Foundation Design Considerations to reduce Construction Problems

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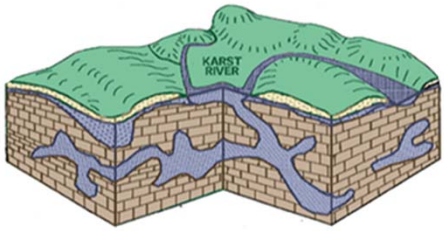
- Introduction: Geological-Geotechnical Conditions
- Drilled Shafts
- Piles

Introduction: Geological – Geotechnical Conditions

- Understand the geological and geotechnical conditions.
- Does the area have unfavorable geological features?
  - ✓ voids, cavities,
  - ✓ artesian water,
  - ✓ Very loose/soft soils

  Are the plans indicating these conditions ?



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Does the area have unfavorable geological features such as voids, cavities, artesian water? Are the plans indicating these? You may want to reconsider the type of foundation and special features after evaluating this. What type of foundation is being used in adjacent projects, or the existing bridge (widening).
What type of foundation was used in adjacent projects, or the existing bridge (widening).

Understand geotechnical conditions

- Use of proper parameters.
- Use of proper analysis approach
- Soil behavior short/long term
- Define your foundation requirements and parameters as much as possible during design. Don't leave loose ends for the CEI people.

- Get the assistance of the geotechnical professional. Even better, let the geotechnical engineer do geotechnical work.

Introduction
Geological – Geotechnical Conditions

Constructions Problems arise when:

- Unanticipated rock/soil behavior and ground water hydraulic conditions.
- We have not described properly the geological materials (rock type, hard material, caving conditions) and obstructions from construction debris
- The geological, geotechnical and construction conditions are not accurately presented in the Plans
- We need to request extra lengths or request additional work during construction.

Constructions Problems arise if we have not describe properly our geological conditions. Contractor may encounter hard conditions for which he was not prepared. Claims may occur if the Contractor feels that the plans did not represent the information properly (hard material,

- caving conditions, obstructions from constructio

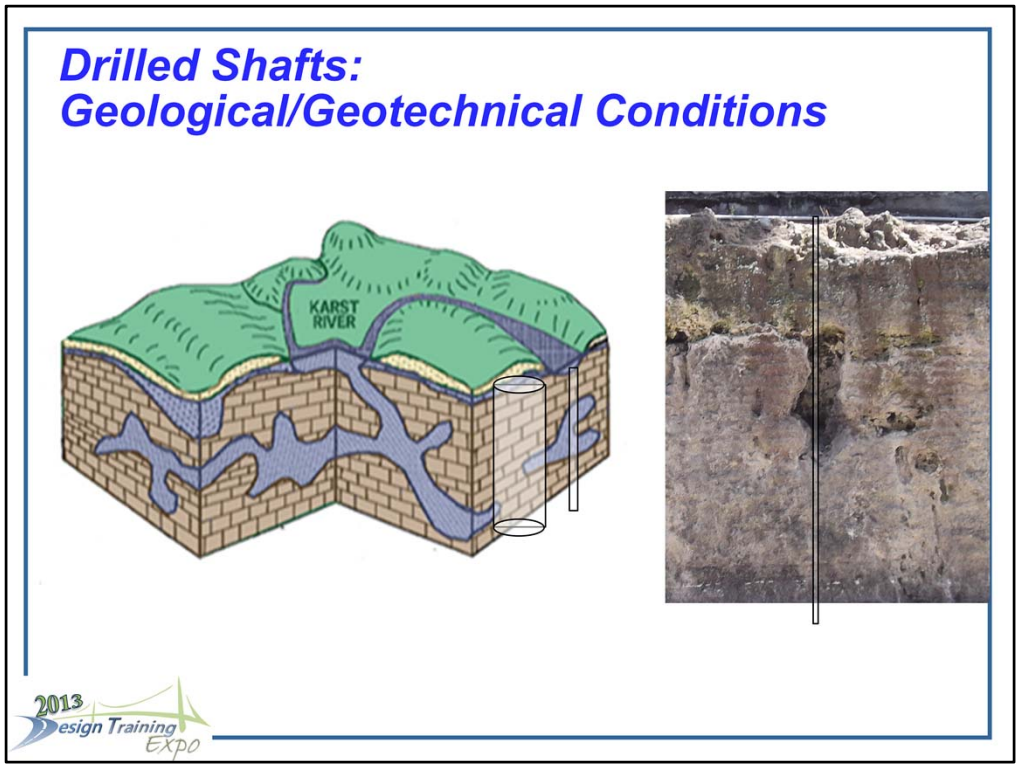
n debris). Unanticipated quantities may end

up being
too costly.

