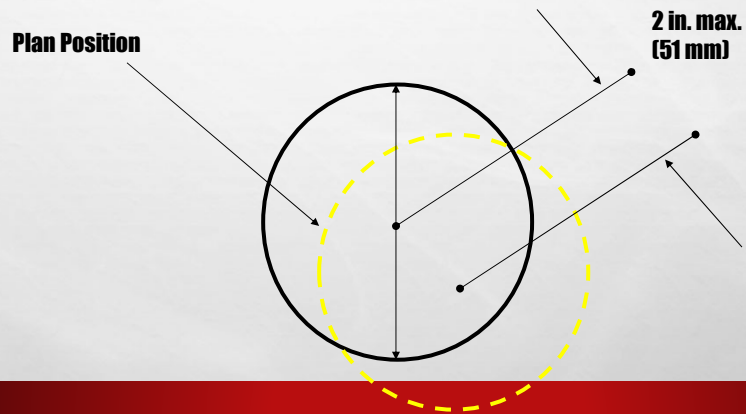
- TRIAL SHAFTS ARE USED TO TEST THE CONTRACTORS METHODS.
- THIS CAN INCLUDE DRILLING, SEALING OF GROUNDWATER SETTING OF CASING, SETTING REBAR CAGES, AND CONCRETE PLACEMENT.
- THE TRIAL SHAFT SHOULD BE DRILLED TO THE MAXIMUM DEPTH OF ANY PRODUCTION SHAFT SHOWN ON THE PLANS.

3



4

Is the shaft being constructed in the correct location & within tolerance?



11-15

5



6

AUGER SOIL MANTLE

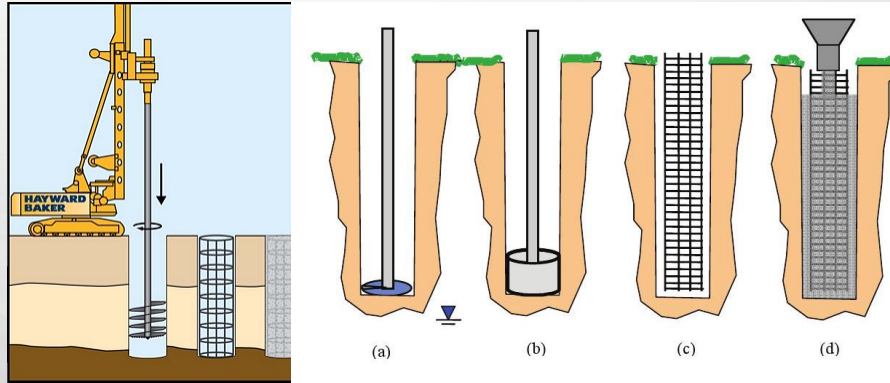
- **EXCAVATION OF THE SOIL MANTLE CAN BE DONE BEFORE THE CASING IS SET.**
- **USE A WEIGHTED TAPE TO CHECK PROGRESS OF THE EXCAVATION.**

7



8

Dry Pour Method



9

Drill Shaft Dry Pour Method



10

TEMPORARY CASING



11

VIBRATING THICK-WALLED PERMANENT CASING



12

INSPECTOR CHECKLIST

At this point the Inspector should record the following:

Material Augered from Shaft

Type of Casing

Length and Size of Casing

Elevation of Top of Casing

Anything out of the ordinary. Excessive time, material not as shown on plans.

13

ROCK SOCKET EXCAVATION

- **ROCK SOCKET CAN BE AUGERED OR CORED.**
- **ROCK SOCKET MAYBE WET OR DRY**
- **PAY CLOSE ATTENTION TO WHAT TYPE OF MATERIAL IS BEING EXCAVATED. WHAT IS THE FOUNDATION MATERIAL SUPPOSED TO BE? LIMESTONE, SHALE ETC**
- **MEASURE ELEVATION FROM KNOWN REFERENCE POINT**
- **DO NOT OVER EXCAVATE THE DEPTH OF THE SHAFT.**

14

EXCAVATION OF THE BEDROCK



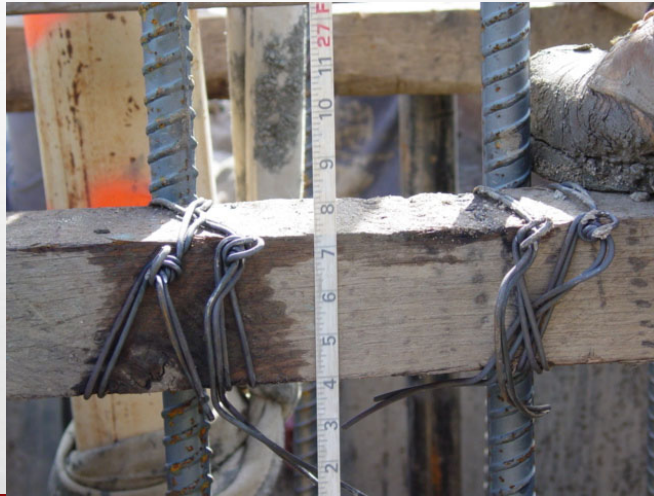
15

CHECK DEPTHS WITH A WEIGHTED TAPE



16

MEASURE TO A KNOWN REFERENCE POINT



17



18

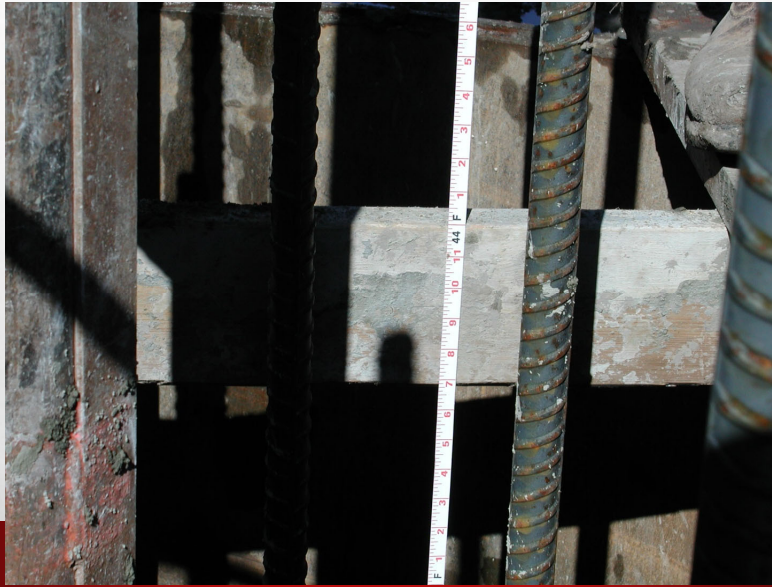


19



20

CHECK THE DEPTHS!



21

CLEANING OUT THE ROCK SOCKET **THIS MAY BE DONE SEVERAL TIMES!**



22



23



24

CLEANING OUT ROCK SOCKET

- [HTTPS://YOUTU.BE/RT004LJYG9G](https://youtu.be/RT004LJYG9G)

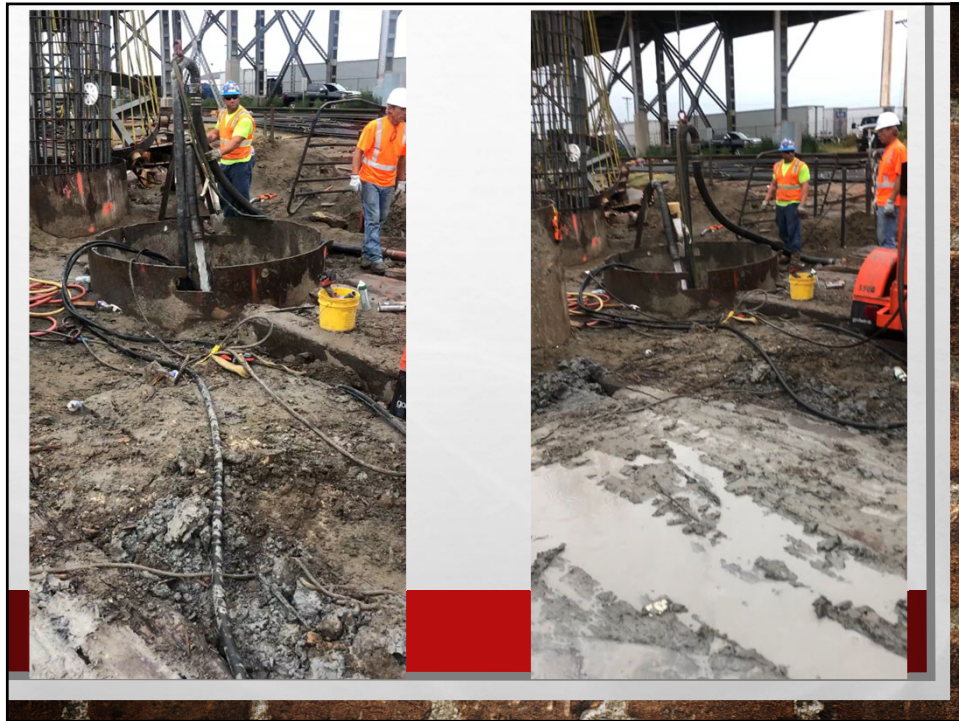


25

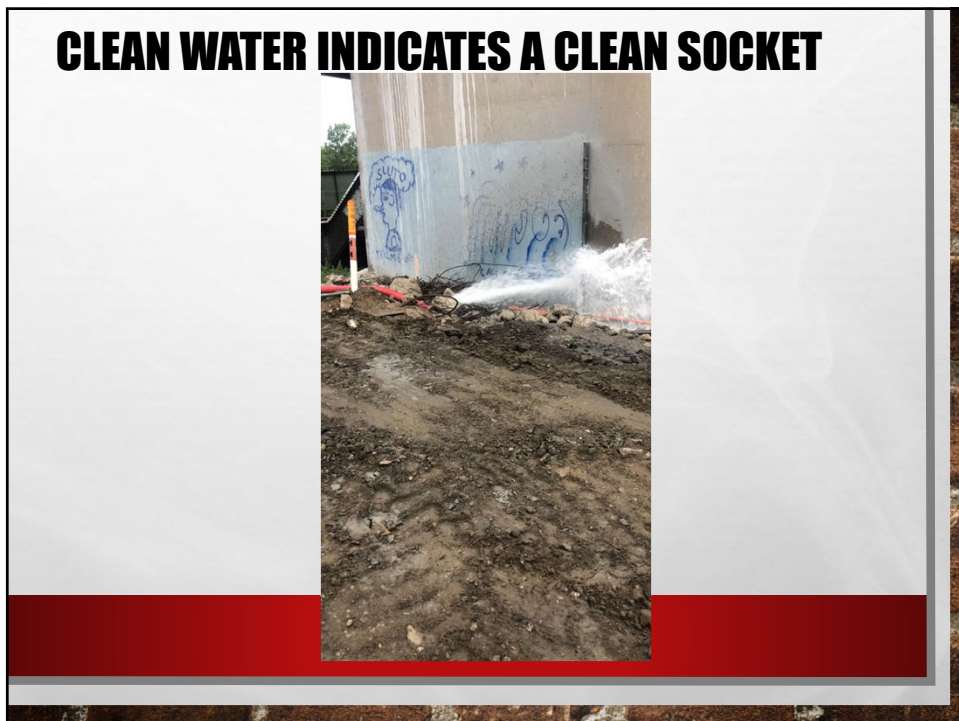
AIR LIFT PUMP



26



27



28

CLEANED ROCK SOCKET



29

ROCK SOCKET SHOULD BE FREE OF DEBRIS AND RELATIVELY FLAT. THE AUGERS OR OTHER EQUIPMENT USED TO EXCAVATE THE ROCK SOCKET SHOULD BE WITHIN 3/8THS OF AN INCH PER FOOT FROM VERTICAL.



30

PERMANENT CASING

Permanent Casing is required when you have a wet pour or specified on the plans.

Permanent Casing must be water-tight and can be a corrugated metal pipe or a thick walled metal pipe.

Casing can not be more than 1 inch out or round.

Deviation of a chord must be less than or equal to 2 inches.

31

INSTALLATION OF CMP PERMANENT CASING



32

INSTALLATION OF PERMANENT CASING



33

CLASS EXERCISE

3 drilled Shafts

Drilled Shaft inspection procedure

**What documentation and equipment
will you need**

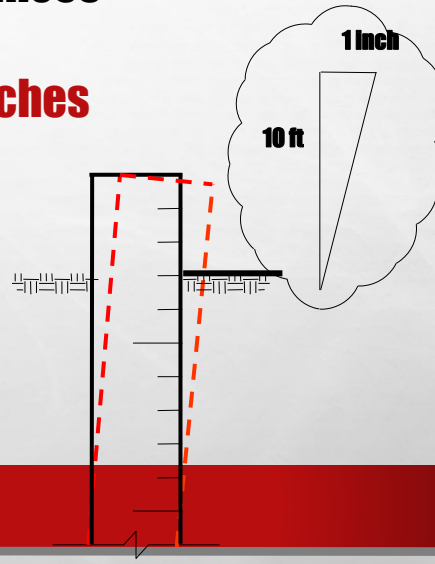
Which of any are acceptable

**If not acceptable, why not and what is
your next step?**

34

Is the shaft within allowable vertical alignment tolerances

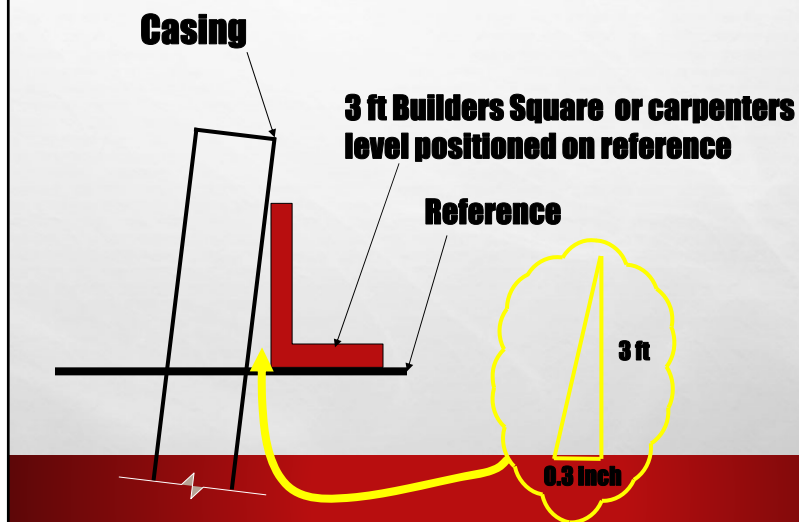
Maximum is 6 inches out of alignment



11-41

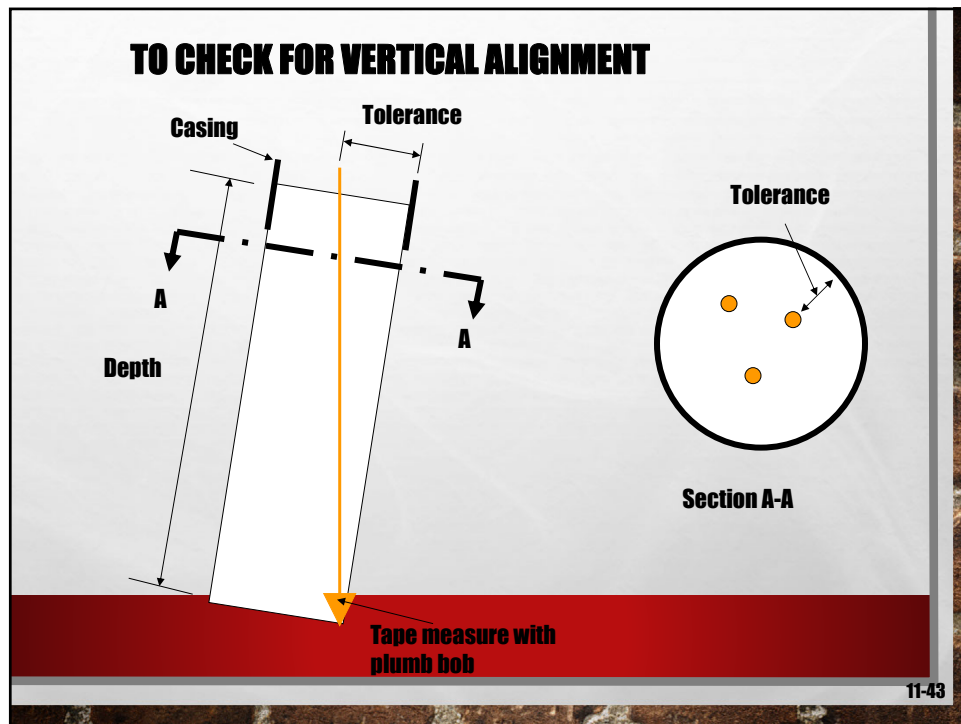
35

TO CHECK FOR VERTICAL ALIGNMENT

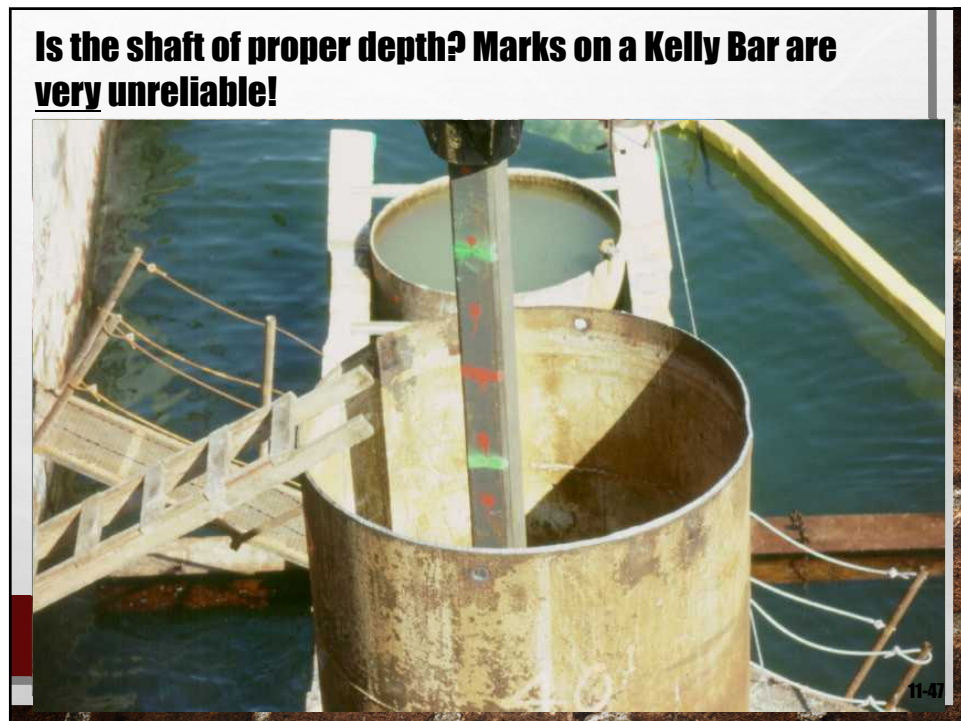


11-42

36



37



38

Does the shaft bottom meet the requirements?

ROCK SOCKET EXCAVATION INSPECTION

- **Maximum depth of sediment or debris = $\frac{1}{2}$ of Sediment over 75% of the shaft bottom.**
- **Dry Shafts no more than 4 inches of water in a 5 minute Period and the shaft can be dewatered so only 2 inches of water is left in the shaft.**
- **Inspection of a wet shaft.**

11-56

39



40

CHECK DEPTHS WITH A WEIGHTED TAPE



41



42

VIDEO RECORDING

- **ON ANY SHAFT 6 FOOT IN DIAMETER OR OVER A DOWN HOLE CAMERA MUST BE USED.**
- **THE HOLE CAN BE PUMPED OUT THEN FRESH CLEAN WATER PUMPED BACK INTO THE SOCKET**
- **OR A FLOCCULENT CAN BE USED TO SETTLE OUT THE CUTTINGS AND CLEAR UP THE WATER.**

43

VIDEO RECORDING



44

VIDEO RECORDING CONTINUED



45

SHAFT CLEANLINESS

Shaft cleanliness is important for:

A) end-bearing shafts

B) side-friction shafts

 **C) both of the above**

D) none of the above

11-62

46

TYPICAL PROBLEM



11-65

47

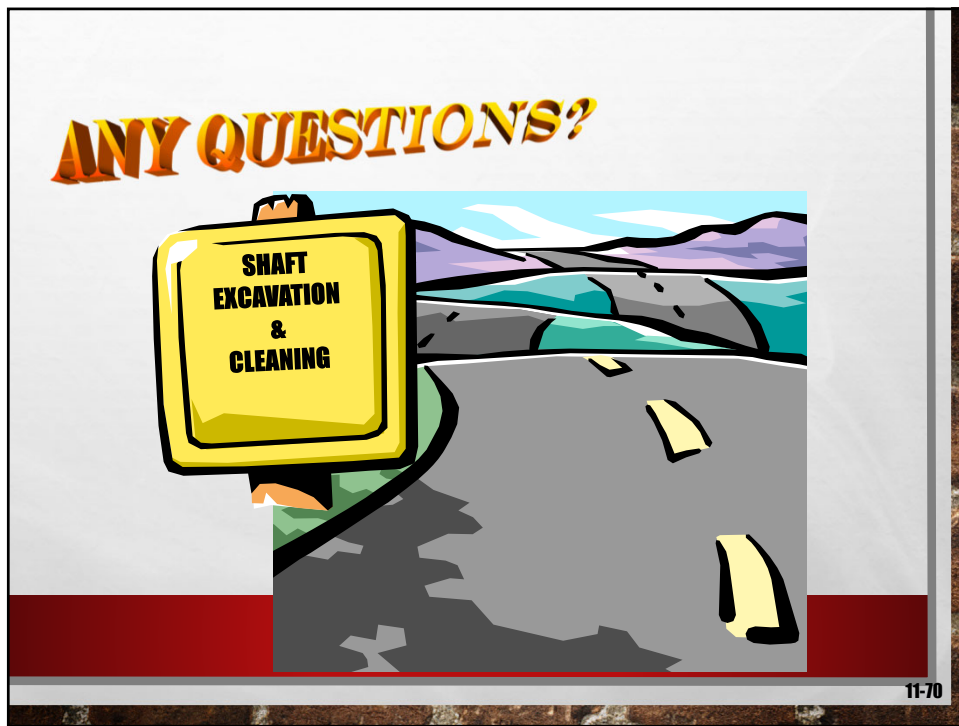
**Very large defect found
by Sonic Echo test.
Probably due to dirty hole.**



No concrete

11-67

48



Reinforcing Cage Drilled Shaft Inspection



1

1

Inspector Duties

- Responsible for:
 - Verifying proper reinforcing steel diameter, length, spacing and quantity
 - Verifying the steel is properly tied in place
 - Verifying proper spacer installation



2

2

Special Provision 15-07007-R01 Slide 1

- This is for noise wall, high mast towers, overhead sign structures, traffic signals, electric lighting systems and other specified items
- Basically, the same requirements for placing steel as section 703



3

3

Special Provision 15-07007-R01 Slide 2

- Sonic testing pipes are not required
- Spacer requirements are the same
- Usually, smaller shafts than what are required for bridge structures



4

4

Requirements for Shaft before reinforcing steel placement (slide 1)

