Kansas State University | Salina

Drilled Shaft Inspection Workbook

Certified Inspector Training Program

AD ASTRA PER ASPERA

Kansas

Department of Transportation

Drilled Shaft Inspection Certification Workbook

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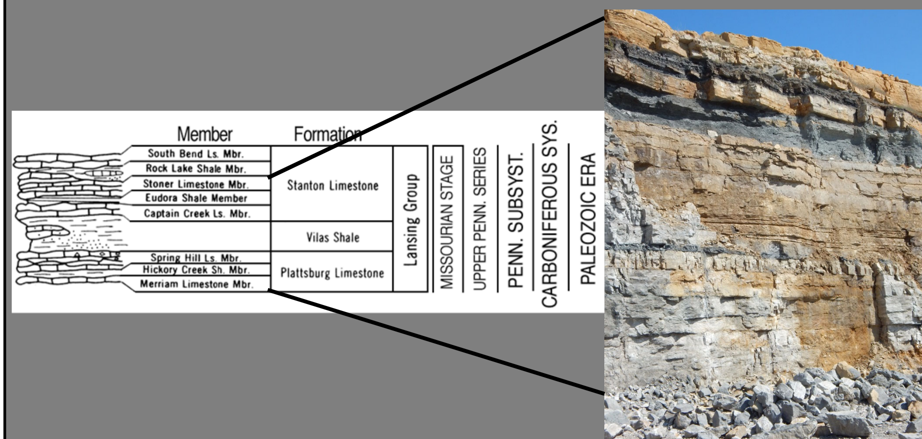
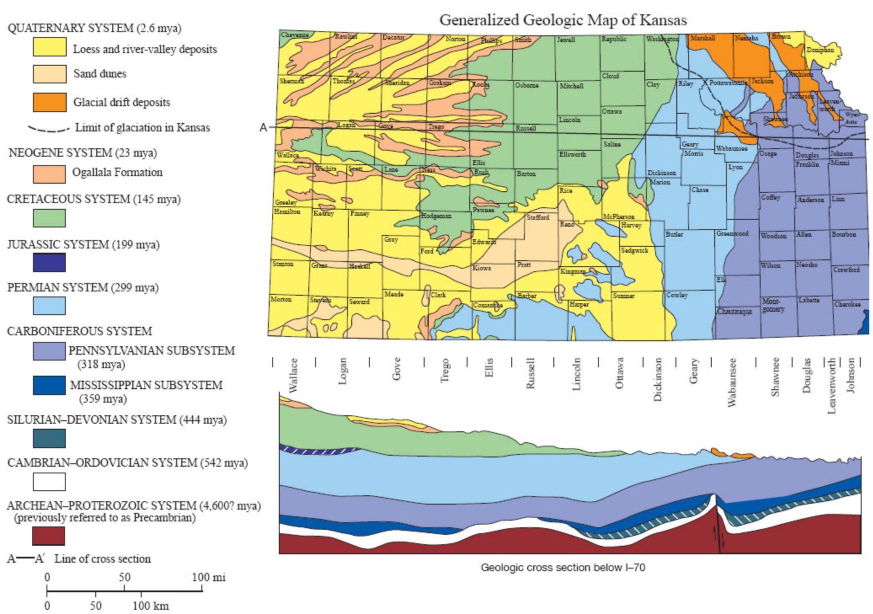
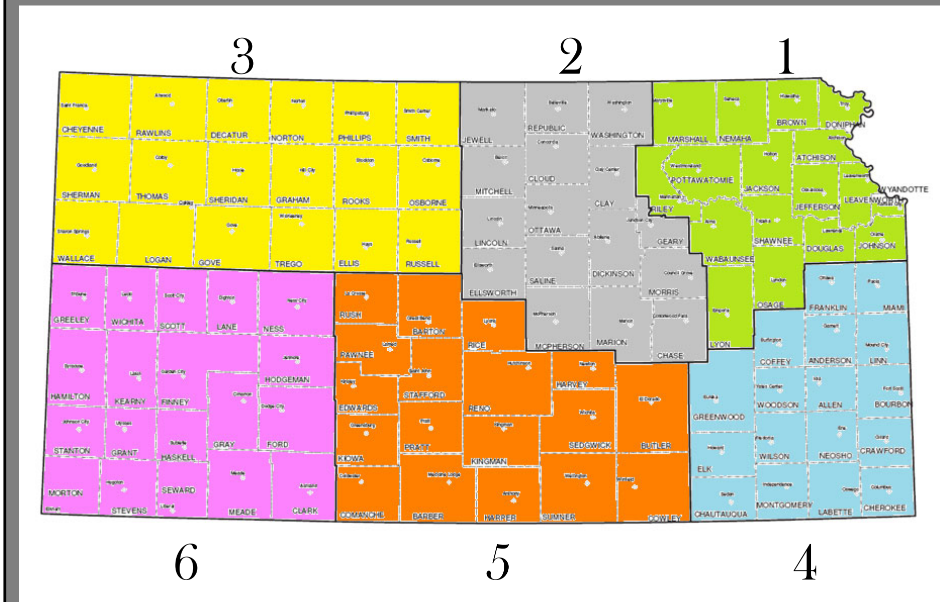
Drilled Shaft CIT Class
Kansas Geology 101



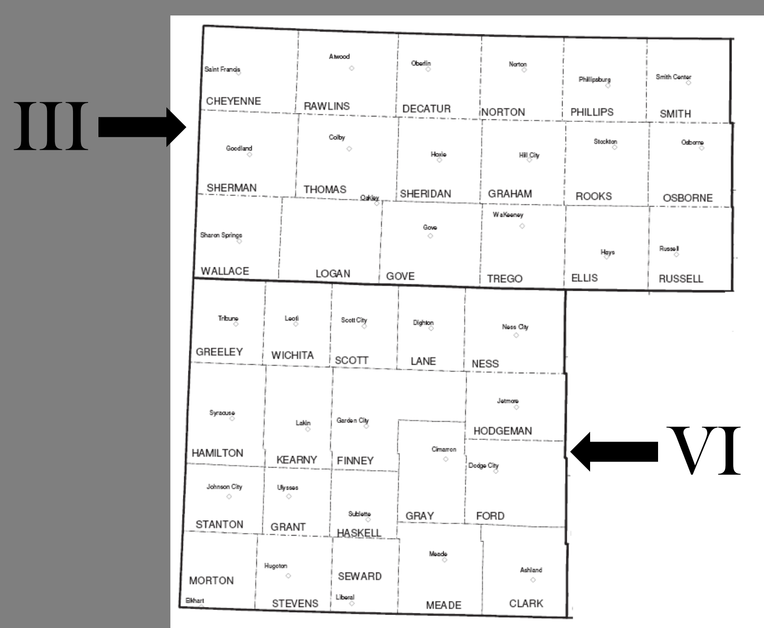
Kyle Halverson
Chief Geologist



Districts within the State

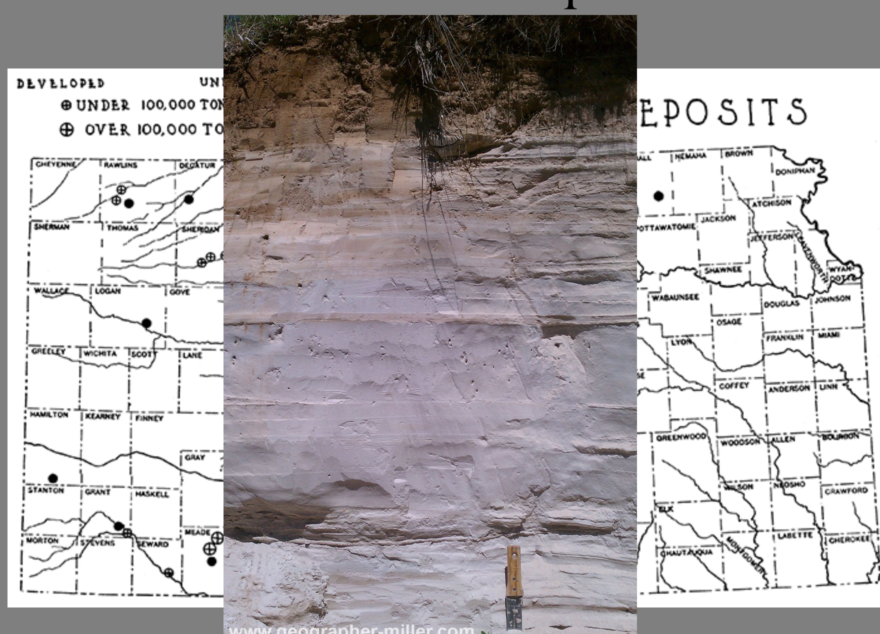


District III and VI



View from Mount Sunflower
Elevation 4039

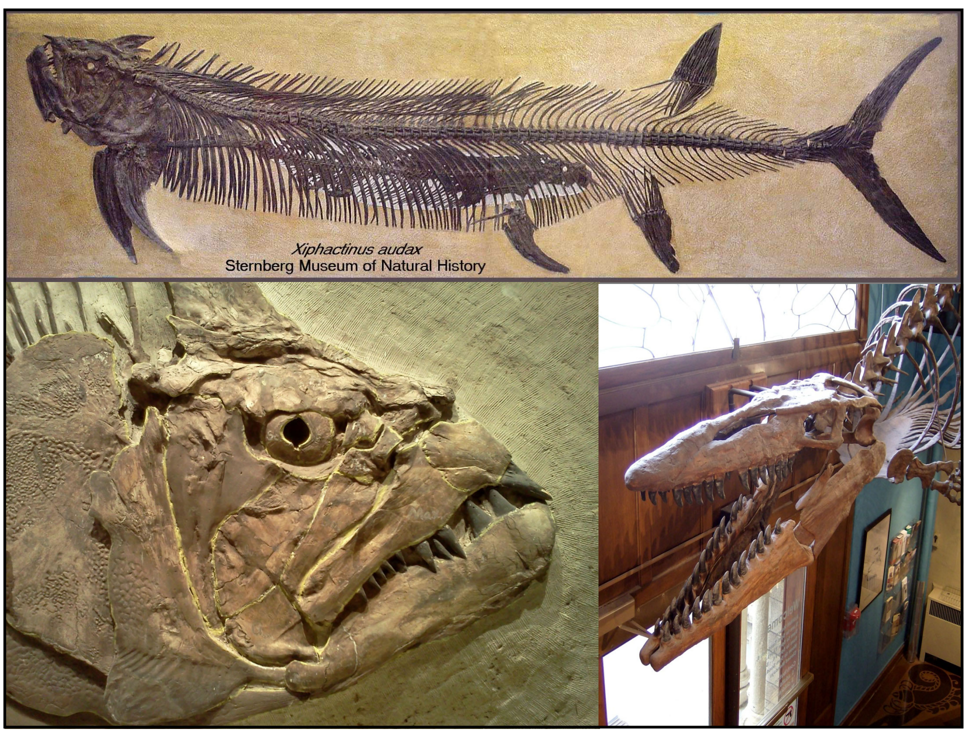
Volcanic Ash Deposits

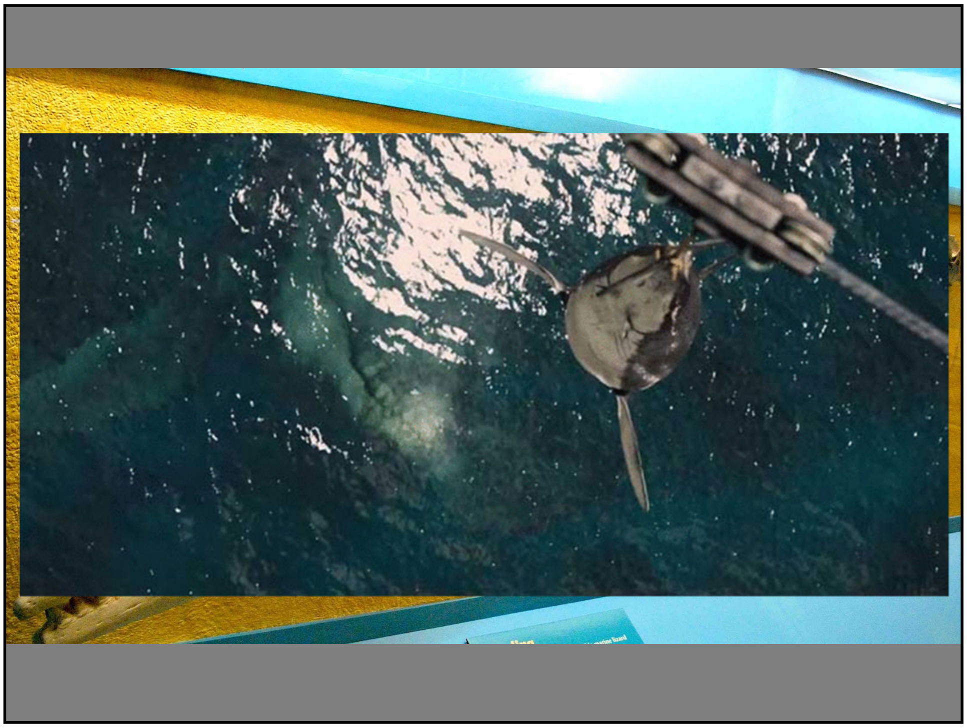


Ancient North American Sea
65 to 135 million years ago

Camel Rock Kiowa County

Arikaree Breaks Cheyenne CO.

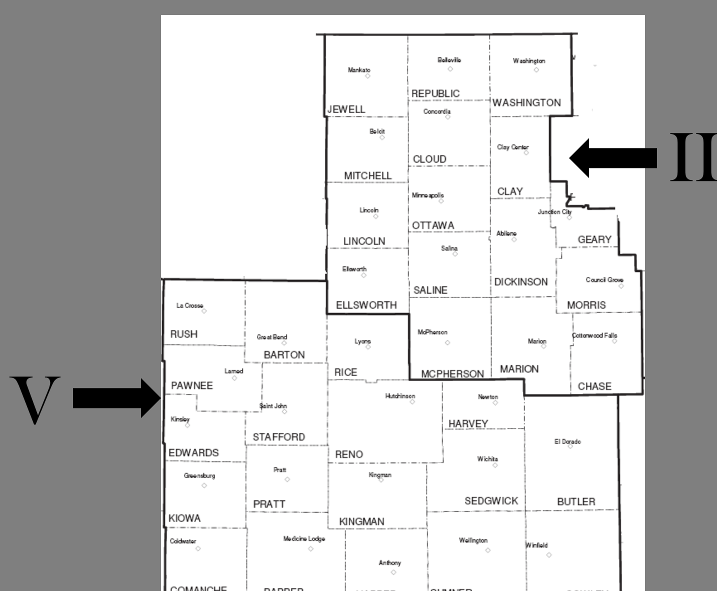

Xiphactinus audax
Sternberg Museum of Natural History

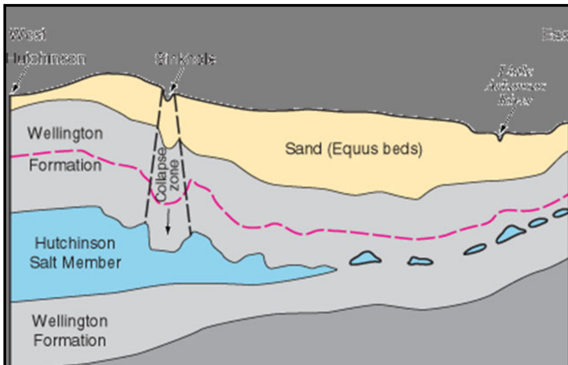


What to expect in your district

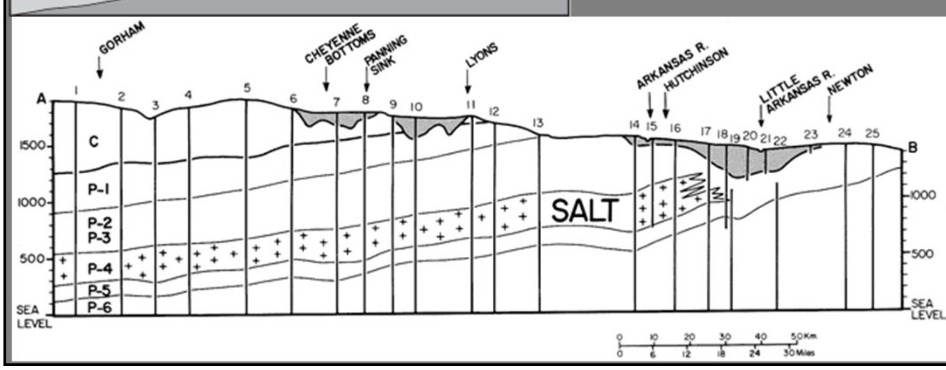
- Districts 3 & 6- Weak limestones and shales, and thick deposits of sand and soil. Drilled shafts have been constructed in these districts when bedrock is close to the surface and of good quality. Most of the time the depth to bedrock and the poor quality of bedrock, limits drilled shaft construction.

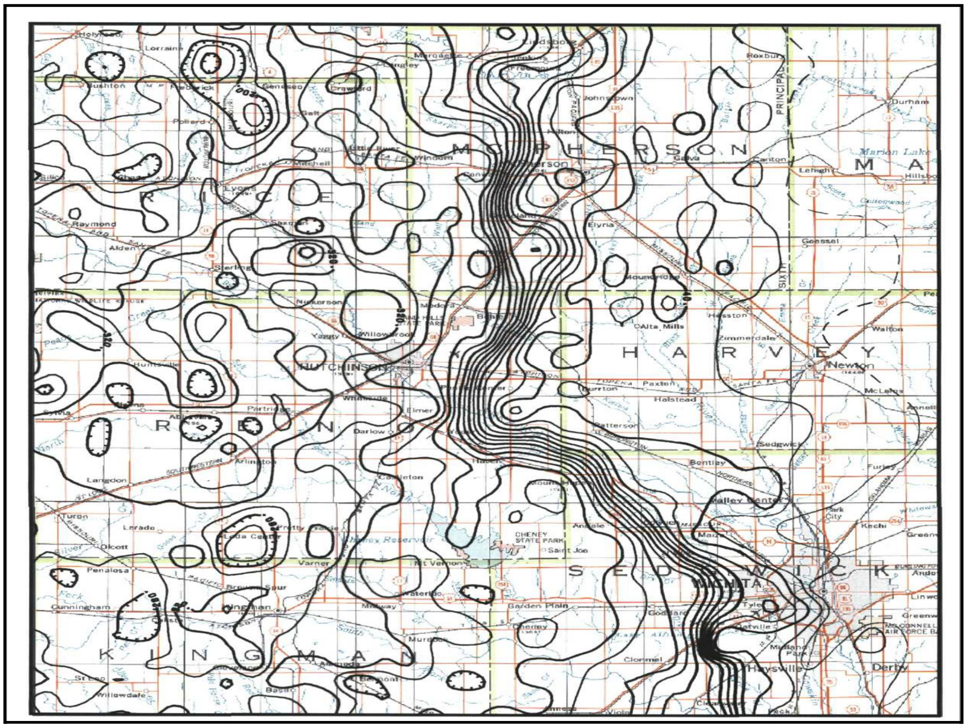
District II and V

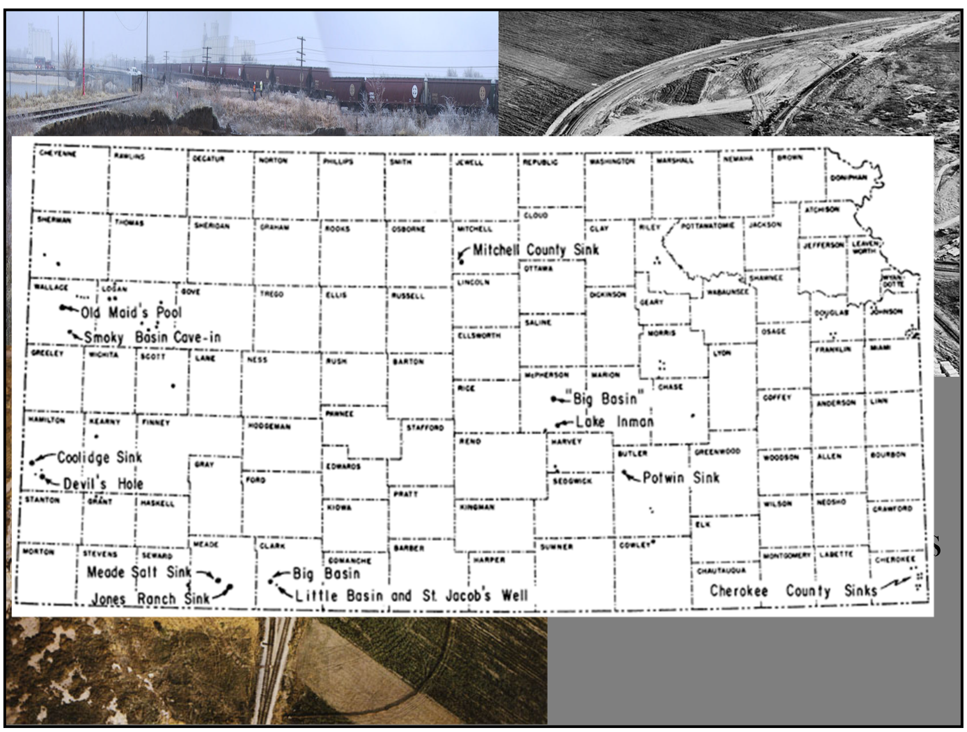




Salt in Kansas



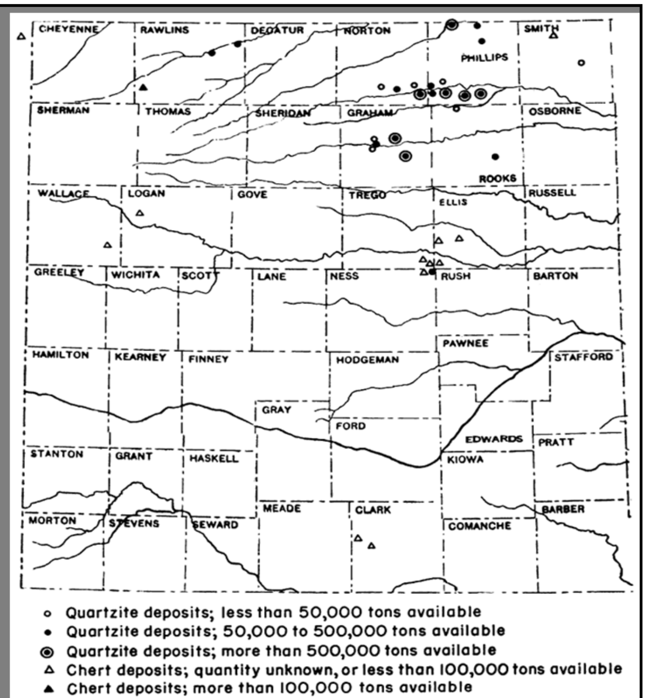

M C P H E R S O N
R I C E
H A R V E Y
R E N O
S E D G W I C K
K I N G M A N
HUTCHINSON
Newton


Mitchell County Sink
Old Maid's Pool
Smoky Basin Cave-in
"Big Basin"
Lake Inman
Coolidge Sink
Devil's Hole
Potwin Sink
Meade Salt Sink
Jones Ranch Sink
Big Basin
Little Basin and St. Jacob's Well
Cherokee County Sinks

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.

Where you can find the Green Rock!



Post Rock Quarry

Sand Dunes

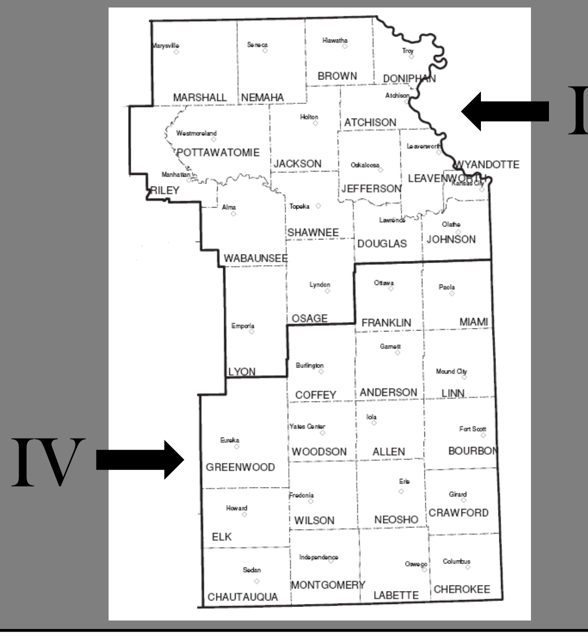
What to expect in your district.

- 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.

What to expect in your district.

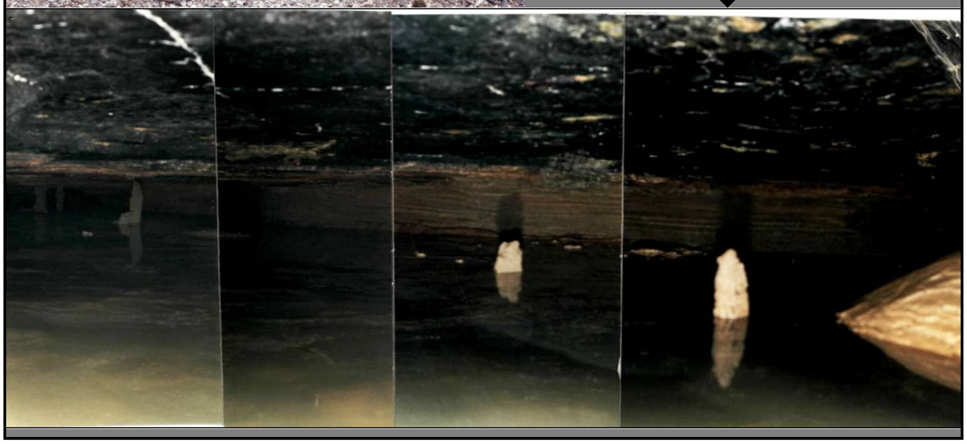
- District 5- Limestone (east), shale, and thick layers of sand. Eastern part (Butler and Cowley Co.) is similar to District 4. Western part has weaker shales and lots of sand that can very deep (100ft +) Drilled shafts can be placed but depth to bedrock and foundation material must be considered.