1. Drilled Shafts: Geological/Geotechnical Conditions

Ensure Geology is properly described in the plans:

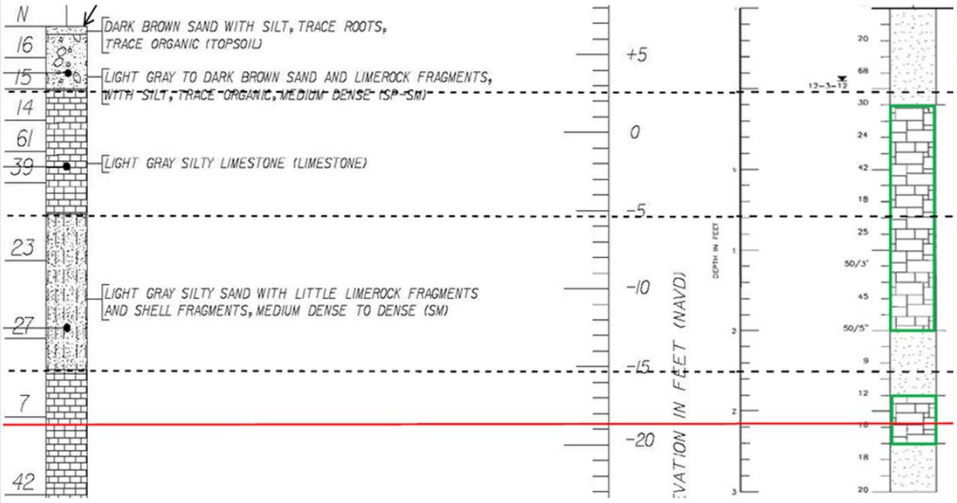
- ✓Difficulties describing rock:
  - ✓1-3/8" Spoon sampler disturbs, breaks up rock into small gravel and sand particles.
  - ✓Space variability. Layer thickness may change with location.
  - ✓Local voids filled with sand may not be necessarily continuous layers. For a 3" hole they may look as continuous layers. In the big picture is a rock formation.
  - ✓Tendency of being conservative for design.



When samples by just SPT normal methods this formation may end up being not properly described. A local void 1-2 ft wide may not make too much difference regarding the difficulty of drilling for a drilled shaft (4 ft dia or larger).

If casing were used to drill the soil borings to contain fluid losses, indicate so.

Drilled Shafts: Geological/Geotechnical Conditions



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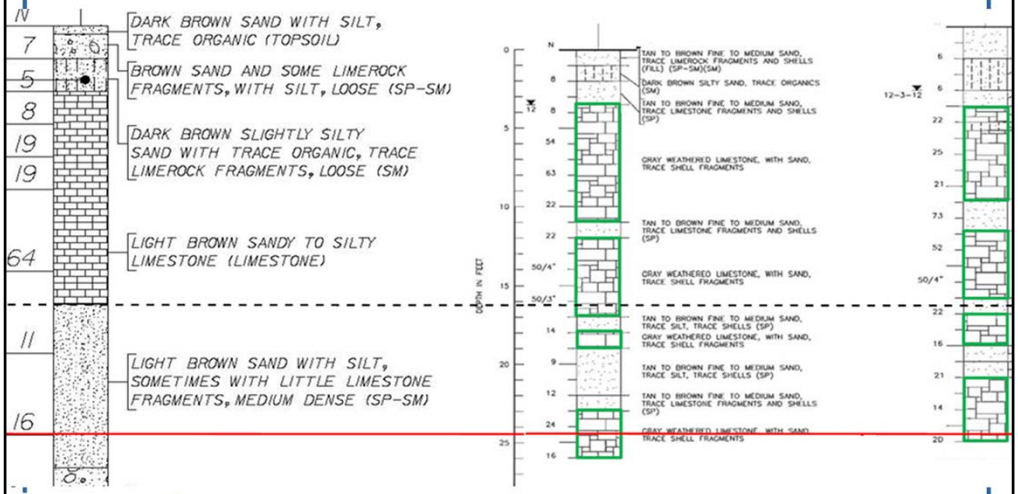
Drilled Shafts: Geological/Geotechnical Conditions



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Drilled Shafts: Geological/Geotechnical Conditions

- ✓ Research/learn local Geology. Involve people with experience in the area.
- ✓ Be accurate in your rock description. If possible, include the name of the rock formation in the description. Will the sand layers actually be local void pockets of a rock formation that could require rock drilling equipment?
- ✓ Will there be layers with tendency to cave?
- ✓ Will there be expected fluid losses? Indicate fluid losses in the log/casing used in the soil borings.
- ✓ Will there be a potential for artesian water?
- ✓ Make sure the boring location is accurate.

