Drilled Shafts for Iowa DOT Bridge Project: Really a "First"

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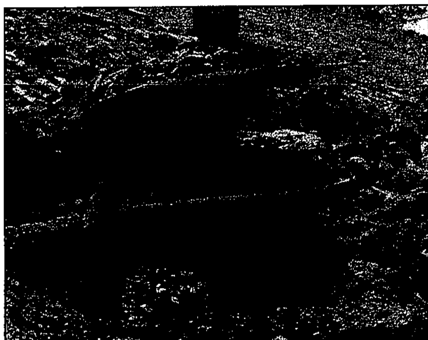

A 54-inch rock auger shown with hard shale cuttings being removed from the excavation of the east drilled shaft of Pier No.1

Until recently, the use of drilled shafts by the Iowa DOT has been limited, their traditional foundation of choice being steel H-piles. In the past, drilled shafts had been used by the DOT for foundations in the Missouri River border bridges, and at times when construction vibration issues were critical. This was the case when foundations were being installed near adjacent buildings, or where vibration impact might have affected existing bridge units. In these cases, drilled shafts were deemed preferable to driven piles.

Experiences related to a recent Iowa DOT bridge project may have changed the DOT's attitude about the appropriateness of drilled shafts in a variety of environments not only those restricted, past instances. Of specific relevance is a project that was constructed in Dallas County, Iowa. The following project description, (including photos), for a pretensioned, prestressed concrete beam bridge on U.S. 169 over Bulger Creek and the Iowa Interstate Railroad, was supplied to Foundation Drilling magazine by Wayne A. Sunday, Construction Field Engineer, Office of Construction, Iowa DOT.

Project Description

"This project involved a 592'-6 x 40' Pretensioned Prestressed Concrete Beam Bridge on U.S. 169 over Bulger Creek and Iowa Interstate Railroad in Dallas County, Iowa. This bridge consists of six spans with all substructure foundation construction on steel HP 10x42 piling except for Pier No. 2 which was specified as a spread footing.

Early in the project the contractor made a proposal to construct drilled shaft foundations for Piers No. 1 & 2 in lieu of the specified steel H-pile and spread footing designs. The basis for the contractor's request was to eliminate the need to construct cofferdams for foundation construction of these two piers. The specified pier foundations required approximately 20'-25' of excavation which would necessitate the use of cofferdams. **The contractor felt the use of drilled shaft foundation construction would significantly reduce the required depth of excavation and thereby also reduce construction time.**

The contractor hired a consultant to design the drilled shaft foundations for Piers No. 1 & 2 to be proposed as an alternate foundation design. The drilled shaft foundation design is based on a vertical compressional design load of 1,025 kips (maximum axial load using service load groupings reduced to 100 percent) for each drilled shaft. The drilled shaft bearing capacity was designed for friction bearing in hard shale only using an allowable bonding stress of 17 psi (includes a factor of safety of 2). End bearing was not considered in the original design, nor in the hard shale layer. (See figure 1, p.16)

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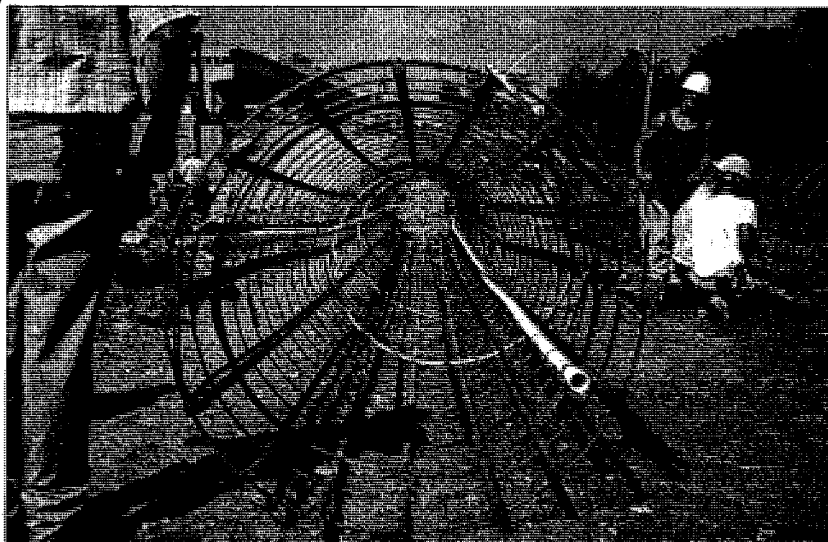
Review and evaluation of the sections of hard shale cores. Persons in this photo from left to right are Curtis Monk - FHWA Bridge Engineer, [illegible] - FHWA Transportation Engineer for Northeast and East Central Iowa, [illegible] - Iowa DOT Soils Design Engineer, and [illegible] - FHWA Transportation Engineer for Northwest, [illegible] and Southeast Iowa.