Districts I and IV



Covered Mine Shaft

Coal Mine



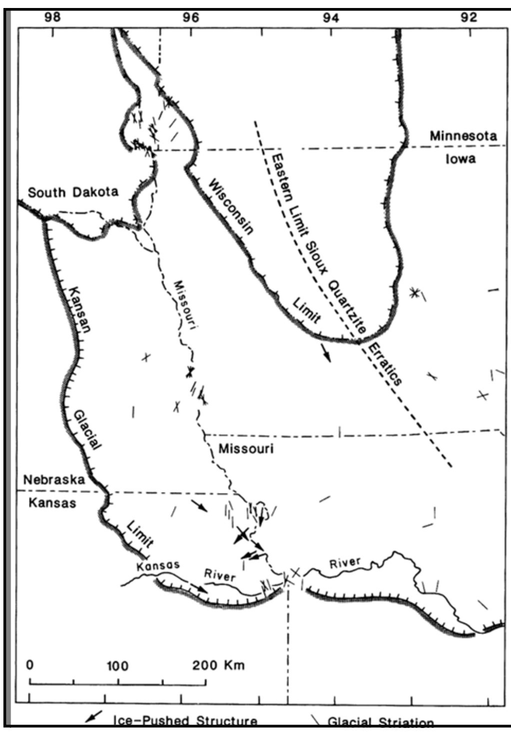
Chat Piles and Mine Work

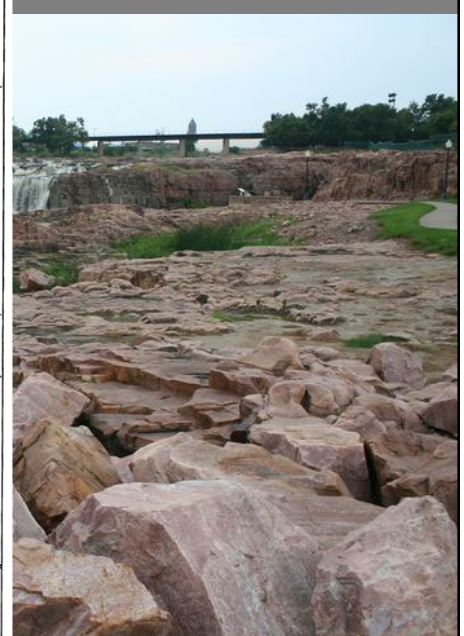

A
B
C


Drive
View Nort

Thicker Limestones and alternating rock types

Glacial Erratic's





What to expect in your district.

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

Common Rock Types?

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

Who you need to Contact

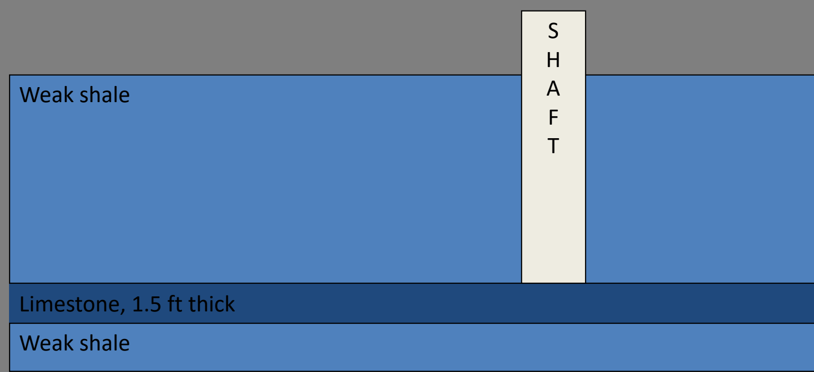
- District 1- John Barker
  - (785)291-3861
- Districts 2 & 3- Neil Croxton
  - (785)-263-4597
- District 4- Denny Martin
  - (620)431-1000
- Districts 5 & 6-Art Peterson
  - (316) 320-1721

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

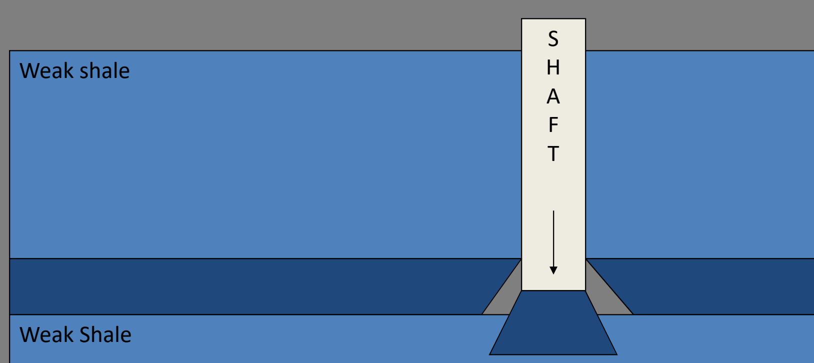
Punch Out

Drilled shaft on too thin of Limestone



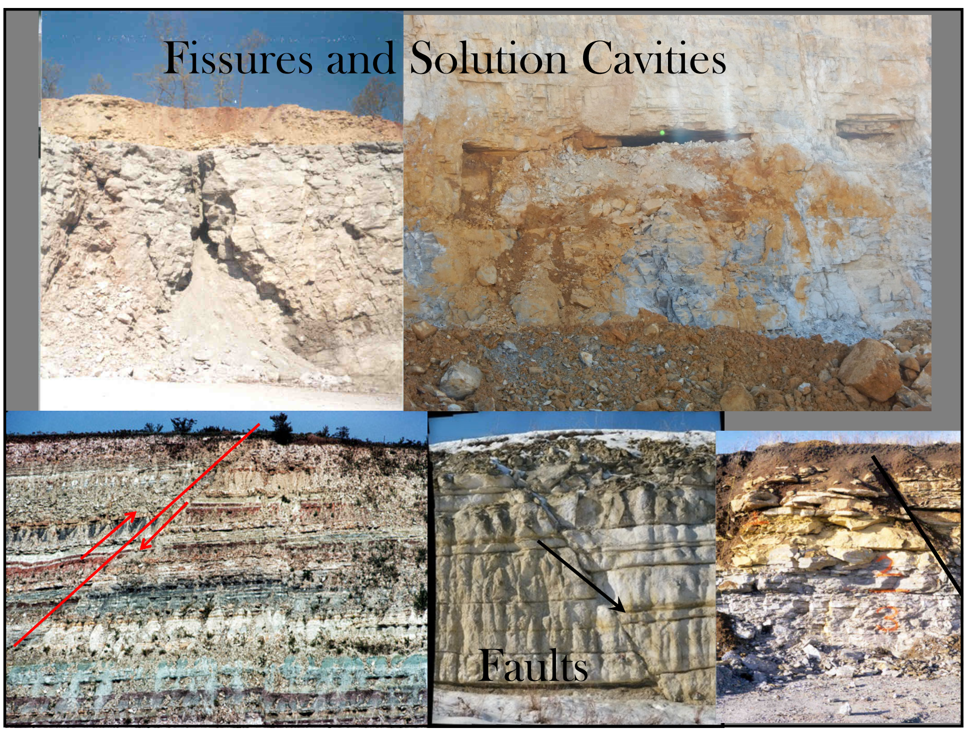
Punch Out

- What can happen



GEOLOGIC PROBLEMS

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




Bedding
Weak Shale underlying Limestone
Weak Shale underlying Limestone
Bedding

The Geology Report and the Purpose for it

When in doubt…………

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

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.

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?

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.

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?

Geology at Bridge Site -Bedrock

- <u>**Stranger Formation,**</u>
- **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.

Bedrock Continued

- <u>**Stanton Limestone Formation**</u>
- **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

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.

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**
- **<u>Vilas Shale Formation</u>**
- 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.

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?

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.

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."

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

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.

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

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.

Issues with the Investigative Cores

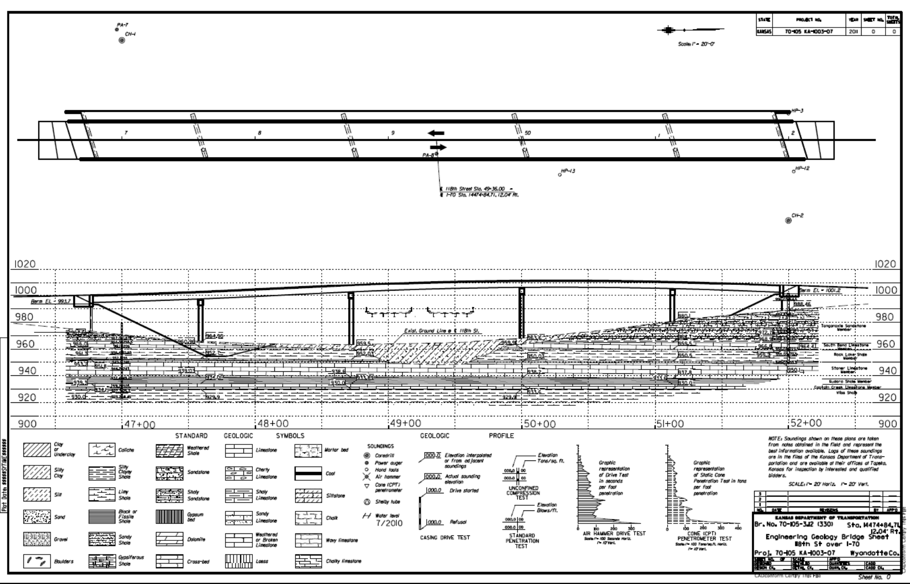
- Location
- Logs
- Recovery
- Not notified

HYDROLOGY

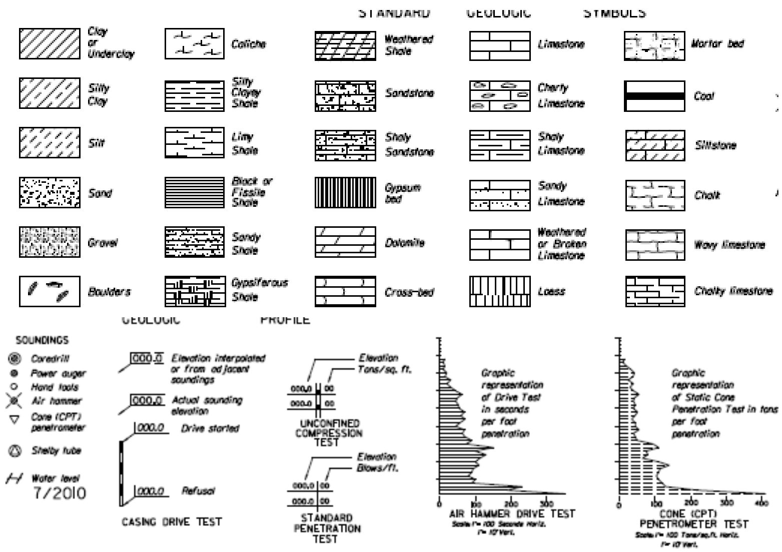
- States if dewatering equipment will be needed
- Gives ground water elevations
- Also can State if casing will be used

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.

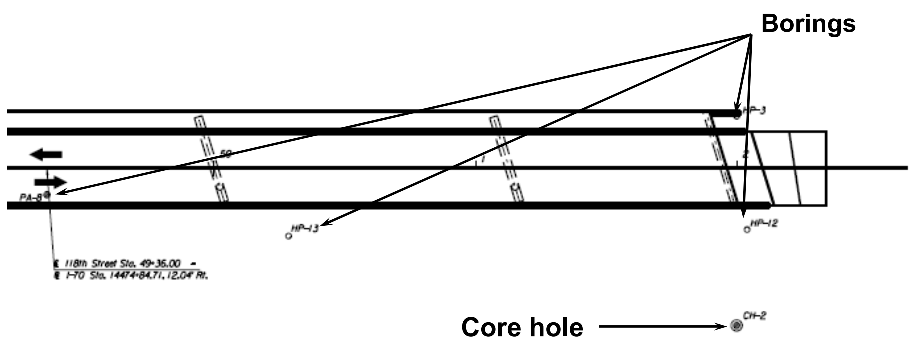
Engineering Geology Sheet-
Some things you might like to know.



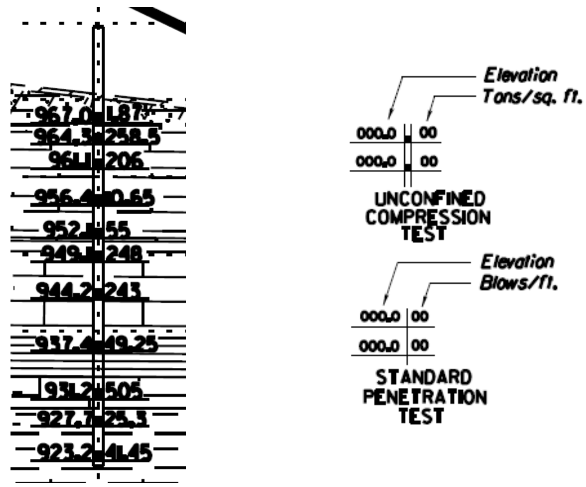
Engineering Geology Sheet-
Geology



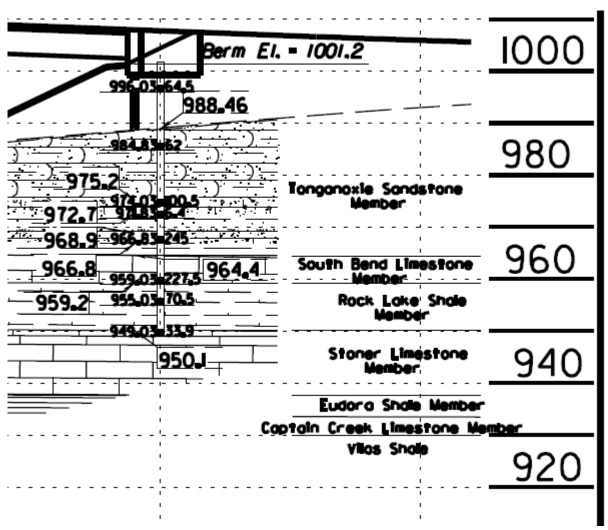
Engineering Geology Sheet-
Shows the Geology Investigative holes



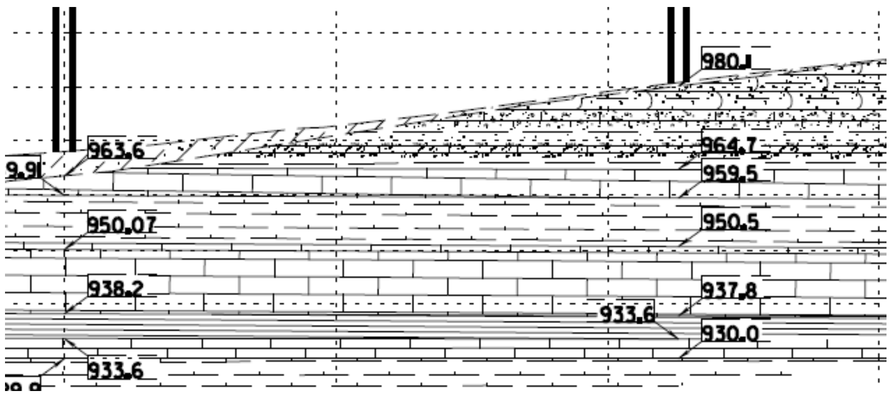
Engineering Geology Sheet- Unconfined compression test



Engineering Geology Sheet- Formations



Engineering Geology Sheet- Elevations



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

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

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.

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

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

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.

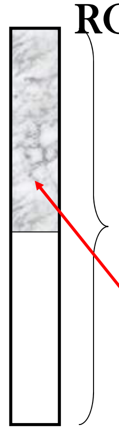
Rock Core Recovery

- 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= $\frac{\text{Length of Core Recovered}}{\text{Length of Core Run}}$ X 100

Rock Core Recovery

Sample

ROCK CORE RECOVERY (REC)



Length of Run = 5.0’

Recovered 2.6’

REC = 2.6’/5.0’= 52%

Rock Quality Designation

- Rock Quality Designation (RQD)
  - Defined as the sum of all recovered pieces of rock core greater then 4” in length by the length of core run and is expressed as a percentage.
  - % RQD= <u>**Sum of Pieces >4”**</u> X 100

    Length of Core Run

RQD-Rock Quality

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

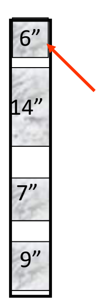
Sample Problems

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.

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

Sample

Length of Run = 5.0'



Recovered pieces

RQD = 36"/60"= 0.6 x100= 60%

Sample Problems

Can REC be greater than 100%?
YES

Can RQD be greater than REC?
NO

Can RQD be greater that 100%?
NO

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?

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:

The End

Questions?

Session 2:
Design,
Specifications, and
Plans

Seth Weber –
Bridge Design

KDOT
IKE
THE EISENHOWER LEGACY TRANSPORTATION PROGRAM

1

Learning Objectives

- Obtain a general understanding of drilled shaft design.
- Learn the specification covering drilled shaft construction.
- Know where to look for information about drilled shaft designs and details on the plan documents.

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Topics to Discuss

- Drilled Shaft Design
- Specifications for Drilled Shafts
  - Concrete Mix
  - Casing Requirements
- Plans
  - Design Data
  - Design Details
- Osterberg Cell

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Drilled Shaft Design

- Why use drilled shafts?
  - Footing Piles would be short
  - The water table is too high
  - The rock is too deep for an economical spread footing
  - There are concerns about pile driving vibrations or noise

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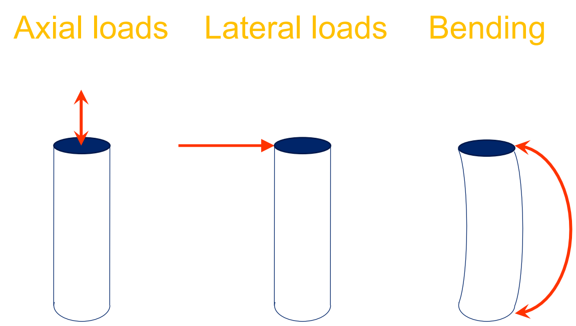
Drilled Shaft Design

- What loads are drilled shafts designed for?
  - Axial – Forces applied perpendicular to the cross section of the shaft
  - Lateral – Forces applied parallel to the cross section of the shaft.
  - Bending – Forces causing rotation of the cross section



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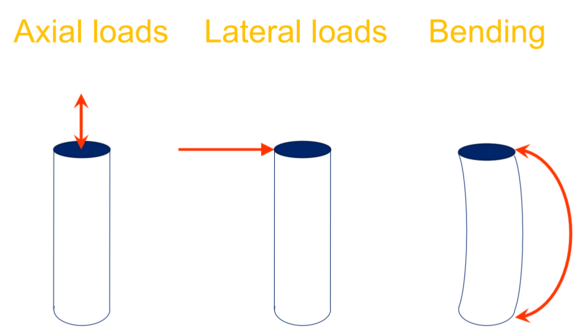
Drilled Shaft Design

- Examples of Axial Loads:
  - The self weight of the bridge
  - Traffic that drives over the bridge.
- Examples of Lateral and Bending Loads:
  - Wind
  - Stream Forces
  - Moments caused by the structure itself and traffic
  - Seismic Forces



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Drilled Shaft Design

- How does the soil counteract the Axial forces?
  - Axial loads are resisted by the end bearing strength of the soil and/or friction forces.
    - For Limestone:
      - End Bearing = 25-30 tsf
      - Skin Friction = 27 tsf
    - For Shale:
      - End Bearing = 10-15 tsf
      - Skin Friction = up to 11 tsf
- How does the soil counteract the Lateral and Bending forces?
  - Lateral and Bending loads are resisted by the soil mantle and fixity at the rock socket.

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Specification – Section 703

- 703.1 – Description
- 703.2 – Materials
- 703.3 – Construction Requirements
- 703.4 – Measurement and Payments

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Specification – Section 703

- 703.1 - Description

BID ITEMS	UNITS
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 the cased method.)

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Specification – Section 703

- 703.2 - Materials
  - a: Concrete – Grade 4.0 concrete complying with Sections 401, 402, and 1102 unless otherwise shown in contract documents.
    - Target Slump = 9” ± 1”
    - Do not withhold water at the plant!
    - Do not add water at the site!
  - b: Grout/Flowable Fill – cementious grout complying with Division 1700
    - Used to backfill cross-hole sonic testing pipes and core holes
    - Must have a 28 day compressive strength of 1000 psi
    - Use mortar sand, FA-M (Section 1102) mixed with 2 bags of of Type II Portland cement per cubic yard
    - The water to cement ration must be less than 1

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Specification – Section 703

- 703.2 - Materials
  - a: Concrete
    - Grade 4.0 concrete complying with Sections 401, 402, and 1102 unless otherwise shown in contract documents.
  - b: Grout/Flowable Fill
    - Cementious grout complying with Division 1700
  - c: Granular Backfill Material
    - Material accepted by the engineer based on visual inspection
  - d: Reinforcing Steel
    - Steel shall comply with Division 1600
  - e: Casing
    - The engineer will accept the casing based on compliance with the specified requirements and visual inspection

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Specification – Section 703

- 703.3 – Construction Requirements
  - a: General
    - Includes specifications on drilled shaft lengths and installation plans
  - b: Investigative Core Hole
    - Includes specifications on core hole samples, how to handle and maintain core samples, and boring logs required for KDOT review
  - c: Excavating the Drilled Shaft
    - Includes specifications on excavation tolerances and when closely spaced drilled shafts can and cannot be excavated
  - d: Placing Reinforcing Steel and Sonic Testing Pipes
    - Includes specifications on tying and placing reinforcement cages, preparing and placing sonic testing tubes, and sonic tube testing.
  - e: Final Inspection and Access
    - Includes specifications on inspecting the drilled shaft for cleanliness and construction tolerances

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Specification – Section 703

- 703.3 – Construction Requirements Cont.
  - f: Placing Drilled Shaft Concrete
    - Includes specifications on dry and wet pour placement and for the three methods (A,B,and C) of placing concrete in the shaft.
  - g: Raising Temporary Casing
    - Includes specifications for when the temporary casing is allowed to be removed
  - h: Curing
    - Includes specifications for curing the drilled shaft concrete after placement
  - i: Sonic Testing
    - Includes specifications on performing the sonic testing, logging equipment and procedure, and submitting the test for KDOT review.
    - Also includes specifications on coring in the case of an anomaly indicated by the test and filling the core holes and pipes after the testing is complete
  - j: Backfill
    - Includes specifications on backfilling spaces between the permanent casing and the temporary casing.

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Concrete Mix Design

- 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.

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Concrete 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	No. 200
MA-3	Optimized All Concrete		0	2-12	Note[1]	Note[1]	Note[1]	Note[1]	Note[2]	Note[2]	Note[2]	95-100	98-100
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	98-100
MA-5	Optimized Drilled Shafts		0	2-12	8 min	22-34		55-65		75 min		95-100	98-100
MA-6	Optimized for Bridge Overlays		0	0	2-12	Note[1]	Note[1]	Note[1]	Note[2]	Note[2]	Note[2]	95-100	98-100
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

[1]Retain a maximum of 22% (24% for MA-6) and a minimum of 6% of the material on each individual sieve.
[2]Retain a maximum of 15% and a minimum of 6% of the material on each individual sieve.

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Concrete Mix Design

- What are we looking for in a concrete mix?
  - 703.2a
    - Grade 4.0 concrete that complies with Sections 401 (General Concrete), 402 (Structural Concrete), and 1102 (Aggregates for Concrete Not Placed on Grade)
    - Target Slump = 9” ± 1”
      - Concrete should flow between the rebar cage without being vibrated
    - Do not withhold water at the plant!
    - Do not add water at the site!

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Concrete Mix Design

- Trial Mix
  - The concrete specification requires that a trial batch be produced and tested, unless a positive history exists. This is the time to perform a slump loss analysis. This includes the slump loss test.
  - The trial batch conducted by the concrete producer is observed by the contractor and engineer, typically onsite to model site conditions (drive time, revolutions of truck, etc.)

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Concrete Mix Design

- Trial Mix
  - Slump Loss Test:

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: 5/21/2012
11:15 AM	0:00	9 1/4	-	-	78.1	78.1	
11:45 AM	0:30	9	-	-	80.4	80.0	Time Test Started
12:15 PM	1:00	8 3/4	-	-	83.3	80.2	11:15 AM
12:45 PM	1:30	8 1/2	-	-	86.2	83.8	
1:00 PM	1:45	7 3/4	-	-	87.3	83.8	Contract Number:
1:15 PM	2:00	7	-	-	87.4	85.1	
1:30 PM	2:15	7	-	-	89.1	88.0	
1:50 PM	2:35	6 1/2	-	-	91.2	89.6	Project Number:
2:05 PM	2:50	5	-	-	93.2	90.0	67 C-4270-01
2:20 PM	3:05	4	-	-	94.5	89.2	
2:35 PM	3:20	3 1/2	-	-	95.4	90.3	Ready Mix Plant:
2:50 PM	3:35	2	-	-	95.6	91.5	O'Brien Ready Mix
							Parson's
							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.