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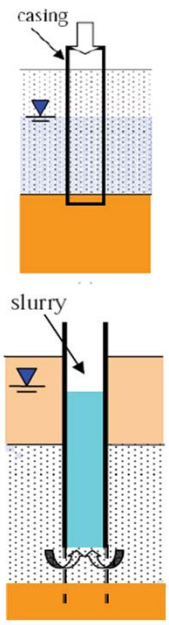
Drilled Shafts: Shafts adjacent to MSE walls and sensitive structures

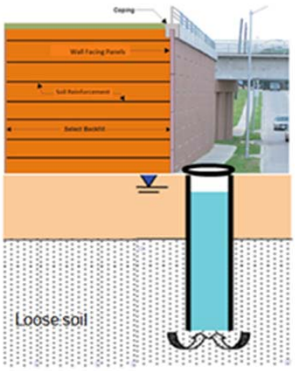
- Shaft construction may produce settlements and vibrations and even soil failure.
- Need to protect existing structures: walls, foundations, railroad tracks, utilities.
- Consider specifying casing to a firm competent layer/rock.
- Consider specifying non-vibratory methods to install/remove casing.
- In new projects: Consider schedule shafts prior to the MSE wall construction

Drilled Shafts: Shafts adjacent to MSE walls and sensitive structures

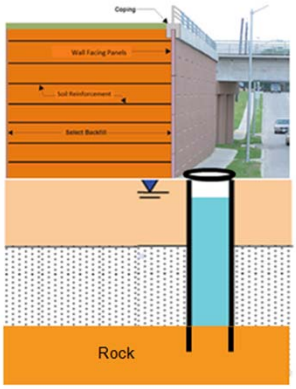


- Ensure the plans calling for the right casing tip elevation. Is the casing tip we are specifying properly sealing the loose material? Are we reaching rock with the permanent casing?
- A bottom failure may occur if the casing does not seal properly. This may be serious if there is an MSE wall next to it. The stresses could become just too much for the soil at the bottom.
- Casing shall be installed prior to excavation. No predrilling shall be done (this is actually against the specs).

Drilled Shafts: Shafts adjacent to MSE walls and sensitive structures



Unsafe condition



Safe condition

Drilled Shafts: Shafts adjacent to MSE walls and sensitive structures

Soil failure

Wall settlements

Non –Vibratory Casing installation

If there are sensitive adjacent structures to the shaft, casing should not be installed with vibrations. Example:

FOR CONSTRUCTION OF DRILLED SHAFT LOCATED 9 FEET OR LESS (CLEAR DISTANCE) FROM EXISTING MSE WALLS, OSCILLATION OR OTHER NON-VIBRATORY INSTALLATION AND REMOVAL OF STEEL CASING WILL BE REQUIRED. VIBRATION OF STEEL CASING IS PROHIBITED.

Casing with cutting teeth

oscillator

Rotator

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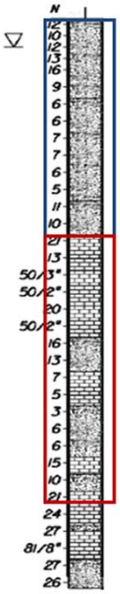
Non –Vibratory Casing installation

Casing with J slotted cuts

Casing twister

Drilled Shafts: Permanent Casing

- Typical Designers specification of **permanent** casing:
  - **Fixed diameter** (ID= shaft diameter) and depth.
  - Casing tip elevation specified
  - This will work well if below the casing tip the material can be reasonably be stabilized with slurry.

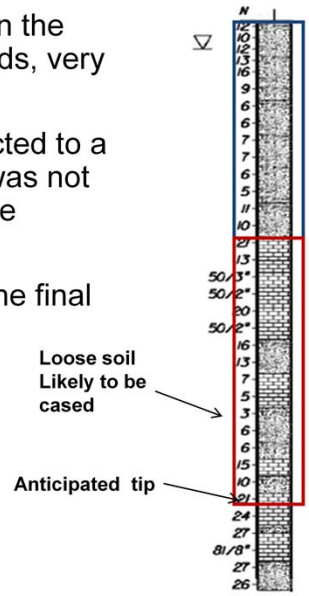


If you feel the need to specify permanent casing beware of the following:

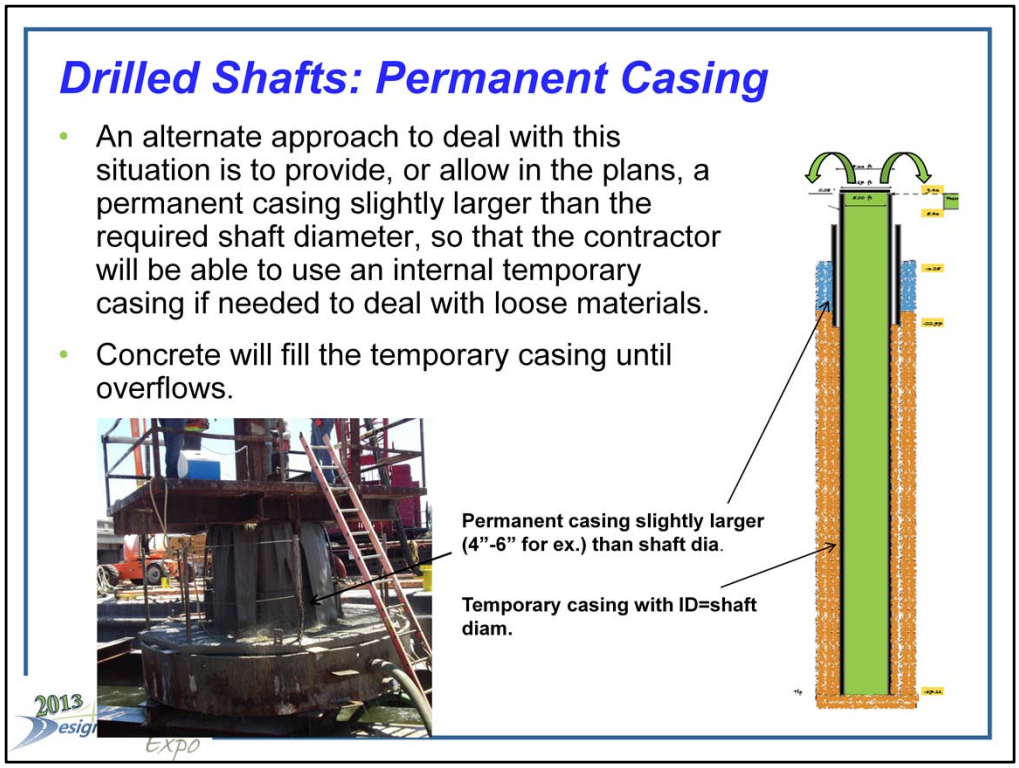
Examine the conditions carefully:
Are the plans calling for the right casing tip elevation? Is the casing tip we are specifying properly sealing the loose material? Are we reaching rock with the permanent casing? Will the final depth require the excavation to go through caving materials deeper than the permanent casing we are specifying?

Drilled Shafts: Permanent Casing

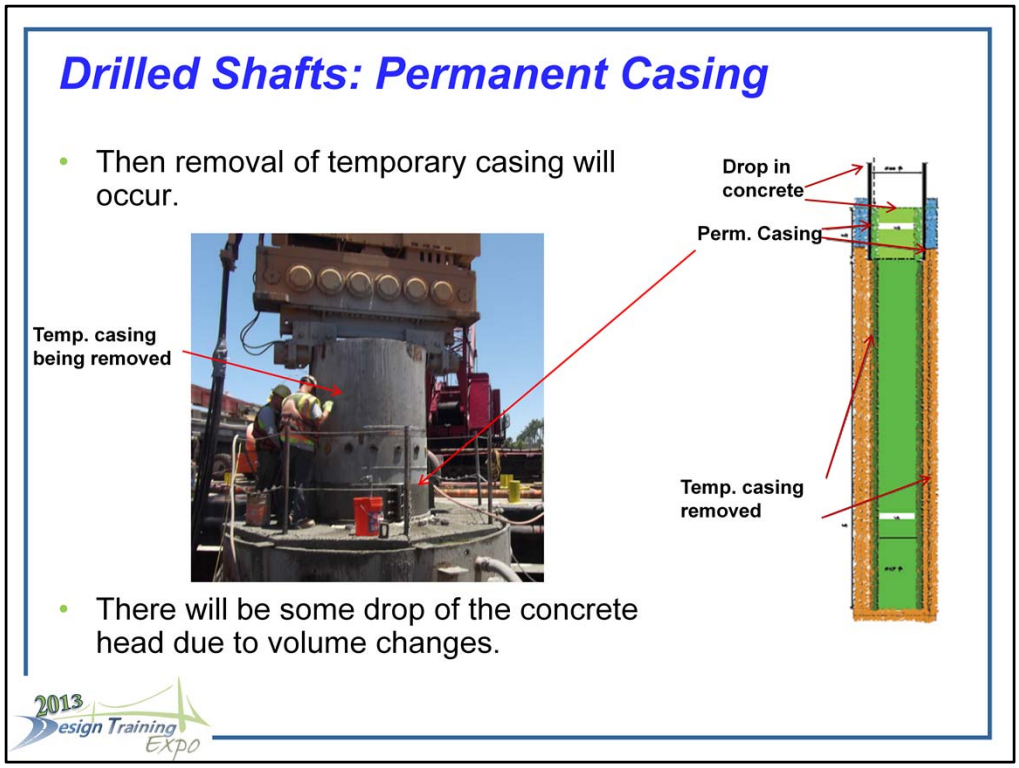
- Casing may need to go deeper than the permanent casing tip specified (voids, very weak soils).
- Temporary cased zones are subjected to a 50% side friction reduction. If this was not considered in the original design the socket will have to be extended.
- Permanent casing to be raised to the final casing tip elevation.



Will the permanent casing need to go deeper than the permanent tip we are specifying? This may require extending the shaft (some side friction is lost). The contractor will require an extra effort adding casing, trying to over pour to get good concrete and then pulling partially the casing. There may be a potential for claim if the conditions were not properly identified.