- Outlined in Standard Specifications Division 700 Special Provision 15-07015-R02 section 703.3c for shafts equal or greater to 72" in diameter founded in shale or as required by the Bridge Foundation Geology Report
 - Shaft drilled using a full diameter flight auger or core barrel
 - Use a full-size clean-out bucket a minimum of 95% of the diameter of the rock socket
 - Sound the bottom of the finished shaft using a weighted tape
 - Contractor shall provide access to the entire perimeter of shaft

5



5

Requirements for Shaft before reinforcing steel placement (Slide 2)

- Section 703.3c
 - Flocculate the finished shaft to increase the visibility in water for underwater video
 - Prior to concrete placement, perform a video inspection to inspect sides and base of rock socket
 - This video needs to be reviewed with the Engineer prior to placement to verify cleanliness of the shaft

6



6

Requirements for Shaft before reinforcing steel placement (slide 3)

- For all other shafts as outlined in Standard Special Provision 15-07015-R02 section 703.3e
 - Visual inspection; or
 - Underwater inspection using probes; or
 - Down hole television camera and video recordings



7

7

Placing Reinforcing Steel and Sonic Testing Pipes (slide 1)

- See Standard Specifications Division 700
- Reinforcing Steel section 703.2 d
 - Refers to Division 1600
 - Sections 1601 Steel Bars for Concrete Reinforcement
 - Section 1604 Helical Reinforcement
 - Section 1605 Reinforcing Steel Splices
 - Section 711 Reinforcing Steel
- Sonic Testing Pipes 703.2 f
 - Provide pipe that complies with Division 1900



8

8

Placing Reinforcing Steel and Sonic Testing Pipes(slide 2)

- Section 703.3 d
 - This section outlines the requirements for placing reinforcing steel and sonic testing pipes
- Reinforcing steel
 - Tie all intersections
 - Place reinforcing steel as one unit
 - Place 1 non-corrosive circular spacer per 30 inches of circumference of the reinforcing cage
 - Spacers will be spaced 2 to 4 feet from bottom and top not to exceed intervals 10 feet vertically
 - Also, in Section 711 of specification



9

9

Placing Reinforcing Steel and Sonic Testing Pipes(slide 3)

- Reinforcing Steel
 - If shaft is lengthened and the length of the cage is required to be increased, make sure splice is at the bottom of the reinforcing steel cage
 - ***If the cage is required to be lengthened, contact the state bridge office for guidance on splicing**



10

10

Placing Reinforcing Steel and Sonic Testing Pipes(Slide 4)

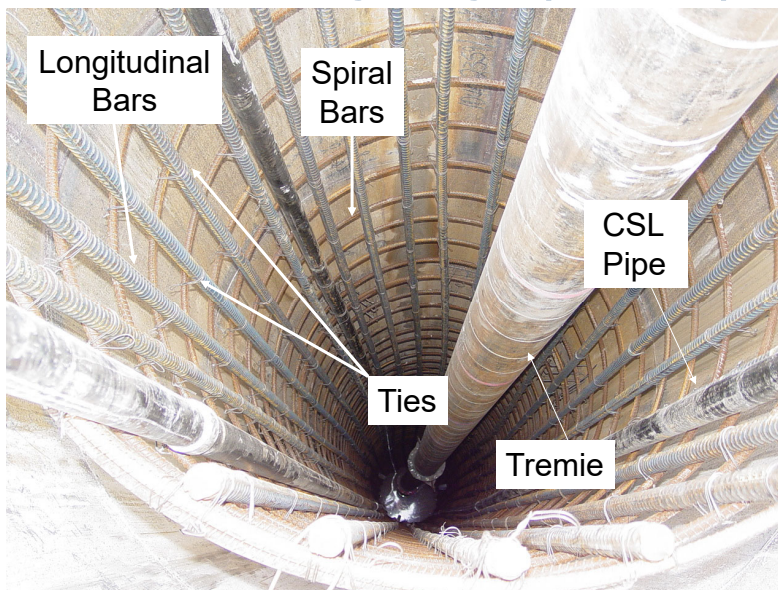
- Section 703.3 d
 - Sonic testing pipes
 - Serve no structural significance
 - Sonic testing pipes are full length of shaft and a minimum of 12 inches above top of concrete
 - These pipes must extend to the bottom of the shaft

11



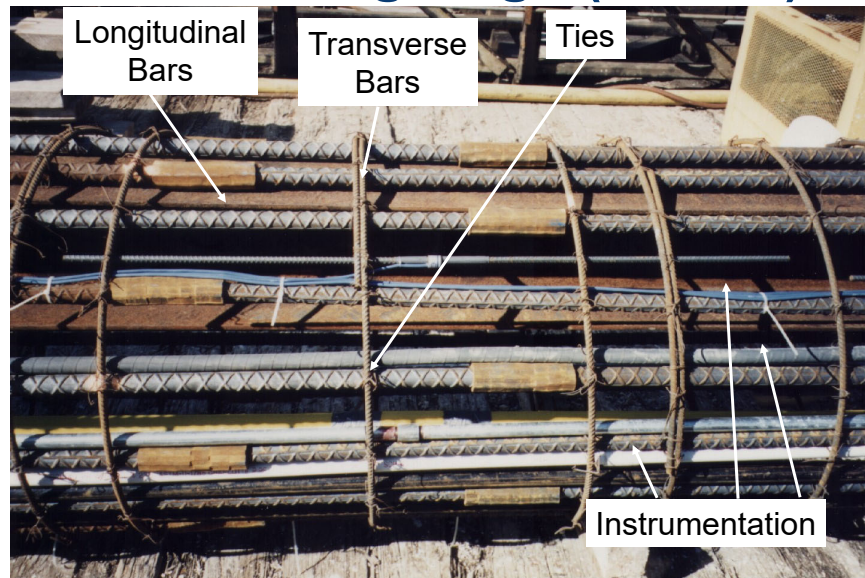
11

Reinforcing Cage (slide 1)



12

Reinforcing Cage (slide 2)



13

Sample drilled shaft inspection checklist

Reinforcing Cage	Yes No	NA
21. Is the rebar the correct size and configured in accordance with the project plans?		
22. Is the rebar properly tied in accordance with 2015 Standard Specifications part 703.3 d?		
23. Does the Contractor have the proper spacers for the steel cage in accordance with 2015 Standard Specifications part 703.3 d?		
24. If the cage is spliced, was it done in accordance with the contract documents and was the State Bridge office consulted?		
25. Is the steel cage secured from settling and from floating (during concrete placement cages sometimes rise with the concrete)?		
26. Is the top of the steel cage at the proper elevation?		

14

Contact Information

- Mervin Lare
- Mervin.Lare@ks.gov
- Phone 785-250-4793



Reinforcing Cage Drilled Shaft Inspection



1

Reinforcing cage construction

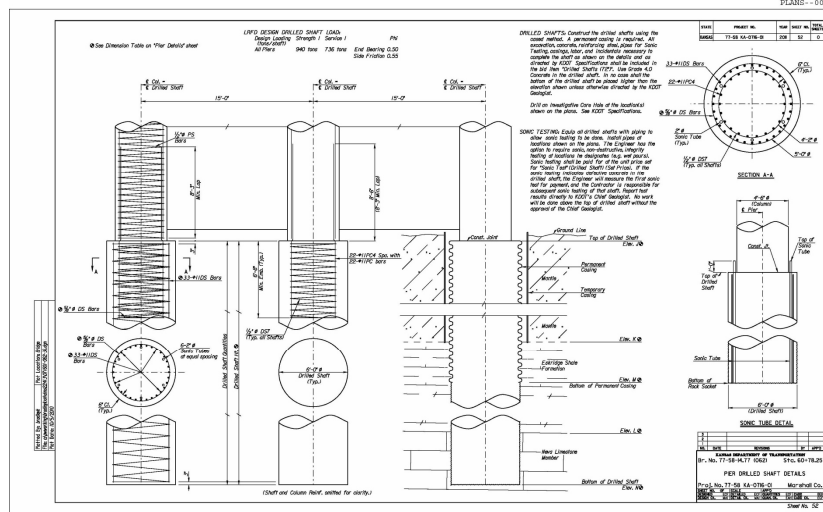
- Reinforcing steel cage construction and placement
 - Shall be completely assembled prior to placement
 - Placed immediately after inspection and acceptance of shaft
 - Internal stiffeners removed as cage is placed in the excavation



2

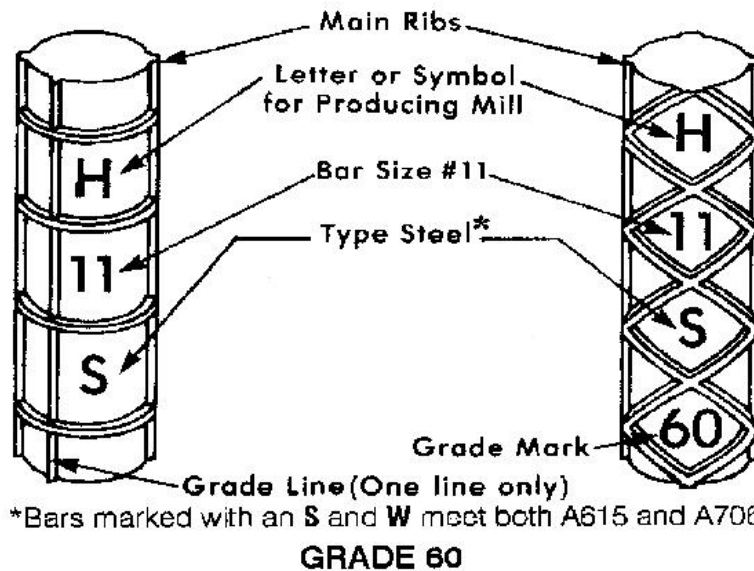
2

Is the rebar the correct size and configured in accordance with the project plans?



3

IDENTIFICATION MARKS ASTM STANDARD REBARS



4

ASTM STANDARD REBARS

Bar No.		Weight/Mass		Diameter	
US	SI	Lbs/Ft	KG/M	in	mm
3	10	0.376	0.560	0.375	9.5
4	13	0.668	0.994	0.500	12.7
5	16	1.043	1.552	0.625	15.9
6	19	1.502	2.235	0.750	19.1
7	22	2.044	3.042	0.875	22.2
8	25	2.670	3.973	1.000	25.4
9	29	3.400	5.060	1.125	28.7
10	32	4.303	6.404	1.250	32.3
11	36	5.313	7.907	1.375	35.8
14	43	7.650	11.380	1.750	43.0
18	57	13.600	20.240	2.250	57.3



5

Reinforcing steel storage & handling

- Should not be stored in contact with soil
- Keep away from oil or other deleterious materials
- Adequate supports provided during lifting



6

6

Storage & handling



7

Properly Tie Reinforcing Steel(Slide 1)



8

Properly Tie Reinforcing Steel(slide 2)



9

Spacers

- What are spacers used for?
- To maintain the minimum required clearance between the cage and the walls of the shaft

10

Spacer placement

- Start spacers 2' to 4' from the bottom and top of cage
- Up the cage at intervals not exceeding 10 ft. intervals

11



11

Drilled Shaft Spacers

- Circular Non-corrosive spacers must be used.
- Must maintain a minimum clearance as defined in the plans between the outside of the cage and shafts walls (usually 6")

12

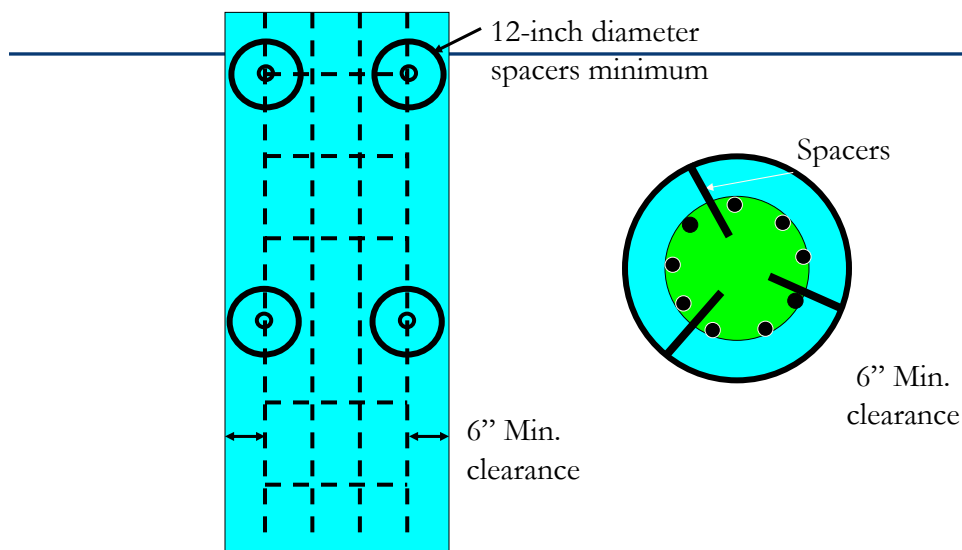


12

Spacer Requirements

- The specification requires the following
- Minimum of one non-corrosive circular spacer per 30" of circumference of the reinforcing steel cage

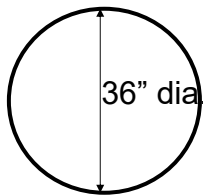
Clearance



Circumference of a Circle

Circumference (C) = πD Where: C = circumference
 D = diameter = 2 times radius
 $\pi = 3.142$

PROBLEM



What is the circumference
 of the shaft in inches and in feet?

$$C = \pi D$$

$$C = 3.142 (36")$$

$$C = 113.1 \text{ inches}$$

$$C = \pi D$$

$$C = 3.142 (3 \text{ ft.})$$

$$C = 9.43 \text{ ft.}$$

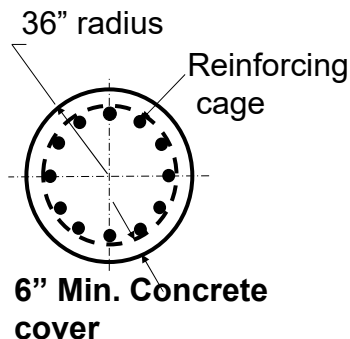


15

Circumference of the Reinforcing Cage(Slide 1)

$$\text{Circumference (C)} = \pi D$$

Where: Diameter of cage = Shaft diameter
 minus 2 times the Concrete cover
 D = diameter = 2 times radius
 $\pi = 3.142$

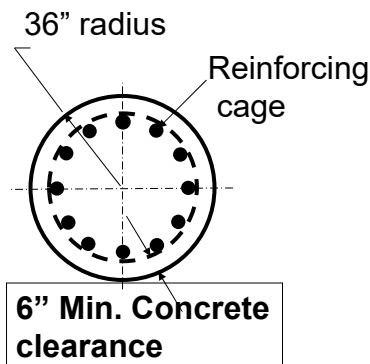


What is the circumference
 of the reinforcing cage in
 inches.?



16

Circumference of the Reinforcing Cage(slide 2)



What is the circumference of the reinforcing cage in inches.?

$$D = 72" - 2 \times \text{Req'd Clearance}$$

$$D = 72" - 12" = 60"$$

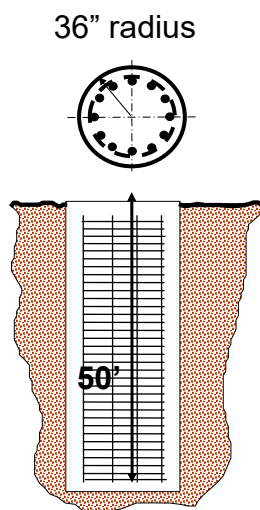
$$C = \pi D \text{ or } 3.142 \times 60"$$

$$C = 189"$$



17

Side Spacer for Shaft Alignment(slide 1)



...spacing devices shall be used at sufficient intervals [near the bottom and at intervals not exceeding 10 feet up the shaft] Use a minimum of one spacer per 30 inches of circumference of cage with a minimum of three at each level.

How many side spacers are required shaft?

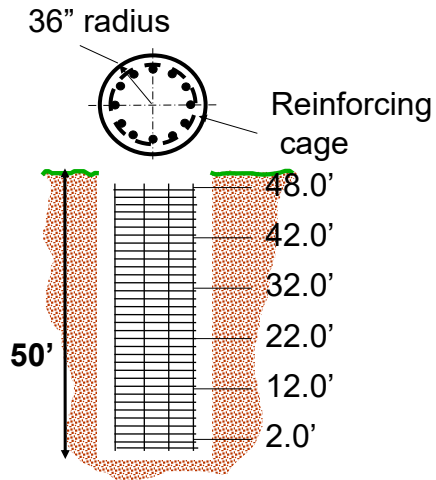
How many levels?

Total number of spacers =



18

Side Spacer for Shaft Alignment(slide 2)



How many side spacers are required shaft?

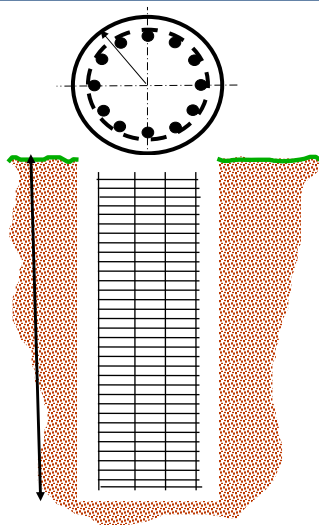
$$\text{Number of spacers per level} = \frac{189''}{30''} = 6.3 = 7$$

How many levels? ➡ 6

$$\text{Total number of spacers} = 7 \times 6 = 42$$

19

Side Spacer for Shaft Alignment(slide 3)



Cage Diameter (in.)	No. of spacers required
---------------------	-------------------------

30	4
36	4
42	5
48	6
54	6
60	7
66	7
72	8
78	9
84	9

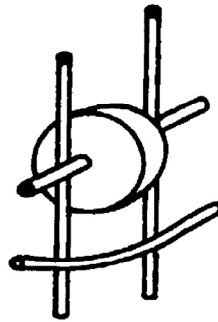
20

20

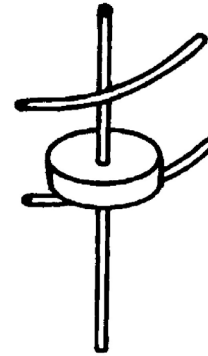
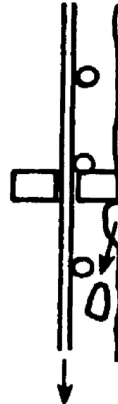
Spacer Clearance



(a) Correct



(b) Incorrect



21

Install proper number of spacers around and up the shaft



22

Typical Spacers(slide 1)

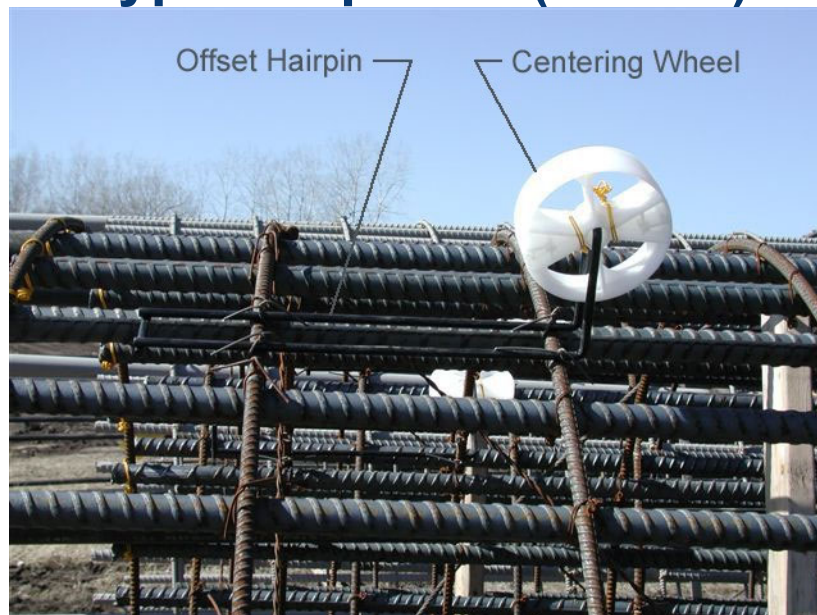


Click the spacers into place.



23

Typical Spacers(slide 2)



Offset Hairpin

Centering Wheel



24

Typical Spacers(slide 3)



25

Contact Information

- Mervin Lare
- Mervin.Lare@ks.gov
- Cell 785-250-4793



26

Reinforcing Cage Drilled Shaft Inspection Cross Hole Sonic Log



1

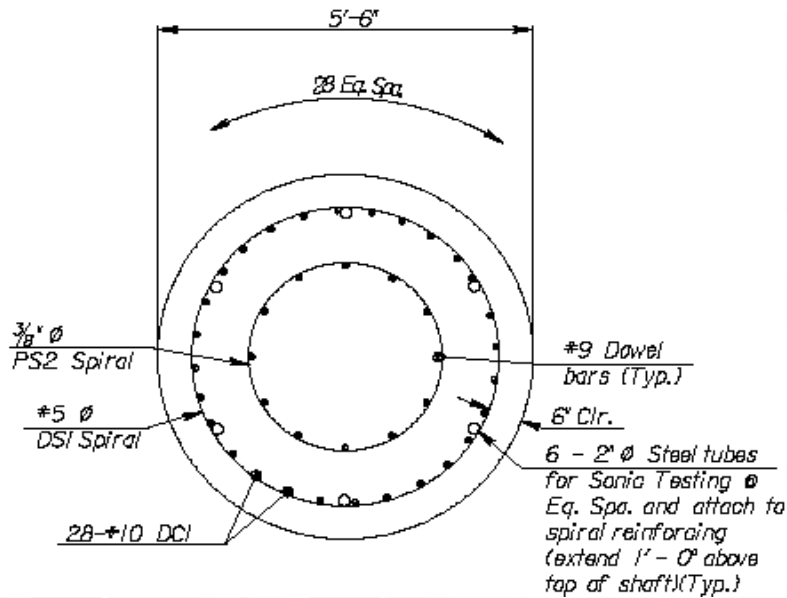
Sonic Testing Pipes

- Why do we need these in drilled shafts?
 - Sonic testing pipes are for testing the concrete in the shaft only, there is no structural significance
 - Sonic testing pipes are required in every drilled shaft for bridges.
 - Not required for shafts in noise walls, high mast towers or overhead structures

2

2

Cross-hole Sonic Logging (CSL) Tubes 1



3

Cross-hole Sonic Logging (CSL) Tubes 2

- 2015 Standard Specifications Division 700 section 703.2 f. Sonic Testing Pipes:
 - Division 1900 provide 2-inch diameter steel pipe that complies with ASTM A 53 or ASTM A 500, Grade B, Standard Weight.

4

Placing Sonic Testing Pipes 1

- Section 703.3 d
 - Sonic testing pipes
 - Sonic testing pipes shall be full length of shaft and a minimum of 12 inches above top of concrete
 - These pipes must extend to the bottom of the shaft



5

5

Placing Sonic Testing Pipes 2

- When it states place at the bottom of the shaft, if the shaft is extended, sometimes the rebar cage will still be at the same elevation, but the shaft will be deeper by 6". The sonic pipes must extend to the bottom of the shaft so that the entire shaft can be tested.