[illegible]

Following review of the proposed design by the Iowa DOT Office of Bridges & Structures and Soils Design Office, including several consultations with the design consultant, the proposed drilled foundation shaft design was approved."

The overall description tells only part of the story. There were some very interesting project details not the least of which was that the DOT approached the project as one allowing for "value engineering", and also required that bidders were able to fulfill fairly rigorous prequalification criteria. This is something the ADSC has been promoting for some time. The criteria utilized in the project's Special Provisions were included in the *Drilled Shaft Installation Plan*. Those criteria, and the drilled shaft installation plan are as follows:

Drilled Shaft Installation Plan

"The Engineer may request the Contractor to provide the following information regarding Contractor personnel or the Subcontractor responsible for drilled shaft construction.

1. A list of at least (3) projects completed on which the Contractor or Subcontractor has installed drilled shafts of a diameter and length similar to those shown in the value engineering proposal.
2. The list of the above projects shall contain names and phone numbers of the owner's representatives who can verify the Contractor's or Subcontractor's participation on those projects.
3. A signed statement that the Contractor has inspected the project site and all the subsurface information made available.

Prior to constructing the drilled shafts, the Contractor shall submit an installation plan for review by the Engineer. This plan shall provide information on the following:

1. Name and experience record of the drilled shaft superintendent in charge of the drilled shaft operations for this project.
2. List of proposed equipment to be used including cranes, drills, augers, bailing buckets, final cleaning equipment, desanding equipment, slurry pumps, core sampling equipment, tremies or concrete pumps, casings, etc.
3. Details of overall construction operation sequence and the sequence of shaft construction in bents or groups.
4. Details of shaft excavation methods.
5. When slurry is required, details of the methods to mix, circulate and desand slurry. If polymer slurry is proposed, submit data on load transfer and manufacturer's requirements for slurry control.
6. Details of methods to clean the shaft excavation.

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Drilled shaft reinforcing cage with load cell being lowered into the east drilled shaft No. 1.

7. Details of reinforcing steel placement including support and cage centering methods.
8. Details of concrete placement including procedures for tremie or pumping methods.
9. Concrete mix proposal."

The Special Provisions section went on to include a lengthy construction plan, which allowed for the use of the slurry method of construction, utilizing either mineral or polymer slurries, and/or the use of casing. The slurry section spelled out a slump range or 6-8 inches, (specifically described, as "8 inches plus or minus 1 to 1-1/2 inches"), as well as related construction procedures. These included the appropriate slurry tests. Specifications for both mineral and polymer slurries were provided. While the slurry specifications relative to density and viscosity were not exactly those recommended by ACI 336 and the ADSC, they were well within acceptable parameters. The slurry part of the specification was definitely of the "method" rather than the "performance" variety. (It might be of interest to note that when it comes to general construction procedures, the *ADSC recommends performance specifications,* however, in the case of mineral and polymer slurry construction, the guidelines should not be as flexible. Slurry construction requires special experience and strict adherence to acceptable procedures). The remainder of the specifications were also "method oriented." As it turned out, slurry was not used. The following construction plan outlines how the shafts were to be installed.

Shaft Construction

"The drilled shafts may be constructed by either the wet method or casing method as necessary to produce sound, durable concrete foundation shafts free of defects.