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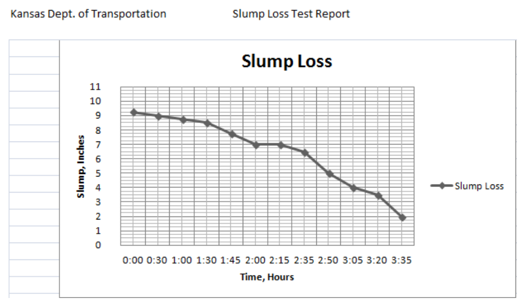
Concrete Mix Design

- Trial Mix Slump Loss Test:

Kansas Dept. of Transportation Slump Loss Test Report

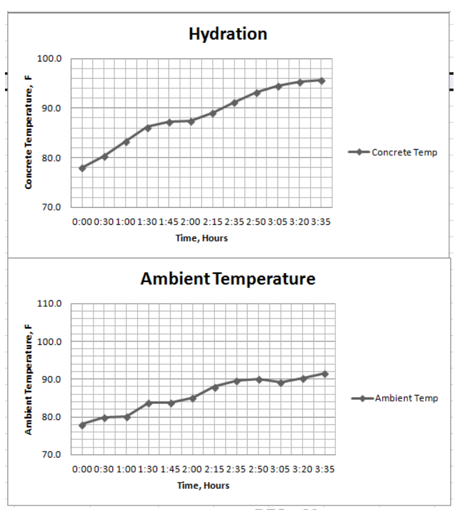
Time	Elapsed Time	Slump from In-Place (In.)	Slump from Mixer Truck (In.)	% Air (if Entrained)	Concrete Temp	Ambient Temp	Date of Test: 5/21/2012
11:15 AM	0:00	9 1/4	-	-	78.1	78.1	
11:45 AM	0:30	9	-	-	80.4	80.0	Time Test Started
12:15 PM	1:00	8 3/4	-	-	83.3	80.2	11:15 AM
12:45 PM	1:30	8 1/2	-	-	86.2	83.8	
1:00 PM	1:45	7 3/4	-	-	87.3	83.8	Contract Number:
1:15 PM	2:00	7	-	-	87.4	85.1	
1:30 PM	2:15	7	-	-	89.1	88.0	
1:50 PM	2:35	6 1/2	-	-	91.2	89.6	Project Number:
2:05 PM	2:50	5	-	-	93.2	90.0	67 C-4270-01
2:20 PM	3:05	4	-	-	94.5	89.2	
2:35 PM	3:20	3 1/2	-	-	95.4	90.3	Ready Mix Plant:
2:50 PM	3:35	2	-	-	95.6	91.5	O'Brien Ready Mix
							Parson's
							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.



Concrete Mix Design

- Trial Mix Slump Loss Test:
  - Other Graphs



DES - 20

Casings

- Specification 703.2e – Materials
  - Must have sufficient thickness to carry working stress and construction loads
  - Minimum of 14 gage corrugated metal pipe for permanent casings
  - If required, provide permanent casing that is no more than 1” out of round
  - The deviation of a chord from end to end shall be at maximum 2”
  - The Engineer will accept the casing based on compliance with specified requirements and visual inspection

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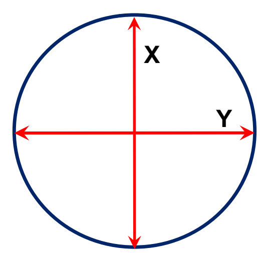
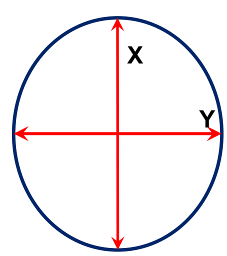
Casings

- Specification 703.2e – Materials
  - If X = Y
    - Casing is round



  - If X>Y or Y>X
    - Casing is “Out of Round”
    - If the difference between X and Y is not more than 1”, the casing is acceptable



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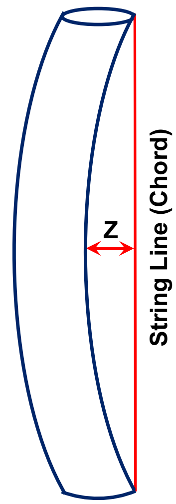
Casings

- Specification 703.2e – Materials
  - String Line (Chord) is from end to end of shaft
  - If "Z" is no more than 2" then casing is acceptable



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DES - 23

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Casings

- Specification 703.3g – Raising Temporary Casing
  - Do not remove temporary casing until the concrete has met the following conditions:
    - Shafts have been allowed to set for a minimum of 24 hours after concrete placement and the concrete has developed 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 the completion of the concrete placement.
  - Immediately after completing concrete placement in the permanent casing, it is acceptable to raise and hold the temporary casing at the embedment depth + 6"

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Casings

- Make sure the minimum rock socket length is provided
  - Do not try to make a hole dry by advancing the casing
    - This is a case where deeper in not better
    - Set the bottom of the casing where 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.

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Plans

- General Notes Sheet – Contains notes for construction of the drilled shafts
- Construction Layout Sheet – Contains information on the location of the drilled shafts
  - Top of shaft elevations
  - Stations of the piers along Crown Grade or Profile Grade
- Engineering Geology Sheet – Contains information on the shaft depths and geological investigations
  - Top of shaft elevation
  - Tip elevations
- Pier Details Sheet – Contains information on the pier and drilled shaft locations
  - Drilled shaft spacing
- Drilled Shaft Details Sheet – Contains information on drilled shaft reinforcement and size and casing depths. Typically includes notes and elevations for the shafts as well.

DES - 26

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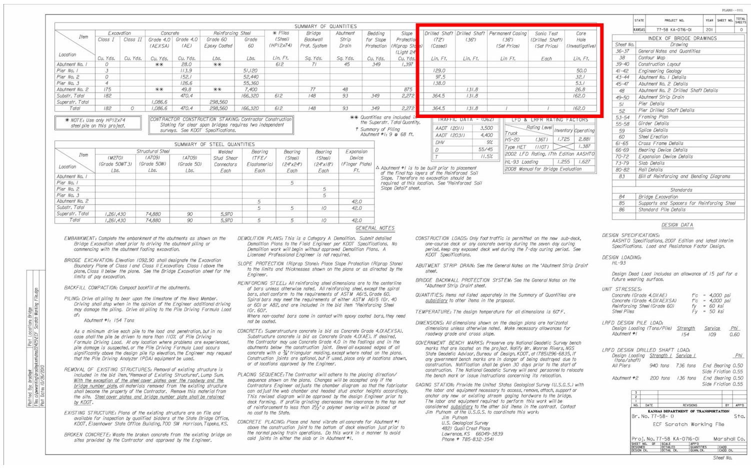
Plans - General Notes Sheet Example



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Plans – Typical Notes

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 (42")". 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 location(s) 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.

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Plans – Other Notes

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.

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.

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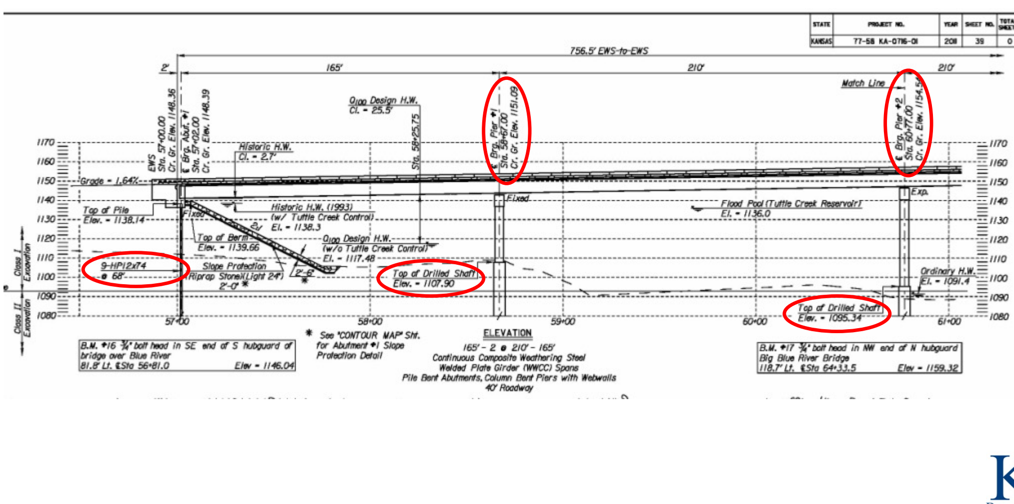
Plans – Construction Layout



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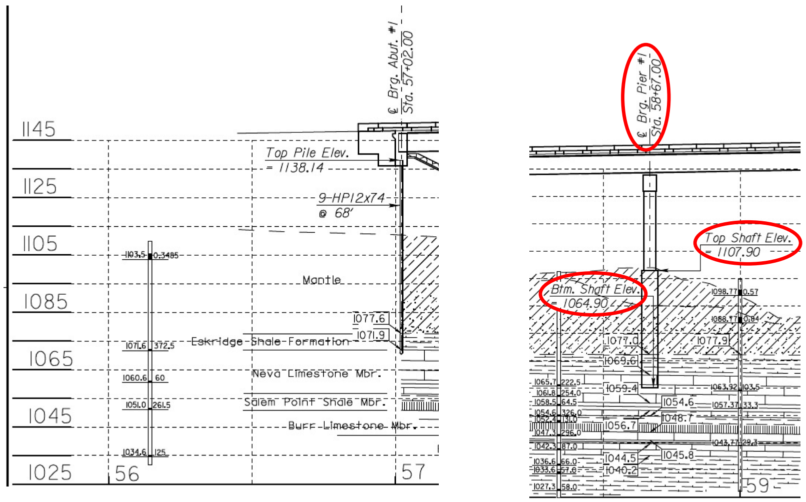
Plans – Engineering Geology



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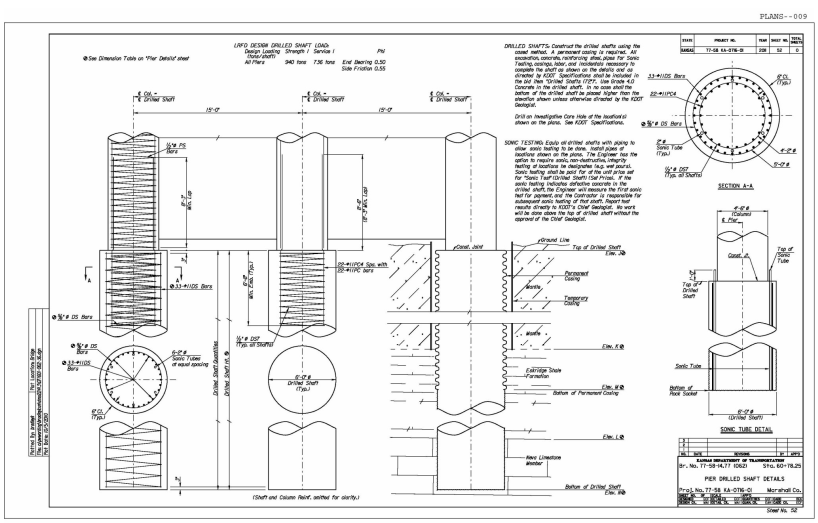
Plans – Pier Details



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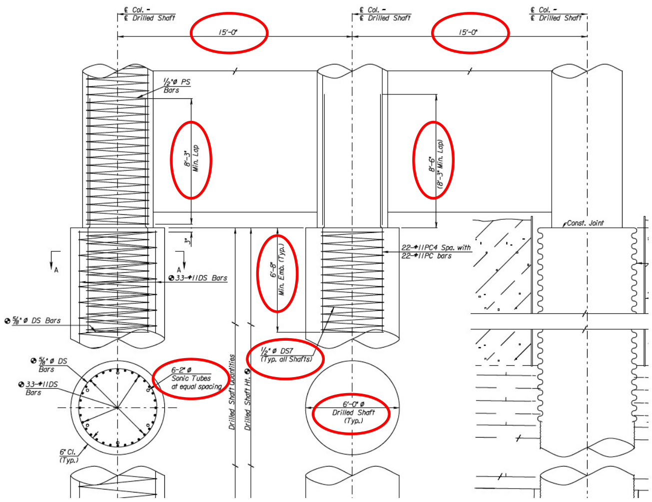
Plans – Drilled Shaft Details



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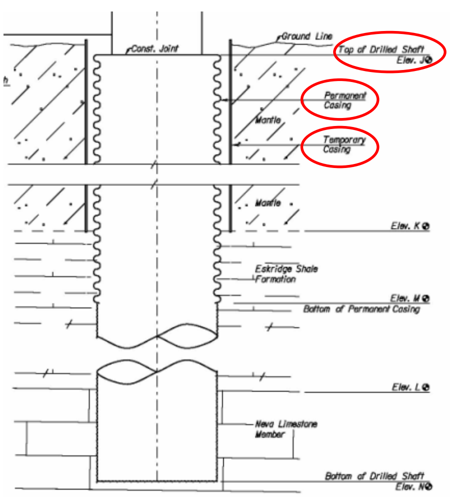
Plans – Drilled Shaft Details



ELEVATION TABLE

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	1109.78
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

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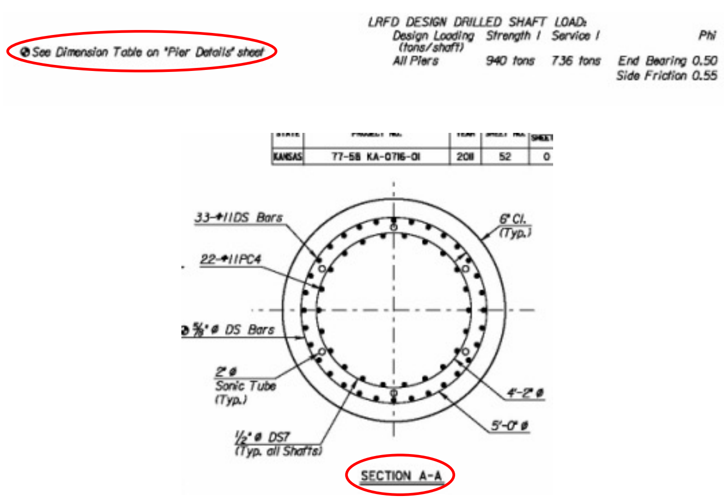
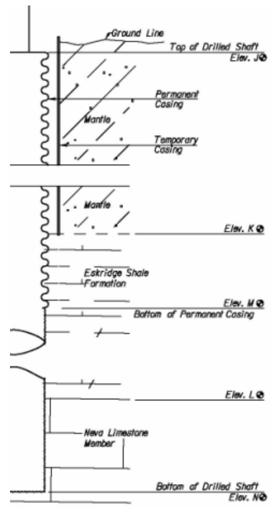
Plans – Drilled Shaft Details





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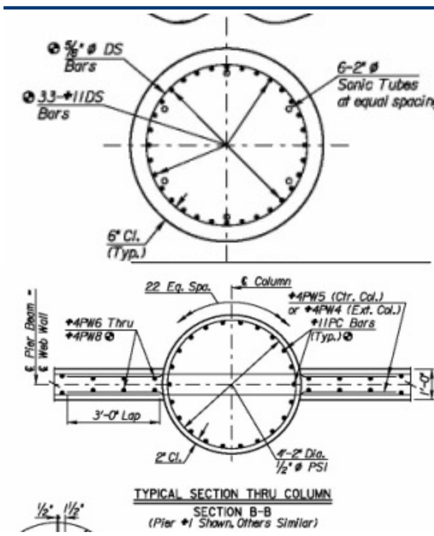
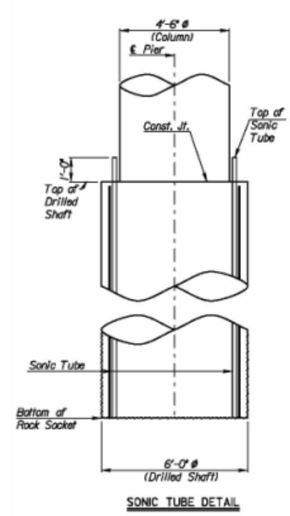
Plans – Drilled Shaft Details





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Drill Rig

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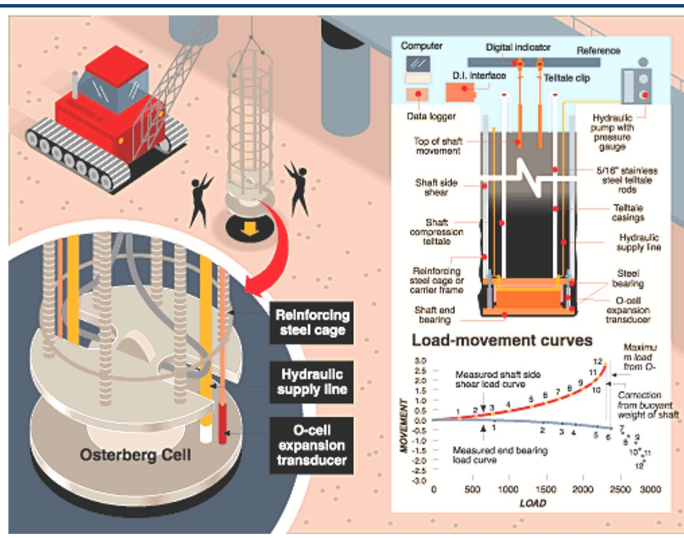
Osterberg Cell



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Osterberg Cell

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Osterberg Cell

- Why do we use O-Cell tests?
  - The test shaft in the O-Cell test will behave similar to production shafts. This gives the contractor a heads up on construction practices needed on the site
  - The test provides real skin friction and end bearing values
  - Should give the same capacity data (or more) that was calculated
  - Provides the most economical shaft for the structure
- Downsides?
  - It's not cheap!

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Questions?

- Contact me at Seth.Weber@ks.gov
- Or through Canvas

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DRILLED SHAFT EQUIPMENT

BY

KYLE HALVERSON

CHIEF GEOLOGIST

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

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

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

Drilled shafts are often used for tower structures to resist uplift loads and for constructability

Light tower Shafts maybe set into bedrock or soil.

Drilled shafts used in an tangent-pile retaining wall for excavation support

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

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

Basic elements of a drilled shaft rig

DRILLED SHAFT RIGS

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

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

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

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

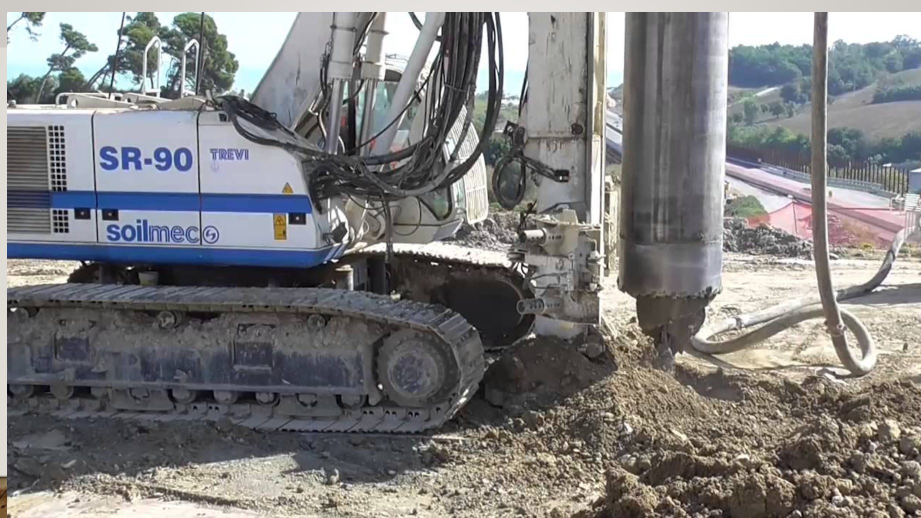
Crane attachment, mounted on a bridge platform that can drill to 328 ft. with torque of 340 kN-m

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.

SOILMEC SR-90

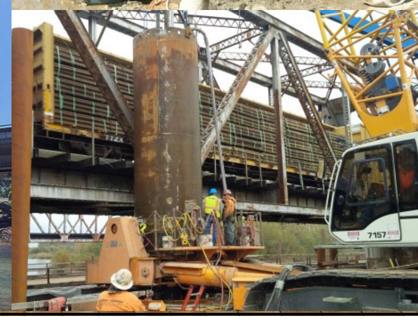
Can be configured with dual rotary heads to install casing while drilling inside the casing with an auger



The Leffer Oscillator

installs casing by oscillation
soil is excavated from inside as casing is advanced

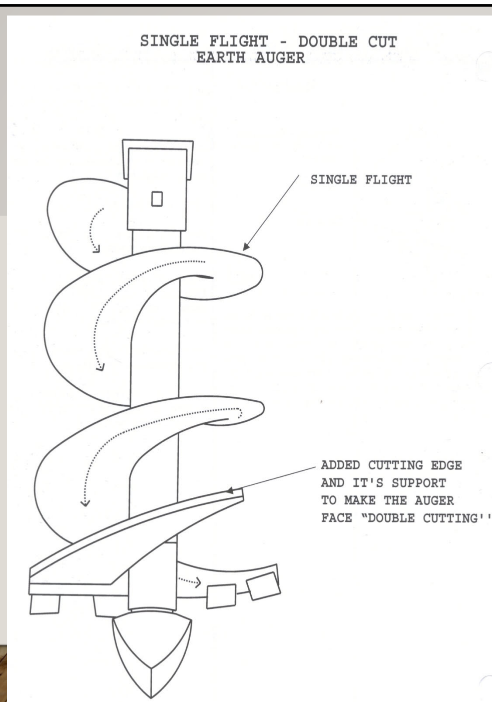
7 ft. diameter shafts, 69-121 ft. deep

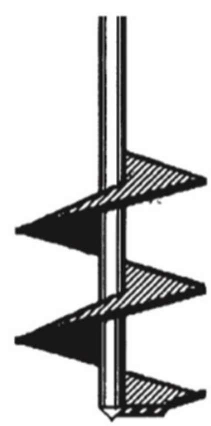


Clamshell hammer grab tool

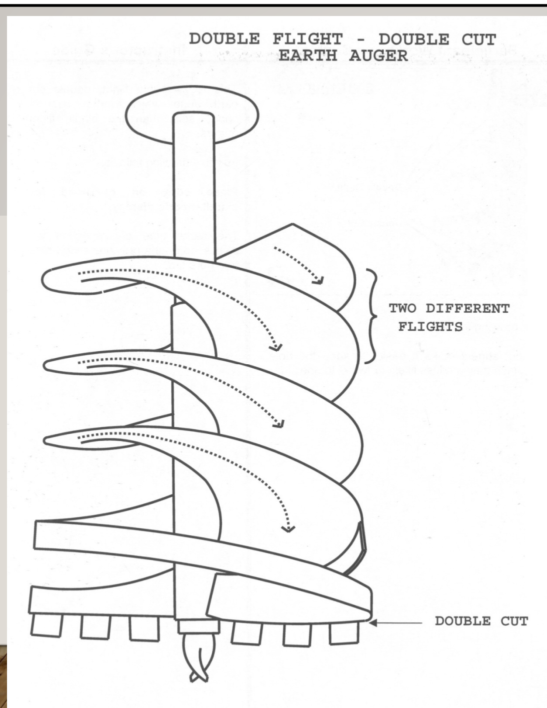
AUGERS

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





Single Flight Auger.

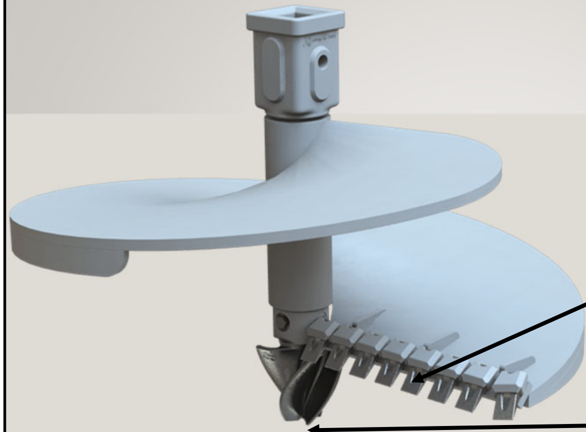


Double Flight Auger.

ADJUSTABLE DIAMETER SOIL AUGER

Single-Flight

Soil Auger

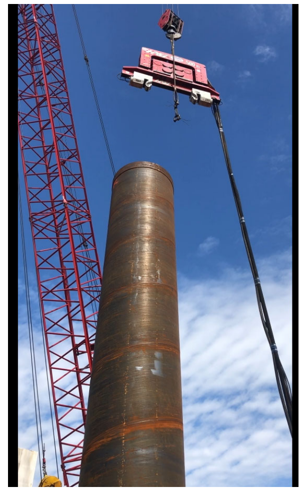


6-33

Casing may be placed by:
gravity (it's own weight)

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

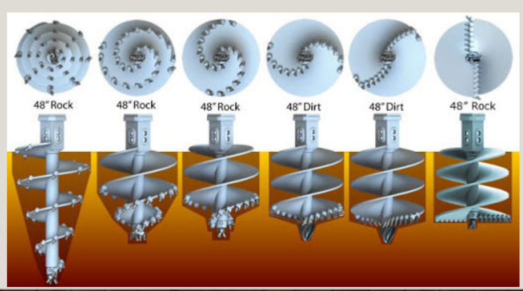
Vibratory Hammer
Make sure hammer has two clamps
One is for sheet pile installation!