6

Cross-hole Sonic Logging (CSL) Tubes 1

- 2015 Standard Specifications Division 700 section 703.3 d Placing Reinforcing Steel and Sonic Testing Pipes:
 - Remove corrosion protection coating from sonic testing pipes by sandblasting to bare metal
 - Place number of testing pipes shown in contract documents



7

7

Cross-hole Sonic Logging (CSL) Tubes 2

- 2015 Standard Specifications Division 700 section 703.3 d Placing Reinforcing Steel and Sonic Testing Pipes:
 - Pressure test each pipe before installation in the reinforcement cage
 - Test all pipes after being placed and tied in reinforcement cage



8

8

Cross-hole Sonic Logging (CSL) Tubes 3

- 2015 Standard Specifications Division 700 section 703.3 d Placing Reinforcing Steel and Sonic Testing Pipes:
 - When the drilled shaft is greater than 30 feet in length, perform a second test after reinforcing steel is installed in shaft
 - Pipe must be pressurized to 100 psi pressure loss can not be greater than 5% in 3 minutes

CSL Pipe 1



CSL Pipe

CSL Pipe 2



11

Contact Information

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- Mervin.Lare@ks.gov
- Cell 785-250-4793



12

Reinforcing Cage Placement Drilled Shaft Inspection



1

SPLICING OF CAGE 1

- If the rebar cage must be extended splices usually will be made at the bottom of the cage
- Remember that the CSL tubes must go to the bottom of the shaft

2

2

SPLICING OF CAGE 2

- Typical plan notes might say:
 - Minimum of one-half of longitudinal bars extended on bottom
 - Tie or spiral bars continue for the extra depth
 - Stiffener bars extended to final depth



3

3

SPLICING OF CAGE 3

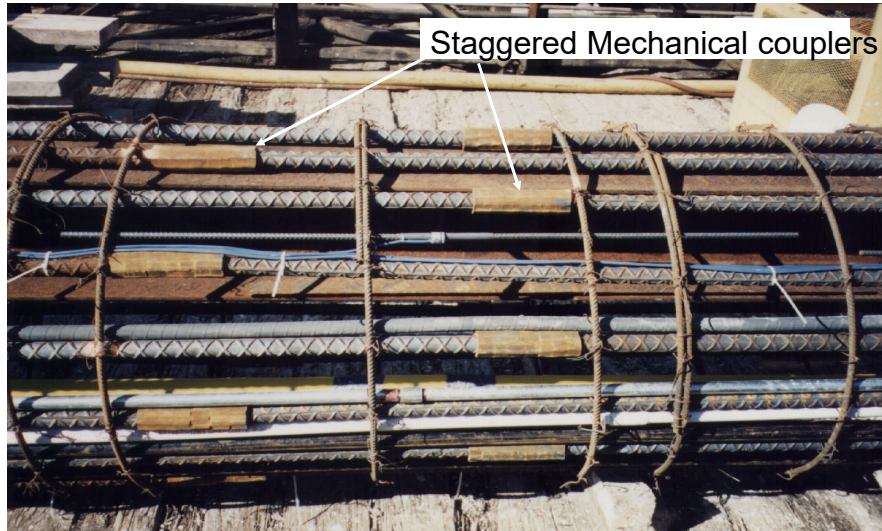
- Occasionally, due to a variety of things, the shaft will be deeper than the length of the cage and a splice will be required
- Typically, the specifications or plans will contain the requirements for splicing, remember contact State Bridge Office



4

4

SPLICING OF CAGE 4



5

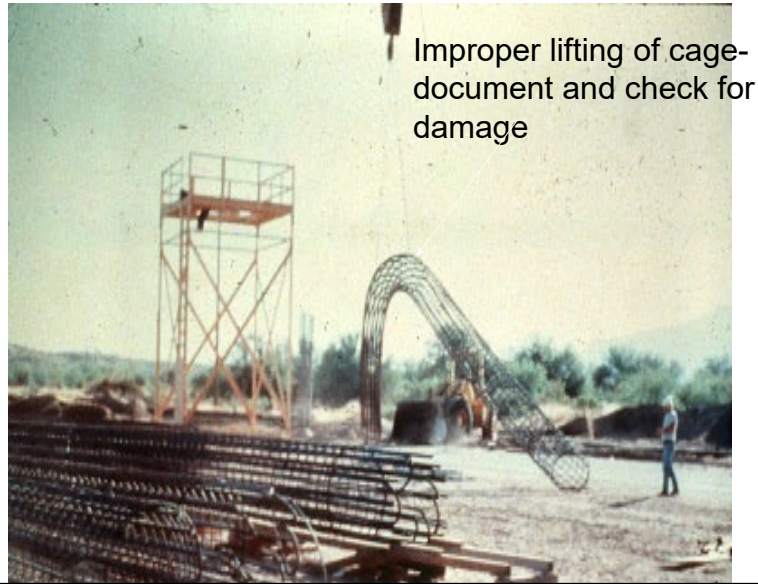
Cage Placement 1



Cage bent 90°

6

Cage Placement 2



7

Cage Placement 3



8

Cage Placement 5



9

Cage Placement 6



10

Cage Placement 7



11

Cage Placement 8



12

Cage Placement 9



13

Cage Placement 10



14

Cage Placement 11



15

Cage Placement 12



16

Cage Placement 13



17

Cage Placement 14



18

Keeping the cage in place 1

- Once cage is set need to keep it place so it does not move during placement of the concrete
- Cage could lift out of concrete from pressure

19



19

Keeping the cage in place 2



20

Keeping the cage in place 3



21

Keeping the cage in place 4



22

Contact Information

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- Mervin.Lare@ks.gov
- Cell 784-250-4793



Reinforcing Cage Pictures



Kansas
Department of Transportation

1

When things go bad

Kansas
Department of Transportation

2

2

When things go bad 1



3

When things go bad 2



4

When things go bad 3



5

When things go bad 4



6

When things go bad 5



7

When things go bad 6



8

Contact Information

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- Mervin.Lare@ks.gov
- Cell 785-250-4793



DRILLED SHAFT CONCRETE PLACEMENT

SETH WEBER
ENGINEERING ASSOCIATE - BRIDGE DESIGN

CON - 1

1

Placing Drilled Shaft Concrete - 1

**Two Methods for Shaft Pours used
by KDOT are:**

- ▣ Dry Pour Method
 - Cased
 - Uncased
- ▣ Wet Pour Method
 - CASED ONLY

CON - 2

2

Placing Drilled Shaft Concrete - 2

- ▣ Is it a Dry Pour or Wet Pour?
- ▣ How is the appropriate method determined?
 - Is the shaft Dry?
 - ▣ Dry Pour Method
 - Is there water in the Shaft?
 - ▣ Can the water be pumped down to within 2" or less of the bottom of the shaft and refill 4" or less in depth in 5 minutes when the pump is shut off?
 - Yes, could use dry pour but remember only 2" of water is allowed in the bottom of the shaft when concrete placement begins
 - No, then it must be a wet pour

CON - 3

3

Free Fall Method

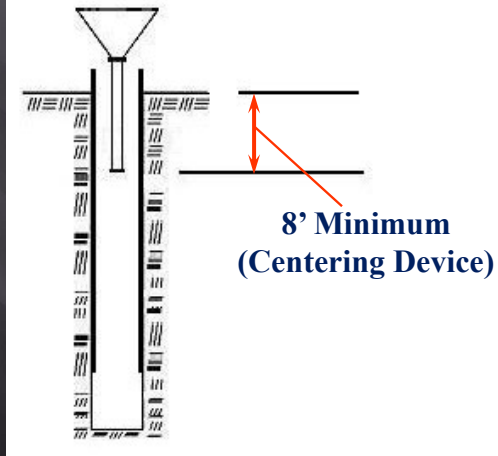


CON - 4

4

Dry Pour Method Cased Shaft

Unlimited Free Fall

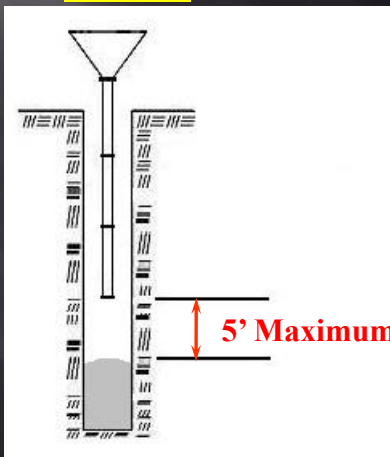


CON - 5

5

Dry Pour Method Uncased Shaft

Limited Free Fall



CON - 6

6

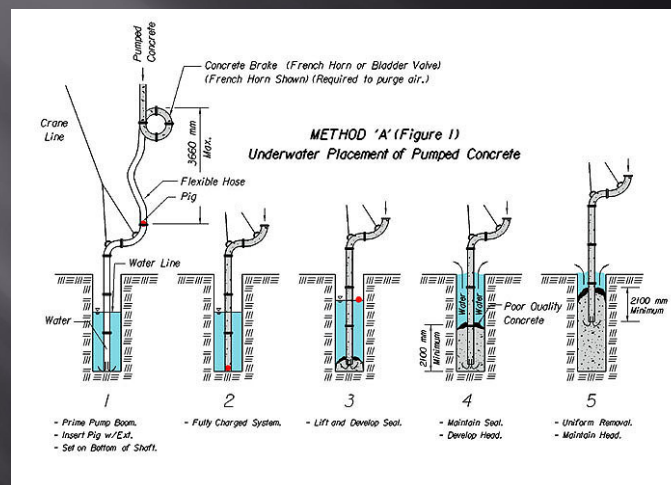
Concrete Placement Wet Pour Method - 1

- ▣ To separate the ground water from plastic concrete these are essential items.
 - Static Water Level
 - Fully Charge
 - Initial Seal
 - Embedment
 - Over Pump

CON - 7

7

Concrete Placement Wet Pour Method - 2



Static Water Level Fully Charge Initial Seal Embedment Over Pump

CON - 8

8

Method “A” with a French Horn



The French Horn minimizes air being pumped through the concrete during initial placement

CON - 9

9

703.3 Construction Requirements Placing Drilled Shaft Concrete



French Horn

Insert Pig here

Using a sealed discharge pipe with a pump

CON - 10

10

▣ Tremie Equipment - 1



CON - 11

11

▣ Tremie Equipment - 2



CON - 12

12

Example Pigs



1 lb./ Ft³ – 30 IFD

CON - 13

13

Pig Manufacturer: Girard Industries



6531 North Eldridge Parkway
Houston, Texas 77041-3507, USA

Phone Toll Free: (800) 231-2861

Web Address: www.girardind.com

CON - 14

14

Pig Manufacturer: Future Foam

Future Foam
Wes Putnam
Newton, KS
(316) 283-8600

CON - 15

15

▣ Tremie Assembly - 1



CON - 16

16

▣ Tremie Assembly - 2



CON - 17

17

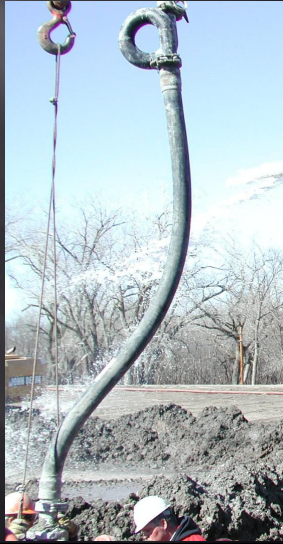
▣ Tremie Assembly - 3



CON - 18

18

▣ Tremie Assembly - 4



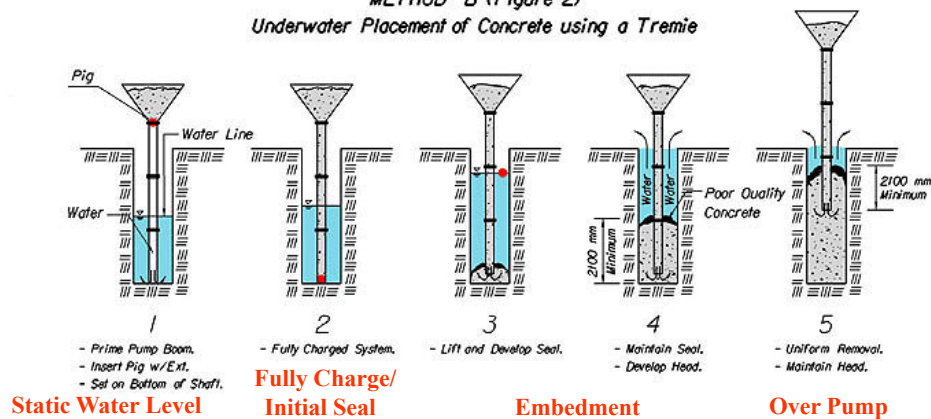
CON - 19

19

▣ Method "B"

▣ Pig

METHOD 'B' (Figure 2)
Underwater Placement of Concrete using a Tremie



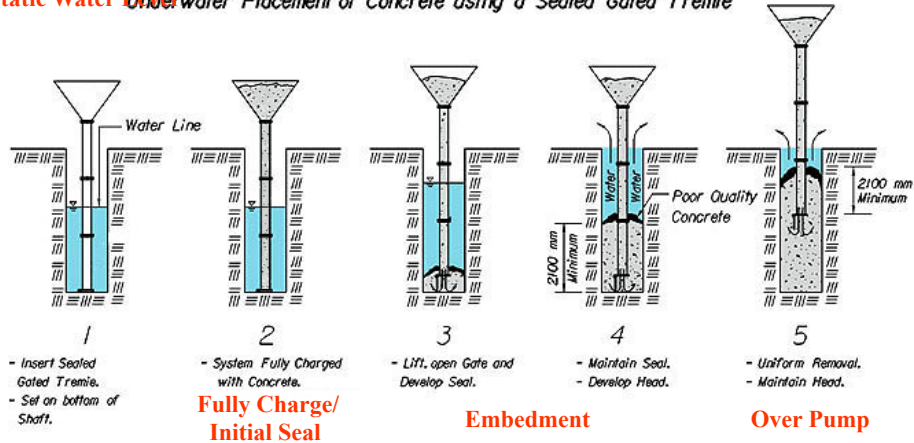
CON - 20

20

Method "C" Sealed Gated Tremie - 1

METHOD 'C' (Figure 3)

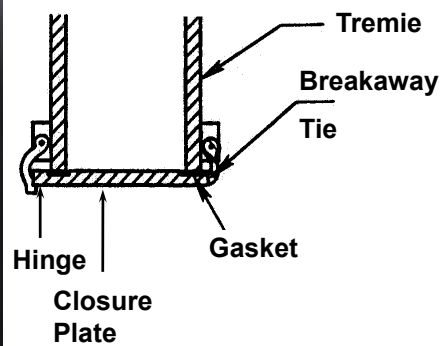
Static Water Level Underwater Placement of Concrete using a Sealed Gated Tremie



CON - 21

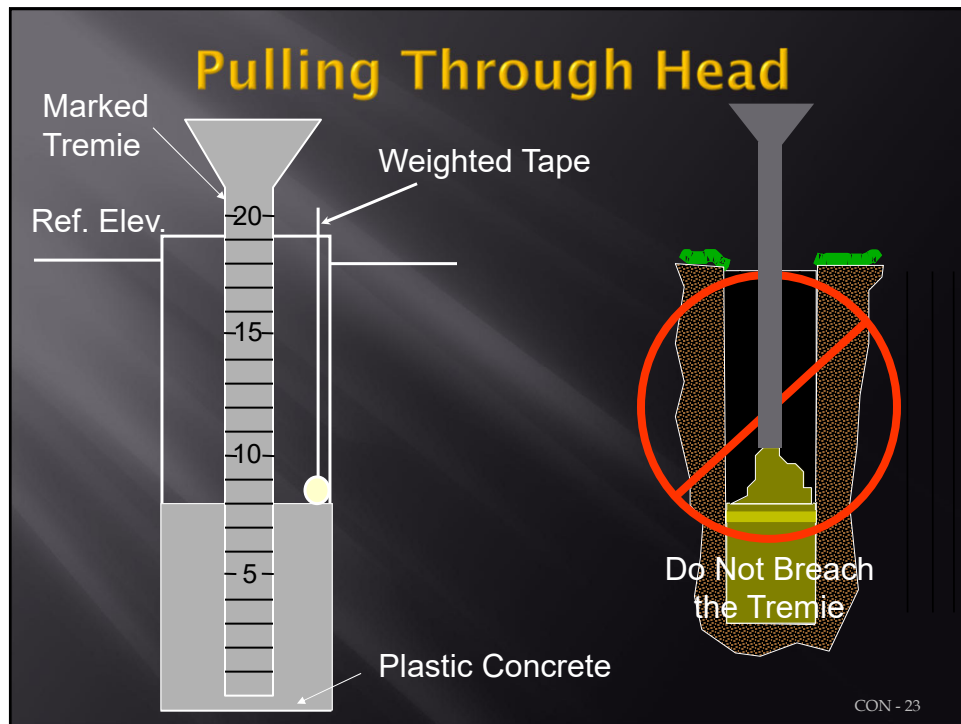
21

Method "C" Sealed Gated Tremie - 2



CON - 22

22



23



24

▣ Drilled Shaft Construction - 1



CON - 25

25

▣ Drilled Shaft Construction - 2



CON - 26

26

▣ Drilled Shaft Construction - 3



CON - 27

27

▣ Drilled Shaft Construction - 4



CON - 28

28

▣ Drilled Shaft Construction - 5



CON - 29

29

▣ Drilled Shaft Construction - 6



CON - 30

30

Raising Temporary Casing

- ▣ Sites with temporary casings only.
 - **Not allowed since 2007 specs.**
- ▣ Sites with a permanent and temporary casing.
(In accordance with 703.3.g)

g. Raising Temporary Casing. Do not remove the temporary casing until the concrete in the shaft has met the following conditions

- Completed shafts have been allowed to set for a minimum of 24 hours after the concrete placement and
- Developed a compressive strength of 1800 psi; or
- If the compressive strength does not meet 1800 psi, the Engineer may allow the Contractor to proceed when the shaft has cured 5 days after completion of the concrete placement.

However, immediately after completing concrete placement in the permanent casing, it is acceptable to Raise and hold the temporary casing at the embedment depth plus 6 inches.
Before raising the temporary casing completely, backfill the space between the 2 casings according to Subsection 703.3j.

CON - 31

31

Measurement and Payment

- ▣ Completed Shaft
- ▣ Casings
- ▣ Sonic Tests
- ▣ Investigative Core Holes

CON - 32

32

Concrete Volumes Form

Compute Concrete Curve

**Fill in before
placement starts**

**During Placement
Slope of the line
Is key to
Detecting trouble**

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION
SHOULDRIFT CONCRETE TIE VOLUMES
 (ENGLISH/METRIC)

1300-010-00
 CONSTRUCTION
 11/00
 Page 1 of 1

Project Name _____	Page _____ of _____
FIN Project No. _____	Plate No. _____
Contractor _____	Shaft No. _____
Inspected By _____ Date _____	Station _____
Approved By _____ Date _____	Offset _____

Concreting Curve

Steep line using
too little Concrete

Theoretical Line

Shallow line using
Too much concrete

Concrete Volume Place (cuyd/m³)

Volume Delivered _____	VD _____ cuym³	Lineal Volume of Retain Tolerances, etc. AR _____	
Volume in Lines _____	VL _____ cuym³	(RBARS) (AR) + (R) (AR) = () () () = _____	m³
Wastage _____	VW _____ cuym³	(RBARS) (AR) + (R) (AR) = () () () = _____	m³
Volume Placed + VD+VL+VW = _____	VP _____ cuym³	Rock Socket Length _____	RSL _____ ft/m
Theoretical Vol. _____	VT _____ cuym³	Est. Rock Socket Volume From Curve _____	VRS _____ cuym³
Overpour(VP-VT) _____	OP _____ cuym³	Ad. Rock Socket Volume VRS + VRS = (AR) (RSL) - V _____	cu
		(cu) + (m³) / (m³) - (m³) = _____	m³
		Avg. Rock Socket Vol. = SQRTR[VRS / (0.7854) (RSL)] _____	m
		SQRT(1.273) / (cu / ft) = _____	in
		SQRT(1.273) / (m³ / ft) = _____	m

33

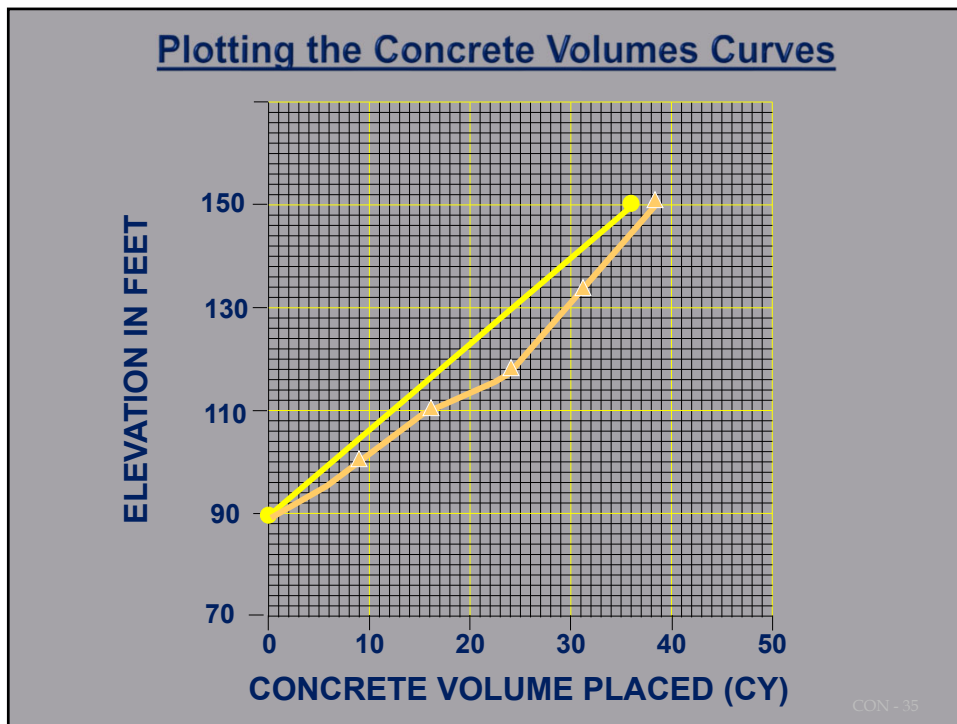
Concrete Volume Curves

❑ Concrete Volume Curve can be the first line of defense to recognize this is a deficient shaft.