Provide or allow a permanent casing slightly larger than the required shaft diameter, so that contractor will be able to use an internal temporary casing as needed. This will allow contractor to use a temporary casing as deep as he wants to deal with weak and/or porous soils.



After concrete overflows and the temporary casing is removed we should expect a drop in the concrete.
Not a problem: the concrete is clean and there is no fluid over the concrete. Tremie can be reinserted and refill the shaft.
Contractor will need to watch that the concrete does not drop too much to produce an intrusion of soil and water from the outside.

DRILLED SHAFTS :*Shafts for Miscellaneous Structures*

Issues with hard rock:

- Difficulty drilling. Identify properly the rock conditions.
- In sign structures: Being conservative is not always good. It could create unnecessary construction problems.
- For sign structures: Hard rock does not need to be designed as a sand. This will create unnecessary hardship on the contractor.

(One shaft was 53 ft deep. Contractor equipment broke and lost the auger at 48 ft deep. The shaft was lost). Again knowledge of the area geology important. This shaft could have been designed easily with a 5 Tsf side friction.

DRILLED SHAFTS :*Shafts for Miscellaneous Structures*

Issues with loose to very loose sands:

- Difficulty supporting excavation.
- Difficulty cleaning: Loose sands are difficult to clean.
- Consider a shorter shaft with larger diameter.
- Typically contractors for this type of shafts are not used to handle deep temporary casing.

DRILLED SHAFTS :*Permanent Casing Issues*

Permanent Casing in Shafts for Miscellaneous Structures

Caution to Designers/Reviewers:

The FDOT procedure in the MATHCAD sheet for miscellaneous structures does not apply to permanent steel casing. The Beta (O'neill) and the Gamma (FDOT) method are for cast in place concrete-sand side friction.

$$\text{Torsion} = \frac{\left[\pi \cdot b \cdot \left(L_{torSand}\right) \cdot \gamma_{soil} \cdot \left(\frac{L_{torSand}}{2}\right) \cdot \left(\omega_{fdot}\right) \cdot \frac{b}{2} + \pi \cdot \left(\frac{b}{2}\right)^2 \cdot L_{torSand} \cdot \left(\gamma_{concrete}\right) \cdot \frac{b}{3} \cdot \mu\right]}{SF_{tor}}$$

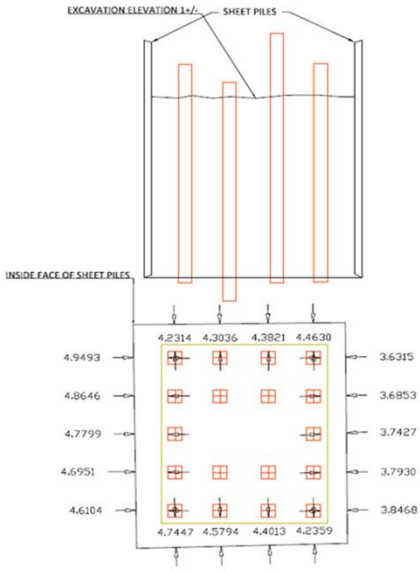
2. Pile Issues- Deep Temporary Sheetpiles

If piles are driven to close to temporary sheetpiles:

- There will be an additional friction due to the displacement of soil between sheetpiles and the concrete pile which densifies the soil between.
- And after the piles are driven the sheetpiles are removed. The lateral confinement is lost since the restraining sheet pile is not there anymore;
- Vibration may loosen the soil reducing the friction.
- The improvement that happened by displacing the soil during driving will be reduced by removing the sheet pile.