ROCK AUGERS

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

- Tapered Geometry
- Conical (Bullet) Carbide Teeth



6-36

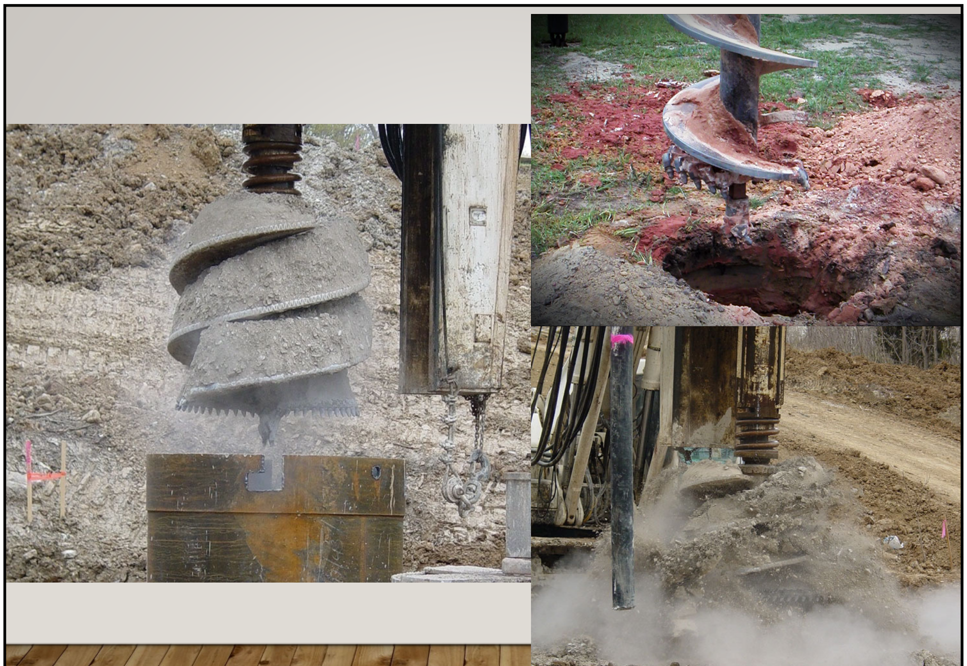
ROCK AUGERS

Pocket

Carbide tip tooth

Carbide tip
Replaceable tooth
Stinger

6-37

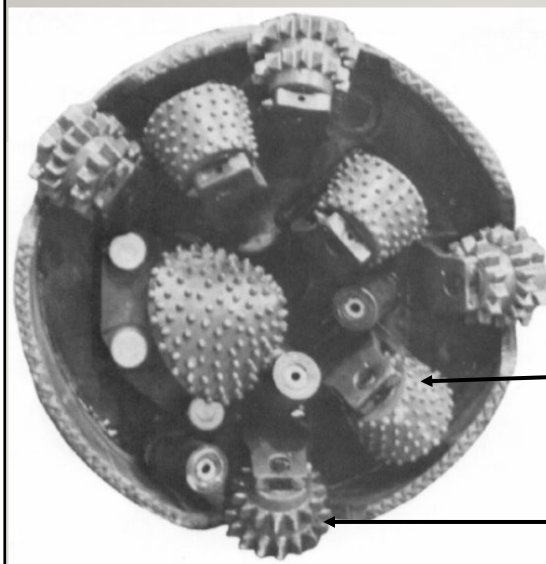


ROCK
CORE
BARREL

END VIEW OF CORE BARREL

ADDITION OF ROLLER CONE BITS FOR HARD BEDROCK

ROCK BITS



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

Circulating bit

Replaceable Roller Bits

Down hole Hammer Bit for very hard rock

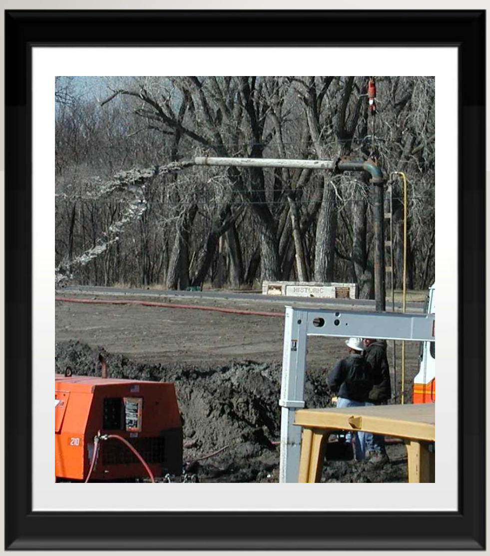
CLEAN OUT BUCKET

CLEANOUT BUCKET IN OPERATION

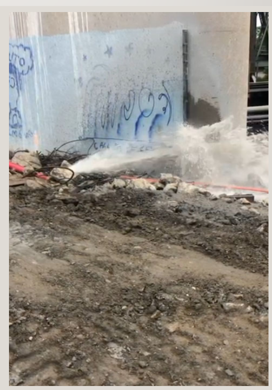
CLEANOUT TOOL

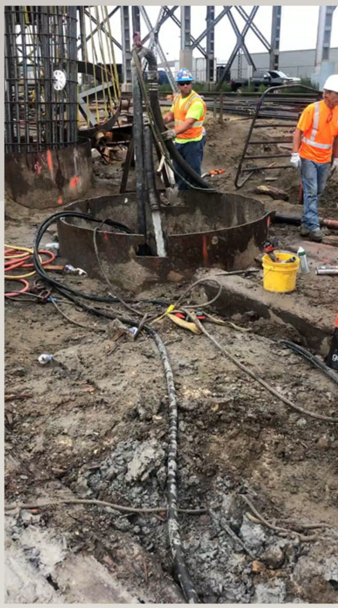
Final cleaning down-the-hole pump

6-52



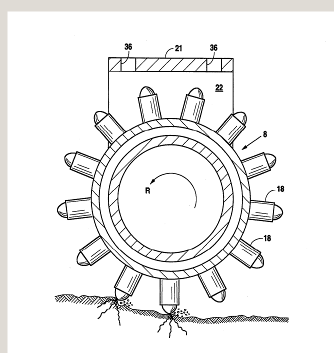
AIR LIFT

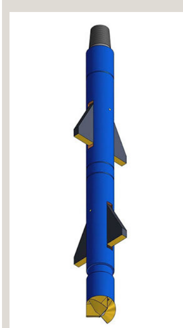




Overreaming Bucket

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





6-58

WHAT WILL THE INSPECTOR NEED AT THIS POINT?

- Weighted Tape
- Field Book
- Bridge Foundation Geology Report

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

- Tool and Casing Diameters
- Casing Lengths
- Casing Cleanliness

Good Luck!

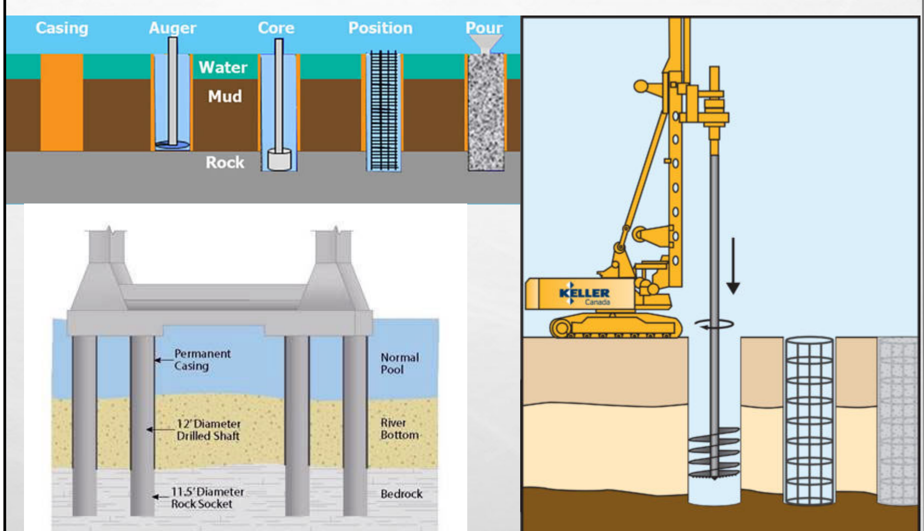
DRILLED SHAFT EXCAVATION AND CLEANING

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

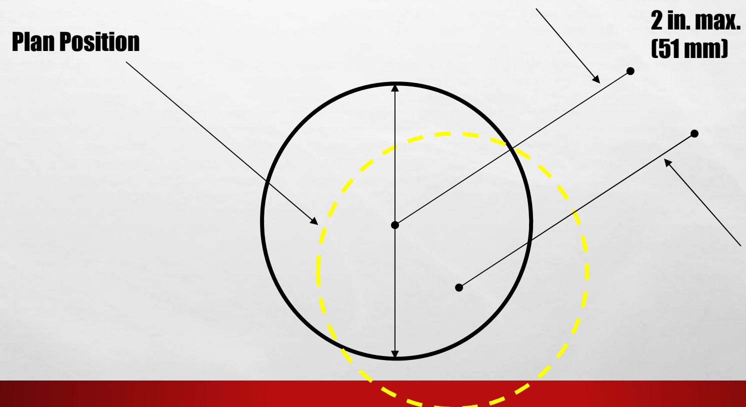
TRIAL DRILLED SHAFT

- 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.



11-3

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

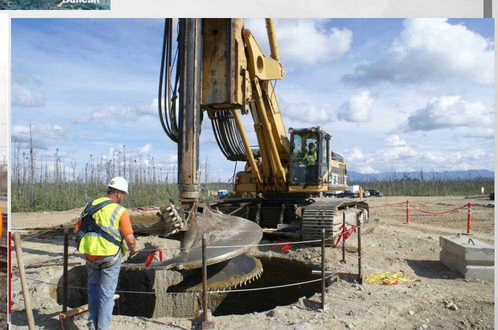


11-15

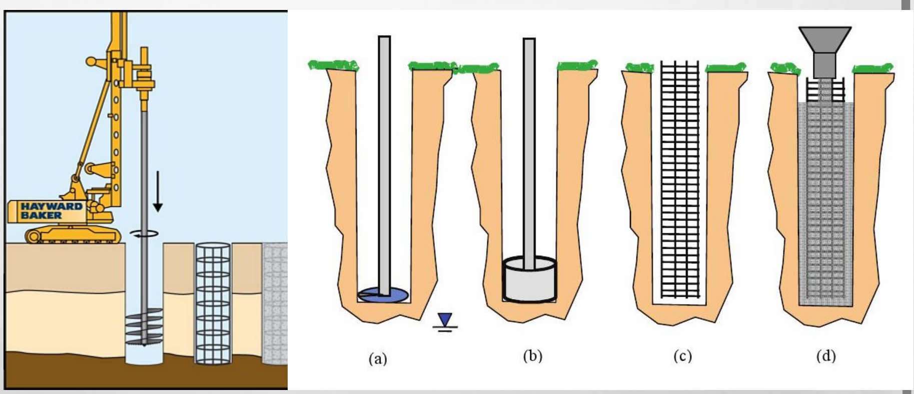
AUGER SOIL MANTLE

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

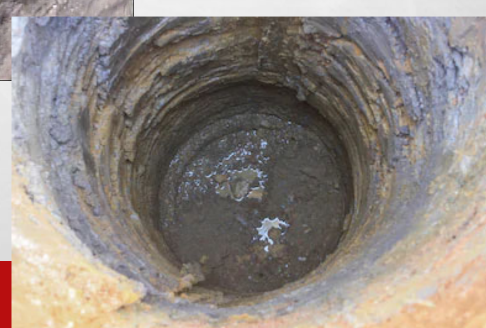
Auger Soil Mantle



Dry Pour Method



Dry Pour Method



TEMPORARY CASING

VIBRATING THICK-WALLED PERMANENT CASING

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.

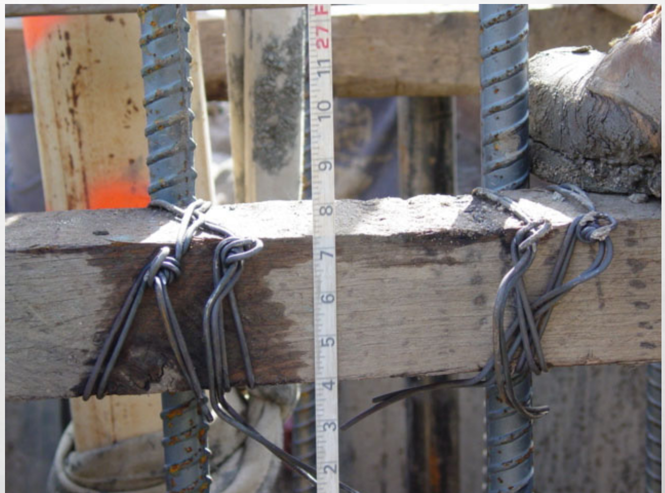
ROCK SOCKET EXCAVATION

- 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.

EXCAVATION OF THE BEDROCK

CHECK DEPTHS WITH A WEIGHTED TAPE

MEASURE TO A KNOWN REFERENCE POINT



CHECK THE DEPTHS!

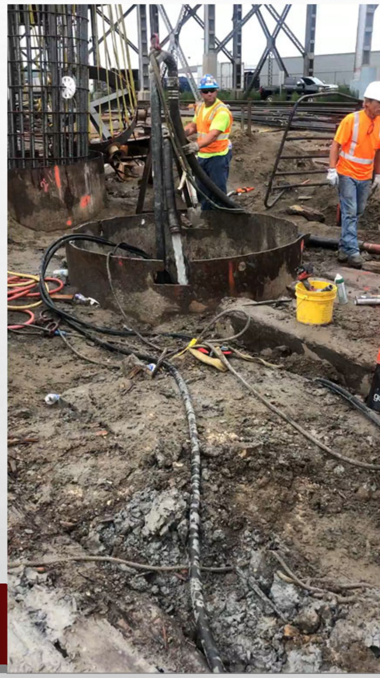
CLEANING OUT THE ROCK SOCKET

THIS MAY BE DONE SEVERAL TIMES!

CLEANING OUT ROCK SOCKET

- HTTPS://YOUTU.BE/RTOO4LJYG9G

AIR LIFT PUMP



CLEAN WATER INDICATES A CLEAN SOCKET

CLEANED ROCK SOCKET

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.

PERMANENT CASING

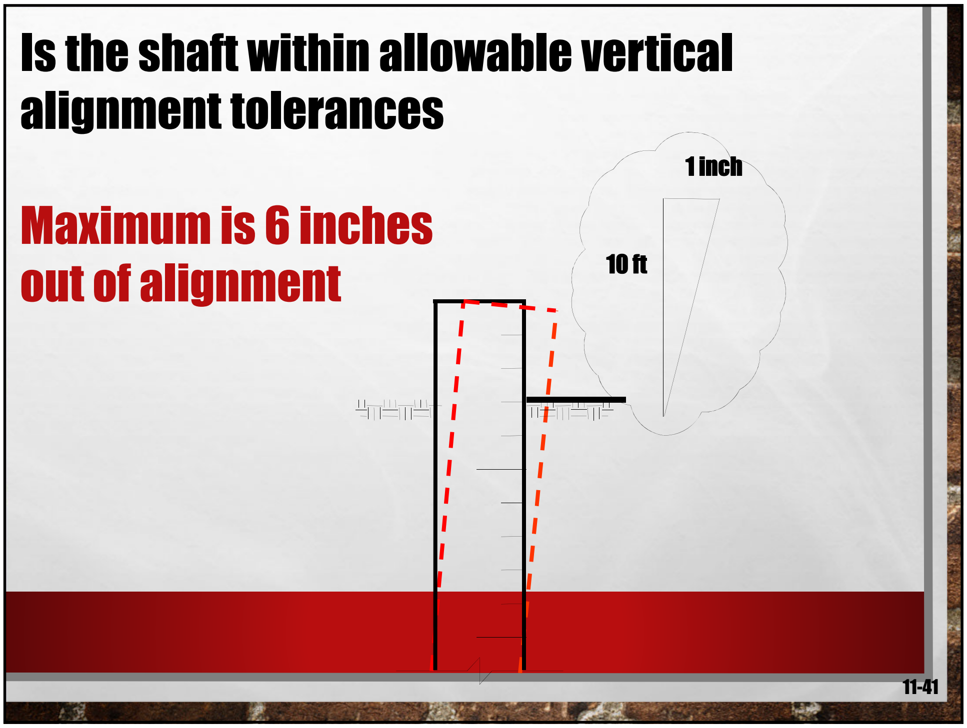
- Permanent Casing is required when you have a wet pour or specified on the plans.
- Permanent Casing must be water-tight and can be a corrugated metal pipe or a thick walled metal pipe.
- Casing can not be more than 1 inch out or round.
- Deviation of a chord must be less than or equal to 2 inches.

INSTALLATION OF CMP PERMANENT CASING

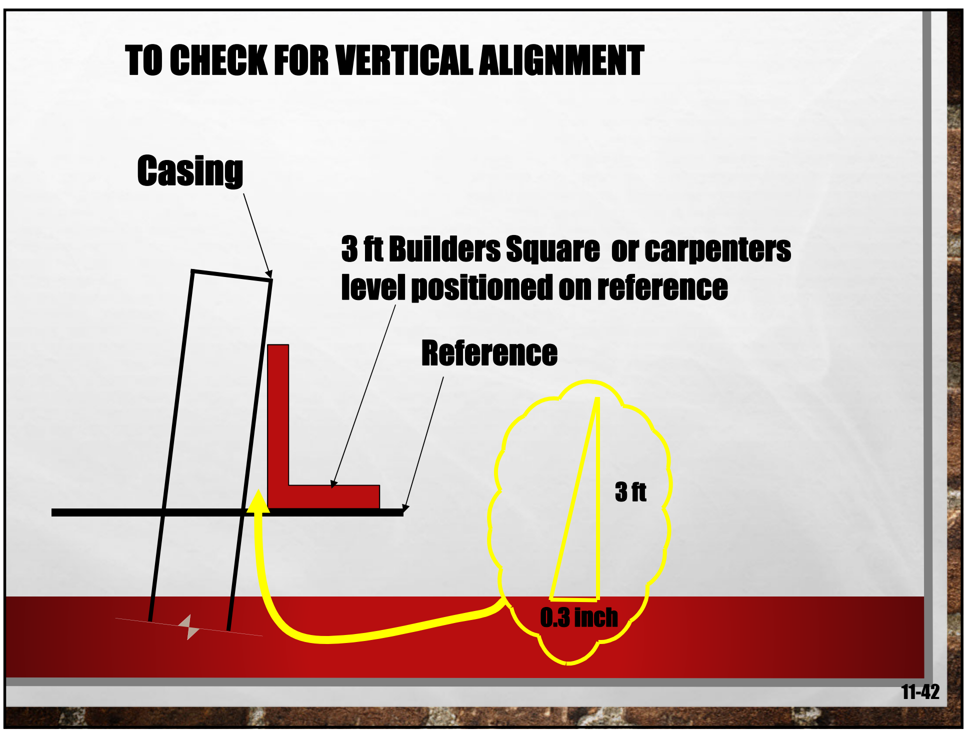
INSTALLATION OF PERMANENT CASING

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?

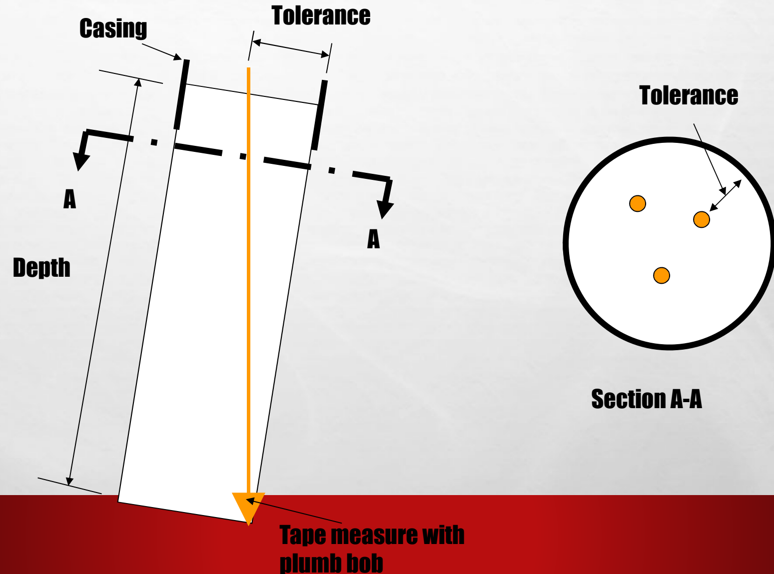


Is the shaft within allowable vertical alignment tolerances
Maximum is 6 inches out of alignment
1 inch
10 ft
11-41



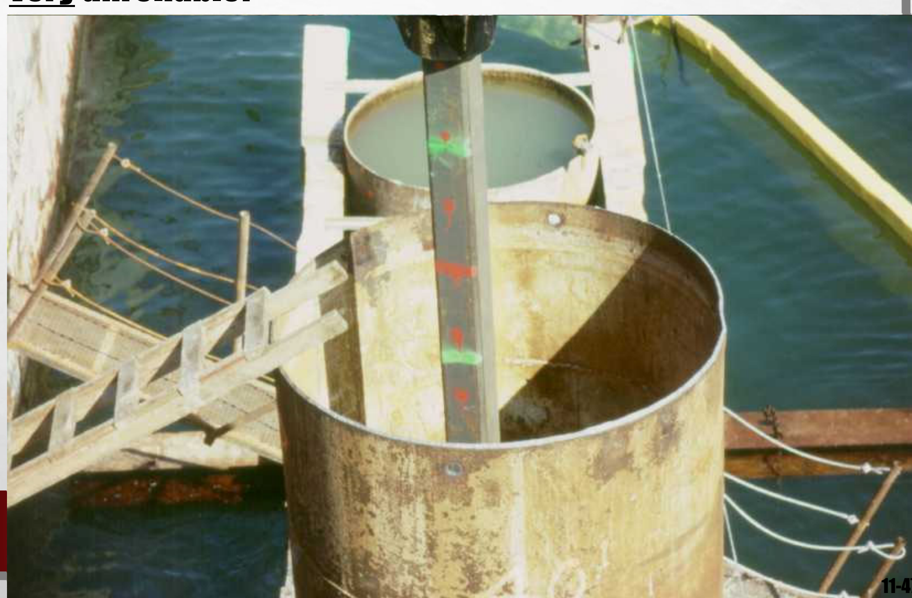
TO CHECK FOR VERTICAL ALIGNMENT
Casing
3 ft Builders Square or carpenters level positioned on reference
Reference
3 ft
0.3 inch
11-42

TO CHECK FOR VERTICAL ALIGNMENT



11-43

Is the shaft of proper depth? Marks on a Kelly Bar are <u>very</u> unreliable!



11-47

Does the shaft bottom meet the requirements?

ROCK SOCKET EXCAVATION INSPECTION

- **Maximum depth of sediment or debris = ½ 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

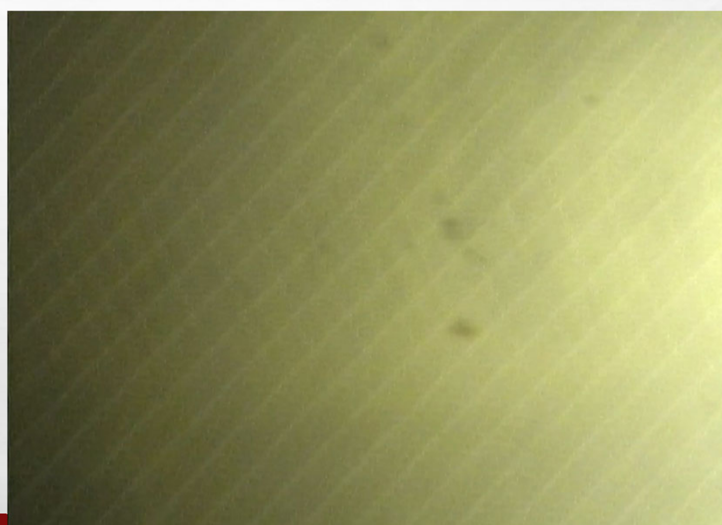
CHECK DEPTHS WITH A WEIGHTED TAPE

11-59

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.