❑ This is much easier and often much cheaper to address **before** the concrete has set up



34



35

Determining Concrete Volumes

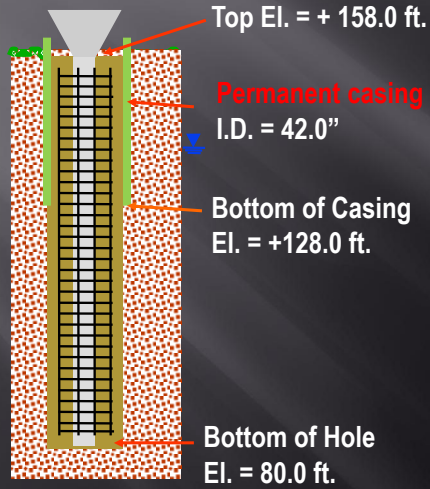
To perform your responsibilities and complete the Concrete Placement and Volume Form, you need to know how to:

- Calculate the theoretical volume of the shaft
- Determine the depth to top of concrete in the shaft
- Plot the actual concrete volume versus the theoretical volume
- Recognize problems based upon the concrete volume plots

CON - 36

36

CONCRETE VOLUMES PRACTICE PROBLEM #1 - 1



1. Calculate the theoretical volume of the hole

$$\text{Volume} = \text{Depth} \times \text{Area} / 27$$

$$\text{Depth} = 158 - 80 = 78 \text{ feet}$$

$$\text{Area} = 0.25 \times \pi \times D^2$$

$$D = 3.5 \text{ ft}$$

$$\text{Area} = .25 \times \pi \times 3.5^2$$

$$= 9.62 \text{ ft}^2$$

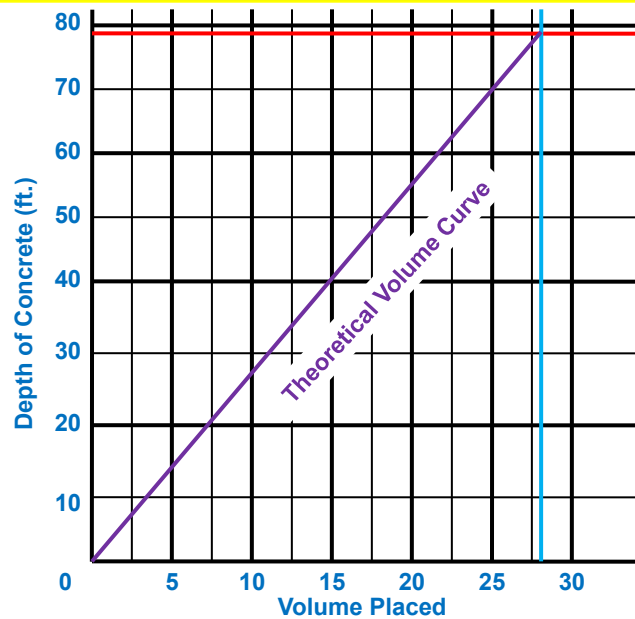
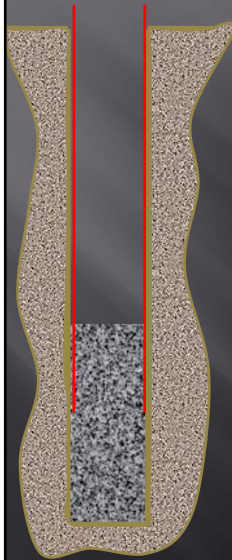
$$\text{Volume} = 78 \times 9.62 / 27$$

$$= 27.8 \text{ Cu Yds.}$$

CON - 39

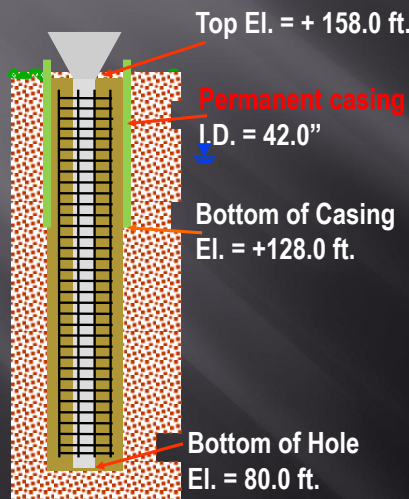
39

Volume Curve



40

CONCRETE VOLUMES PRACTICE PROBLEM #1 - 2



2. Concrete volume following each truck

Calculate the rise of the top of concrete per cubic yard

= Shaft Length/Shaft Volume

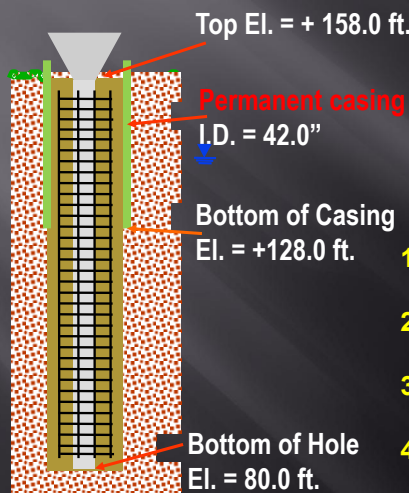
= (158.0-80.0) ft./ 27.8 cu. Yd.

==>2.8 feet "filled" per cu yd

CON - 41

41

CONCRETE VOLUMES PRACTICE PROBLEM #1 - 3



2. Concrete volume following each truck

Assume: 9 cu yds per truck
2 cu yds waste on first truck
--2.8 feet "filled" per cu yd

1st truck (9-2) X 2.8 = 19.6 ft. 19.6 ft.

2nd truck 9 X 2.8 = 25.2 ft 44.8 ft.

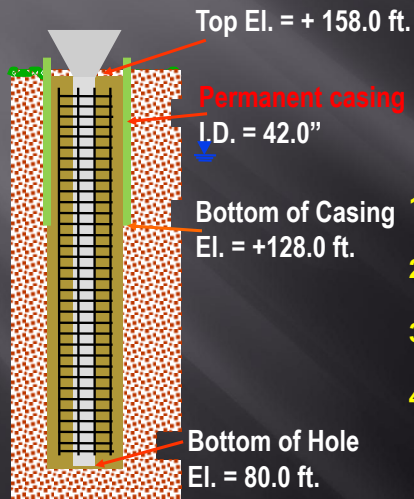
3rd truck 9 X 2.8 = 25.2ft. 70.0 ft.

4th truck 8' + waste

CON - 42

42

CONCRETE VOLUMES PRACTICE PROBLEM #1 - 4



3. Take Tape Measurement and Calculate ACTUAL Concrete Depth

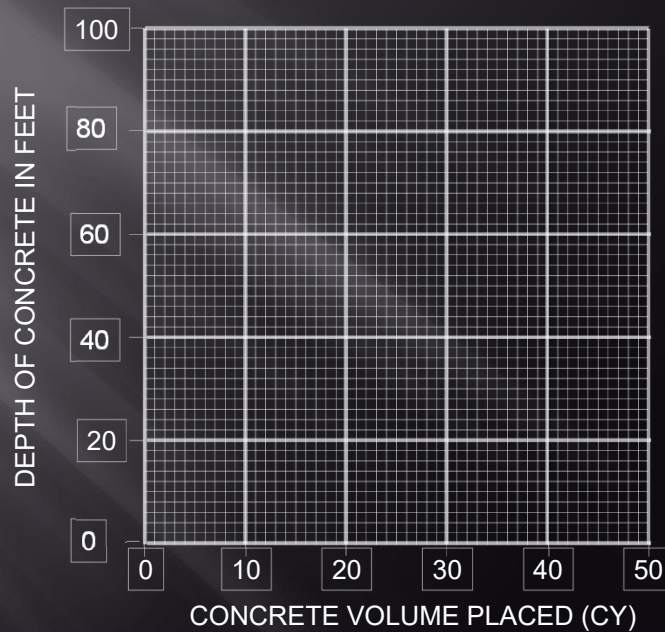
	Tape Length	Concrete Depth
1 st truck	<u>59.0 ft.</u>	19.0 ft.
2 nd truck	<u>37.0 ft.</u>	41.0 ft.
3 rd truck	<u>12.0 ft.</u>	66.0 ft.
4 th truck	12' + waste	

Shaft Length minus Tape

CON - 43

43

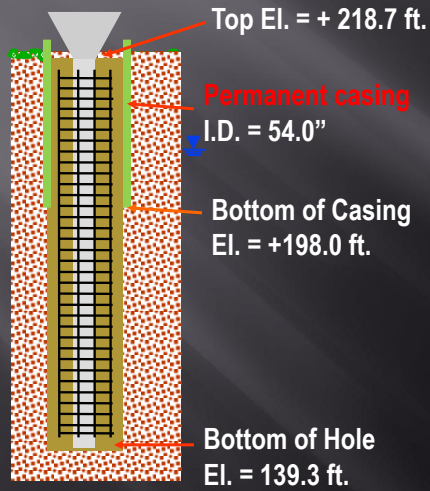
Plot the Concrete Volume Curves for the problem 1



CON - 44

44

CONCRETE VOLUMES PRACTICE PROBLEM #2 - 1



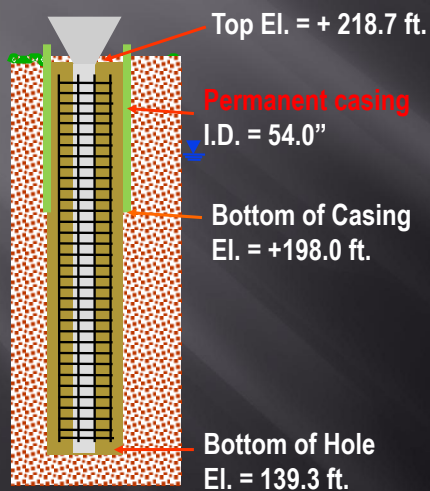
1. Calculate the theoretical volume of the hole

Total Volume = 46.8 cubic yards

CON - 45

45

CONCRETE VOLUMES PRACTICE PROBLEM #2 - 2



2. Concrete volume following each truck

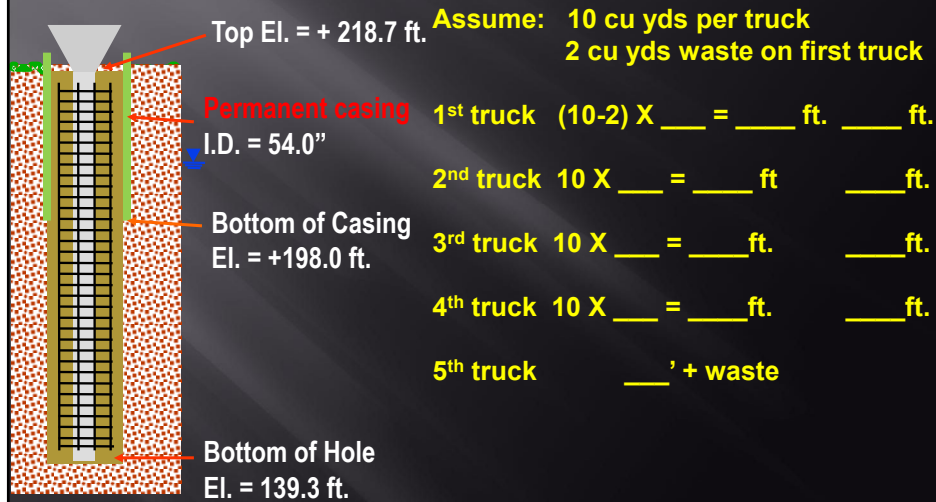
Calculate the rise of the top of concrete per cubic yard

=>1.7 feet "filled" per cubic yard

CON - 46

46

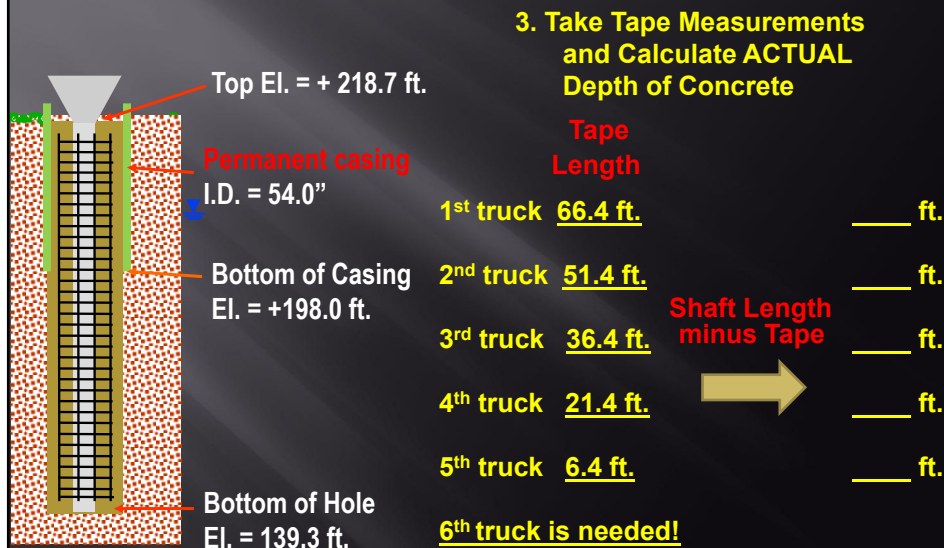
CONCRETE VOLUMES PRACTICE PROBLEM #2 - 3



CON - 47

47

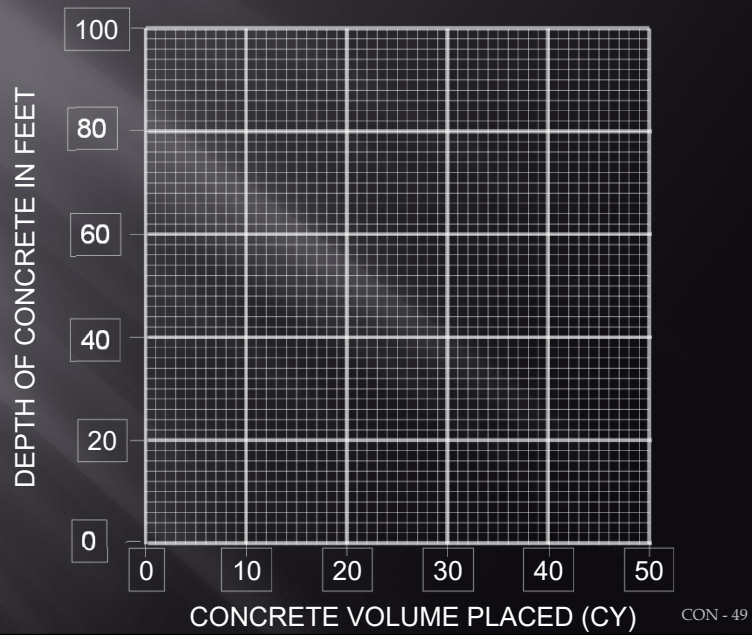
CONCRETE VOLUMES PRACTICE PROBLEM #2 - 4



CON - 48

48

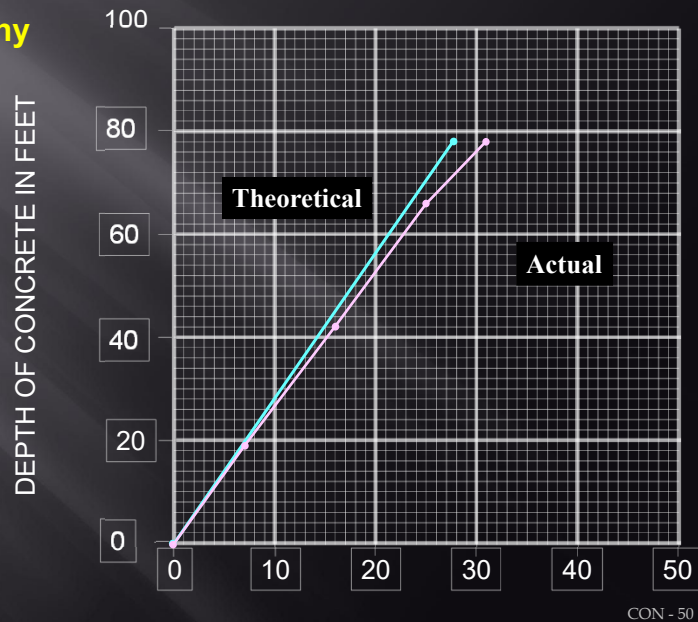
Plot the Concrete Volume Curves for the problem 2



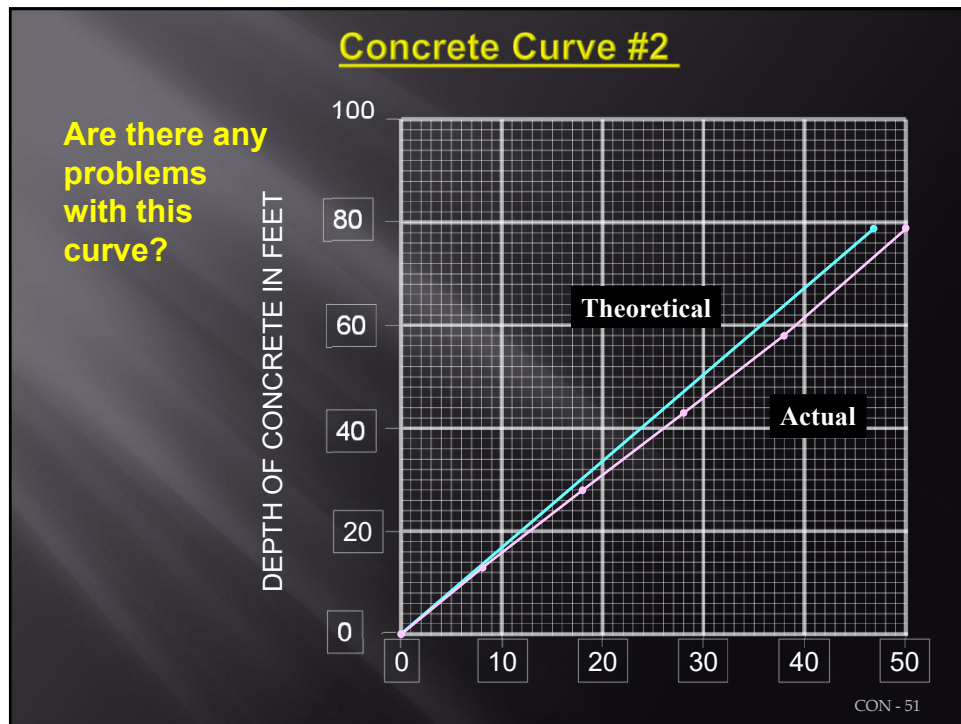
49

Concrete Curve #1

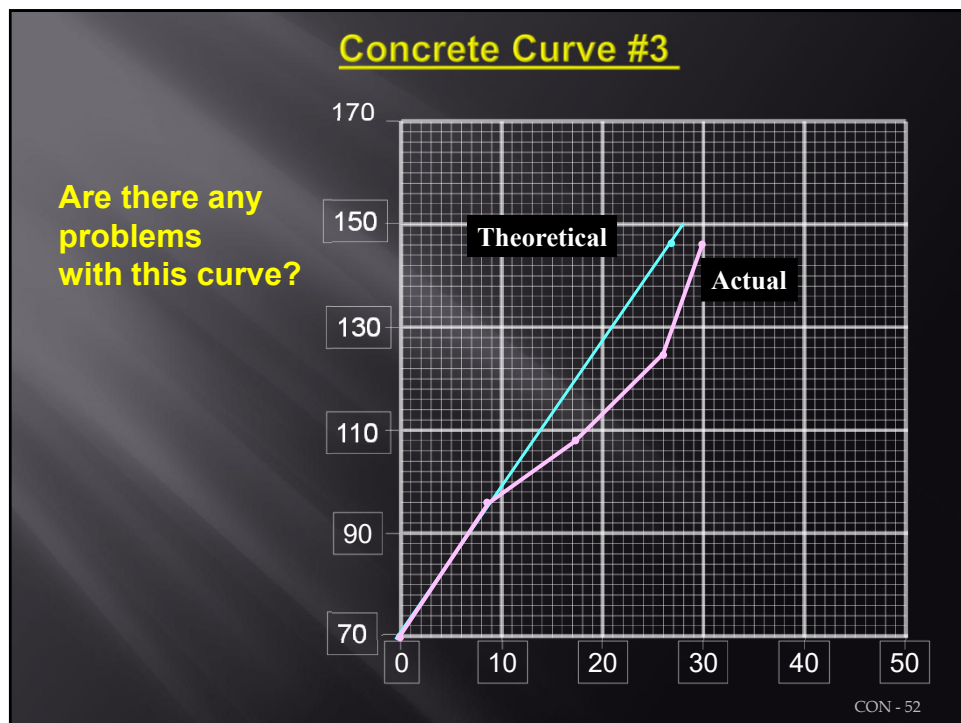
Are there any problems with this curve?