A. The wet construction method consists of keeping the shaft filled with slurry a minimum of 4.0 feet above the highest expected water table during drilling and excavation, desanding of slurry when required and final cleaning of the excavation by means of a bailing bucket, air lift, pump or other approved device and placing shaft concrete which displaces the slurry.

B. The casing method is used to advance the drilled shaft through unstable material. The Contractor will install a temporary casing of sufficient diameter to accommodate the construction of the drilled shaft within.

Material within the limits of the temporary casing will be removed down to rock. Once this material is removed, the Contractor will begin drilling the rock socket to the elevation shown on the

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value engineering proposal.

Following completion of the rock socket drilling and prior to placement of the reinforcing steel and concrete, the Contractor shall install a CMP permanent casing the same diameter as the rock socket. The permanent casing shall not extend past 1 foot into the rock socket.

Prior to removing the temporary casing, the void between the permanent casing and the temporary casing shall be filled as directed by the Engineer. The void shall be filled with flowable mortar, clean sand or lean concrete. Existing soil conditions may dictate which method is approved by the Engineer.

C. The Contractor shall adjust operations so that the maximum time that the slurry is allowed to remain in the shaft is 24 hours. If a slurry cake builds up on the shaft sidewalls, the Contractor shall remove it at no additional cost.

D. If mineral slurry is used, the shaft sidewalls shall be reamed prior to placement of reinforcement.

E. The Contractor shall clean the base of each shaft so that a minimum of 50% of the base will have less than 1/2 inch of sediment at the time of concrete placement. The maximum depth of sediment or debris at the base of the shaft shall not exceed 1-1/2 inches.

F. Surface and subsurface obstructions shall be removed by the Contractor. Special tools and procedures may be required. No separate payment will be made for removing obstructions.

G. The Contractor shall extend drilled shaft tip elevations if the Engineer determines that the material encountered during excavation is unsuitable or differs from that anticipated in the design or the drilled shaft."

The Special Provisions stated clearly that there would be no special payment made for the removal of obstructions. There was no distinction made as to earth versus rock removal. At this point in their experience with drilled shafts, the DOT feels more comfortable with having their work bid *unclassified.* Perhaps this will change as they become more familiar with the system and explore the advantages of bidding drilled shafts under a unit priced approach. It should be pointed out that the contract documents used for this project did include ***Changed Conditions Clauses.*** It is clear that the Iowa DOT has done its homework relative to minimizing possible project conflicts.

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All in all, the specifications, though rigorous, were in close conformance with those promoted by ACI and the ADSC.

Osterberg Load-Cell Test

The Iowa DOT determined that it would be useful to conduct a load test to confirm the design assumptions being made about this particular project, and to provide additional information that might prove to be useful on future projects. In order to achieve this dual goal, an Osterberg Load Test was conducted by Loadtest, Inc. The Osterberg Load Cell (O-Cell) has become a popular design confirmation device for State Departments of Transportation throughout the U.S. **In many instances drilled shafts have become the deep foundation of choice for DOTs due in no small measure to the utilization of the O-Cell prior to final design decisions being made.** In this case the test was carried out by Jeff Goodwin of Loadtest's Maryland Office. One 26" diameter Osterberg Cell with a capacity of 1800 tons in each direction was installed in the 54" diameter by 59.5' deep test shaft. The base of the O-cell was placed 1.1 feet above the bottom. The Osterberg method load test was carried out as follows:

"The 26" diameter O-cell, with its base located 1.1 feet above the base of shaft was pressurized to assess side shear, using the combined end bearing and side shear of the 1.1 foot long shaft section below the base of the O-cell for reaction. The O-cell was pressurized to a maximum load of 1832 tons resulting in a downward movement of 0.60 inches.

The Osterberg method test was also used to assess side shear characteristics of the shaft above the O-cell. A net load of 1762 tons was applied in shear, producing an upward top of O-cell movement of 0.23 inches.