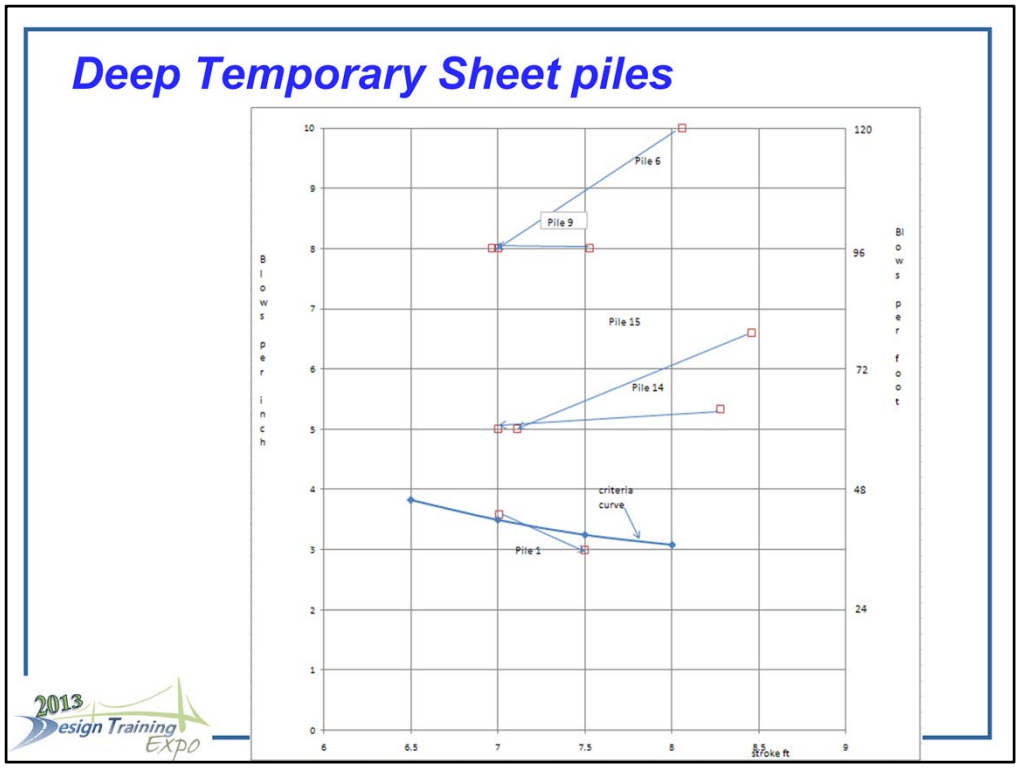
We need to pay attention in foundations driven in sands.
Temporarily increase of side friction that will be lost after removal of the sheet pile.
Particularly critical if the piles stopped above the sheet pile tips. Then we will loose not only part of the friction but a significant part of the bearing. In fact , the vibrations may even create settlement of the soil underneath the tip.
If piles stop significantly above what the test pile indicated we very likely have an effect from the sheet pile.
Also, the simple fact that you are above the elevation you estimated the driving criteria changes the picture.

2. Pile Issues- Deep Temporary Sheet piles

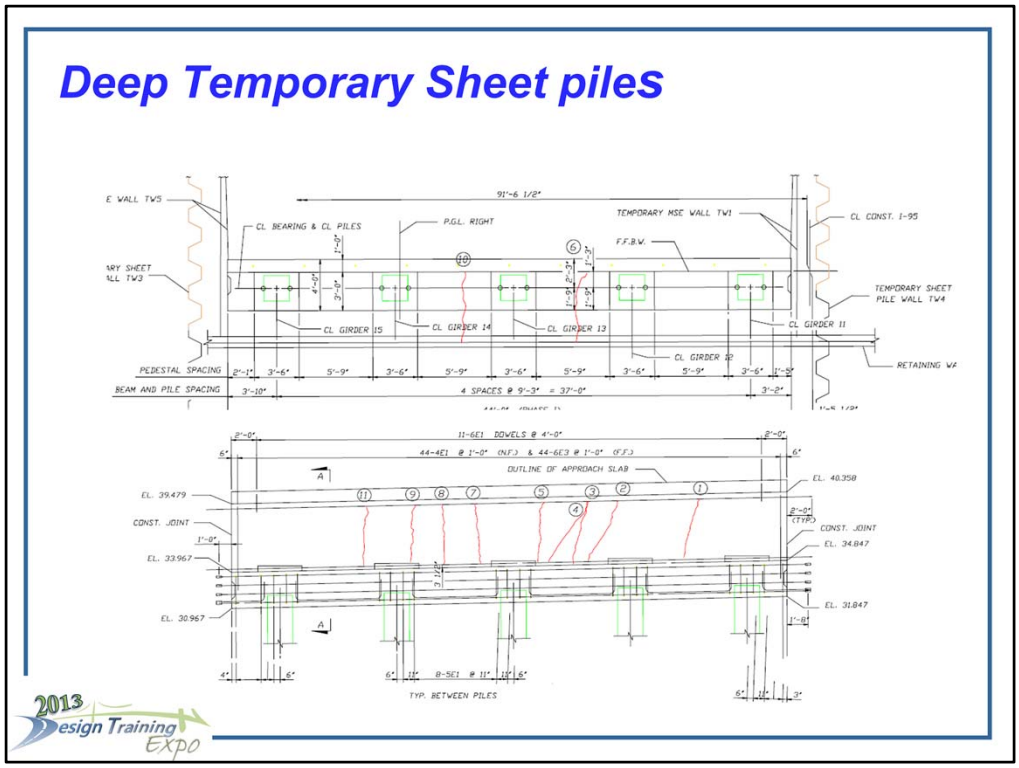


Deep Temporary Sheet piles

Deep Temporary Sheet piles

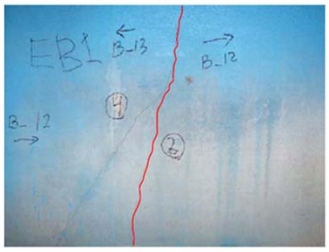


This chart indicates blows/ft before and after temporary sheet pile was lifted. Temporary sheet pile was lifted, but only 5 ft. However, still some blow count loss was observed.