VIDEO RECORDING



VIDEO RECORDING

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

TYPICAL PROBLEM

11-65

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

No concrete

11-67


ANY QUESTIONS?
SHAFT
EXCAVATION
&
CLEANING
11-70

Reinforcing Cage
Drilled Shaft Inspection

1

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1

Inspector Duties

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

2

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2

Special Provision 15-07007-R01

- 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

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3

Special Provision 15-07007-R01

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

4

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4

Requirements for Shaft before reinforcing steel placement

- 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

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5

Requirements for Shaft before reinforcing steel placement

- 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

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6

Requirements for Shaft before reinforcing steel placement

- 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

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7

7

Placing Reinforcing Steel and Sonic Testing Pipes

- 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

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8

8

Placing Reinforcing Steel and Sonic Testing Pipes

- 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

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9

Placing Reinforcing Steel and Sonic Testing Pipes

- 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

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10

Placing Reinforcing Steel and Sonic Testing Pipes

- 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

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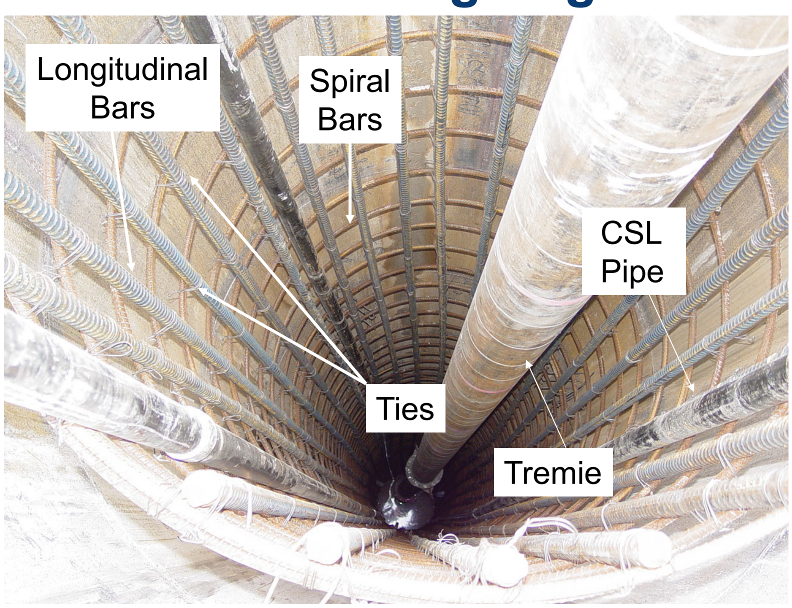
11

Reinforcing Cage



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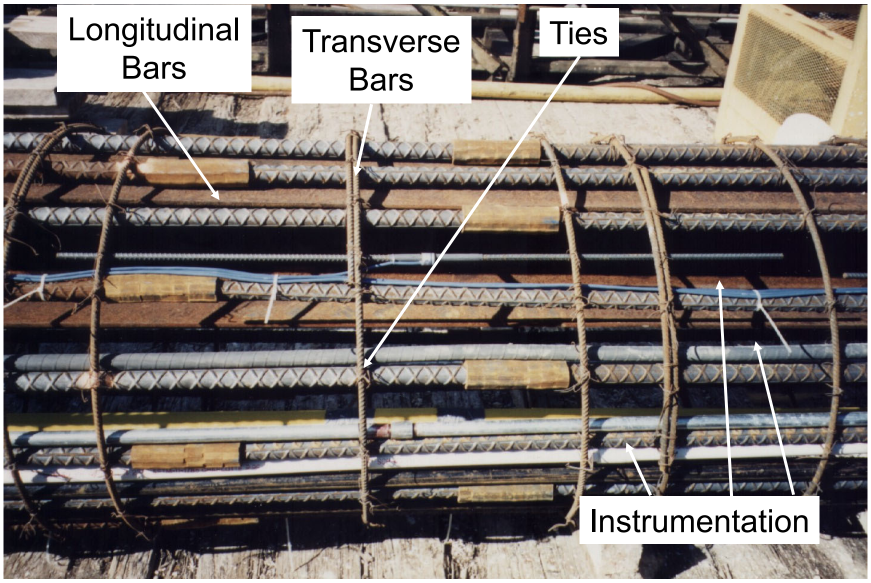
12

Reinforcing Cage



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

- Steve Rose
- Steve.Rose@ks.gov
- Phone 620-727-3709

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15

Reinforcing Cage
Drilled Shaft Inspection

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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

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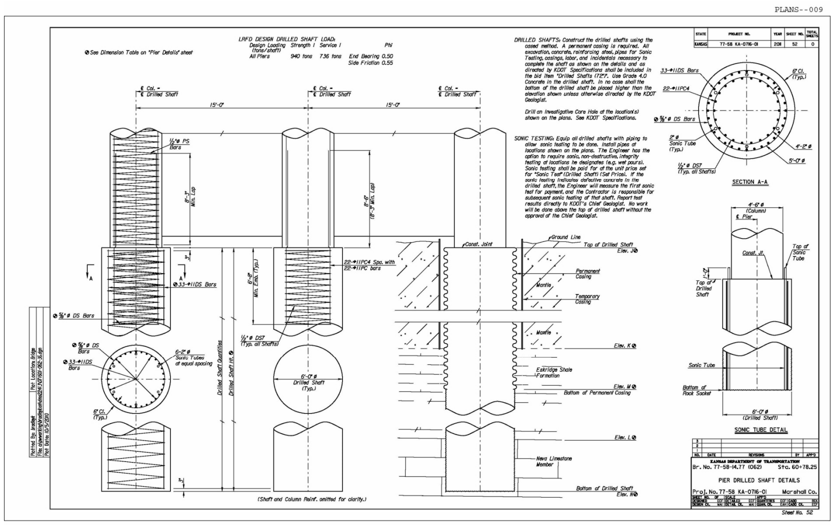
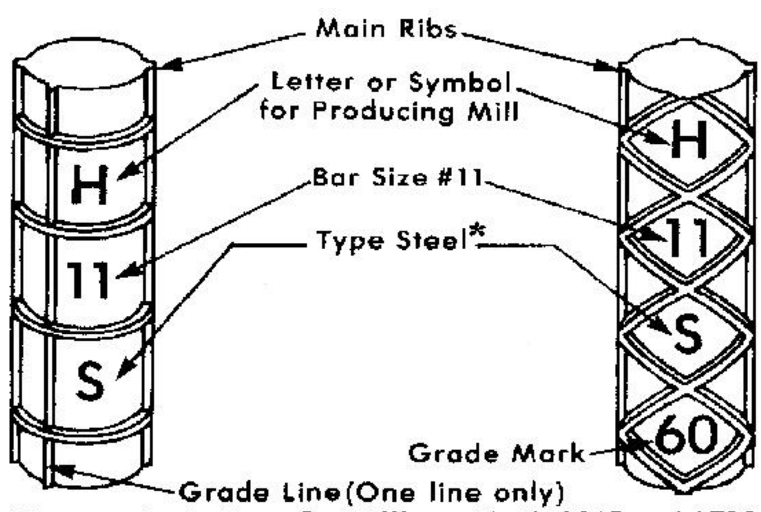
2

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



3

IDENTIFICATION MARKS ASTM STANDARD REBARS



*Bars marked with an **S** and **W** meet both A615 and A706

GRADE 60

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

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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

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6

Storage & handling

Kansas
Department of Transportation

7

7

Properly Tie Reinforcing Steel

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Department of Transportation

8

Properly Tie Reinforcing Steel

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

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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")

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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

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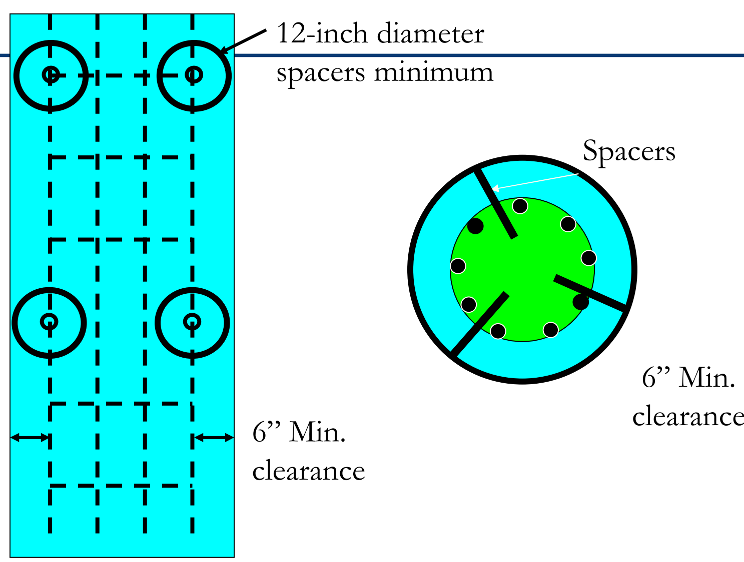
13

Clearance



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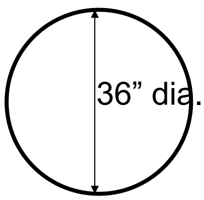
Circumference of a Circle

Circumference (C) = πD

Where: C = circumference
D = diameter = 2 times radius
π = 3.142

PROBLEM



What is the circumference of the shaft in inches?

In feet?

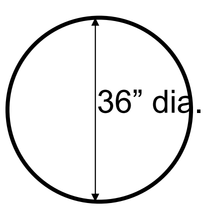
15

Circumference of a Circle

Circumference (C) = πD

Where: C = circumference
D = diameter = 2 times radius
π = 3.142

PROBLEM



What is the circumference of the shaft in inches?

$C = \pi D$

C = 3.142 (36")

C = 113.1 inches

In feet?

$C = \pi D$

C = 3.142 (3 ft.)

C = 9.43 ft.

16

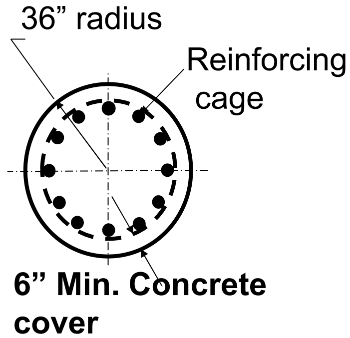
Circumference of the Reinforcing Cage

Circumference (C) = πD

Where: Diameter of cage = Shaft diameter minus 2 times the Concrete cover

D = diameter = 2 times radius

π = 3.142



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

17

Circumference of the Reinforcing Cage

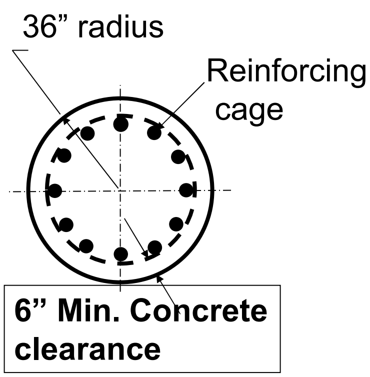
What is the circumference of the reinforcing cage in inches.?

D = 72"– 2 x Req'd Clearance

D = 72" – 12" = 60"

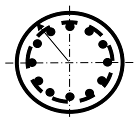
C = πD or 3.142 x 60"

C = 189"

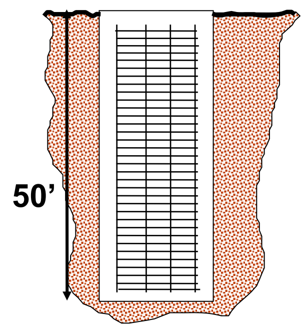


18

Side Spacer for Shaft Alignment



SAME CIRCUMFERENCE AS PREVIOUS PAGE



…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 =

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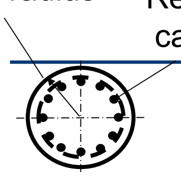
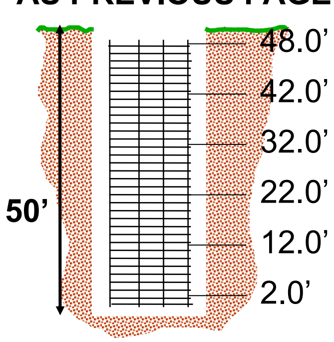
Side Spacer for Shaft Alignment



SAME CIRCUMFERENCE AS PREVIOUS PAGE



How many side spacers are required shaft?

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

How many levels? ➡ **6**

Total number of spacers = 7 X 6 = 42

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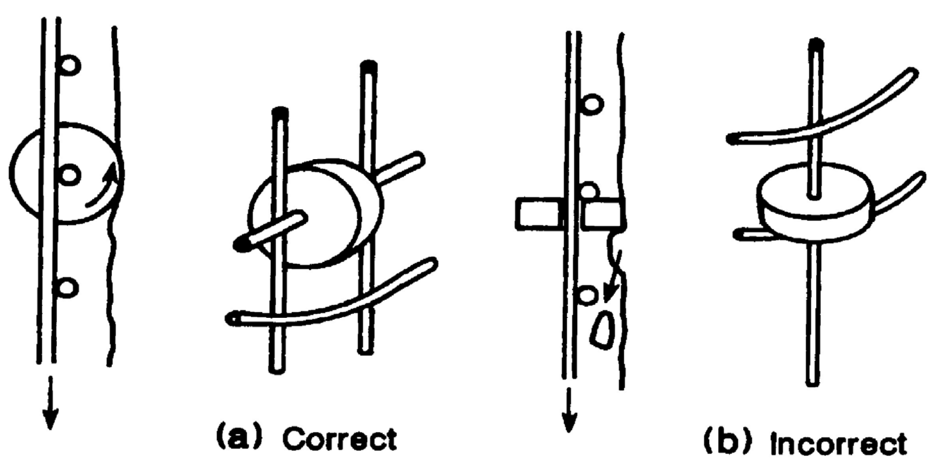
Cage Diameter (in.)	No. of spacers required
30	4
36	4
42	5
48	6
54	6
60	7
66	7
72	8
78	9
84	9

21

21

Clearance



22

Install proper number of spacers around and up the shaft

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Typical Spacers

Click the spacers into place.

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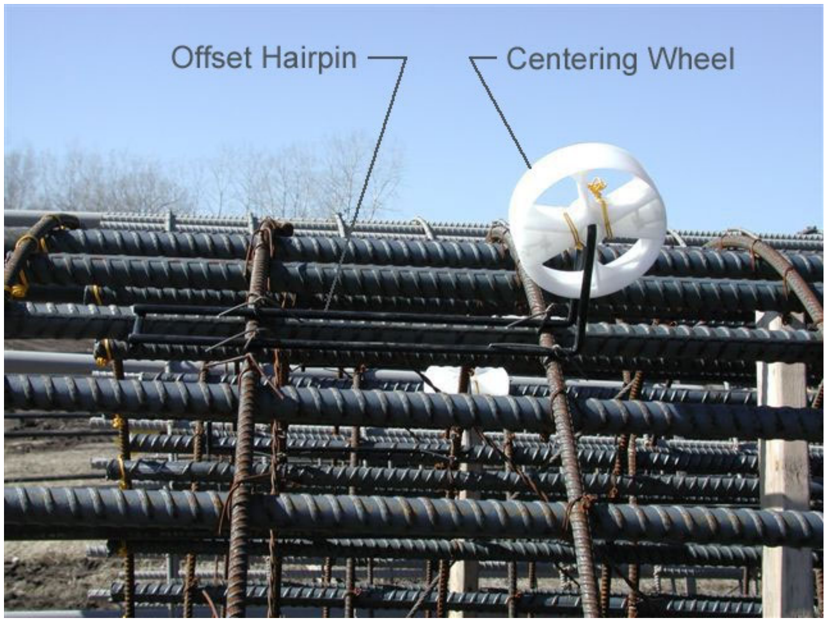

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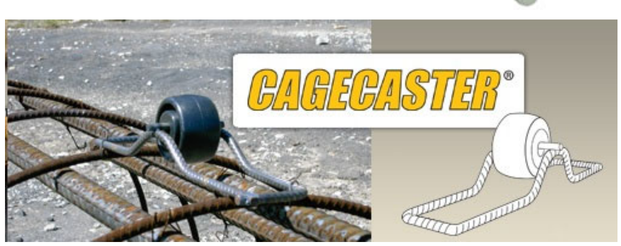

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27

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

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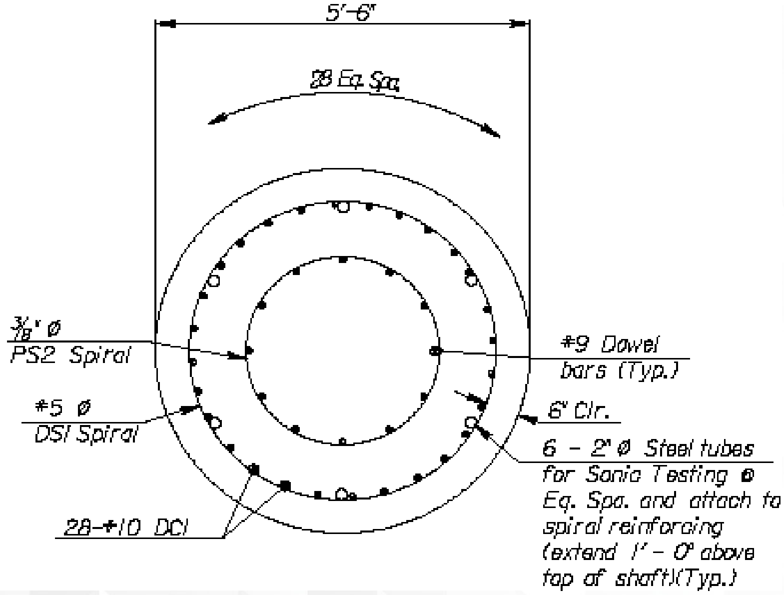
2

Cross-hole Sonic Logging (CSL) Tubes



3

Cross-hole Sonic Logging (CSL) Tubes

- 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

4

Placing Sonic Testing Pipes

- 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

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5

Placing Sonic Testing Pipes

- 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.

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6

Cross-hole Sonic Logging (CSL) Tubes

- 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

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7

7

Cross-hole Sonic Logging (CSL) Tubes

- 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

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8

Cross-hole Sonic Logging (CSL) Tubes

- 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

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Reinforcing Cage Placement
Drilled Shaft Inspection


1

SPLICING OF CAGE

- 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

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2

SPLICING OF CAGE

- 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

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3

SPLICING OF CAGE

- 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

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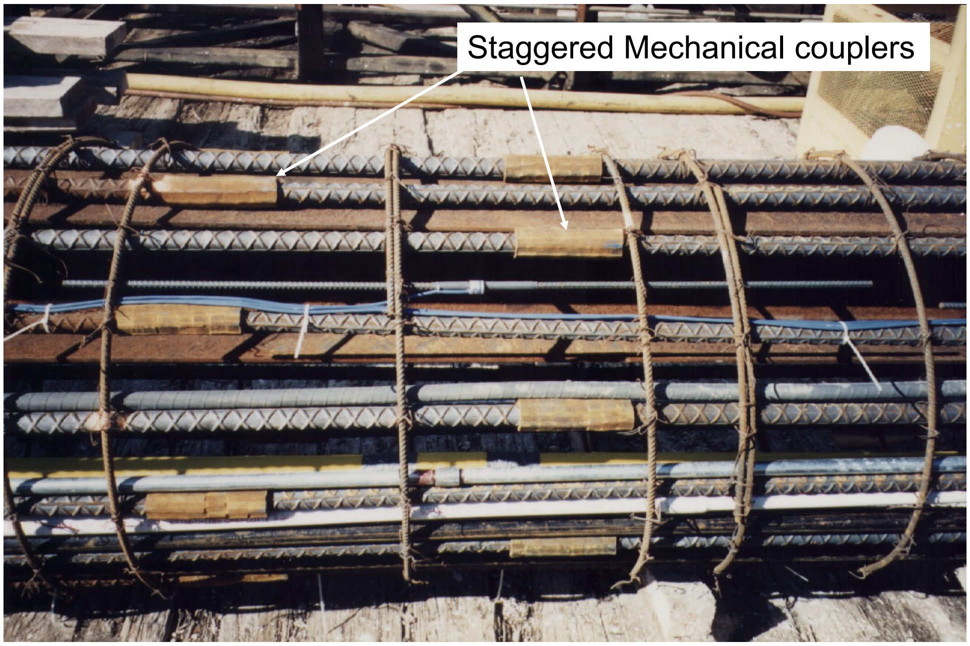

5

Cage bent 90^0

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Keeping the cage in place

- 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

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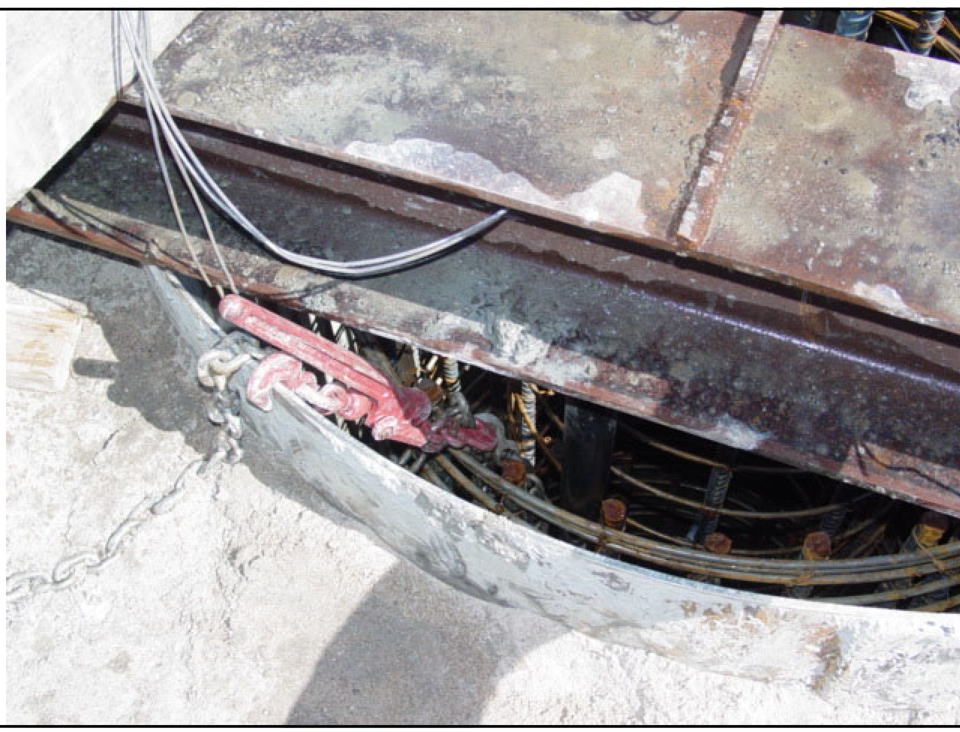
19



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Reinforcing Cage Pictures

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1

When things go bad

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2

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3

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Session 6: Drilled Shaft Concrete Placement

Seth Weber – Bridge Design

KDOT IKE
THE EISENHOWER LEGACY TRANSPORTATION PROGRAM

1

Learning Objectives

- Learn the methods in the specification 703.3f used to place concrete in drilled shafts
- Understand how to identify problems in the drilled shaft from concrete volume curves

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Topics to Discuss

- Dry vs. Wet Pour
- Methods of Concrete Placement
- Procedure for Concrete Placement
- Measurement and Payment
- Calculating, plotting, and interpretting Concrete Volume Curves

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Dry vs Wet Pour

- How to determine if you use a dry or wet pour:
  - Is the shaft dry?
    - Yes: Use the Dry Pour Method
  - Is there water in the shaft?
    - Yes:
      - 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 turned off?
        - Yes: you could use dry pour
          - Only 2” or less of water is allowed in the bottom of the shaft when placement begins!
        - No: use one of the three wet pour methods

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Dry Pour (Free Fall) Method

- Use a centering device to deposit concrete so that the falling concrete does not come into contact with vertical and horizontal reinforcing steel and wire supports
- The centering device must extend 8' into the shaft to control the concrete fall

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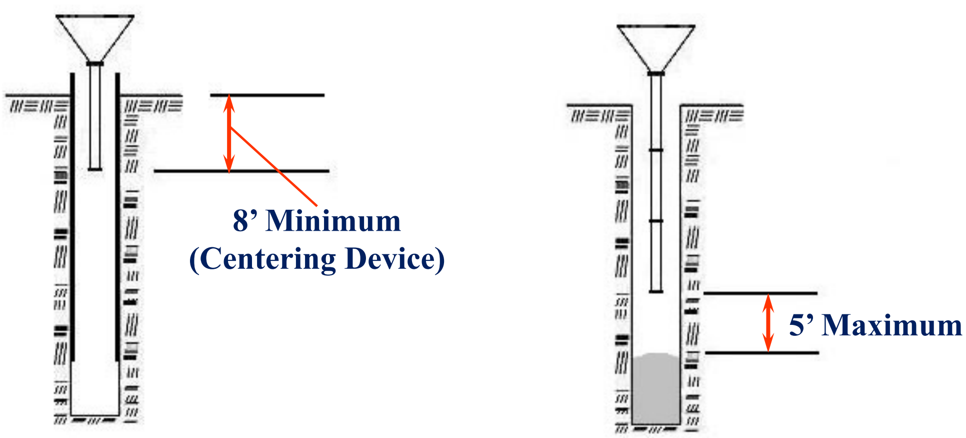
Dry Pour (Free Fall) Method



Unlimited Free Fall Only for Cased Shaft

Limited Free Fall for Uncased Shaft

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Dry Pour (Free Fall) Method

7

Wet Pour Methods

- There are three methods to perform a wet pour in specification 703.3f:
  - Method A – Using a concrete brake, tremie tube, and foam pig
  - Method B – Using a hopper, tremie tube, and foam pig
  - Method C – Using a hopper and gated tremie tube
- To successfully perform a wet pour it is imperative to separate the ground water from the plastic concrete by performing the following steps:
  - 1. Wait for a static water line to develop in the shaft (the water line stays at one elevation)
  - 2. Fully charge the system
  - 3. Develop an initial seal
  - 4. Maintain at least 7' embedment in the concrete while filling
  - 5. Over pump the contaminated concrete

8

Wet Pour Methods

- All methods for placing concrete using the wet pour methods contain the following:
  - Allow the water level to become static (does not change over time)
  - Place the concrete with sealed (watertight) tremie tube or pump with a rigid and watertight extension tube
  - Use a device (a pig or flap gate) to prevent water from entering the tube while charging
    - Commercially available pigs shall be 110% of the diameter of the tube
  - Clearly label the outside of the tremie in 1’ 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 with concrete
  - Once fully charged, raise the tube off the bottom of the rock socket by 1 tube diameter and create a seal for the discharge end of the tube that is 7’ in depth
  - Maintain a minimum head (seal depth) of concrete of 7’ during the entire placement
  - Prior to raising the tube determine the top elevation of fresh concrete and inform the engineer

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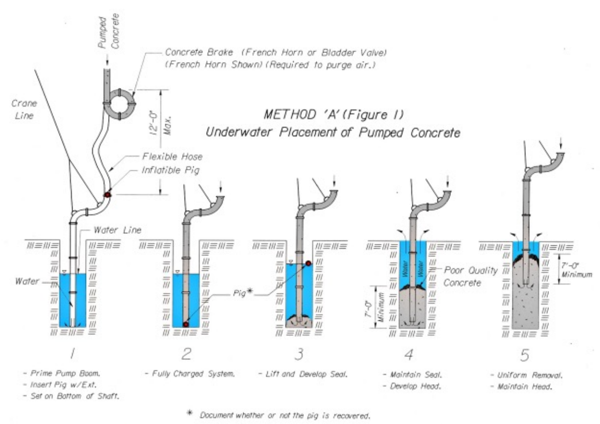
Wet Pour Methods – Method A



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.