Three levels of two sister bar vibrating wire strain gages were installed in the shaft at distances of 12.2, 16.2 and 18.7 feet above the base of the O-cell. The strain gages were used to assess the side shear load transfer within the

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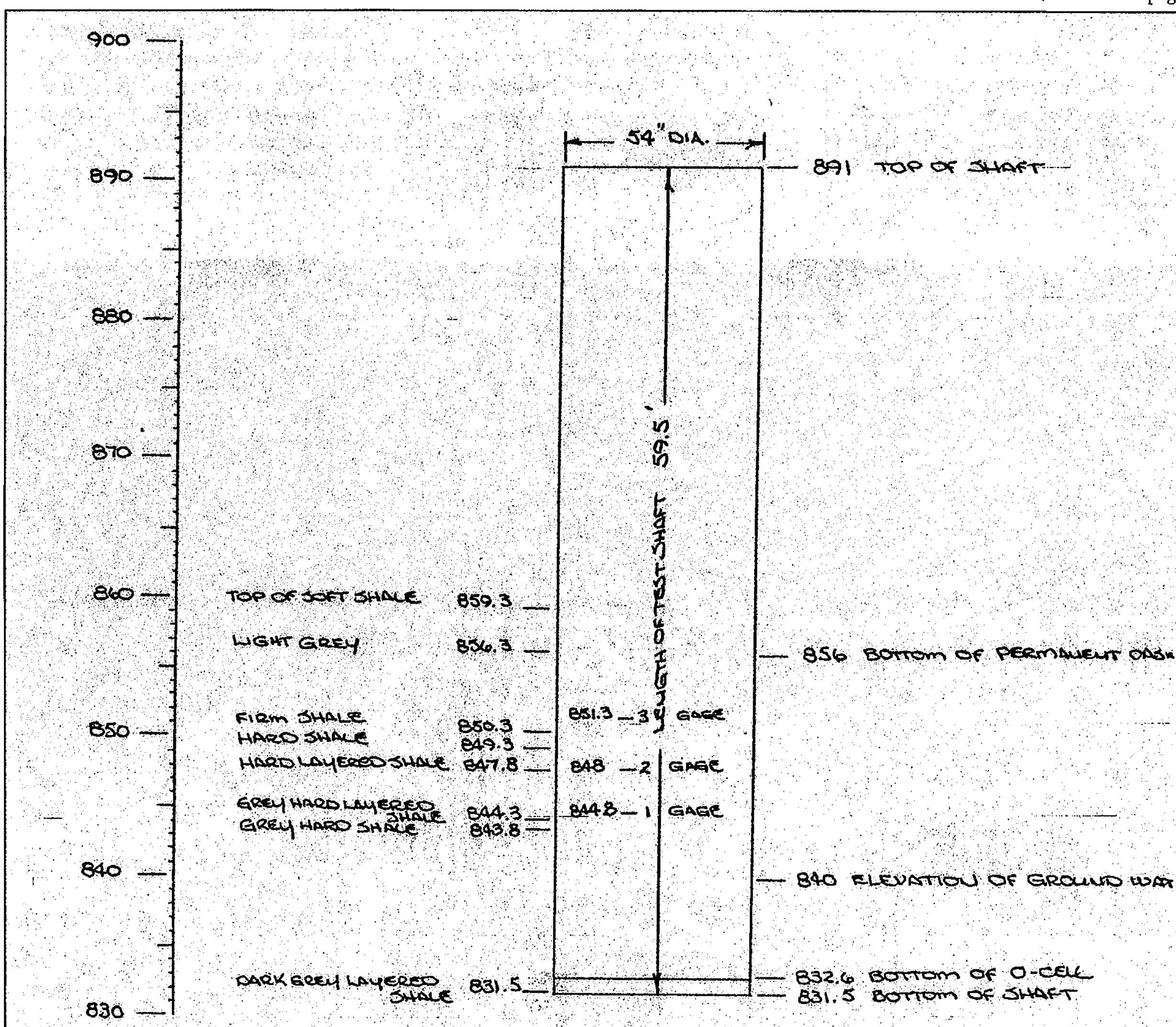