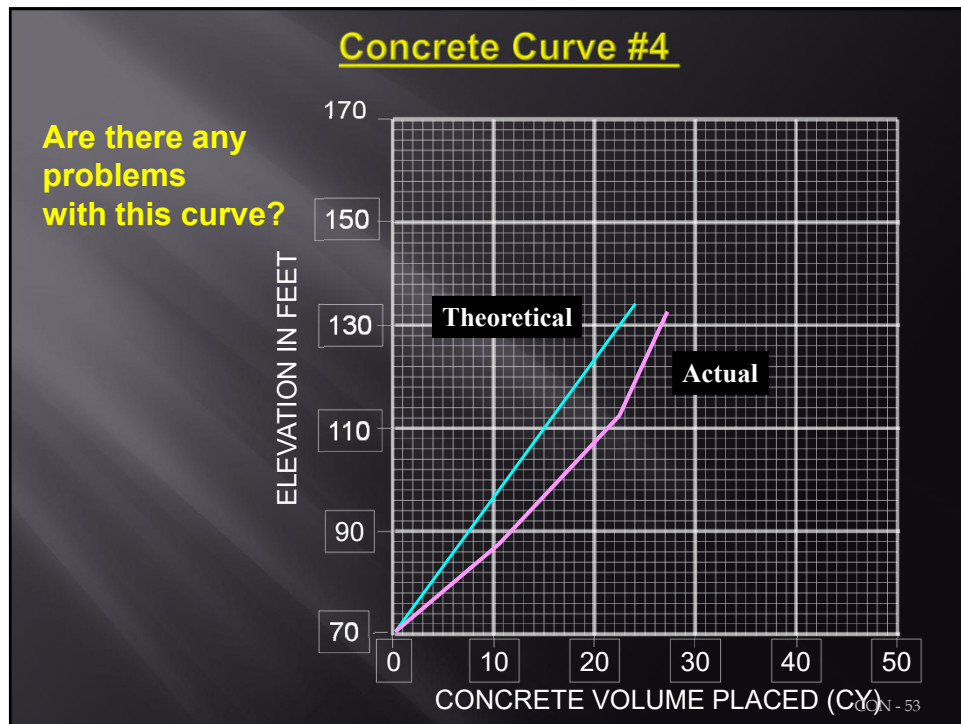
50



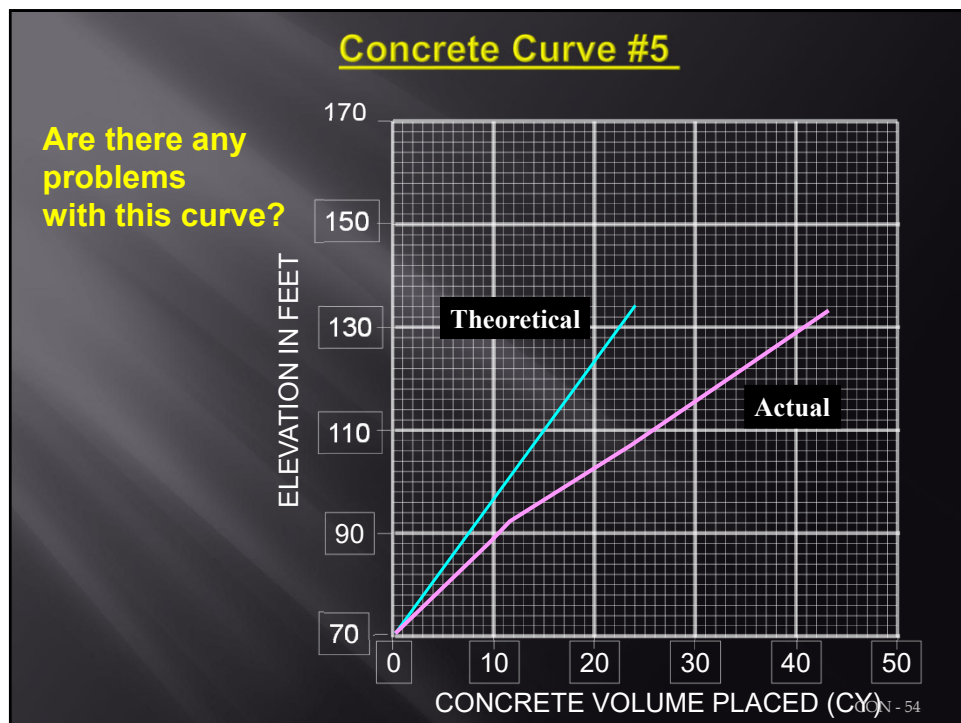
51



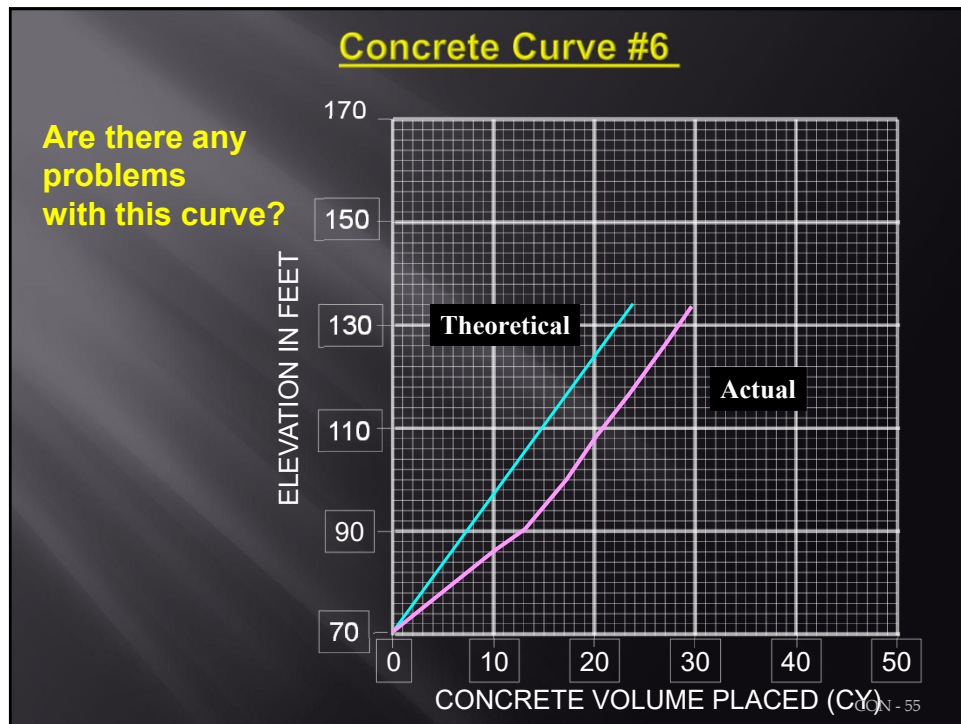
52



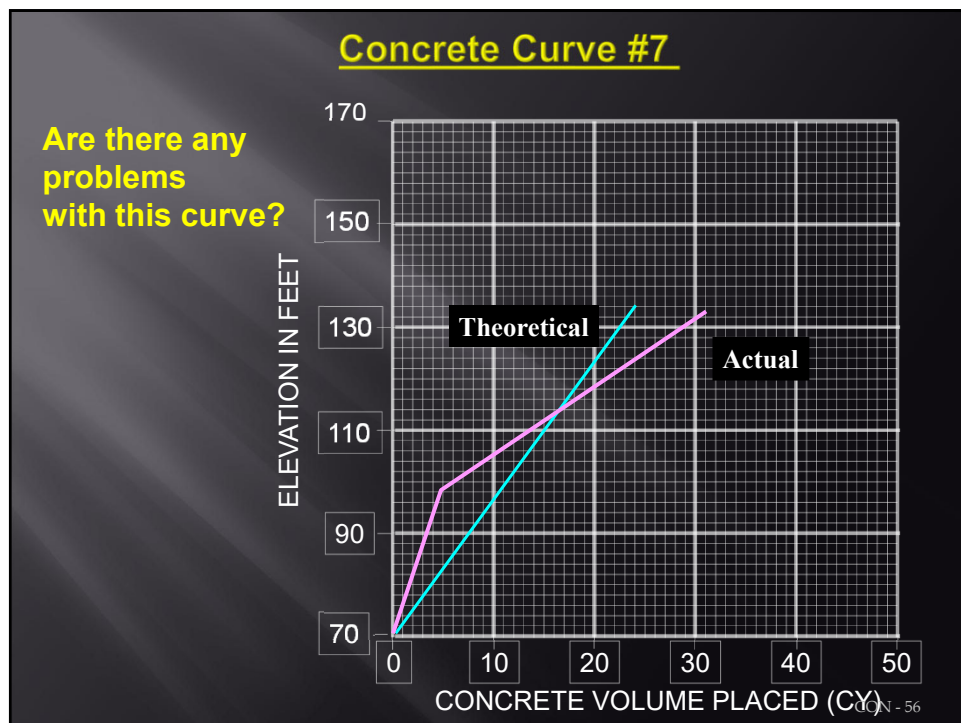
53



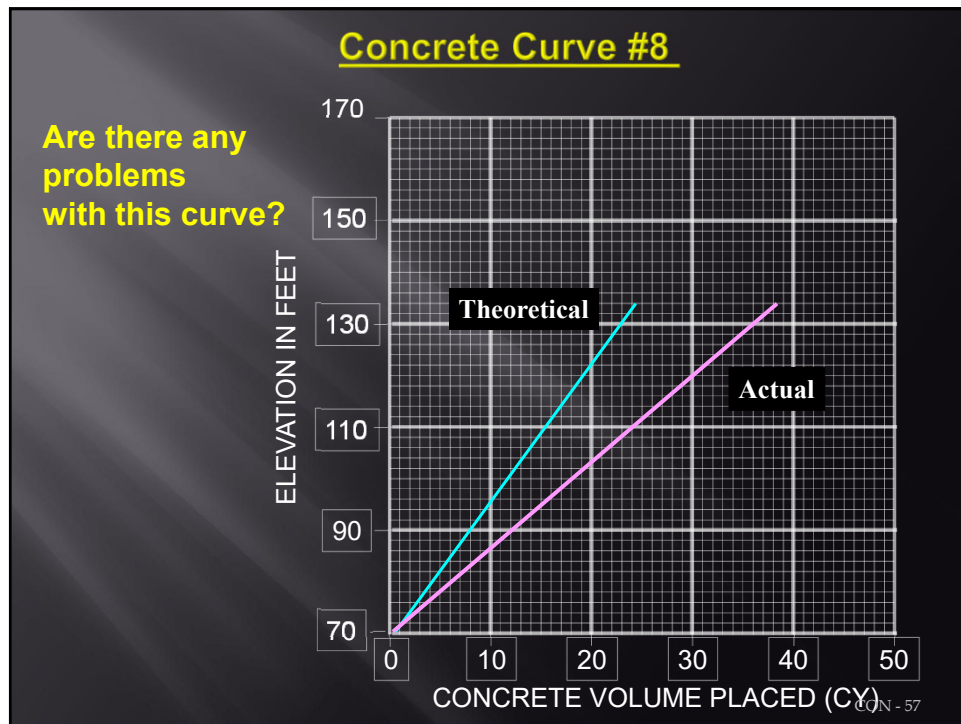
54



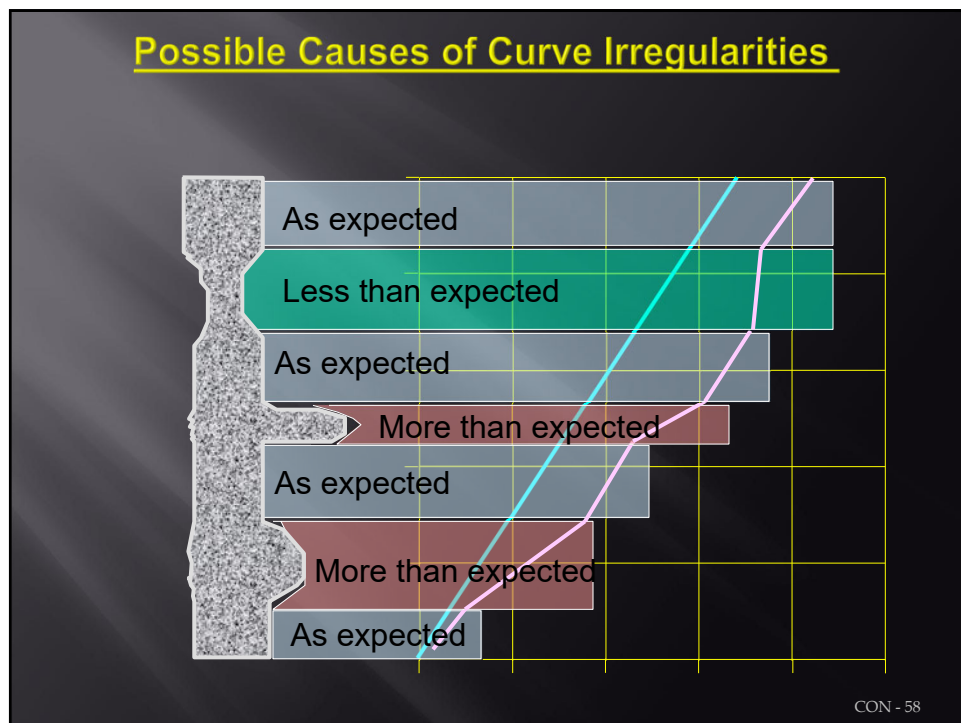
55



56



57



58

Questions?

Call

Seth Weber (o) (785) 291-3416

or

Kyle Halverson (o) (785) 291-3860

CON - 59

POST INSTALLATION & INTEGRITY TESTING

1-4-4
1

1

POST INSTALLATION TESTS

To determine if the shaft, as constructed, will carry the loads designed for.

LOAD TESTS



To evaluate the soundness or “integrity” of the constructed shaft.

INTEGRITY TESTS

1-7
2

2

INTEGRITY TESTS

- Cross-hole Acoustic (“CSL”)
- Thermal Integrity Profiling (TIP)
- Gamma-Gamma Logging
- Echo Sounding
- Coring
- Visual Observation

13-19
3

3

INTEGRITY TESTING

“Anomalies.” unusual patterns: voids or poorly consolidated concrete.

Anomalies are probably structural defects if they correlate to some potentially damaging occurrence during construction recorded by the Inspector.

14-20
4

4

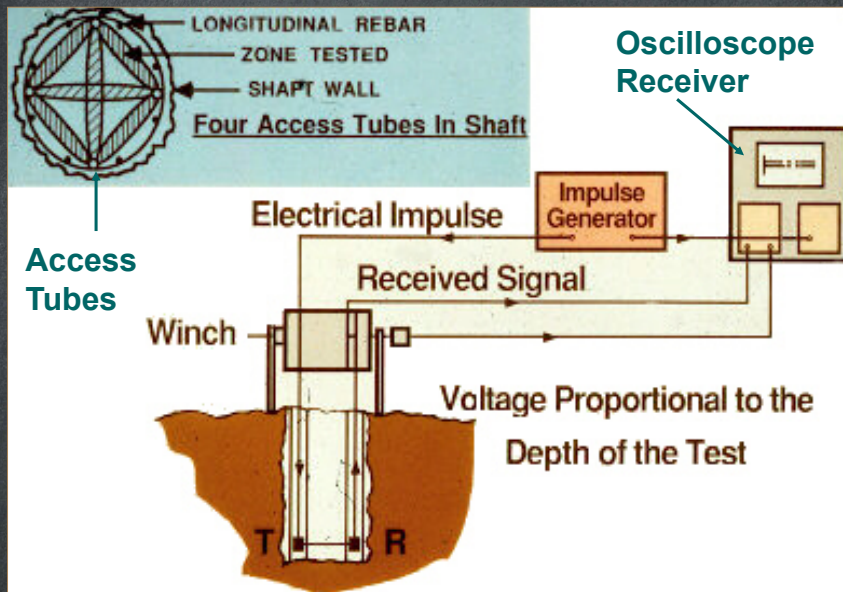
Cross-hole sonic logging (CSL)

- ◆ Several steel access tubes are placed regularly around the inside circumference of the cage. One per foot of shaft diameter is a good rule of thumb. Up to 8 but at least 4.
 - Place inside cage because “shots” can not be received through rebar
- ◆ “Shots” are made from a source that generates acoustic energy to an energy receiver in another tube at the same elevation. Both the time of travel from the source tube to the receiver tube and the amount of energy transferred between tubes are indicators of the presence of either sound concrete or defective concrete.
- ◆ In order to help maintain bond between the tubes and concrete and to couple the transmitter and receiver to the concrete, the tubes must be filled with water before the concrete is placed.

5

5

Cross-hole sonic logging



16-27

6

Source and Receiver Tools for CSL Test



14/30

7

CSL Receiver



8

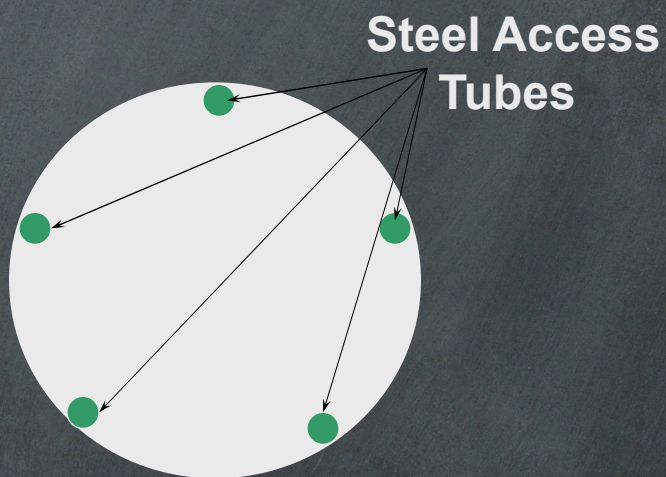
8

Pulley



9

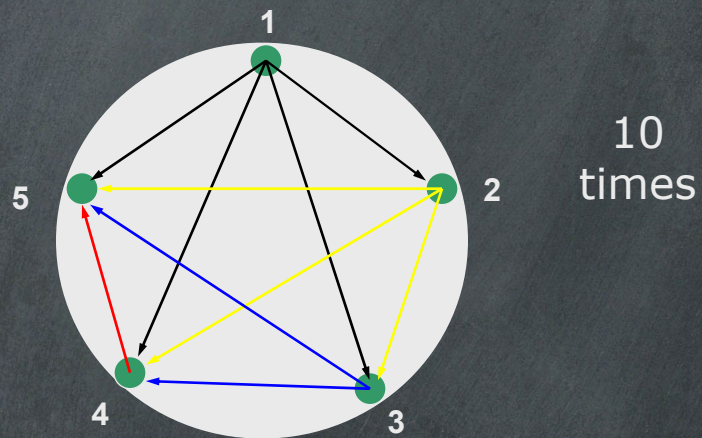
Sonic Logging



10

10

Sonic Logging Combinations



11

11

Sonic Logging-Inspectors

- ◆ What an inspector needs to look for when examining the tubes:
 - Check tubes for inside defects or obstructions
 - Make sure tubes are watertight
 - Check to see if watertight caps are on both ends of the tubes
 - Check for damaged or bent tubing
 - Lacquer on the tubes

12

12

Access Tubes for Down-Shift Tests



13

Sonic Logging Information

- ◆ When is test ran?
 - Between 2 and 21 days after shaft is completed.
- ◆ Who runs the test?
 - A consultant will run the first test, and provide a report indicating if any anomalies were found.
 - Currently, if anomalies are found a consultant will run more tests after defects have been resolved.

14

14

Sonic Logging Information Cont.

- ◆ What not to do:
 - Do not allow the contractor to fill CSL tubes until all tests and remediation procedures have been completed and shaft has been accepted.

15

15



16

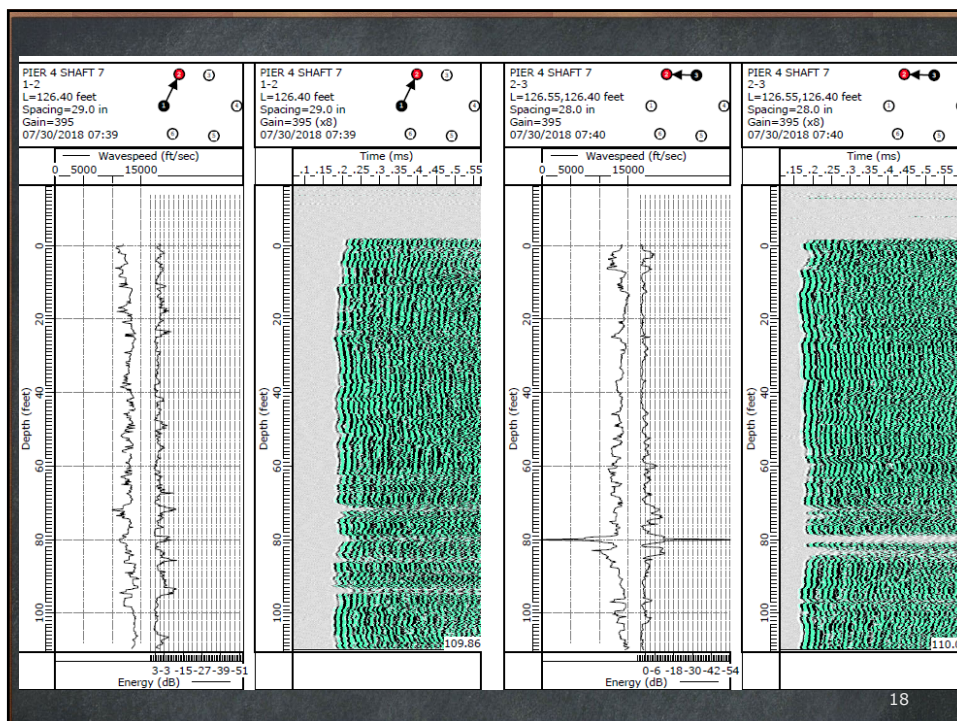
16

The velocity drop criteria are as follows

Percent velocity drop	Action taken
0-10%	Acceptable, review by geology
10% - 15%	Questionable, review by geology & design, may core
>15%	A core will be taken, remediation is possible, Review, Remediate and Retest

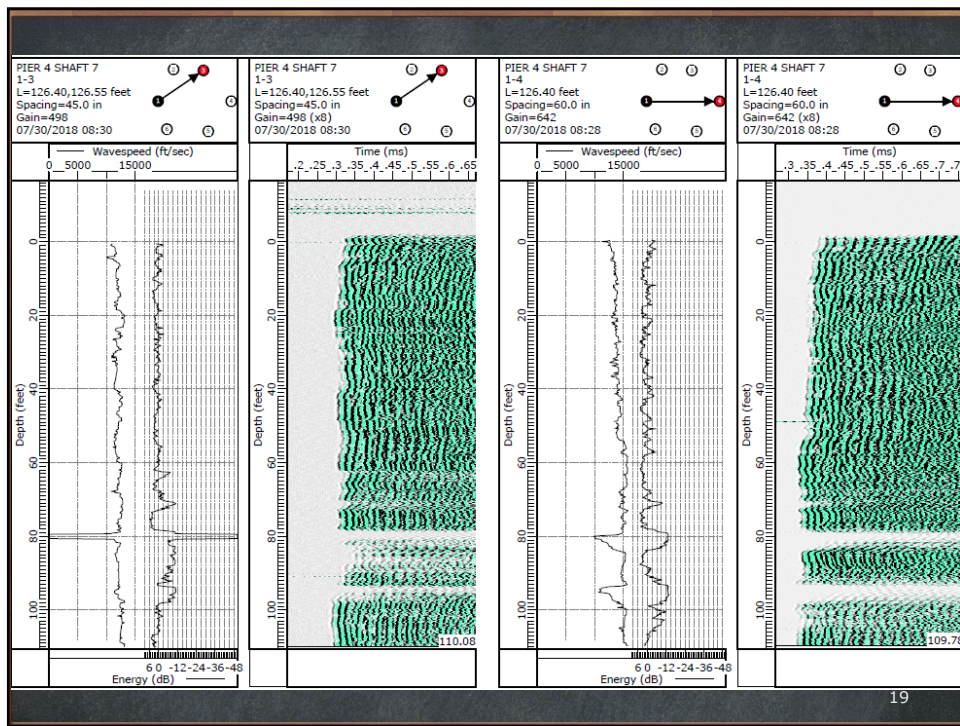
17

17

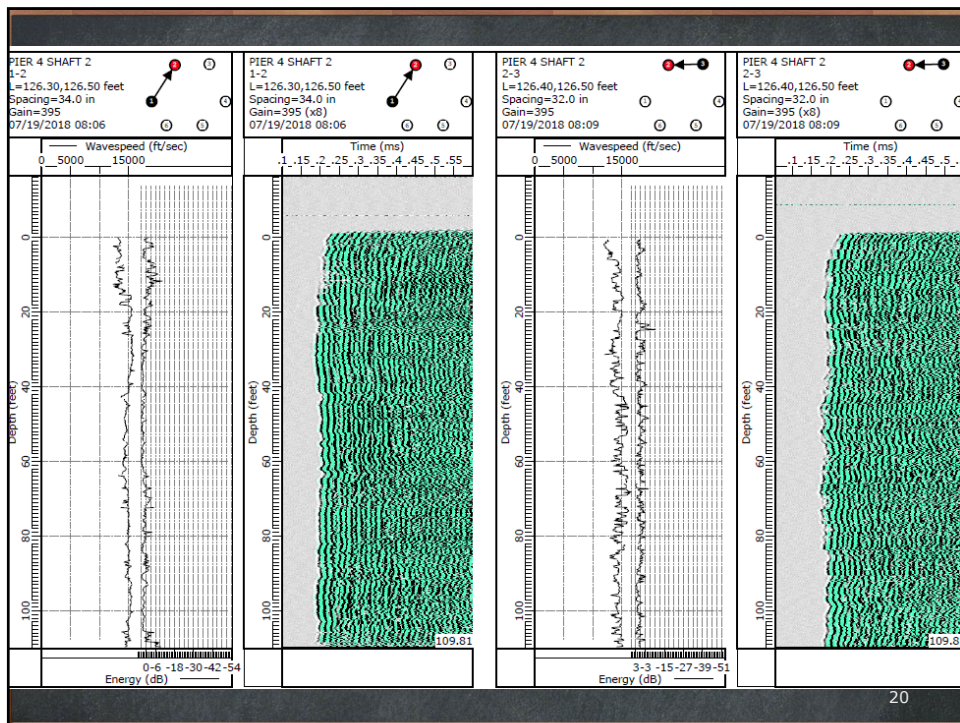


18

18



19



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Sonic Logging-Completed

- ◆ When all testing and remediation procedures have been completed and shaft has been accepted:
 - Fill core holes and CSL tubes by pressure grouting with approved materials (subsection 706.2 (b)).
 - Use a pipe extending to the bottom of the hole to fill it from the bottom to the top.

21

21

Sonic Logging-FAQ

- ◆ If you have any questions:
 - **See subsection 706.3 (j) of KDOT standard specs**
 - **Call the Chief Geologist. All CSL results are sent through my office for recommendations!!**

22

22

Gamma Gamma Logging

- ◆ Non-destructive test method.
- ◆ Uses radioactive gamma rays to detect anomalies in the concrete. It is the same principle as a Nuclear Soil Density meter. The higher the density the fewer radioactive particles make it back to the receiver
- ◆ The maximum penetration is within 3 inches of each tube.

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23

Gamma Gamma Logging Cont.

- ◆ The testing procedure utilizes an electric winch to pull a 4-foot probe with the radioactive source at the end, up through PVC pipes installed in the concrete. As the probe moves up through the tubes, it reads average concrete densities at set intervals. These intervals then be later plotted and analyzed.