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Wet Pour Methods – Method A

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

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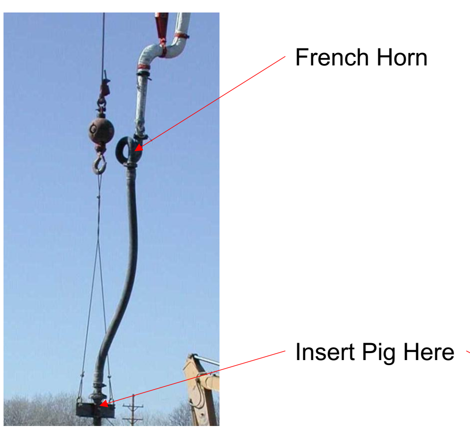
Wet Pour Methods – Method A



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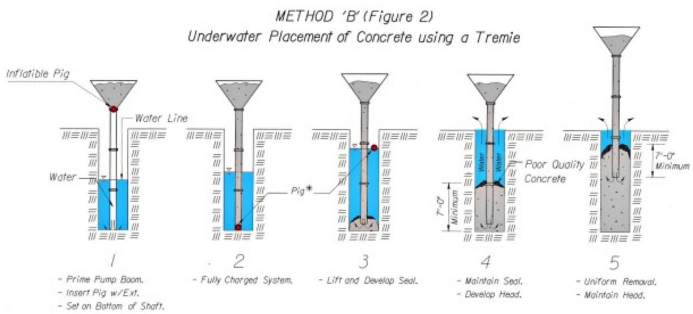
Wet Pour Methods – Method B



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 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.

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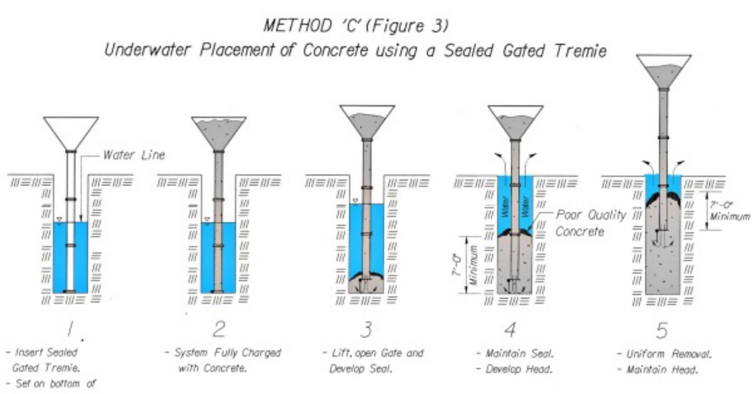
Wet Pour Methods – Method C



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.

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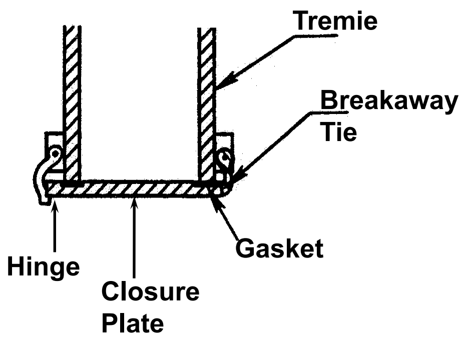
Wet Pour Methods – Method C



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Wet Pour Methods – Commercial Pigs

Example Pigs
Density = 1 $\frac{lb.}{ft.^3}$, 30 IFD

Pig Manufacturers

GIRARD INDUSTRIES

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

Phone Toll Free:
(800) 231-2861

Web Address:
https://girardindustries.com/

Future Foam

Wes Putnam Newton, KS

Phone Toll Free:
(800) 733-8061

Web Address: www.
https://futurefoam.com/

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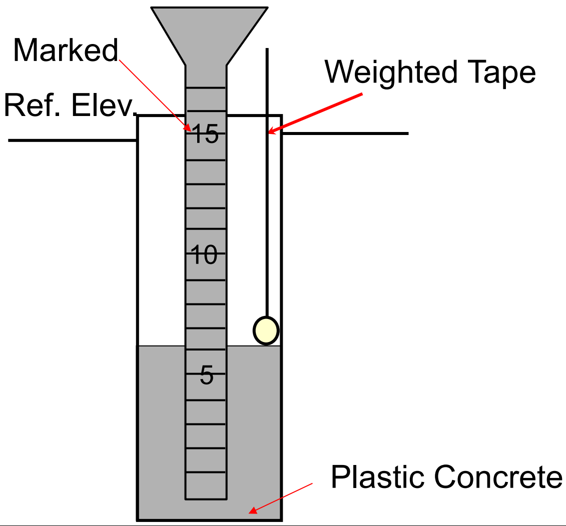
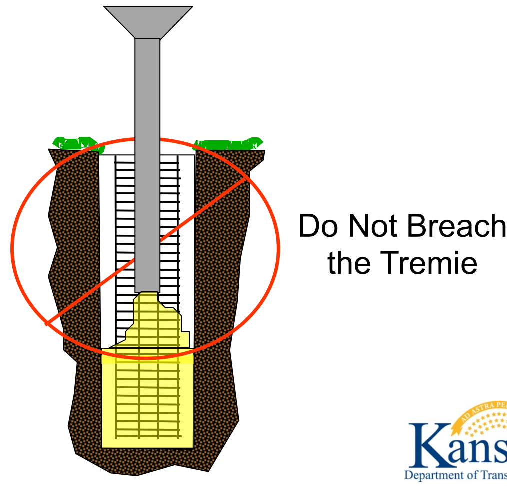
Wet Pour Methods – Maintain Head





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Procedure for Concrete Placement

Mark tremie/ discharge tube

18

Procedure for Concrete Placement

Pump water from the shaft if using dry pour method

19

Procedure for Concrete Placement

Prepare an over pump hole for wet pours

20

Procedure for Concrete Placement

Begin placing concrete
Pump out water from the top of shaft

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Procedure for Concrete Placement

Read the weighted tape and plot concrete volume curves

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Procedure for Concrete Placement

Remove pump once all excess water from shaft is pumped out

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Procedure for Concrete Placement

Over pump to remove contaminated concrete and excess water for wet pours

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Procedure for Concrete Placement

- For sites with permanent and temporary casings, 703.3g allows the contractor to immediately raise and hold the temporary casing at the embedment depth + 6"
- The contractor may remove the temporary casing if the following conditions are met:
  - The completed shafts have been allowed to set a minimum of 24 hours after concrete placement and the concrete has developed a compressive strength of 1800 psi
  - OR, if the compressive strength does not exceed 1800 psi, the Engineer may allow the contractor to proceed when the shaft has cured 5 days after completion of the concrete placement
- Before removing the temporary shaft, the contractor must completely backfill the space between the 2 casing according to 703.3j

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Measurement and Payment

- 703.4
  - a: Drilled Shafts
    - The engineer will measure drilled shafts by the linear foot measure from the bottom of the rock socket to the top of the complete 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 the 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 casings for their convenience
      - Casing is a temporary casing

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Measurement and Payment

- 703.4 Cont.
  - c: Sonic Test (Drilled Shaft)(Set Price)
    - For the initial sonic test on each shaft, the engineer will measure for payment each sonic test per shaft.
      - Sonic logging between all possible combinations of pipes represents a single sonic test
    - When the sonic test indicates defective concrete in the drilled shaft, the engineer requests cores from the shaft
      - The engineer will NOT measure for payment if the cores reveal unsound concrete
        - The engineer will not measure for payment additional sonic test and cores required to validate repairs to the shaft
      - The engineer will measure for payment if the cores reveal sound concrete and pay for the cores as Extra Work according to Section 104
  - d: Core Hole (Investigative)
    - 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' below the drilled shaft tip elevation
  - e: Payment
    - Drilled Shafts and Core Hole (Investigative) will be paid at the contract unit prices
    - Permanent Casing and Sonic Tests will be paid at the contract set unit prices
      - This 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 as Extra Work according to Section 104

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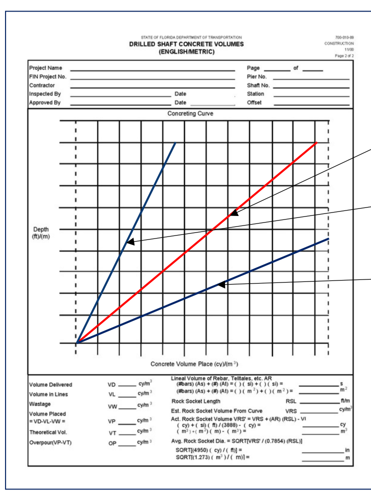
Concrete Volume Curves

- Compute the theoretical Concrete Volume Curve before placement begins!
- You will then make another concrete curve based on what you observe during the concrete placement
- The slope of the lines is the key to detecting problems in the shaft



Theoretical Concrete Volume Curve (what you calculate)

Steep Concrete Curve (too little concrete in steep sections)

Shallow Concrete Curve (too much concrete in the shallow sections)

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Concrete Volume Curves

Concrete Volume Curves can detect problems like this before the concrete sets up

This is much easier to repair and address before the concrete sets up

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Concrete Volume Curves

- In order 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

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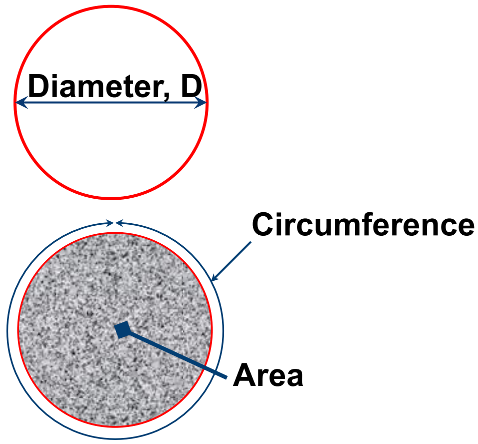
Concrete Volume Curves



- The diameter of the drilled shafts will be provided for you in the plans. In our equations we will call it "D"
- Pi, "π", is approximately equal to 3.14. Most calculators have a button for this number, but if you don't have a calculator this is a reasonable estimate to use in hand calculations.
- Circumference = $\pi * D$
- Area = $\frac{\pi * D^2}{4}$
- Volume = $Area * Length$
  - Length = Top of concrete elevation – bottom of shaft elevation
- Pi is unitless and doesn't need to be converted.
- To convert the diameter into feet use 12 inches = 1 foot
- To convert cu. ft. into cu. yds. use 27 cu. ft. = 1 cu. yds.

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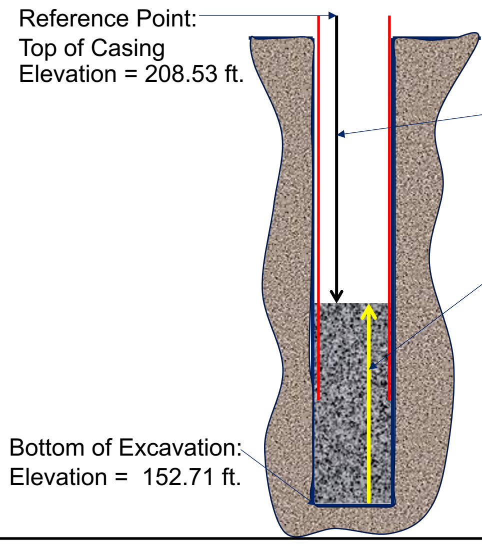
Concrete Volume Curves



Some Terminology

- Measured from the reference point:
  - "Depth of Hole"
  - "Filled to an elevation…"
- Measured from the bottom of shaft:
  - "Depth of Concrete"
  - "To an elevation of…"

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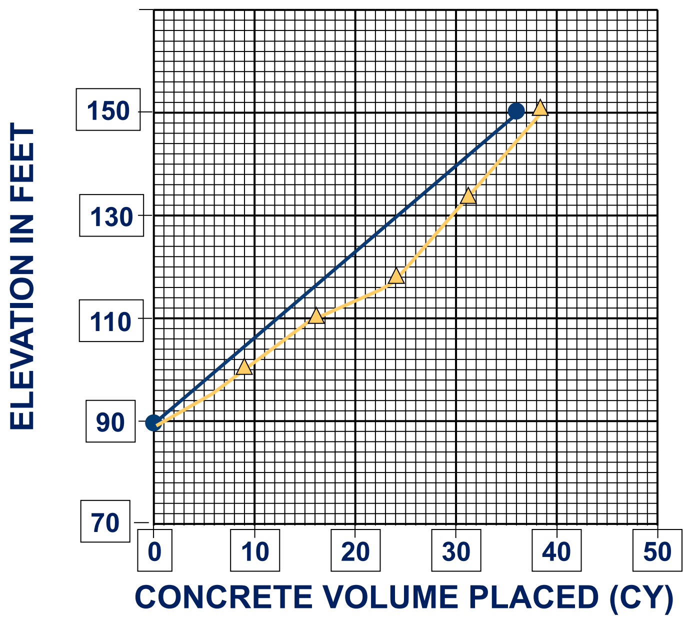
Concrete Volume Curves



1. Plot the theoretical curve (Dark blue line)
   - In this example:
     - the starting, or bottom of shaft, elevation is 90'
     - The top of shaft elevation is 150'
     - We've calculated the theoretical total volume of the shaft to be 36 cu. yds.
2. As each truck of concrete is brought in, plot the total volume of concrete placed in the shaft (orange line) and the elevation of the top of shaft by using the known volumes in the trucks and the weighted tape and reference elevation
   - When the top of shaft elevation has been reached, cease placing concrete and compare the plotted lines for any shaft deficiencies

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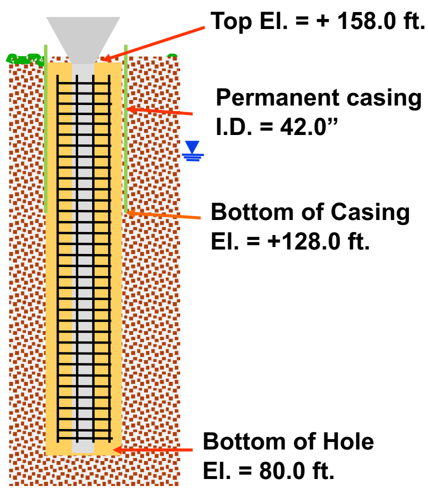
Concrete Volume Curves – Practice Problem



1. Calculate the theoretical volume of the hole in cubic yards

The Shaft Diameter = 42 inches as shown by the inside diameter (I.D.) of the permanent casing.

Area of the Shaft =

Shaft Length =

Volume =

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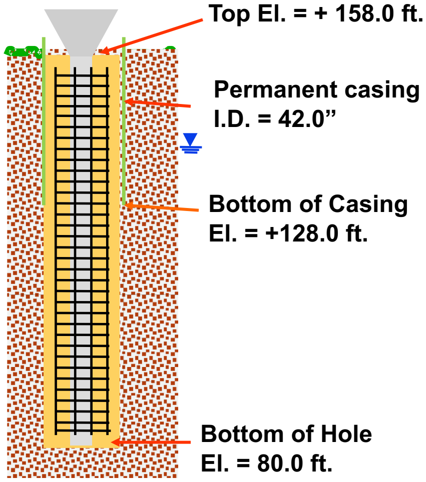
Concrete Volume Curves – Practice Problem



1. Calculate the theoretical volume of the hole in cubic yards

The Shaft Diameter = 42 inches as shown by the inside diameter (I.D.) of the permanent casing.

Area of the Shaft = $\frac{\pi * D^2}{4} = \frac{\pi * (42\ in. * (\frac{1\ ft.}{12\ in.}))^2}{4} = 9.62\ ft^2$

Shaft Length = $158.0\ ft. - 80\ ft. = 78\ ft.$

Volume = $9.62\ ft.^2 * 78\ ft. = 750.36\ ft.^3$

$= 750.36\ ft.^3 * \frac{1\ yds.^3}{27\ ft.^3} = 27.8\ yds.^3$

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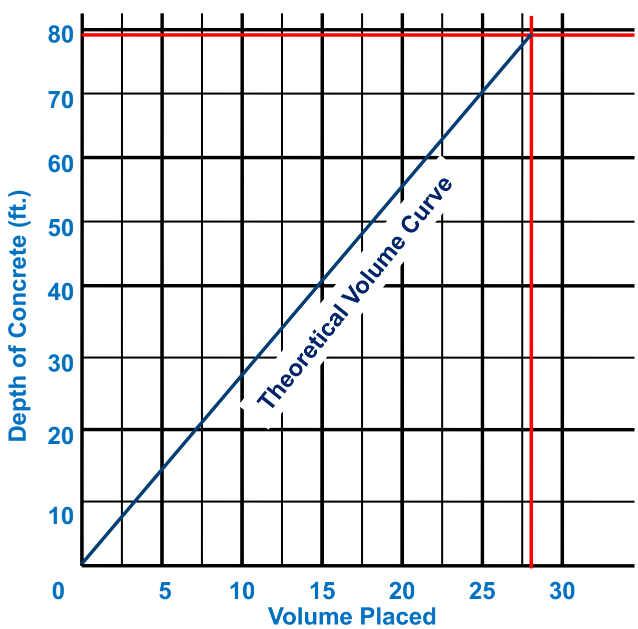
Concrete Volume Curves – Practice Problem



2. Plot the Theoretical Volume Curve

Shaft Length = $78\ ft.$

Volume = $27.8\ yds.^3$

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Concrete Volume Curves – Practice Problem

3. Calculate how much each truck of concrete will fill the hole.
   - For our example, we will assume some values so we can go through the calculations
     - Assumption 1: Each truck has 9 cubic yards of concrete
     - Assumption 2: The first truck will waste 2 cubic yards of concrete for testing the concrete

$Depth = \frac{Volume}{Area}$

Convert Volumes to $ft.^3$: 9 $yds.^3$ = 243 $ft.^3$ AND 2 $yds.^3$ = 54 ft^3

Area of Shaft = 9.62 $ft.^2$

Use a table to help you organize your calculations.

Truck	Concrete Volume $ft.^3$ [$yds.^3$]	Fill Depth of Truck Concrete $ft.$	Total Concrete Depth $ft.$
1st	$243 ft.^3 - 54 ft.^3 =$ $189 ft.^3$ [7 $yds.^3$]	$\frac{189\ ft^3}{9.62\ ft^2} = 19.6\ ft.$	$19.6 ft.$
2nd	$243\ ft.^3$ [9 $yds.^3$]	$\frac{243\ ft^3}{9.62\ ft^2} = 25.3\ ft.$	$19.6\ ft. + 25.3\ ft. = 44.9\ ft.$
3rd	$243\ ft.^3$ [9 $yds.^3$]	$\frac{243\ ft^3}{9.62\ ft^2} = 25.3\ ft.$	$44.9\ ft. + 25.3\ ft. = 70.2 ft.$
4th	$(7.8\ ft.) * (9.62\ ft.^2)$ = 75.0 $ft.^3$ [2.78 $yds.^3$]	$78\ ft. - 70.2\ ft = 7.8\ ft.$	$70.2\ ft. + 7.8\ ft. = 78 ft.$

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Concrete Volume Curves – Practice Problem

4. Place the concrete and take readings from the weighted tape after each truck and determine the actual depth of concrete. Compare these with the target concrete depths calculated in the previous slide. For this example, we have provided tape readings.

Shaft Length = 78 $ft.$ from previous slides

Truck	Theoretical Total Concrete Depth ($ft.$)	Tape Reading to Top of Concrete ($ft.$)	Actual Total Concrete Depth ($ft.$)
Empty Shaft	0 $ft.$	78 $ft.$	0 $ft.$
1st	19.6$ft.$	59 $ft.$	78 $ft.$ - 59 $ft.$ = 19 $ft.$
2nd	44.9 $ft.$	37 $ft.$	78 $ft.$ – 37 $ft.$ = 41 $ft.$
3rd	70.2$ft.$	12 $ft.$	78 $ft.$ – 12 $ft.$ = 66 $ft.$
4th	78$ft.$	0 $ft.$	78 $ft.$

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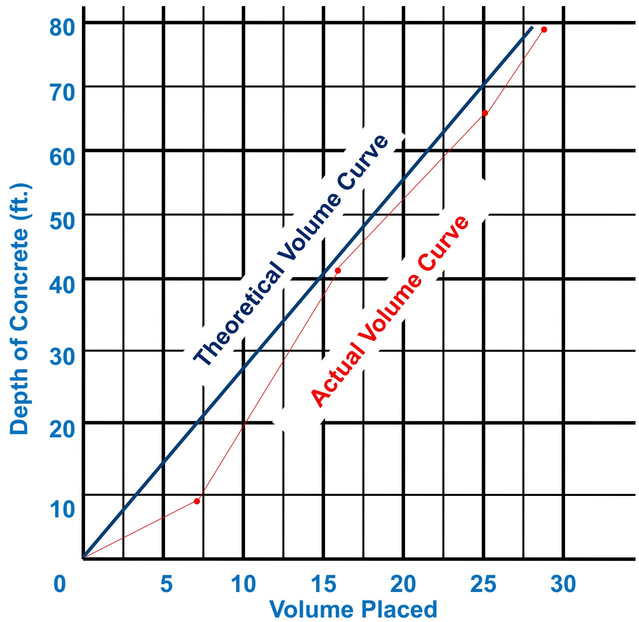
Concrete Volume Curves – Practice Problem



5. Plot the Actual Volume Curve

Shaft Length = 78 $ft.$

Volume = 27.8 $yds.^3$

Truck	Total Volume of Concrete (yds^3)	Actual Total Concrete Depth ($ft.$)
Empty Shaft	0 $yds.^3$	0 $ft.$
1st	7 $yds.^3$	9 $ft.$
2nd	16 $yds.^3$	41 $ft.$
3rd	25 $yds.^3$	66 $ft.$
4th	27.8 $yds.^3$ + Waste	78 $ft.$

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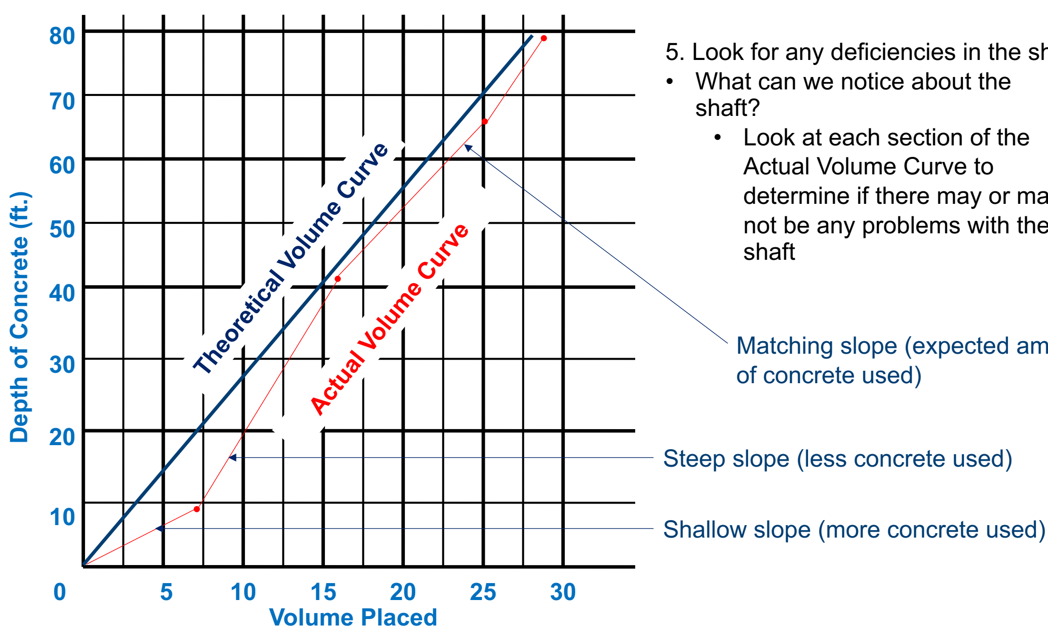
39

Concrete Volume Curves – Practice Problem



5. Look for any deficiencies in the shaft
- What can we notice about the shaft?
  - Look at each section of the Actual Volume Curve to determine if there may or may not be any problems with the shaft

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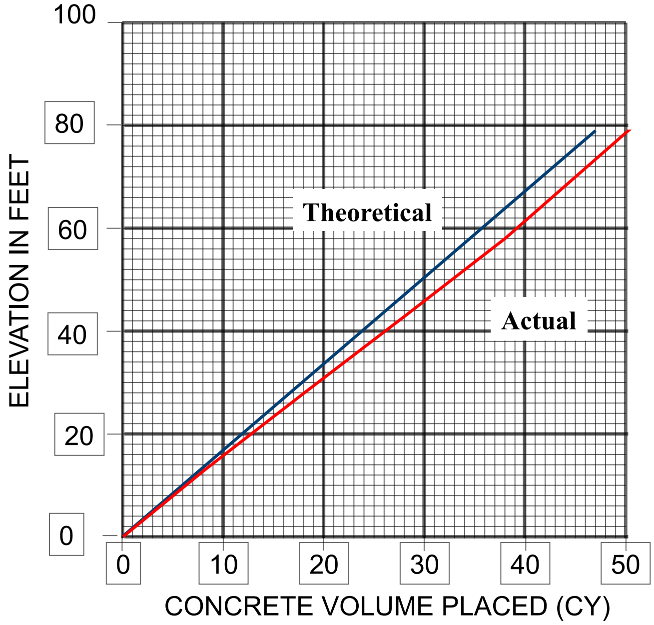
40

Concrete Volume Curves – Interpreting Results



Are there any problems with this shaft?

How do the slopes of the lines compare?

Are there any sections that raise red flags?