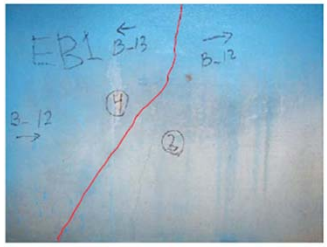


End bent piles were placed with very high blows, but stopped above the sheet pile tips. Later after constructing the superstructure there were cracks in the end bent. Piles lost capacity after removal of the sheet pile.

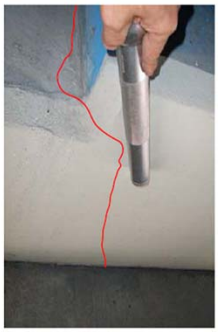
Deep Temporary Sheetpiles



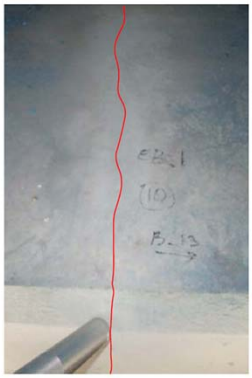
END BENT I (BACK WALL) - CRACK # 3



END BENT I (BACK WALL) - CRACK # 4
PIERS (12-13)



END BENT II (BENT CP)
CRACK # 8A - PIERS (12-13)



END BENT I (BENT CAP) - CRACK # 10
PIERS (13-14)

Deep Temporary Sheetpiles

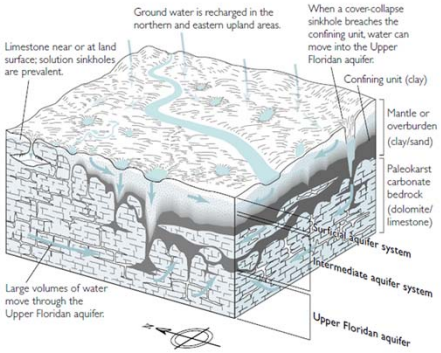
- Designers may consider:
  - ✓ Avoid cantilever sheet piles. Use braced systems with short penetrations
  - ✓ Ensure minimum pile tip is safely below the sheet pile tip.
  - ✓ Pre-drilling.
  - ✓ minimum distances from sheet piling,
  - ✓ Add an additional load to the nominal bearing capacity.

The effect has been also evaluated through PDA/CAPWAP testing to accept piles.

The last option would be to leave the sheet pile in (expensive).

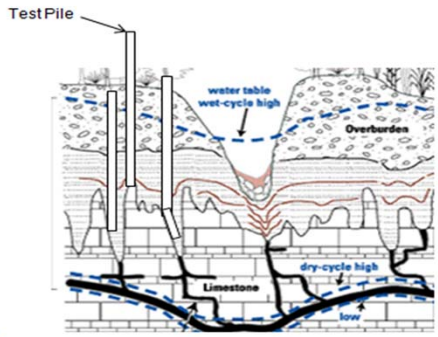
Piles in Karstic areas

- **Karst:** landscape formed from the dissolution of soluble rocks including limestone, dolomite and gypsum. It is characterized by sinkholes, springs, caves, disappearing streams, depressions and underground drainage systems.
- **Top of rock** profile in these areas will be typically irregular, with inclined surfaces and pinnacle forms.