24

24



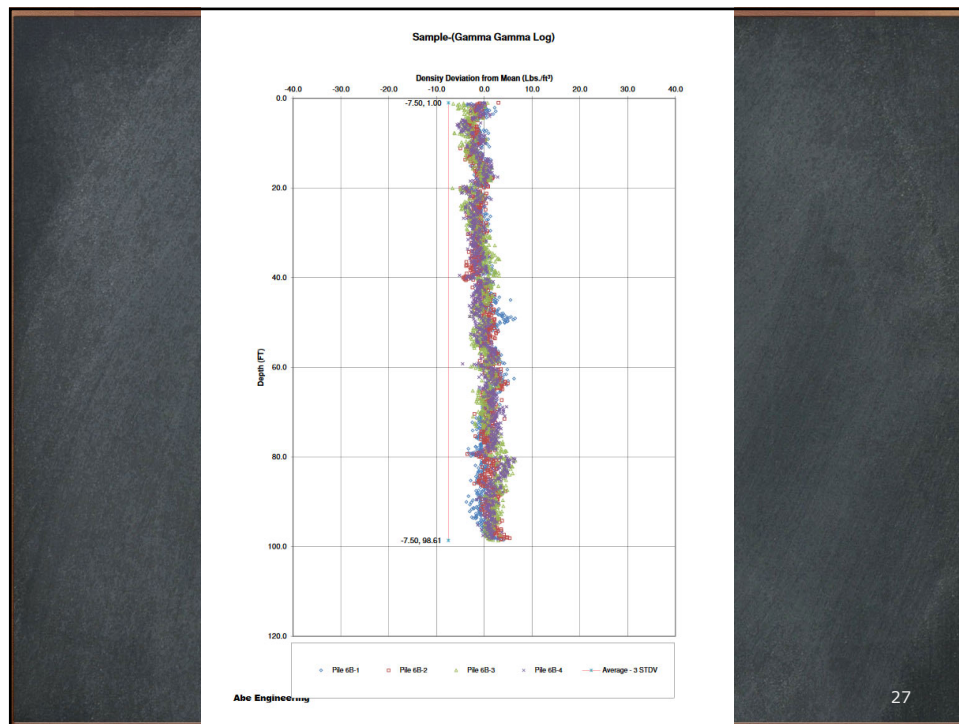
25

Gamma-Gamma Results

- ◆ Results are very similar to CSL in that the data is processed then printed out for each tube tested.

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27

Echo Sounding/Pile Integrity Test (PIT)

- ◆ Seismic investigation on a micro-scale.
- ◆ Used for shafts but also used for structural concrete testing such as walls etc.
- ◆ Hit the concrete with a the instrumented hammer and record the wave returns with the geophones.

28

28

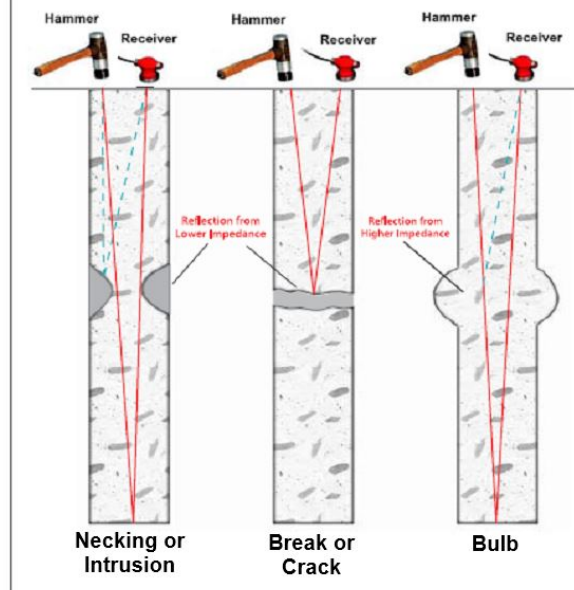
Echo Sounding Equipment



29

29

Sonic Echo Tests



30

30

Thermal Integrity Profiling (TIP)

- ◆ Evaluation of the entire cross-section and the entire length of the deep foundation element measuring heat generated by curing cement to assess the quality of drilled shafts/bored piles, augered cast in place (ACIP)/continuous flight auger (CFA) or drilled displacement piles, slurry walls, barrettes, soil nails, and jet grouted columns.
- ◆ Evaluates concrete quality inside and outside the reinforcing cage
- ◆ Accelerates construction with tests conducted during concrete curing
- ◆ Reveals necking or inclusions, bulges, variations in concrete cover, shape of shaft and cage alignment
- ◆ Thermal Wire® Cables can replace access tubes

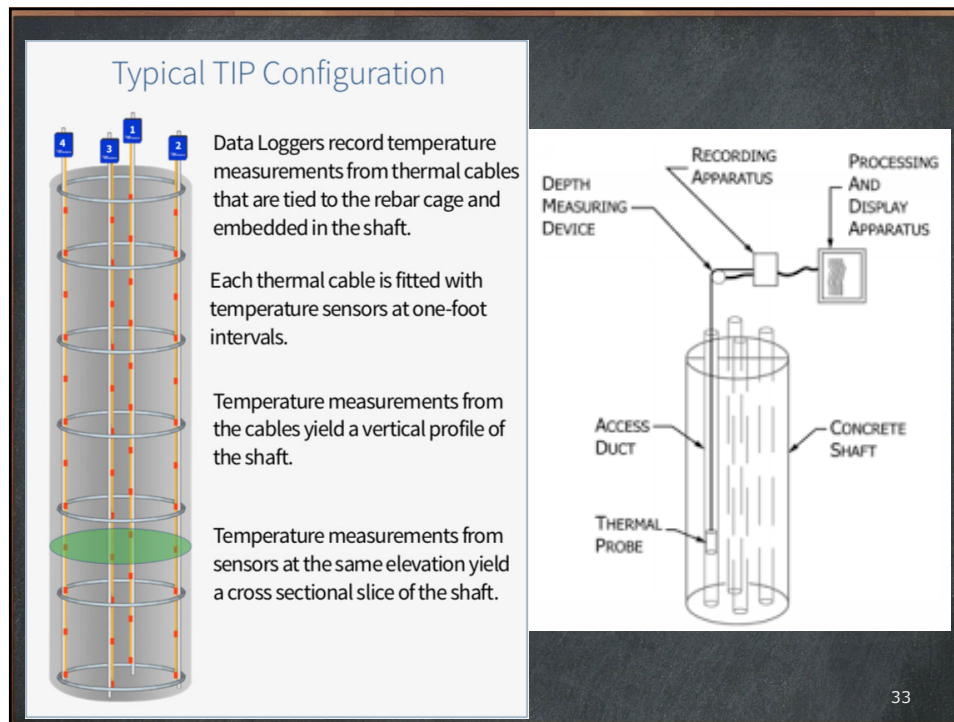
31

31

Thermal Integrity Profiling (TIP) Equipment



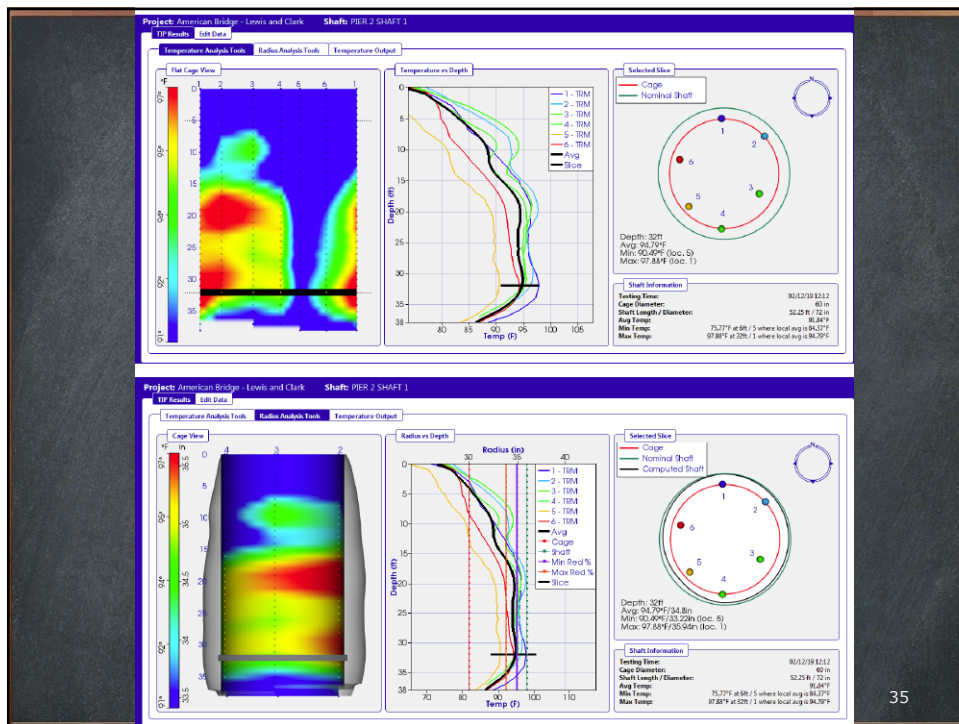
32



33

KANSAS DEPARTMENT OF TRANSPORTATION SPECIAL PROVISION TO THE STANDARD SPECIFICATIONS, EDITION 2015	
THERMAL INTEGRITY PROFILING (TIP) OF DRILLED SHAFT	
1.0 DESCRIPTION Perform the nondestructive testing (NDT) method termed Thermal Integrity Profiling (TIP) by obtaining records of the heat generated by curing cement (hydration energy) to assess the quality of drilled shafts. TIP measurements that are colder than normal indicate necks, inclusions, or poor quality concrete, while warmer than normal measurements are indicative of bulges. Variations of temperature between the tubes reveal cage eccentricity. Provide all materials, equipment, and labor necessary to conduct TIP testing on production drilled shafts. The TIP testing will meet the requirements of ASTM D 7949, except as noted below.	
<u>BID ITEM</u> Thermal Integrity Profiling	<u>UNITS</u> Each
2.0 EQUIPMENT Supply all materials and equipment required to perform TIP tests. Equipment to perform the test shall have the following minimum requirements: Probe or wire option. A computer based TIP data acquisition system for: (a) display of signals during data acquisition (probe option only); or (b) to monitor temperature versus time after casting (wire option only). Probe option only. • A thermal probe with 4 infrared sensors equally spaced at 90° around the perimeter that read temperature of the tube wall to within 1°F accuracy; • The probes shall be less than 1.25 inches in diameter and shall freely descend through the full depth of properly installed access tubes in the drilled shafts; • One depth encoder sensor to determine probe depths; and • Ability to collect data at user specified depth increment.	

34



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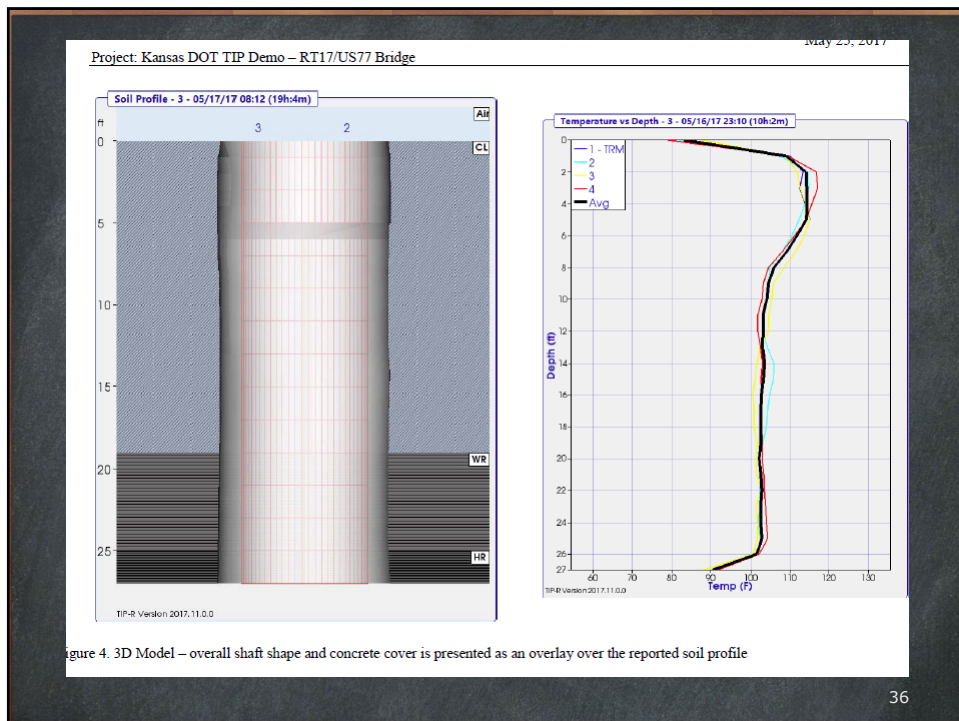


Figure 4. 3D Model - overall shaft shape and concrete cover is presented as an overlay over the reported soil profile

36

Coring

Core Barrel
Bit



37 25

37

Coring Is Not Always
Definitive in Ruling
Out Defects —
Defects Can Be
Missed by the Coring
Tool

KDOT uses coring after
a CSL test has been ran
and defects have been
found.

Not Good



Acceptable



38 26

38

Bad Cores



39

39

Bad Cores-Gravel



40

40

Remediation

- ◆ If a void within the shaft is found
 - Voids might be able to be cleaned out and filled with either
 - ◆ Epoxy- for smaller voids
 - ◆ Grout- for larger voids

41

41

Backfill

- ◆ When temporary and a permanent casing are used, backfill the annular space (between casings) with material specified in the contract documents:
 - Granular material fine enough to fill the entire volume or
 - Grout or flowable fill described in **subsection 706.2 (b) Grout/Flowable Fill**
 - If the plans don't specify a material, use the granular material.

42

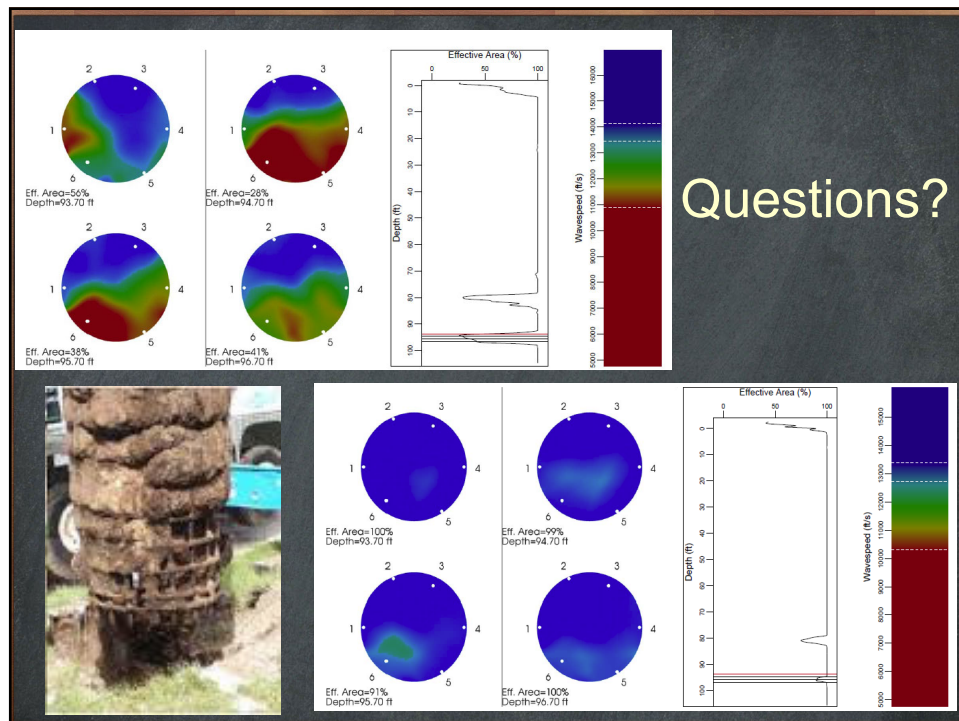
42

Backfill

- ◆ Before completely raising temporary casing, fill the annular space with grout/flowable fill to the top of the casing:
 - If the annular space contains water, use a pump with an extension pipe or tremie (extending to the bottom of the annular space) to fill the annular space.
 - If the annular space is dry, the grout/flowable fill can free fall to the bottom of the shaft.
 - After temporary casing has been removed, filled the rest of the annular space with granular material.

43

43



44

Drilled Shaft Inspection Measurement and Payment



1

Measurement and Payment

- 2015 Standard Specifications Division 700 Special Provision 15-07015 and Special Provision 15-07007
 - Bid Items section 703
 - Drilled Shaft (*) (**) Linear Foot
 - Permanent Casing (*) Set Price Linear Foot
 - Sonic Test (Drilled Shaft)(Set Price) Each
 - Core Hole (Investigative) Linear Foot
- *Size
**Cased (If Contract Documents specify cased method)

2

Measurement and Payment 1

- Bid Items Special Provision 15-07007 Drilled Shaft Special
 - Drilled Shaft (*) (Special) Linear Foot
 - * Size



3

Measurement and Payment 2

- Core Hole (Investigative)
 - These cores are taken at locations shown on the construction layout sheet
 - Nominal 2.125 inch core barrel
 - Contractor must maintain, protect and label the sample and provide core cardboard boxes for storage
 - Investigative core hole determines shaft tip elevation



4

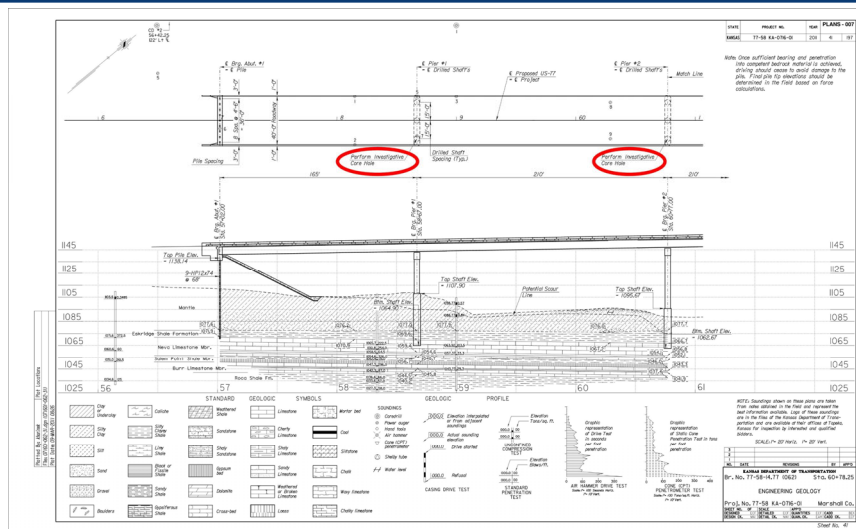
Measurement and Payment 3

- Core Hole (Investigative)
 - Measured from existing ground surface elevation to 6 feet below drilled shaft tip elevation
 - Measure by the linear foot
 - Pay to the nearest 0.1 linear foot



5

Measurement and Payment 4



6

Measurement and Payment 5

- Drilled shaft (*) (**)

Drilled Shaft
(** in)
Cased
Lin. Ft.

Drilled Shaft
(** in)
Lin. Ft.

Permanent
Casing
(** in)
Lin. Ft.



7

Measurement and Payment 6

- Payment for Drilled Shaft (*) (**) includes:
 - Excavation
 - Casing if required (outlined in contract documents)
 - Reinforcing steel
 - Concrete
 - All materials and labor required



8

Measurement and Payment 7

- Completed Shaft – Measured from the bottom of the rock socket to the top of the completed drilled shaft (not existing ground elevation)
 - Measured by the linear foot
 - Pay to the 0.1 of a foot
- The Engineer will not consider a request to increase the bid prices unless the length of the drilled shaft changes by more than 20%



9

Measurement and Payment 8

- Permanent Casing (*) (Set Price)
 - Paid for when required but not specified in the contract documents
- Do not pay for the casing if:
 - Contract documents require a permanent casing
 - Contractor uses the casing for their convenience
 - Casing is a temporary casing



10

Measurement and Payment 9

- Permanent Casing (*) (Set Price)
 - Measured by the linear foot
 - Top of the shaft elevation to bottom of casing
 - Pay to the nearest 0.1 linear foot



11

Measurement and Payment 10

- Sonic Test (Drilled Shaft) (Set Price)
 - Paid for when required by contract documents
 - Test are required for all wet pours
 - Test required on dry pours required when directed by Engineer
 - Test to be completed between 2 and 21 days after shaft is complete



12

Measurement and Payment 11

- Sonic Test (Drilled Shaft) (Set Price)
 - When sonic test are required by contract documents (wet pours)
 - If test shows concrete is defective the test will be measured for payment
 - After the corrections have been made, the shaft will need to be retested, this test will not be measured for payment



13

Measurement and Payment 12

- Sonic Test (Drilled Shaft) (Set Price)
 - Test required by engineer (Dry pours)
 - When not shown on contract documents and sonic test indicate concrete acceptable, the test will be measured for payment
 - When not shown on the contract documents and sonic test indicate concrete is defective, test will not be measured for payment
 - When not shown on the contract documents and sonic test indicate concrete is defective and investigative cores reveal concrete is defective test will not be measured for payment



14

Measurement and Payment 13

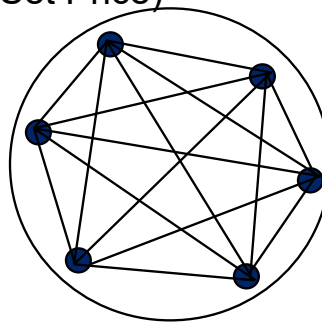
- Sonic Test (Drilled Shaft) (Set Price)
 - Test required by engineer
 - When not shown on the contract documents and sonic test indicate concrete is defective and investigative cores reveal sound concrete test will be measured for payment



15

Measurement and Payment 14

- Sonic Test (Drilled Shaft) (Set Price)



4 tubes
6 tubes
8 tubes

6 combinations
15 combinations
28 combinations

one test
one test
one test



16

Measurement and Payment 15

- Payment for Drilled shafts (*) (**), Permanent casing (*) set price, Sonic Test (Drilled Shaft) (Set Price), and Core hole (Investigative) is made at the Contract unit prices
- Sonic Test (Drilled Shaft) (Set Price) and Permanent Casing (*) are paid for at the Contract set price and is full compensation for the specified work



17

Measurement and Payment 16

- Items paid by adding lines to the contract (Extra work)
 - Extending the length of the shaft by more than 20%
 - Extra reinforcing steel due to lengthening a shaft
 - Post installation coring directed by the engineer



18

Measurement and Payment 17

- Items paid by adding lines to the contract
 - If the Engineer lengthens the drilled shaft during construction, the Engineer will measure and pay for additional reinforcing steel according to the requirements of Section 104.6.
 - Section 104.6 is the section of the specifications covering extra work.



19

Contact Information

- Mervin Lare
- Mervin.Lare@ks.gov
- Cell 785-250-4793



20

Drilled Shaft Inspection Safety



1

Safety

- Safety equipment
- Situational awareness



2

Safety Equipment

- Safety vest
- Hardhat
- Boots
- Hearing protection
- Eye protection
- Lanyards



3

Safety 1

Looks like something is missing from that reinforcing cage?

You think?