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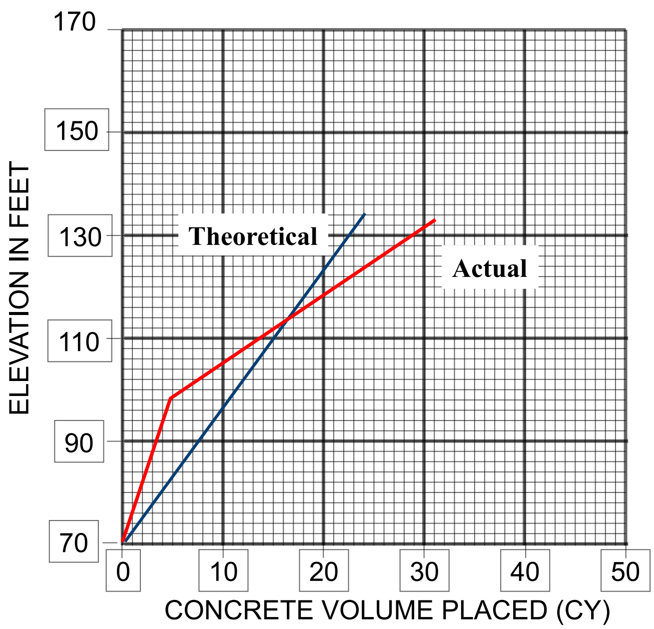
Concrete Volume Curves – Interpreting Results



Are there any problems with this shaft?

How do the slopes of the lines compare?

Are there any sections that raise red flags?

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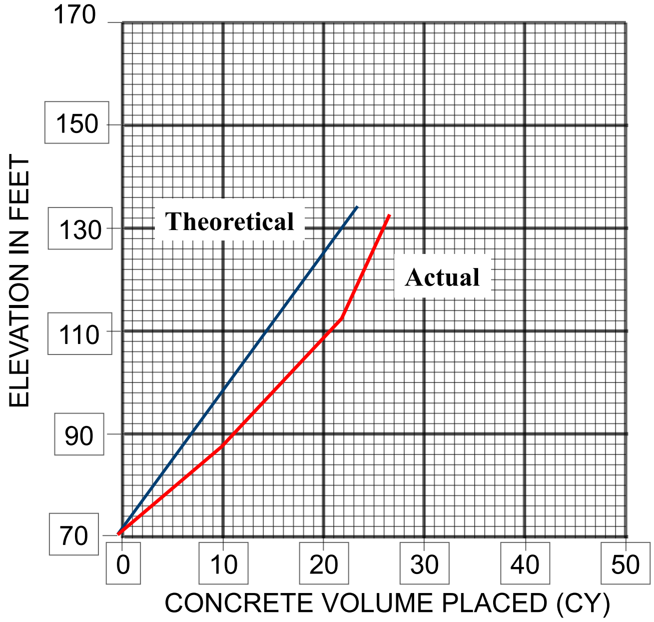
Concrete Volume Curves – Interpreting Results



Are there any problems with this shaft?

How do the slopes of the lines compare?

Are there any sections that raise red flags?

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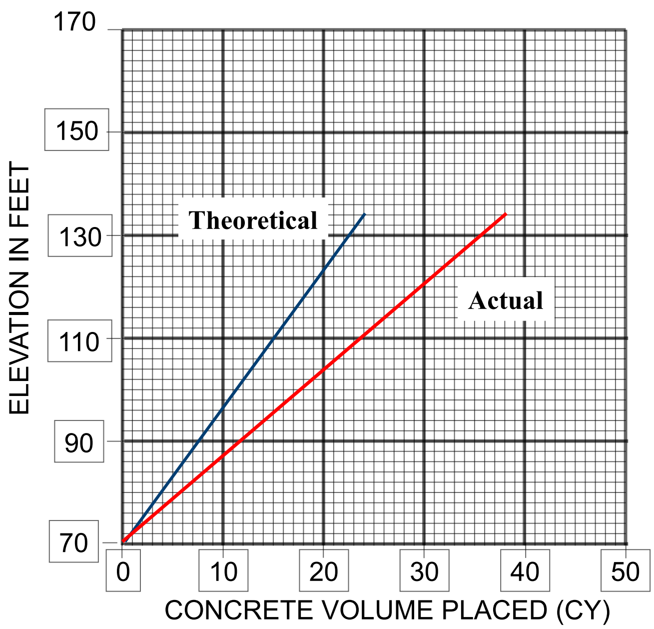
43

Concrete Volume Curves – Interpreting Results



Are there any problems with this shaft?

How do the slopes of the lines compare?

Are there any sections that raise red flags?

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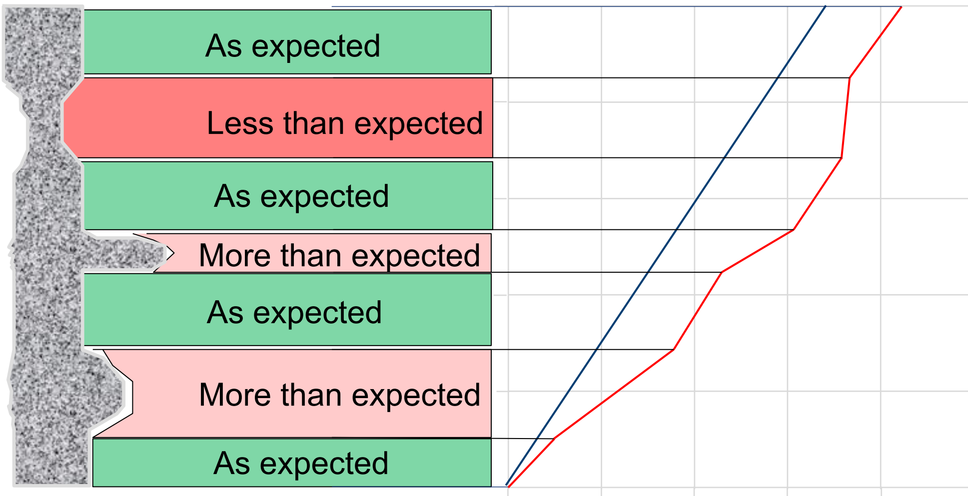
44

Concrete Volume Curves – Interpreting Results



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45

Questions?

- Contact me at Seth.Weber@ks.gov
- Or through Canvas

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46

POST INSTALLATION
&
INTEGRITY TESTING

14-4
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

14-7
2

INTEGRITY TESTS

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

14-19
3

INTEGRITY TESTS

“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.

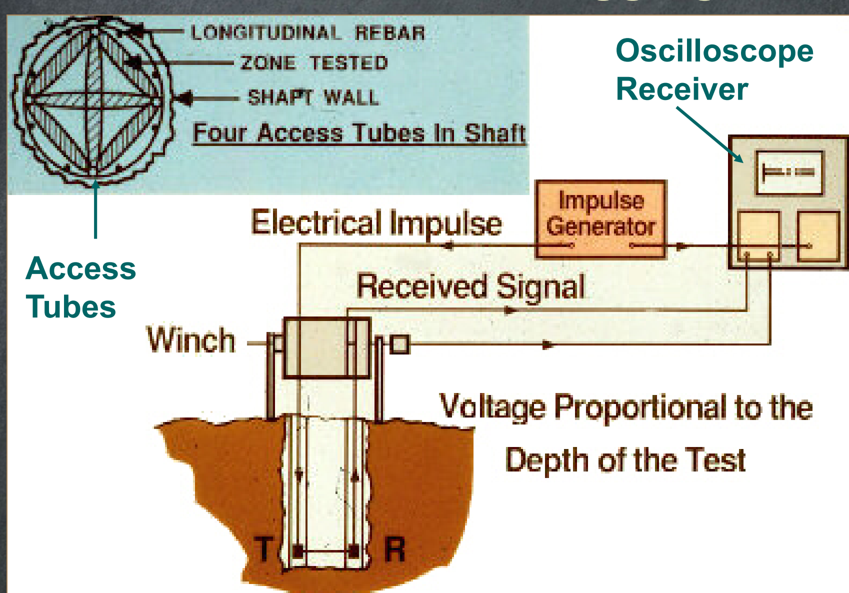
14-20
4

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

Cross-hole sonic logging



14-27

6

Source and Receiver Tools for CSL Test

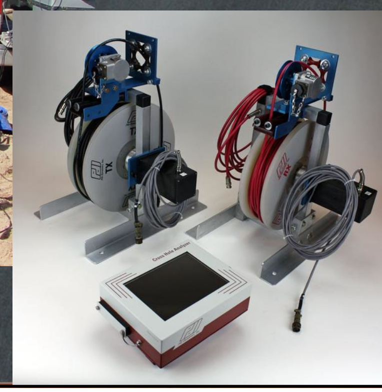
14-30

7

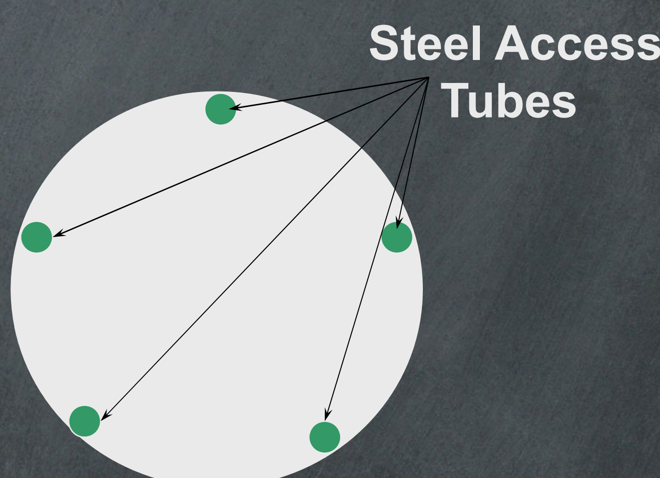
CSL Receiver

8

Pulley

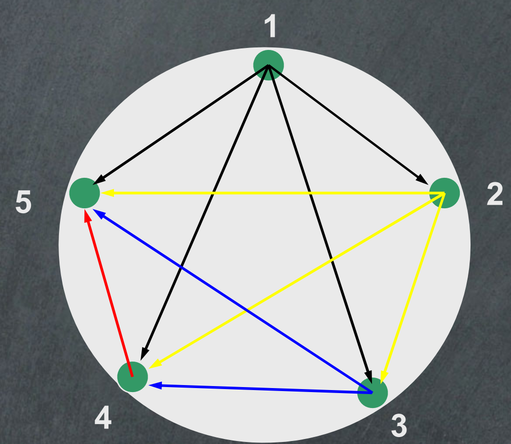


Sonic Logging



10

Sonic Logging



10
times

11

Sonic Logging

- 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

Access Tubes for Down-Shaft Tests

13

Sonic Logging

- 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

Sonic Logging

- 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.

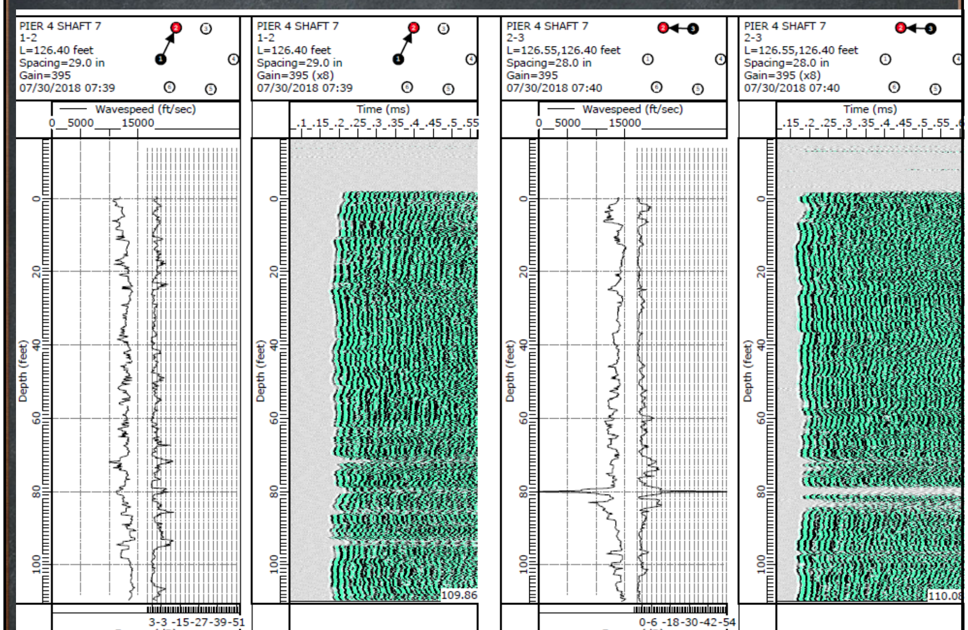
15

16

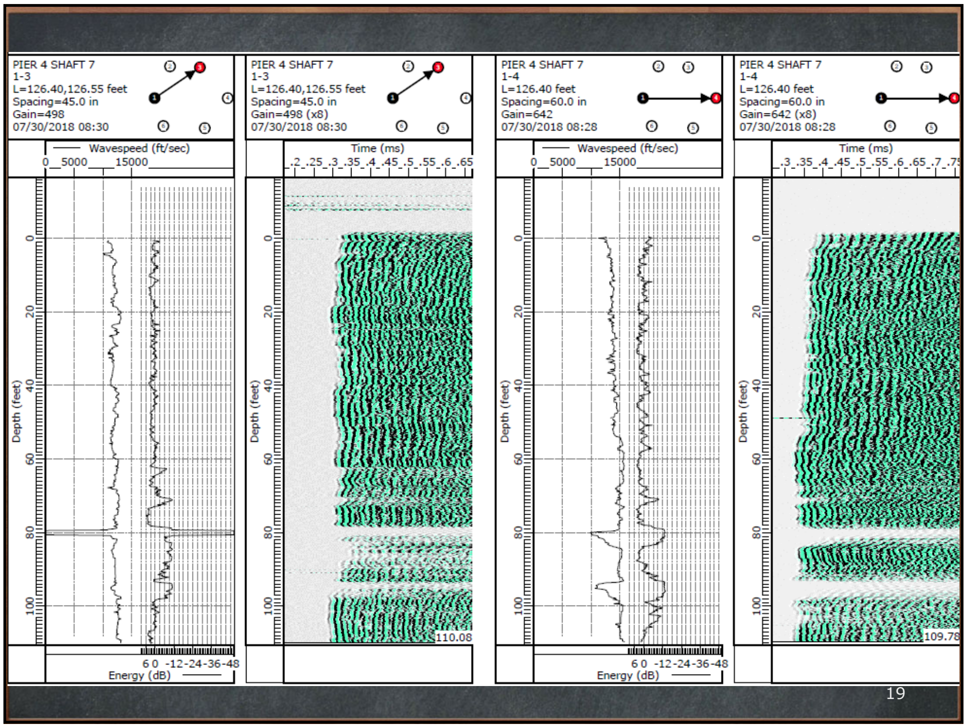
The velocity drop criteria are as follows

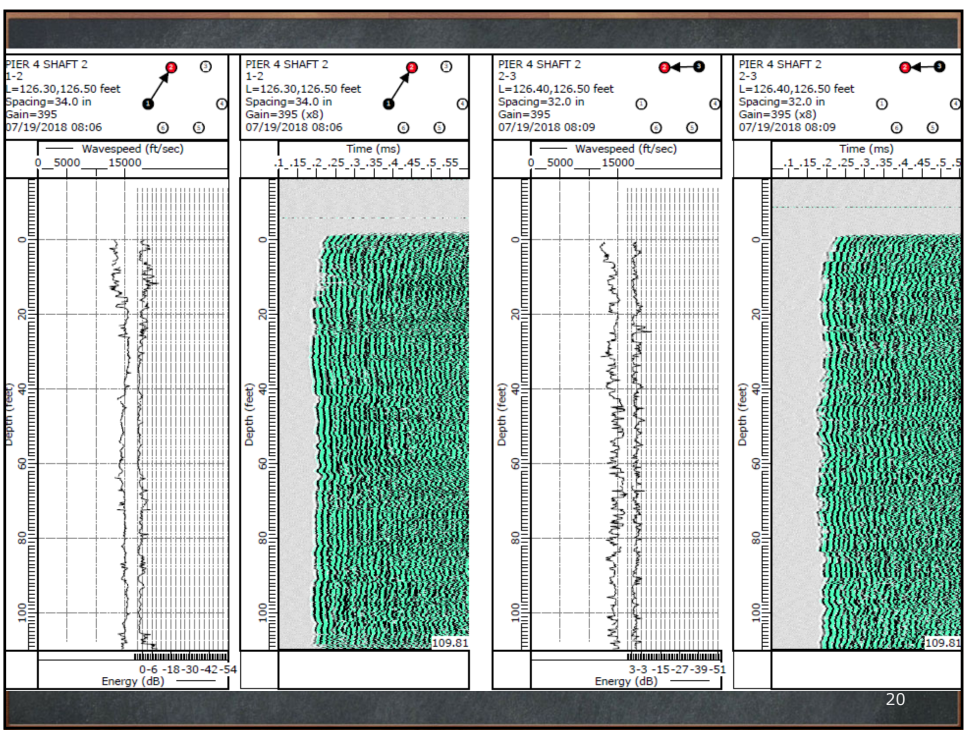
Percent velocity drop	Action taken
0-10%	Acceptable, review by geology
10% - 15%	Questionable, review by geology & design, may core
>15%	A core will be taken, remediation is possible, Review, Remediate andRetest

17



18


PIER 4 SHAFT 7
1-3
L=126.40,126.55 feet
Spacing=45.0 in
Gain=498
07/30/2018 08:30
PIER 4 SHAFT 7
1-3
L=126.40,126.55 feet
Spacing=45.0 in
Gain=498 (x8)
07/30/2018 08:30
PIER 4 SHAFT 7
1-4
L=126.40 feet
Spacing=60.0 in
Gain=642
07/30/2018 08:28
PIER 4 SHAFT 7
1-4
L=126.40 feet
Spacing=60.0 in
Gain=642 (x8)
07/30/2018 08:28
Wavespeed (ft/sec)
Time (ms)
Depth (feet)
Energy (dB)
110.08
109.78
19


PIER 4 SHAFT 2
1-2
L=126.30,126.50 feet
Spacing=34.0 in
Gain=395
07/19/2018 08:06
PIER 4 SHAFT 2
1-2
L=126.30,126.50 feet
Spacing=34.0 in
Gain=395 (x8)
07/19/2018 08:06
PIER 4 SHAFT 2
2-3
L=126.40,126.50 feet
Spacing=32.0 in
Gain=395
07/19/2018 08:09
PIER 4 SHAFT 2
2-3
L=126.40,126.50 feet
Spacing=32.0 in
Gain=395 (x8)
07/19/2018 08:09
Wavespeed (ft/sec)
Time (ms)
Depth (feet)
Energy (dB)
109.81
109.81
20

Sonic Logging

- 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

Sonic Logging

- 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

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.

23

Gamma Gamma Logging

- 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.

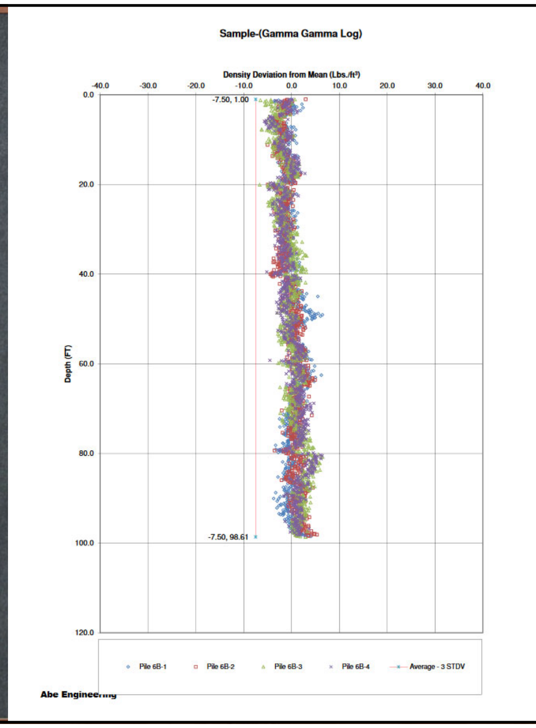
24

25

Gamma-Gamma Results

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

26



27

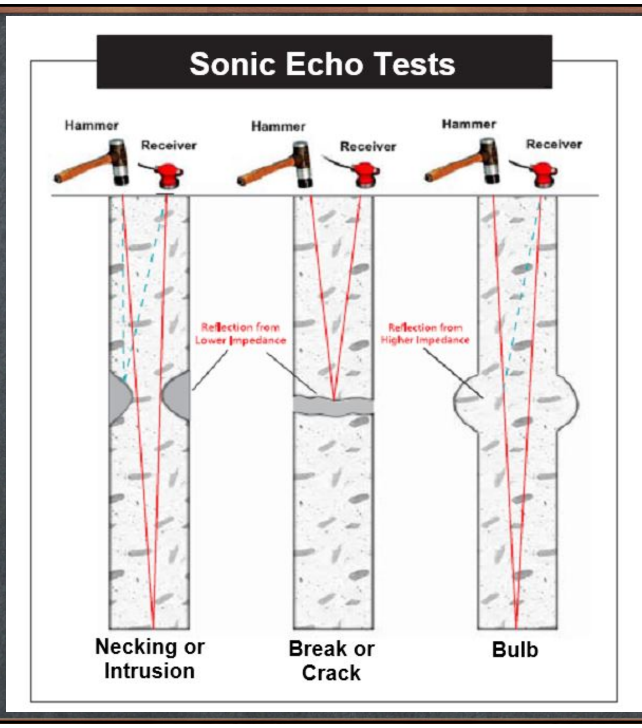
Echo Sounding/Pile Integrity Test (PIT)

- 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

Echo Sounding Equipment

29



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

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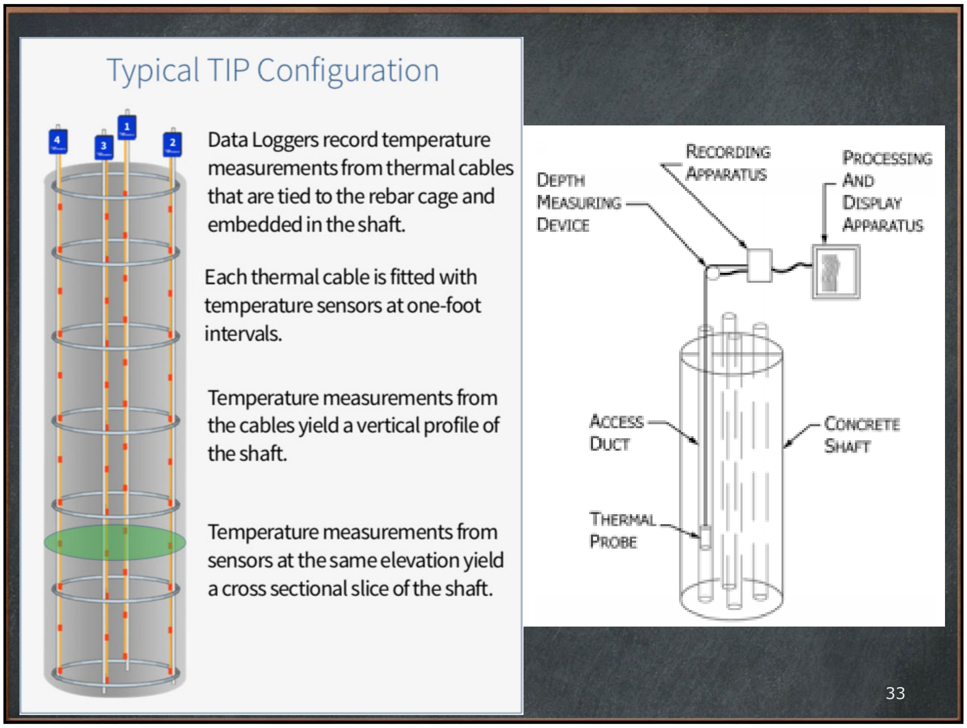
Thermal Integrity Profiling (TIP) Equipment



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.