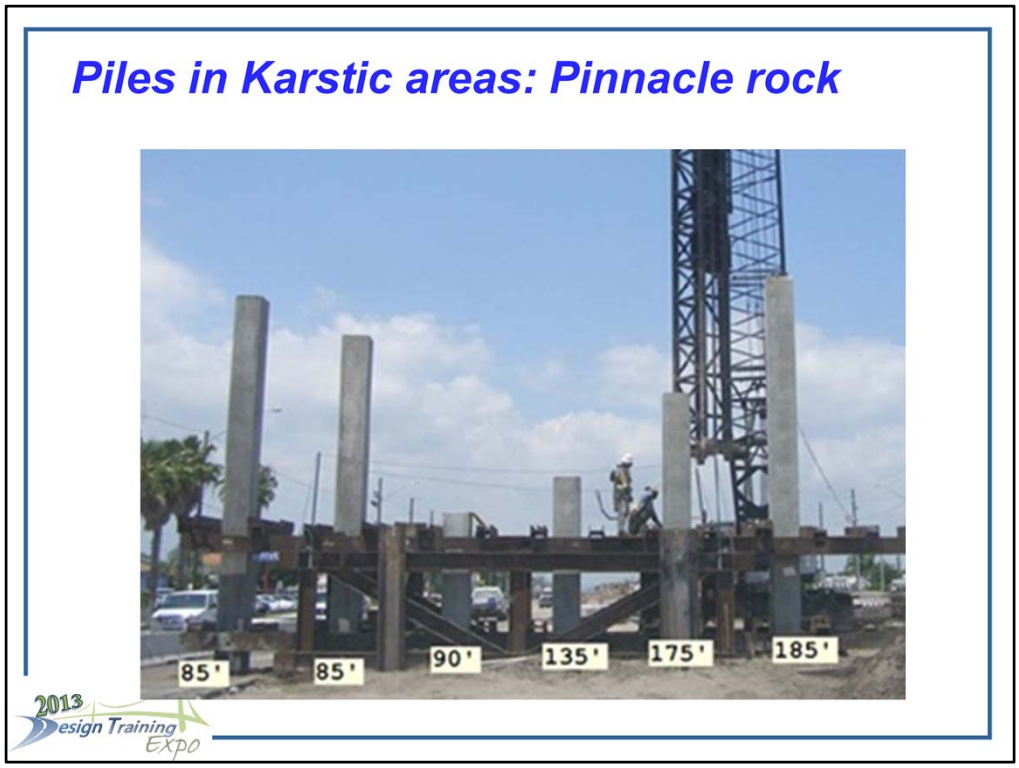


Piles in Karstic areas: Pinnacle rock

- High variability in the rock profile.
  - ✓ It will be very difficult to estimate pile lengths and preformed needs.
  - ✓ Need for splices may occur due to the variability of the rock surface.
- Potential for bending at the bottom of the piles.



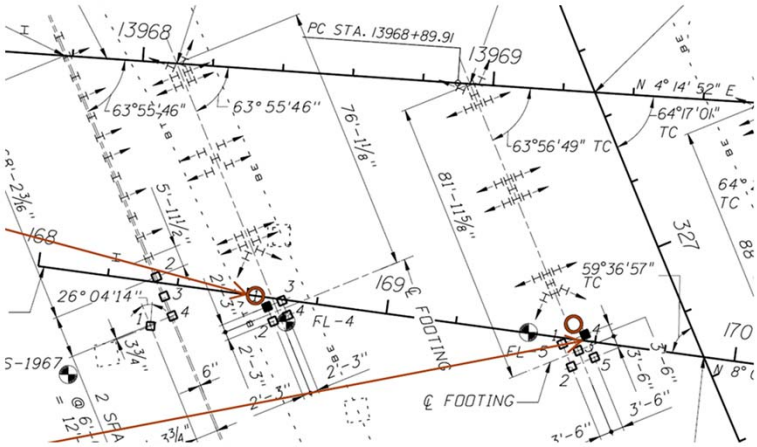
During construction it is difficult to estimate production lengths in concrete piles under these conditions due to the erratic profile of the rock.



During construction it is difficult to estimate production lengths in concrete piles under these conditions due to the erratic profile of the rock.

The pictures were taken from a project in which several piles were broken.
The geology included soil layers (clayey and silty sands, silts and clays) overlying a limestone formation.
There is a sinkhole in the vicinity of the bridge location indicated in the plans.
The Department decided to instrument all the production piles.
This allowed for a reduction of the required nominal loads and verifying the integrity of the piles.
Construction Impacts: Additional instrumentation, splicing, extraction and replacement

Piles in Karstic areas



- Existing piles were steel H piles.
- There is a sinkhole in the vicinity of the area indicated in the plans.

Piles in Karstic areas: Pinnacle rock

- The instrumentation cannot pick up the bending stresses that occur at the bottom part of the pile. By the time the operator detect an anomaly pile is already broken.
- Instrumentation will not pick up the effect of having a non uniform contact stress at the bottom. Stresses at one side could be much higher than the average indicated by the instrumentation.
- Piles could break under measured stresses that appear to be acceptable.

Piles in Karstic areas: Pinnacle rock

- Consider steel piles.
  - ✓ They will resist better the bending effects to an inclined rock profile.
  - ✓ Variability of the profile will be easier to handle since splicing a steel pile will be easier than splicing a concrete pile.
- If still concrete piles are required/desired due to load requirements and corrosion environment: consider 100% dynamic testing. This will minimize the required drive (6" required instead of 2 ft), reduce the required driving resistance and will allow to detect failed piles.

In karstic geologies designers should give consideration of installing steel piles, which handle better the erratic geology than concrete piles.
Need for splices may occur due to the variability of the rock surface. Splicing is more expensive and more time consuming in concrete piles than steel.
There will be bending stresses during installation that may break concrete piles easier than steel piles.
Note: For steel piles, as of Jan 2014, instrumented set-checks and redrives will count as dynamic testing for phi=0.75.

Uplift

- Uplift Capacity Requirements:
  - ✓ Make sure Uplift capacity is really required
  - ✓ Ensure the minimum tip elevation provided addresses also the need of uplift.
  - ✓ If we have to deepen minimum tip el: probable claim.
- It is not possible to provide a driving criteria for uplift.
- Set-checks and re-drives better for side friction determination with signal matching.

Avoid leaving loose end issues for the construction. Define design requirements of uplift during design.
If we have to deepen the min. tip=claim.
Side friction determination based on signal matching is not very accurate when the soil has an important bearing component. Better do analysis in redrives/set-checks.

4. Questions ?