4

Safety 2



Example of ANSI Class III Vest



5

Safety 3

-
- Situational awareness
 - Knowing what's going on around you



6

Safety 4



7

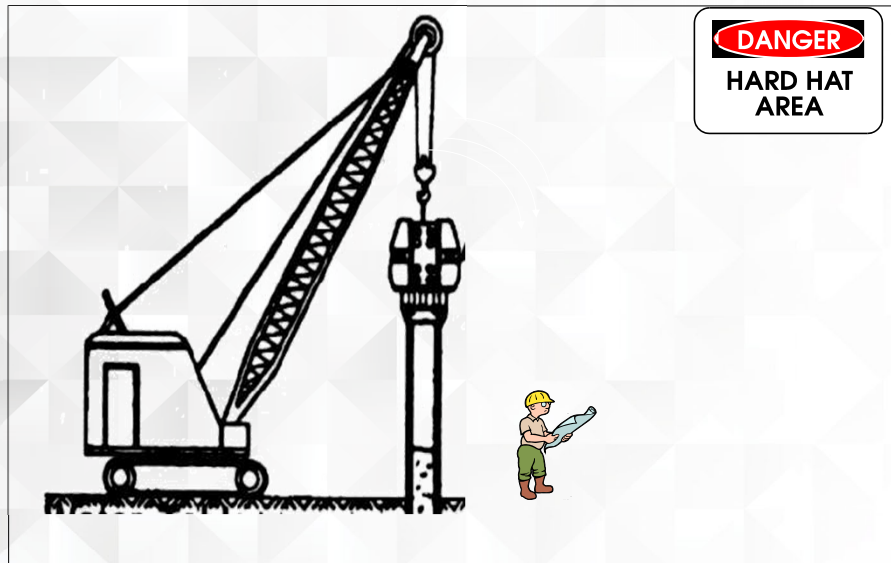
Safety 5



Remember, even a temporary loss of focus can be dangerous

8

Safety 6



9

Safety 7

-
- ALWAYS BE AWARE OF SURROUNDINGS!!!
 - Unprotected Holes

10

Safety 8



11

Safety 9



12

Safety 10

- ALWAYS BE AWARE OF SURROUNDINGS!!!
 - Unprotected Holes
 - Caving Holes



13

Safety 11



Caving/non-cohesive material



14

Safety 12

- ALWAYS BE AWARE OF SURROUNDINGS!!!
 - Unprotected holes
 - Caving holes
 - Overhead equipment



15

Safety 13

Watch for Falling Objects



16

Safety 14



17

Safety 15



Crane Fire



18

Safety 16

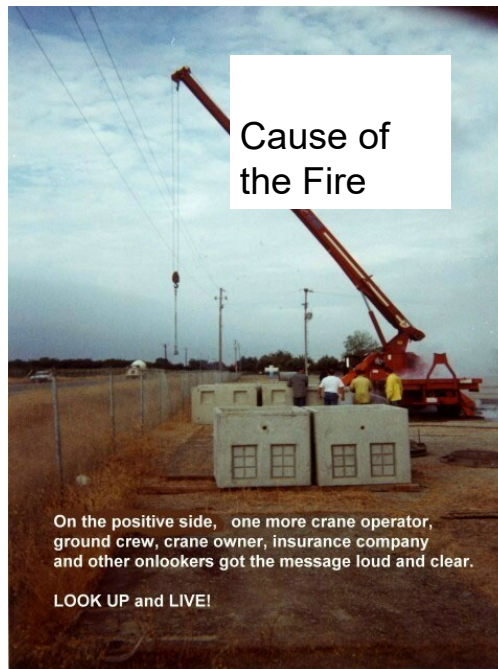


Another
Shot of
the Fire



19

Safety 17



Cause of
the Fire

On the positive side, one more crane operator,
ground crew, crane owner, insurance company
and other onlookers got the message loud and clear.

LOOK UP and LIVE!



20

Safety 18



21

Safety 19



22



23



24

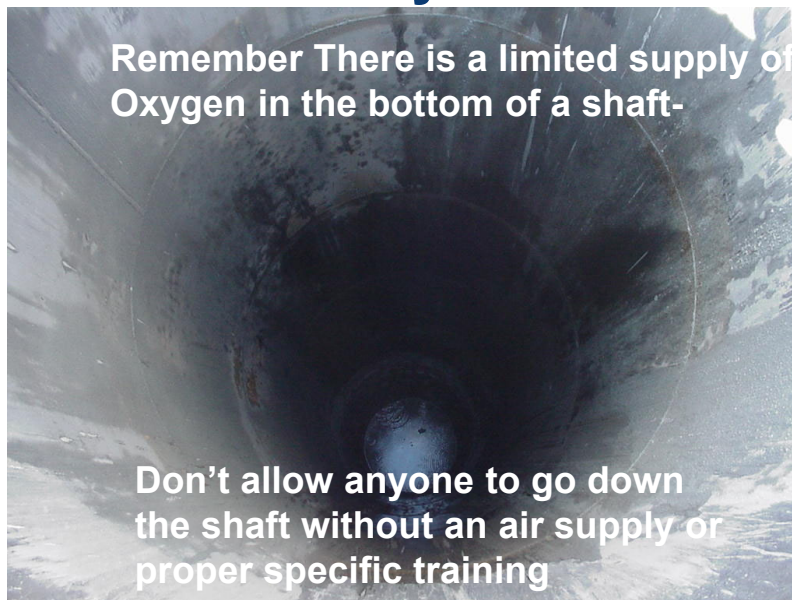
Safety 23

- ALWAYS BE AWARE OF SURROUNDINGS!!!
 - Unprotected holes
 - Caving holes
 - Overhead equipment
 - Rotating equipment



25

Safety 24



26



27



28



Questions?

- Mervin Lare
- Phone 785-250-4793
- Email mervin.lare@ks.gov

PRE-CON & INSTALLATION PLAN

Seth Weber
Engineering Associate – Bridge Design

1

Pre Construction - Drilled shaft meeting - 1

- Request for the Bridge Construction Engineer and Geologist be present
- Request for all subs to be present: Driller, Pumper, Concrete Supplier
- Discuss the Plan in detail

Excavation methods
Rock socket cleaning methods
Placement methods

2

Pre Construction - Drilled shaft meeting - 2

- Request for the Bridge Construction Engineer and Geologist be present
- Request for all subs to be present: Driller, Pumper, Concrete Supplier
- Discuss the Plan in detail
 - Discuss possible problems
 - Discuss how to address these problems if they develop during the operation
 - See the “13 Questions to ask before drilling begins”

3

Thirteen questions to ask prior to a wet pour - 1

1. How is the Contractor going ensure the bottom of the hole is clean?
2. Is the Contractor going to let the water level in the shaft reach its normal static elevation or pump the shaft full of water?
3. How is the Contractor going to place the concrete, pump it through an extension tube or place through a tremie?
4. Is the tremie/extension tube watertight?

4

Thirteen questions to ask prior to a wet pour - 2

5. How will the tremie/extension tube be sealed (separate the ground water and concrete), a "pig" or flap gate on the tremie?
6. What material is being used for the pig?
7. Where is the pig going to be placed in the tremie/extension tube or pump?

5

Thirteen questions to ask prior to a wet pour - 3

8. How is the Contractor going to fully charge the pump tubes or tremie before any concrete is discharged into the shaft?
9. How is the Contractor going to ensure the initial seal (discharge end in fresh concrete) is achieved?
10. How are you going to ensure the discharge end of the tremie/extension tube is sufficiently embedded in the fresh concrete?

6

Thirteen questions to ask prior to a wet pour - 4

11. Is the tremie/extension tube marked in one foot increments?
12. When and how much are you going to lift the tremie/extension tube?
13. How is the Contractor going to over pump the shaft to displace the questionable (i.e. poor quality or frothy) concrete that has risen to the top of the shaft?

7

Questions?

Call

Seth Weber (o) (785) 291-3416

or

Kyle Halverson (o) (785) 291-3860

8



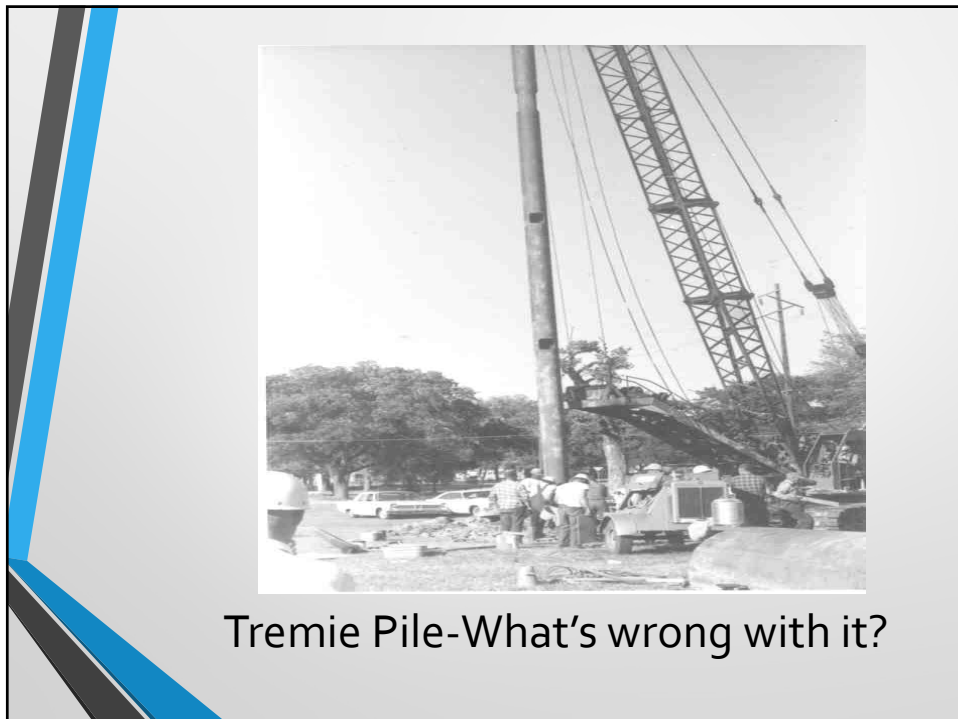
1



2



3



4



5



6

Bad Shafts-Sinking Concrete?



7

More of the same!



8



9



10



11



12

Name two things wrong with this shaft.



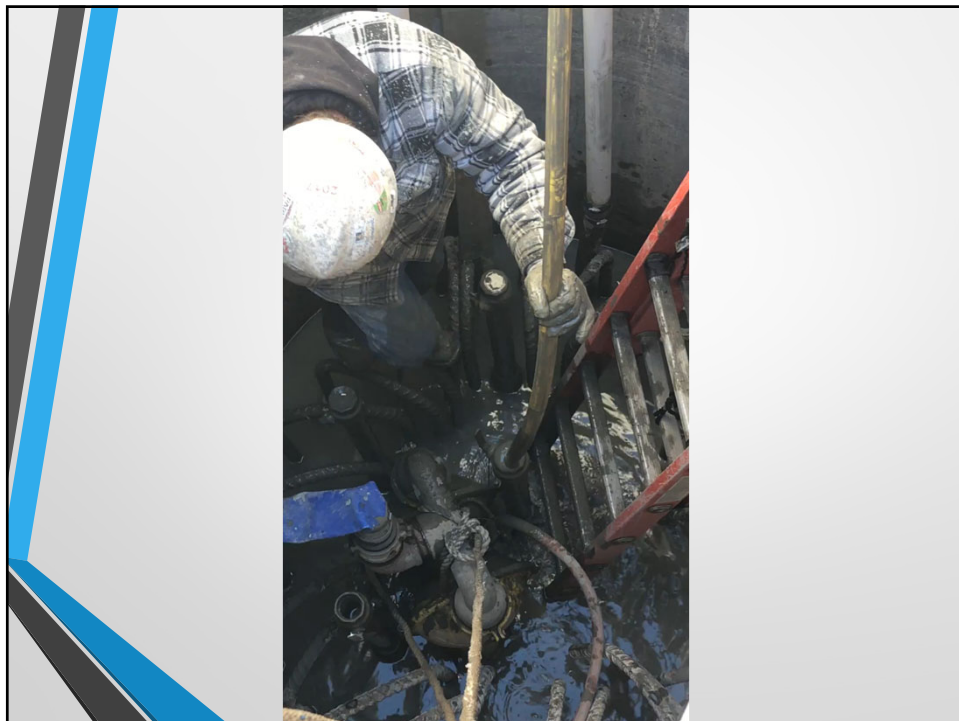
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14



15



16



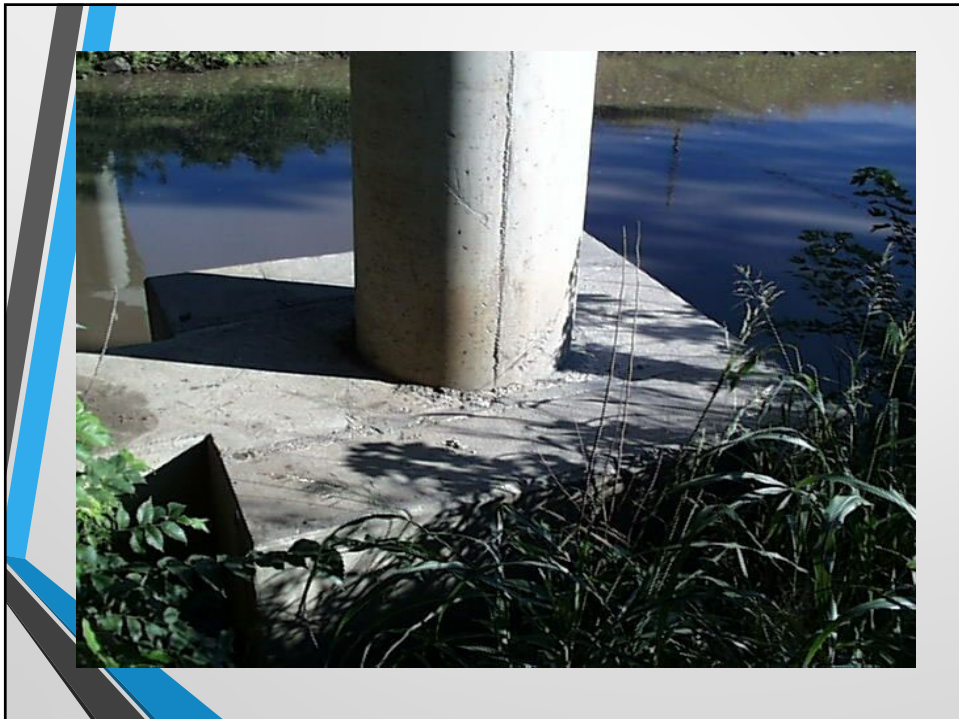
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18



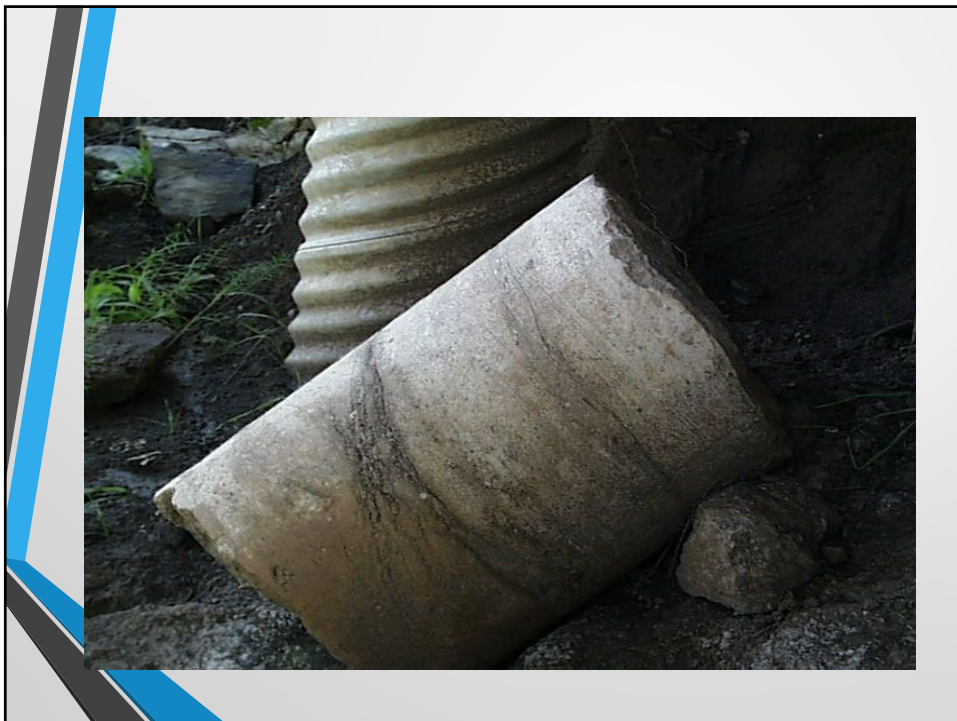
19



20



21



22

TYPICAL PROBLEMS



11-65

23



24



Atchison River Cofferdam Drop

25

Cofferd Dam issues



26

High water
and debris



27

Seal Coarse and 1 Bad Shaft!



28

Lots of water
when 60 feet
below the river!



29

Looking Up!



30

What the finished base is like.



31

Very large defect found
by Sonic Echo test.
Probably due to dirty hole.

No concrete



11-67

32

Any Questions?



703 - DRILLED SHAFTS

SECTION 703

DRILLED SHAFTS

703.1 DESCRIPTION

Construct drilled shafts by the cased or uncased method depending upon site conditions and Contract Document requirements.

BID ITEMS

Drilled Shaft (*) (**)
Permanent Casing (*) (Set Price)
Sonic Test (Drilled Shaft) (Set Price)
Core Hole (Investigative)

*Size

**Cased (If Contract Documents specify the cased method.)

UNITS

Linear Foot
Linear Foot
Each
Linear Foot

703.2 MATERIALS

a. Concrete. Unless otherwise shown in the Contract Documents, provide Grade 4.0 concrete that complies with **SECTIONS 401, 402 and 1102**. Provide a mix design with a target slump of 9 inches $\pm$ 1 inch. Do not withhold mix water at the plant and do not add water at the site.

b. Grout/Flowable Fill. For backfilling the cross-hole sonic testing pipes and core holes, provide cementitious grout (mixed according to the manufacturer's directions) that complies with **DIVISION 1700**.

Provide grout or flowable fill for backfilling the void space between the temporary and permanent casing with:

- 28 day strength of 1000 psi;
- mortar sand, FA-M (**SECTION 1102**) mixed with 2 bags of Type II portland cement per cubic yard; and
- water-to-cement ratio less than 1.

c. Granular Backfill Material. Provide granular backfill material for backfilling the void space between the temporary and permanent casing that is fine enough to fill the entire volume. The Engineer will accept the granular material based on a visual inspection.

d. Reinforcing Steel. Provide steel bars for concrete reinforcement that comply with **DIVISION 1600**.

e. Casing. Provide casing of sufficient thickness to carry the working stresses and loads imposed on the casing during construction. At a minimum, use 14-gage corrugated metal pipe (CMP) for the permanent casing.

If required, provide a permanent casing that is less than or equal to 1 inch out-of-round. The deviation of a chord from end to end shall be a maximum of 2 inches.

The Engineer will accept the casing based on compliance with the specified requirements, and visual inspection for condition.

f. Pipe for Sonic Testing. Provide pipe that complies with **DIVISION 1900**.

703.3 CONSTRUCTION REQUIREMENTS

a. General. Drilled shaft lengths shown in the Contract Documents are an estimate from the top of formation elevations determined from borings. Actual formation elevations encountered at each shaft, may require the actual length of each drilled shaft be adjusted. If the Engineer changes the drilled shaft lengths, the Contractor will be advised (in writing) of the revised bottom of rock socket elevation.

A minimum of 28 days before constructing the drilled shafts, submit an installation plan to the Engineer for review. Include the following:

- Name and experience record of the drilled shaft superintendent in charge of drilled shaft operations;

703 - DRILLED SHAFTS

- List of proposed equipment, such as cranes, drills, augers, bailing buckets, final cleaning equipment, de-sanding equipment, slurry pumps, core-sampling equipment, tremies or concrete pumps and casing; and
- Details of concrete placement, including proposed operational procedures for tremie and pumping methods and method of achieving a sealed tremie or pump.

b. Investigative Core Hole. Provide NX sized (2.125 inches) core samples organized in descending elevation and stored in standard core cardboard boxes. Perform this work, from the existing ground surface elevation, 15 working days in advance of the drilled shaft construction, at locations shown in the Contract Documents or ordered by the Engineer. Extract and maintain a core of the foundation material from 4 feet above the top of the plan tip elevation to 6 feet below the plan tip elevation shown in the Contract Documents. Discard all material extracted above 4 feet above the top of the plan tip elevation. Maintain, protect and label (elevation and location) these samples for review by the KDOT. While drilling, prepare a continuous standard drilling/coring log. The logs shall remain with the sample for review. Survey the location of the core hole with the same construction tolerance as **subsection 703.3c**.

c. Excavating the Drilled Shaft. Prior to constructing drilled shafts, complete the excavation for the entire element.

Locate the top of the shaft within 2 inches of the location shown in the Contract Documents. Unless otherwise shown in the Contract Documents, bore all shafts plumb to within a tolerance of 1 inch per 10 feet of length of shaft, not to exceed 6 inches over the full length of the shaft. The bottom of the shaft shall be nearly flat. The cutting edges of excavation equipment shall be normal to the vertical axis of the equipment within a tolerance of $\pm\frac{3}{8}$ inch per foot of diameter.

Depending upon site conditions and requirements in the Contract Documents, construct the drilled shaft by either the cased or uncased method:

(1) Uncased Method. Use this method at locations anticipated to be free of caving soil or excess water inflow into the excavated shaft. Do not use the uncased method if the actual conditions show the shaft is prone to caving soil, or has water inflow that exceeds the dry pour method requirements in **subsection 703.3f**.

Excavate the shaft without the use of added water or drilling fluid. Completely excavate the shaft in a continuous operation, unless encountering rock or obstructions. Place the concrete without delay.

(2) Cased Method. Use this method at locations with caving soil or excess water inflow into the excavated shaft. Use either a permanent smooth, thick-walled casing, or a combination of a smooth, thick-walled temporary and permanent CMP casing together. All permanent casings shall be watertight.

Advancing shaft excavation by stabilizing the hole with drilling fluid is acceptable. Do not allow drilling fluid to get into the rock socket.

The concrete placement method used in a cased shaft depends on the water inflow requirements in **subsection 703.3f**.

After removal of the overburden, complete the excavation below the top of rock as an uncased core (rock socket) of the diameter shown in the Contract Documents.

Do not excavate closely spaced drilled shafts (3 drilled shaft diameters or less, center to center) until adjacent shafts are completed and cured according to the following criteria:

- Completed shafts have been allowed to set for a minimum of 24 hours after the concrete placement; and
- Developed a compressive strength of 1800 psi; or
- Without testing, the Engineer may allow excavation to proceed when the shaft has cured 72 hours after completion of the concrete placement.

If the Contract Documents specify or the Contractor elects to use permanent thick-walled casing for the closely spaced shafts, the Contractor may excavate multiple closely spaced drilled shafts. Once the concrete is placed, it must be cured according to the criteria above before excavating additional closely spaced drilled shafts.