BID ITEM	UNITS
Thermal Integrity Profiling	Each

2.0 EQUIPMENT

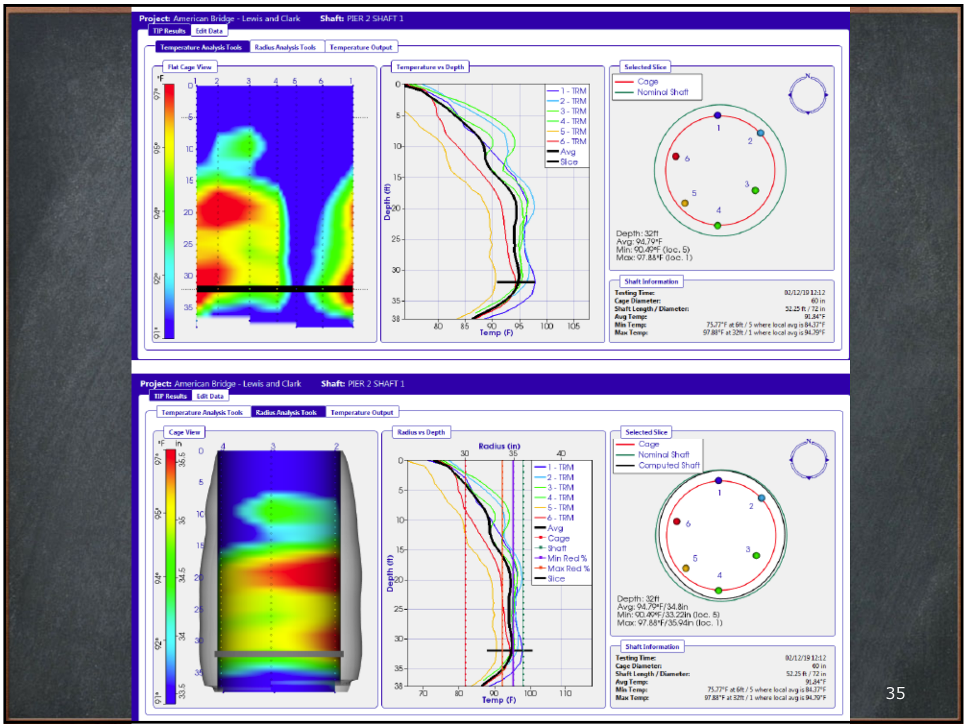
Supply all materials and equipment required to perform TIP tests. Equipment to perform the test shall have the following minimum requirements:

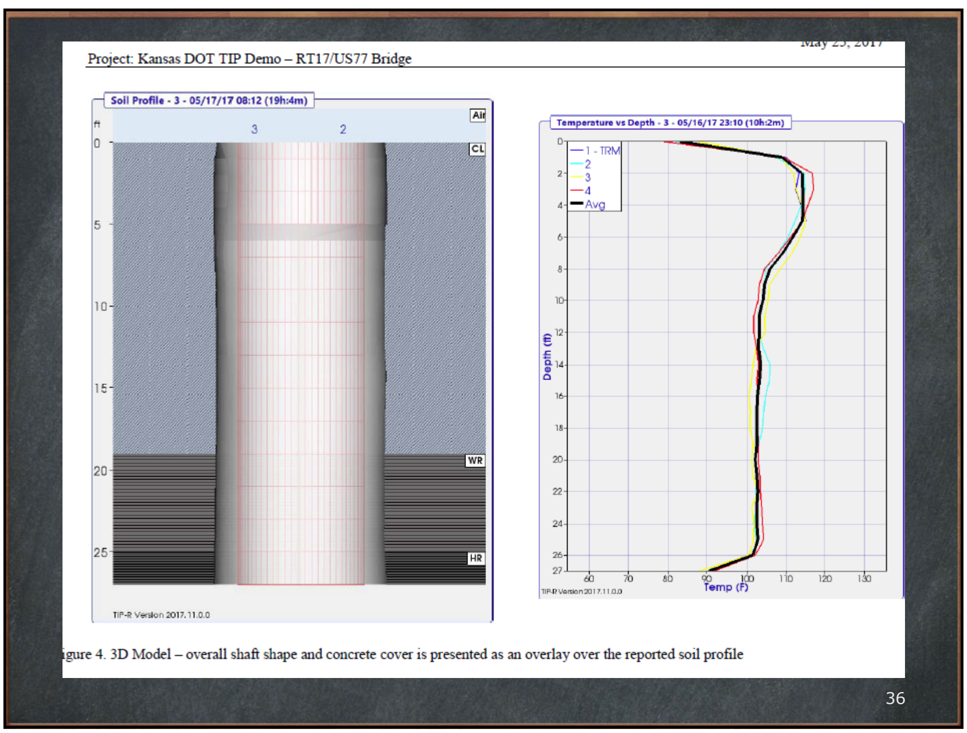
Probe or wire option.

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.


Project: American Bridge - Lewis and Clark
Shaft: PIER 2 SHAFT 1
TIP Results
Edit Data
Temperature Analysis Tools
Radius Analysis Tools
Temperature Output
Flat Cage View
Temperature vs Depth
Selected Slice
Cage
Nominal Shaft
Depth: 32ft
Avg: 94.79°F
Min: 90.49°F (loc. 5)
Max: 97.88°F (loc. 1)
Shaft Information
Depth (ft)
Temp (F)
Cage View
Radius vs Depth
Radius (in)
Computed Shaft
Depth: 32ft
Avg: 94.79°F/34.8in
Min: 90.49°F/33.22in (loc. 5)
Max: 97.88°F/35.98in (loc. 1)
35


Project: Kansas DOT TIP Demo – RT17/US77 Bridge
Soil Profile - 3 - 05/17/17 08:12 (19h:4m)
Temperature vs Depth - 3 - 05/16/17 23:10 (10h:2m)
Depth (ft)
Temp (F)
TIP-R Version 2017.11.0.0
igure 4. 3D Model – overall shaft shape and concrete cover is presented as an overlay over the reported soil profile
36

Coring

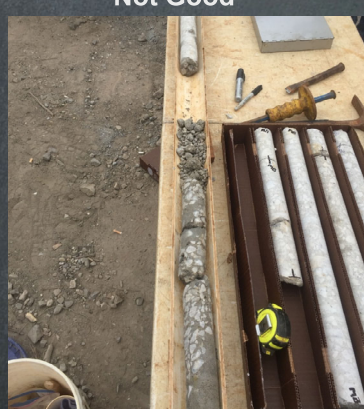
Core Barrel Bit

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

Bad Cores

39

Bad Cores

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

Backfill

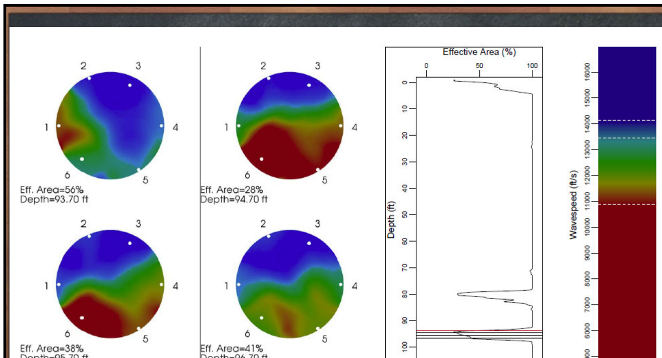
- When temporary and a permanent casing are used, backfill the annular space (between casings) with material specified in the contract documents:
  - Granular material fine enough to fill the entire volume or
  - Grout or flowable fill described in **subsection 706.2 (b) Grout/Flowable Fill**
  - If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

42

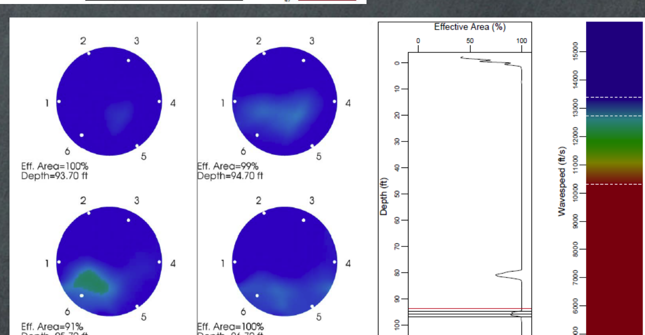
Backfill

- 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 bee removed, filled the rest of the annular space with granular material.

43



Questions?



Drilled Shaft Inspection Measurement and Payment

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)

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Measurement and Payment

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

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Measurement and Payment

- 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

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Measurement and Payment

- 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

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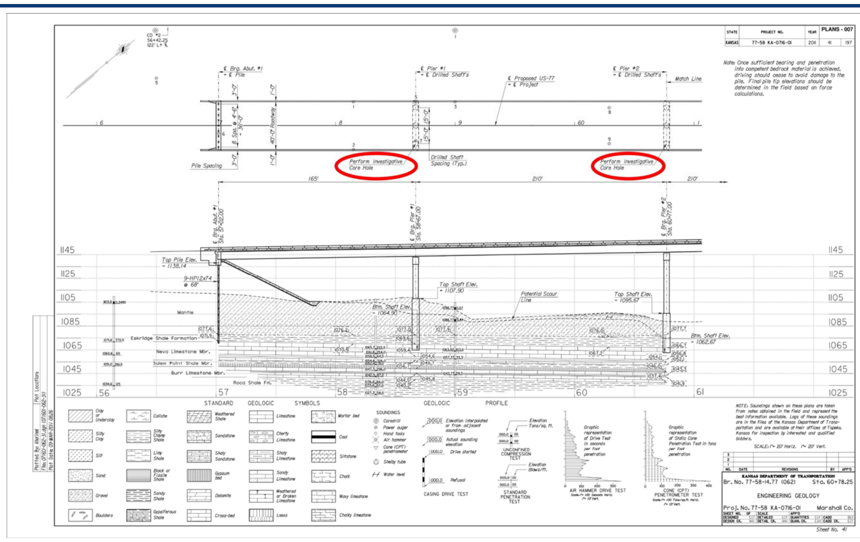
Measurement and Payment



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Measurement and Payment

- Drilled shaft (*) (**)

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

Measurement and Payment

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

Measurement and Payment

- 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%

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Measurement and Payment

- 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

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Measurement and Payment

- 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

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Measurement and Payment

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

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Measurement and Payment

- 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

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Measurement and Payment

- 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

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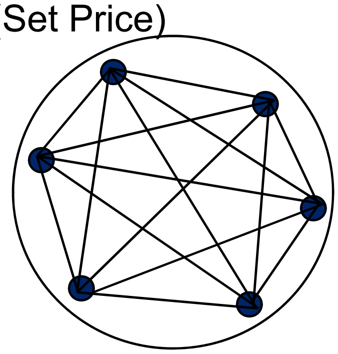
Measurement and Payment

- 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

Measurement and Payment

- Sonic Test (Drilled Shaft) (Set Price)



4 tubes	6 combinations	one test
6 tubes	**15 combinations**	**one test**
8 tubes	28 combinations	one test

Measurement and Payment

- 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

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Measurement and Payment

- 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

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Measurement and Payment

- 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.

Kansas Department of Transportation

Contact Information

- Kevin Palic
- Kevin.palic@ks.gov
- Cell 785-224-1412

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Drilled Shaft Inspection Safety

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1

Safety

- Safety equipment
- Situational awareness

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2

Safety Equipment

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

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3

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4

Example of ANSI Class III Vest

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5

Safety

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

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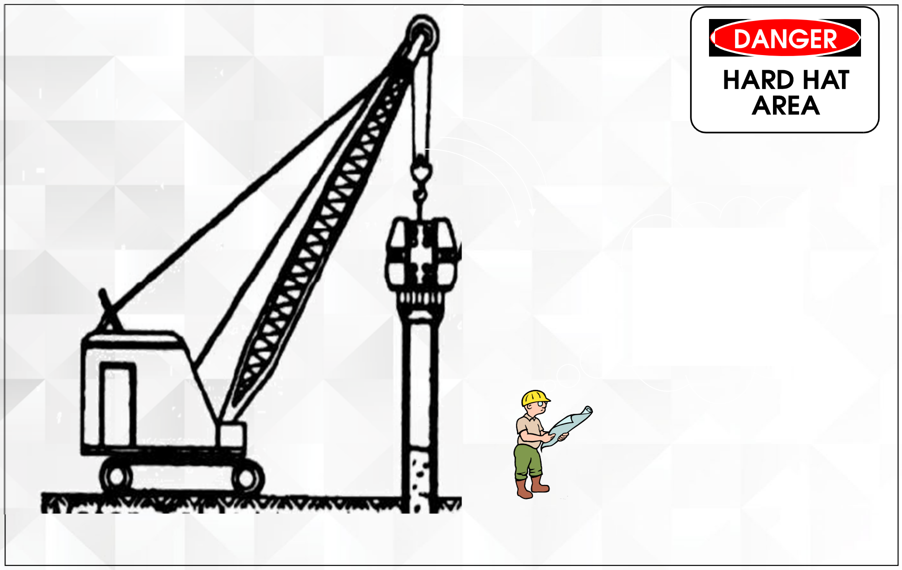
6

Safety

7

Remember, even a temporary loss of focus can be dangerous

8



9

Safety

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

10

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11

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12

Safety

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

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13

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14

Safety

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

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15

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16

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17

Crane Fire

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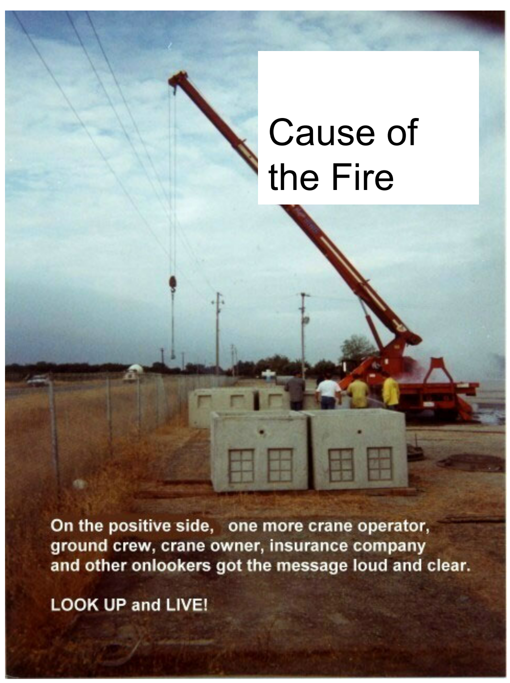
18


Another Shot of the Fire

19


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

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Safety

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

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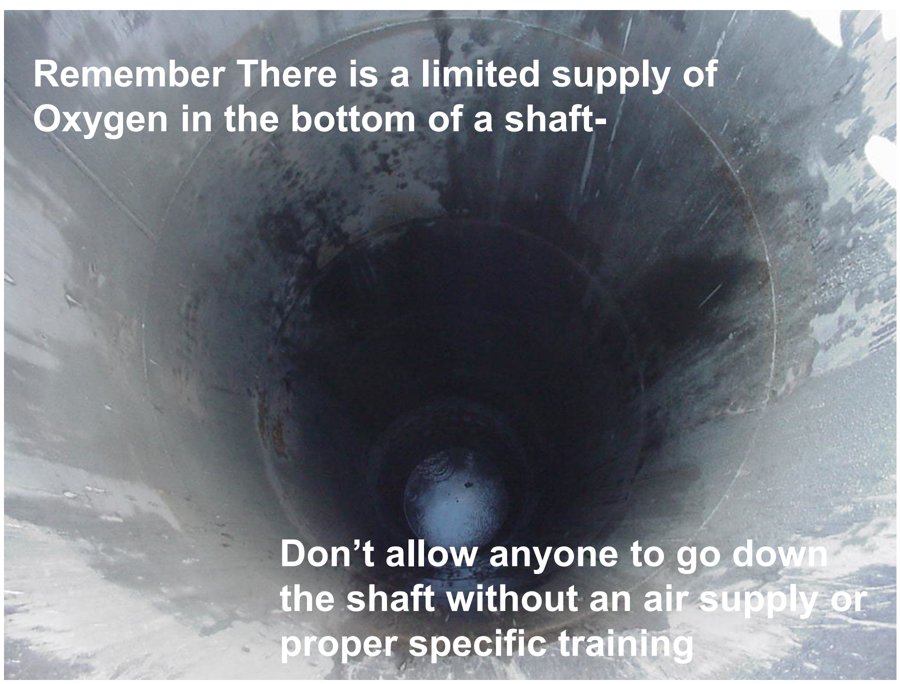

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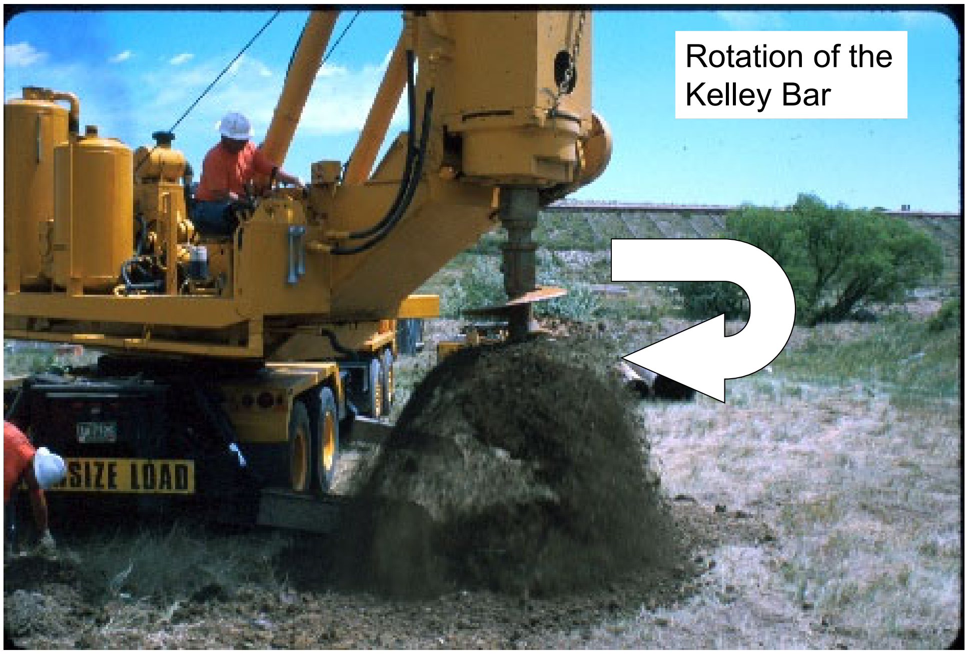

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Questions?

- Steve Rose
- Phone 620-727-3709
- Email Steve.Rose@ks.gov

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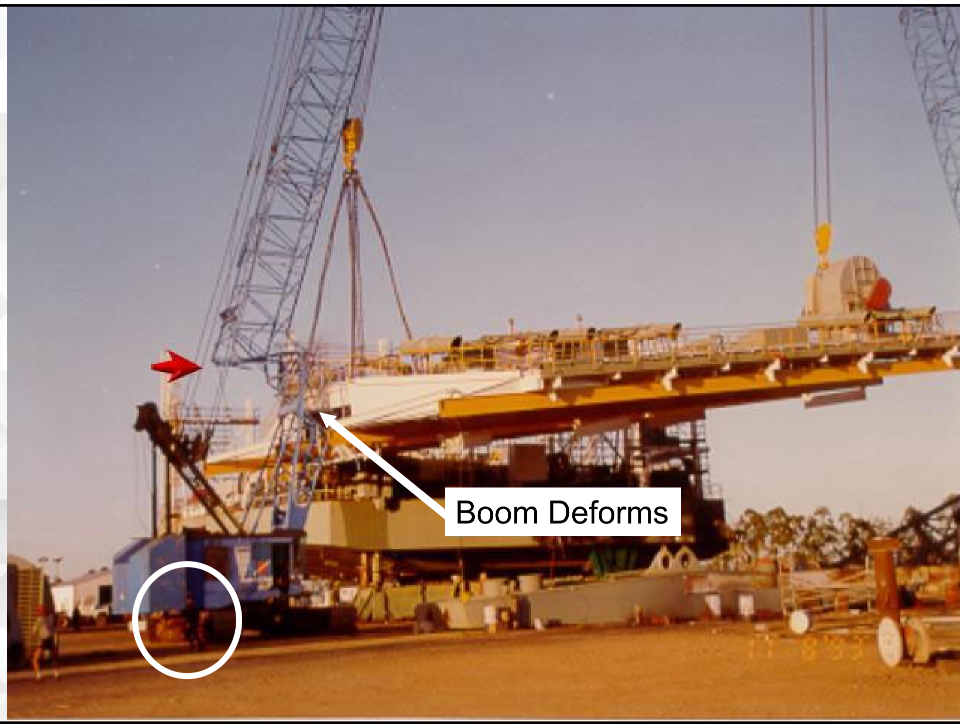

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34


CraneAccidents.com
Operator
11 8 '93
Kansas
Department of Transportation

35


CraneAccidents.com
11 8 '93
Kansas
Department of Transportation

36

37

Operator has Limited Visibility

When approaching the drill rig approach from the front and make eye contact with the operator

38

Safety

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

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39

Session 9: Pre-Con and Installation Plans

Seth Weber – Bridge Design

KDOT
IKE
THE EISENHOWER LEGACY TRANSPORTATION PROGRAM

1

Learning Objectives

- Learn who to invite to the pre-construction meeting and what to discuss during the meeting.

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2

Topics to Discuss

- Who should be at the meeting?
- The “13 Questions to Ask Prior to Construction”

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3

Pre-Construction Meeting

- Request that the following people be present at the meeting:
  - Bridge Construction Engineer
  - The Geologist
  - The Primary Contractor
  - All subs:
    - Driller
    - Pumper
    - Concrete Supplier
    - Etc.
  - Anyone else who may be apart of the construction operations

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4

Pre-Construction Meeting

- Discuss the plan in detail:
  - Excavation Methods – see Bridge Construction Manual
  - Rock Socket Cleaning Methods – see Bridge Construction Manual
  - Placement Methods – See Session 6 in this class
  - What are the possible problems that could arise during construction?
  - How will you address the problems during the operation?

5

13 Questions to Ask Prior to Construction

1. How is the Contractor going to 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 it through a tremie?
4. Is the tremie/ extension tube watertight?
5. How will the tremie / extension tube be sealed? Will the contractor use a “pig” or flap gate?
6. What Material is being used for the pig?

6

13 Questions to Ask Prior to Construction

7. Where is the pig going to be placed in the tremie / extension tube or pump?
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 is achieved?
10. How are you going to ensure the discharge end of the tremie/ extension tube is sufficiently embedded in the fresh concrete?
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 contaminated concrete that has risen to the top of the shaft?

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7

Questions?

- Contact me at Seth.Weber@ks.gov
- Or through Canvas

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8

When Things Go Bad!!!

Spread Footing on Limestone

Tremie Pile-What's wrong with it?

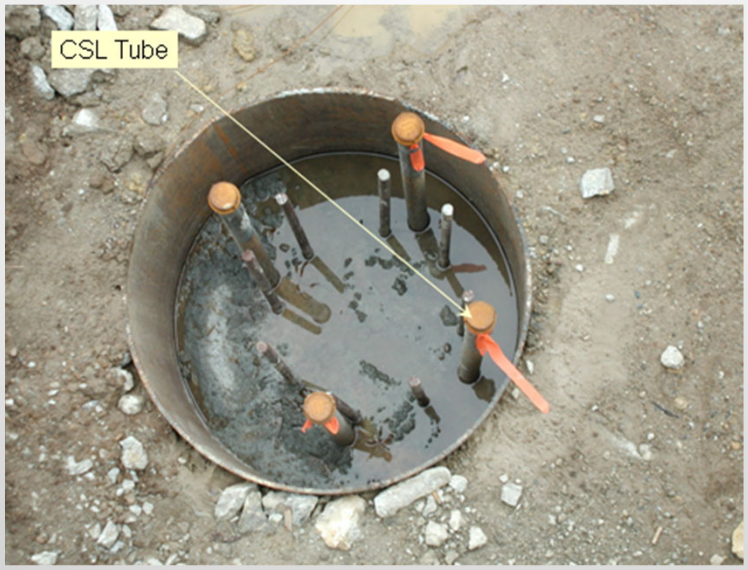
What are they doing wrong?

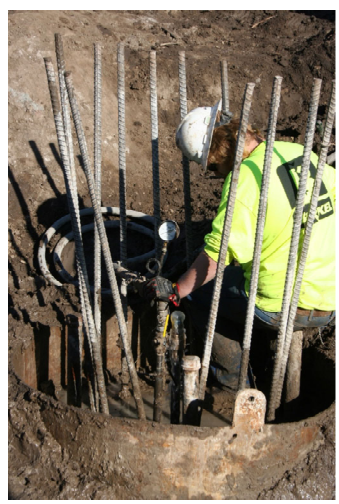
Bad Shafts-Sinking Concrete?

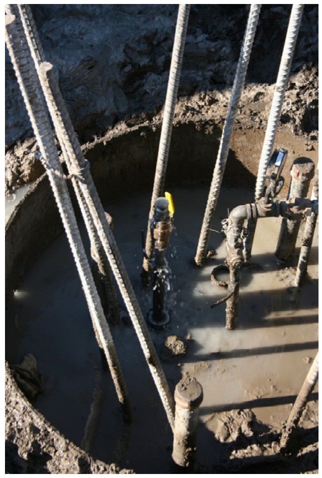
More of the same!

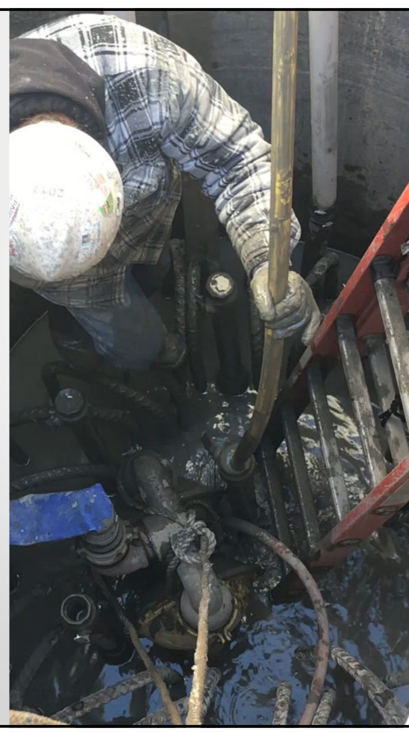

487-0011
GVW 24000

Name two things wrong with this shaft.









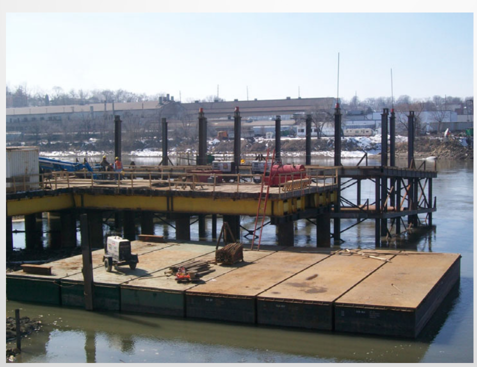

08/02/2012

TYPICAL PROBLEMS

11-65

Atchison River Coffer Dam Drop

Coffer Dam issues



High water and debris

Seal Coarse and 1 Bad Shaft!

Lots of water when 60 feet below the river!

Looking Up!

What the finished base is like.

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

No concrete

11-67

Any Questions?