For drilled shafts equal to or greater than 72 inches in diameter founded in shale, or as required in the Bridge Foundation Geology Report, perform the following, prior to placement of the reinforcing cage:

- Use a full diameter flight auger or core barrel. Extensions to the auger to increase the diameter of the hole are prohibited, except when excavating a belled rock socket with an under ream attachment;
- Use a full size, clean-out bucket a minimum of 95% of the diameter of the rock socket, when needed;

- In the presence of the Engineer, sound the bottom of the finished shaft. Use a weighted tape in a 12-inch grid across the base of the shaft;
- Provide access to the entire perimeter of the shaft;
- Flocculate the finished shaft to increase the visibility in the water, prior to using the underwater video camera. Use a commercially available flocculent agent per the manufacture's recommendations.
- Prior to concrete placement, perform a video inspection to inspect the sides and base of the rock socket. Along with the Engineer, review the video to verify the socket meets the cleanliness portion of this specification, prior to concrete placement;
- Perform sonic testing for all shafts. Submit test results to the Chief Geologist for review. No work will be done above the top of drilled shaft without the approval of the Chief Geologist; and
- Any required repairs or additional testing are the Contractor's expense.

d. Placing Reinforcing Steel and Sonic Testing Pipes. Tie reinforcing steel at all intersections of reinforcement, and place reinforcing steel as a unit for the full length of the shaft, prior to placing any concrete by either pour method. Use a minimum of 1 non-corrosive circular spacer per 30 inches of circumference of the reinforcing steel cage, within 2 to 4 feet of the bottom and top, and at intervals not to exceed 10 feet vertically. If the shaft is deepened and additional reinforcing steel cage is required, make the splice at the bottom of the steel cage.

Remove any corrosion protection coating from the sonic testing pipes by sandblasting. Sandblast the pipes to bare metal. Place the sonic testing pipes within 7 days of sandblasting.

In each shaft, place the number of testing pipes shown in the Contract Documents. All sonic testing pipes shall be the full length of the shaft from the bottom of the rock socket a minimum of 12 inches above the top of the shaft concrete. Before placement, measure and record the length of the sonic testing pipes and elevation of any pipe joints.

If multiple sections of pipe are required to reach the full length, the joints shall be watertight. The joints for all testing pipes in the shaft shall be at the same elevation. Completely seal the bottom of the pipe. After installation, fill pipes with potable water and install threaded caps. All testing pipes shall remain watertight until testing is complete.

Regardless of the connection used, conduct a pressure test of each pipe upon installation in the reinforcement cage.

Test all pipes after being placed and tied in the reinforcement cage. When the drilled shaft is greater than 30 feet in length, perform a second pressure test after the reinforcement and pipes are installed in the drilled shaft but prior to placing the concrete. Pressurize the pipe to 100 psi. Seal the pipe for 3 minutes. Pressure loss can not be greater than 5% in 3 minutes.

e. Final Inspection and Access. At the time of placing the concrete, a minimum of 75% of the base of the shaft must have less than ½ inch of sediment. The Engineer will determine the shaft cleanliness before concrete placement by:

- Visual inspection; or
- Underwater inspection using probes; or
- Down hole television camera and video recordings

Provide access to 100% of the hole from probing purposes. Probing will be done by a tape with a minimum weight of 1 pound.

Review and inspection by the Engineer prior to concrete placement does not relieve the Contractor of the responsibility for producing a defect-free shaft per specifications.

When directed by the Engineer, operate the camera and recorder such that the optimum clarity of the details can be obtained and all surface areas of the shaft, including the rock socket sides and base can be observed. Record video and store tapes such that later review is possible. Label the recorded media, which will become the property of KDOT.

f. Placing Drilled Shaft Concrete. Depending upon site conditions, place concrete by either the dry pour or wet pour method:

- Use the dry pour method if water inflow does not fill the shaft more than 4 inches in depth in a 5 minute period, and the shaft can be dewatered so a maximum of 2 inches of water is standing in the shaft when concrete placement begins.

703 - DRILLED SHAFTS

- When the above 2 conditions can not be met, use the wet pour method.

For both the dry and wet pour methods, the following common requirements for concrete placed in a cased or uncased shaft shall apply:

- Target slump is 9 inches $\pm$ 1 inch;
- Place concrete in the shaft with a continuous operation, without construction joints;
- Do not vibrate concrete;
- Determine the top elevation of the fresh concrete and inform the Engineer; and
- Do not use aluminum concrete pump discharge tubes or tremie tubes.

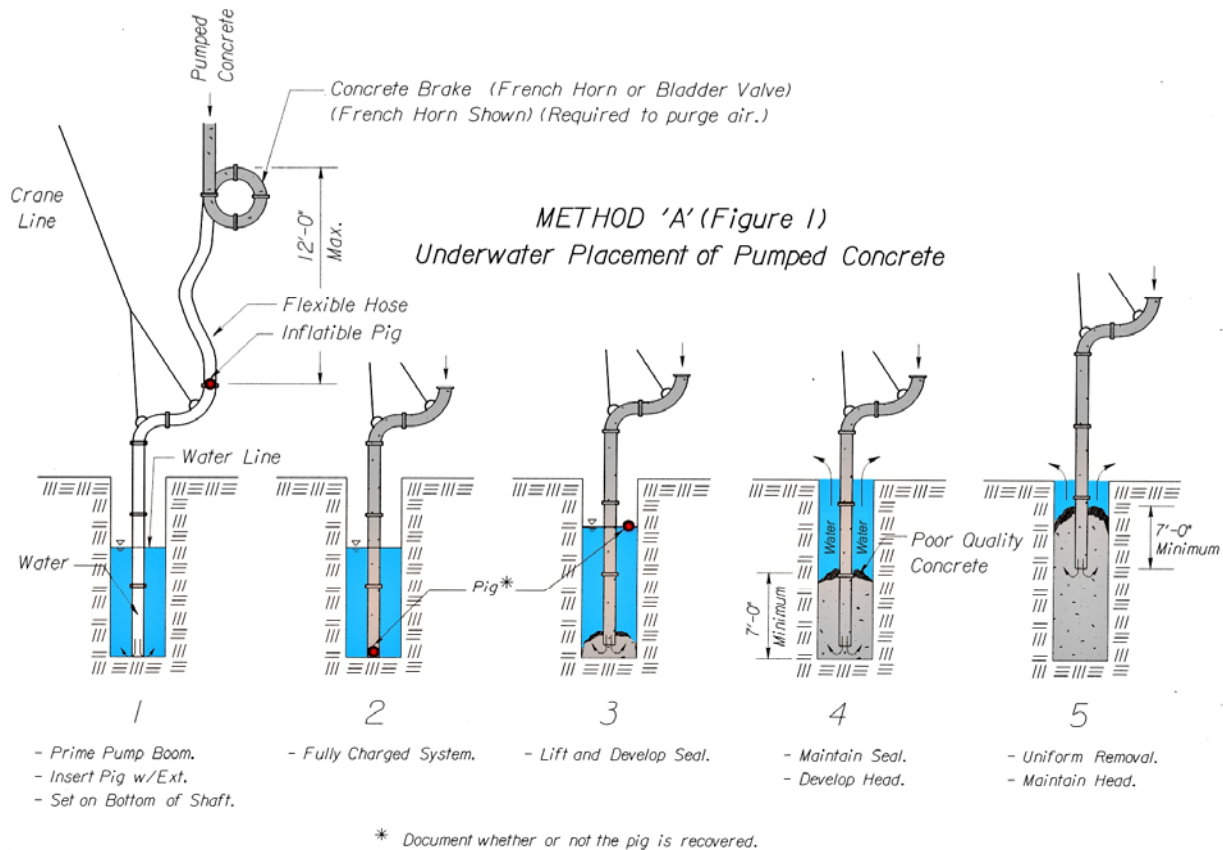
(1) Dry Pour Method. Use a centering device to deposit concrete so the falling concrete shall not come into contact with vertical and horizontal reinforcing steel and wire supports. To control the fall, extend the centering device a minimum of 8 feet into the shaft. For a cased shaft, concrete may free fall to the bottom. For an uncased shaft, the maximum fall for concrete is 5 feet.

(2) Wet Pour Method. Prior to starting concrete placement, allow the water level in the shaft to reach its static level. Place concrete with either a sealed (watertight) tremie tube or pump with a rigid and watertight extension tube. In either case, use a device (i.e. commercially available pig or flap gate) that prevents water from entering the tube while charging with concrete. The commercially available pig shall be a minimum of 110% the diameter of the tube. Clearly label the outside of the tremie and pump tubes in 12-inch increments (starting at the bottom).

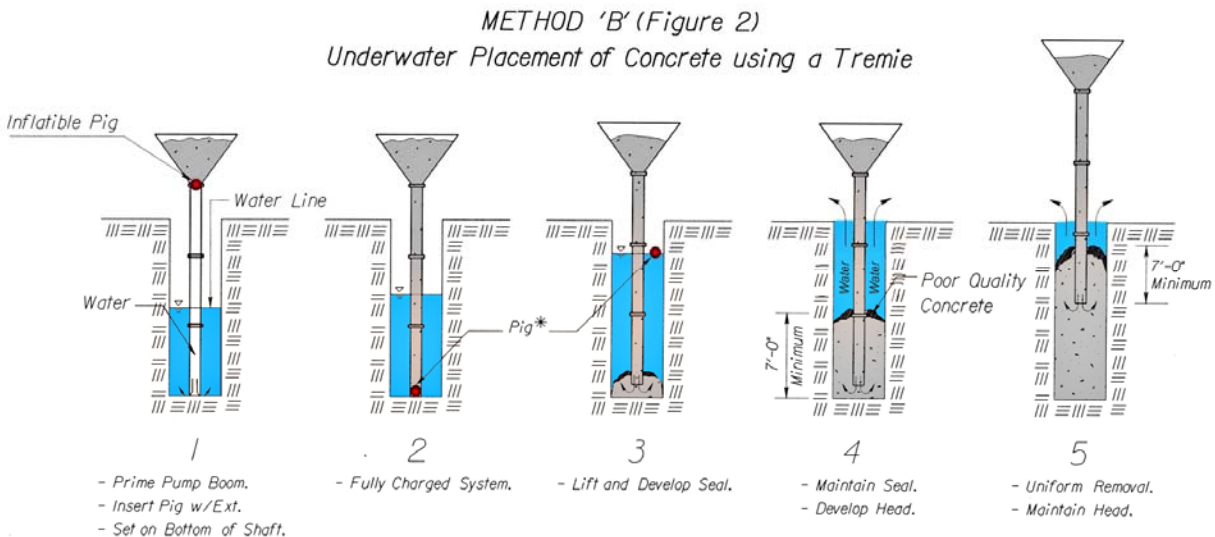
Lower the rigid tube into the shaft with the bottom of the tube resting on the bottom of the rock socket, and fully charge the system (tube and hopper or pumping system) with concrete. Once the system is fully charged, raise the tube off the bottom of the rock socket by 1 tube diameter, and allow the concrete to seal the discharge end of the tube. Maintain the tube at this elevation until a minimum of 7-foot head of concrete is developed. Maintain a minimum 7-foot head of concrete during the concrete placement. Prior to raising the tube, determine the top elevation of the fresh concrete and inform the Engineer.

For wet pours, follow the steps listed in the previous paragraph, regardless of the Method (A, B or C) used to place concrete in the shaft:

703 - DRILLED SHAFTS



Method A (Figure 1): Use a pump and extension tube, with a pig separating the ground water and concrete, to place concrete into the shaft. Install a concrete brake (e.g. bladder valve or French horn) at the end of the pump boom to purge the air from the pump line. Fully charge the boom with concrete (no air gaps) then install the pig in the top of the extension tube.



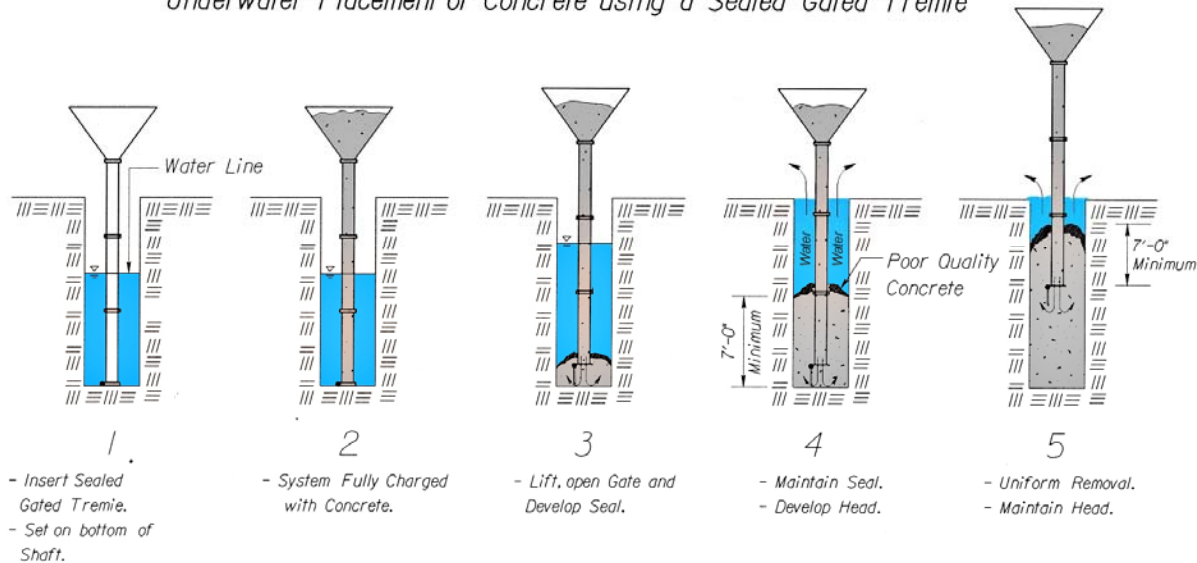
Method B (Figure 2): Use a tremie tube, with a pig separating the ground water and concrete, to place concrete into the shaft. Once the tremie tube is resting on the bottom of the shaft, install the pig just below

703 - DRILLED SHAFTS

the hopper in the top of the tremie tube. Fully charge the tremie tube and hopper (forcing the pig to the bottom of the tremie tube), then raise the tremie tube by 1 tremie diameter and seal the discharge end of the tremie tube with the fresh concrete.

METHOD 'C' (Figure 3)

Underwater Placement of Concrete using a Sealed Gated Tremie



Method C (Figure 3): Use a tremie tube, with a sealed gate separating ground water and concrete, to place concrete in the shaft. Fully charge the tremie tube and hopper, then raise the tremie tube by 1 tremie diameter and seal the discharge end of the tremie tube with the fresh concrete.

When the concrete reaches the top of the shaft, continue placing concrete (over-pump) to expel any excess water, debris or unsound concrete. If the casing extends above the planned shaft elevation the excess material must be expelled by providing an outlet in the casing above the planned elevation if the shaft. Do not bail the excess material out of the shaft. On all wet pours, regardless of the method used, the Engineer will make a set of cylinders (in addition to normal concrete cylinder sampling requirements) from the top of the shaft after completing over-pumping. This set of cylinders will be used to verify a compressive strength of 1800 psi before proceeding with subsequent substructure (i.e. columns, abutments, etc.) construction.

Prior to constructing the portion of the substructure that attaches to the drilled shaft, thoroughly clean the top of the drilled shaft to facilitate the bond at the cold joint.

g. Raising Temporary Casing. Do not remove the temporary casing until the concrete in the shaft has met the following conditions:

- Completed shafts have been allowed to set for a minimum of 24 hours after the concrete placement; and
- Developed a compressive strength of 1800 psi; or
- If compressive strength does not meet 1800 psi, the Engineer may allow the Contractor to proceed when the shaft has cured 5 days after completion of the concrete placement.

However, immediately after completing concrete placement in the permanent casing, it is acceptable to raise and hold the temporary casing at the embedment depth plus 6 inches.

Before raising the temporary casing completely, backfill the space between the 2 casings according to **subsection 703.3j**.

h. Curing. Cure the exposed surfaces of the shafts with wet burlap a minimum of 2 days. Do not use liquid membrane curing.

Cure all cylinders in the field, alongside and under the same conditions as the concrete they represent.

i. Sonic Testing.

(1) General. Perform sonic testing on all drilled shafts constructed by the wet pour method. Perform sonic testing on any dry pour method as directed by the Engineer. Conduct the sonic testing between 2 and 21 days after the drilled shaft is completed. The Engineer has the option to require additional testing.

Secure the services of an independent, experienced testing organization to take the cross-hole sonic logging measurements and issue reports. Submit to the Engineer, the testing organization's record of experience, a written description of the testing procedures, operation manuals for the testing equipment, and samples of previous test results indicating both sound and defective concrete.

(2) Sonic Logging Equipment. Provide sonic logging equipment capable of identifying any faults, honeycombing or poor concrete at KDOT specified operating settings:

- A time base that shall provide the "zero signal" and "first arrival" are 2 to 3 divisions apart on the horizontal axis; and
- Select a gain to produce an amplitude signal that fills $\frac{2}{3}$ to $\frac{3}{4}$ of the screen along the vertical access of the waveform plot for portions of the shaft that correspond to good quality concrete;

Provide test results on thermal or graphical printouts with the vertical scale representing the vertical position along shaft, and the horizontal scale representing the propagation time.

(3) Sonic Logging Test Procedure. Immediately prior to testing, verify the pipes are free from blockages and filled with water. Determine the elevation of the top of the drilled shaft and the top of each pipe. Measure each pipe to determine the depth, and provide the information to the Engineer.

Conduct the sonic logging test procedure between all possible combinations of pipes (i.e. 4 pipes have 6 different combinations, 5 pipes have 10 different combinations, 6 pipes have 15 different combinations, 7 pipes have 21 different combinations, 8 pipes have 28 different combinations, etc.). If the sonic testing detects faults, the Engineer may require retesting with the probes in the same or different horizontal plane.

The testing organization shall make suggestions for changes in the Crosshole Sonic Logging (CSL) testing procedure based on known shaft construction issues or survey access issues. Such changes could include, but would not be limited to changing the frequency of data collection along the length of the shaft or offsetting the transducers from the horizontal plane. Any such suggested changes in CSL data collection procedures must be approved in advance by the Engineer.

Immediately prior to testing, verify the pipes are free from blockages and filled with water. Determine the elevation of the top of the drilled shaft and the top of each pipe. Plumb each pipe to determine the depth, and provide the information to the Engineer.

Configure sonic logging to settings in **subsection 703.3i.(2)**.

Use a winch to simultaneously raise the probes from the bottom of the pipes at a maximum rate of 12 inches per second. Take all slack out of the cables before switching on the analyzer.

(4) Record of Testing. After completing sonic testing, provide the Chief Geologist the report of the CSL test results stamped by a licensed Professional Engineer that includes data plots (recorded on thermal or graphical printouts) with the profiles referenced to the top of the shaft or top of the pipe elevation. A copy of the report shall be sent by the testing organization to the Contractor. No work shall be done above the top of the drilled shaft without approval from the Chief Geologist. Inform the Engineer on site of any faults, honeycombing or poor concrete detected by a fainting of the signals and a sudden lengthening of the propagation time. Diagram (horizontal and vertical cross-sections) any defects found within the shaft to identify the location, width and thickness of the defect. Provide the report of CSL results, stamped by a licensed Professional Engineer, within 1 week of conducting the sonic test. The CSL practitioner does not have the information available to make recommendations for shaft acceptance or correction as part of the normal course of testing a shaft.

(5) Coring. If the sonic logging inspection indicates an anomaly for any zone of the shaft represented by loss of signal, a reduction in apparent sonic velocity greater than 15%, or where the velocity is equal to or less than 15% and as directed by the Chief Geologist, or where a survey was not complete due to problems associated with access tubes, drill cores (NX size, 2.125 inches or larger) at locations and depths approved by the Engineer. Drill cores NX size (2.125 inches, or larger), however if the location of the anomaly prevents an NX size core, with the approval of the Engineer, drill a smaller size (minimum A size, 1.25 inch) core. Mark the beginning and end of each core and record the total length of the core and the total length recovered, core recover must be greater than 95%. Provide the Engineer the recorded information and the core samples labeled with their location and relative elevation. If the concrete is defective, submit a written proposal to repair the drilled shaft. The proposal must be approved by the Engineer before repairs commence.

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(6) Filling Core Holes. Fill core holes by pressure grouting with non-shrink grout described in **subsection 703.2b**. Use a pipe extending to the bottom of the hole to fill it from the bottom to the top.

(7) Filling Pipes. After completing sonic testing and final acceptance of the drilled shaft is made, fill the sonic testing pipes with the specified non-shrink grout. If the Contractor can expel enough water from sonic testing pipes leaving 2 feet or less of standing water in the sonic testing pipe, grout may free fall to the bottom of the pipe. If more than 2 feet of water remains in the bottom of the sonic testing pipe, prevent the grout from free falling through the water using a tremie tube extending to the bottom of the sonic testing pipe.

j. Backfill. When a temporary casing and a permanent casing are used, backfill the space (between casings) with the material specified in the Contract Documents:

- Granular material fine enough to fill the entire volume; or
- Grout or flowable fill described in **subsection 703.2b**.
 - If the space contains water, use a pump with an extension pipe or tremie (extending to the bottom of the space) to fill the space.
 - If the space is dry, the grout/flowable fill may free fall to the bottom of the shaft.
 - Fill the space with grout/flowable fill to the top of the casing, then, completely remove the temporary casing.

When the Contract Documents do not specify a material for backfill, use the granular material before extracting the temporary casing. After extracting the temporary casing, fill the rest of the space with granular material.

703.4 MEASUREMENT AND PAYMENT

a. Drilled Shafts. The Engineer will measure drilled shafts by the linear foot measured from the bottom of the rock socket to the top of the completed drilled shaft. The Engineer will not consider a request for additional compensation, unless the overall length of a drilled shaft changes by more than 20%.

b. Permanent Casing. The Engineer will measure the accepted permanent casing by the linear foot, if a permanent casing is required, but not specified in the Contract Documents. The Engineer will not measure the permanent casing if:

- Contract Documents require Drilled Shafts (Cased).
- Contractor uses the casing for their convenience.
- Casing is a temporary casing.

c. Sonic Test (Drilled Shaft) (Set Price).

(1) Sonic Testing specified in Contract Documents. When shown in the Contract Documents, the Engineer will measure each designated sonic test, per shaft (i.e. sonic logging between all possible combinations of pipes represents a single sonic test).

(2) Sonic Testing requested by the Engineer.

- When the Engineer requests sonic tests not shown in the Contract Documents, and the sonic testing indicates the concrete is acceptable, the Engineer will measure each sonic test, per shaft (i.e. sonic logging between all possible combinations of pipes represents a single sonic test).
- When the Engineer requests sonic testing not shown in the Contract Documents, and the sonic testing indicates defective concrete in the drilled shaft, the Engineer will not measure for payment the sonic testing of that shaft.
- When the Engineer requests sonic testing not shown in the Contract Documents, the sonic testing indicates defective concrete in the drilled shaft, the Engineer requests cores from the shaft, and the cores reveal unsound concrete, the Engineer will not measure for payment the sonic testing or cores for that shaft.
- When the Engineer requests sonic testing not shown in the Contract Documents, the sonic testing indicates defective concrete in the drilled shaft, and the Engineer requests cores from the shaft, and the cores reveal sound concrete, the Engineer will measure for payment each sonic test, per shaft (i.e. sonic logging between all possible combinations of pipes represents a single sonic test). The Engineer will also pay for the cores as Extra Work according to **SECTION 104**.

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(3) Core Hole (Investigative) specified in the Contract Documents. When shown in the Contract Documents, the Engineer will measure the investigative core hole by the linear foot, from the existing ground surface to 6 feet below the drilled shaft tip elevation.

d. Payment. Payment for "Drilled Shaft" and "Core Hole (Investigative)" at the contract unit prices, and "Permanent Casing" and "Sonic Test" at the contract set unit prices is full compensation for the specified work.

If the Engineer lengthens the drilled shaft during construction, the Engineer will measure and pay for additional reinforcing steel as Extra Work according to **SECTION 104**.