Figure 1

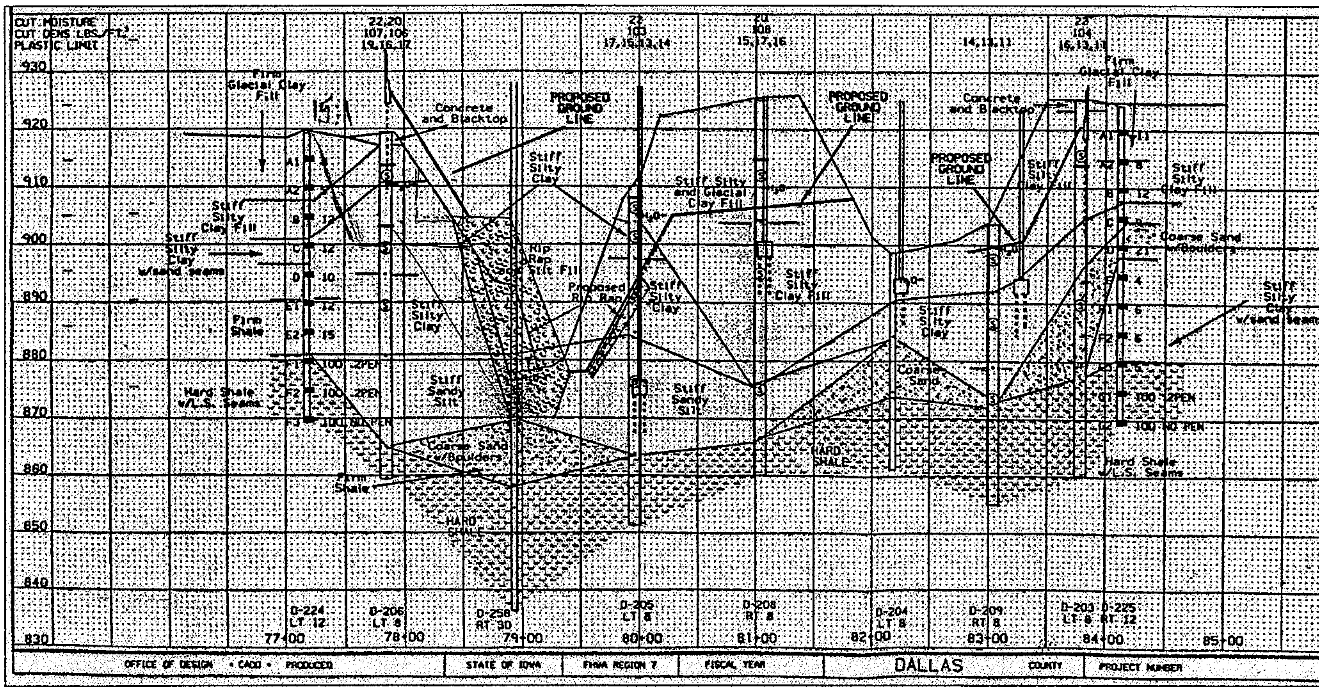

Figure 2 Bulger Bridge Soil Survey

shaft above the Osterberg cell.

Discussion of Results

End Bearing/Socket Resistance: The maximum load applied to the base of the shaft was 1832 tons. At this loading, the measured downward movement was 0.60 inches. The ultimate end bearing capacity was not reached at this loading.

As might have been expected, the O-cell load test confirmed the design assumptions and provided important information for drilled shaft foundations that will now be used for future Iowa DOT highway bridge projects.

Side Shear: The maximum load applied to the shear section above the O-cell was 1762 tons (i.e. 1832 tons minus buoyant weight of shaft of 69 tons). At this point the total upward movement was 0.23 inches. At this loading, the ultimate side shear capacity was approached but not reached.

Equivalent Top Load: A combined total shaft load of 2785 tons applied to the shaft would result in a settlement of 0.24 inches.

Creep Limit: The side shear creep data indicated that a creep limit was not reached. The base of O-cell creep data indicates shaft base creep limit was reached at a loading of 1700 tons.

Strain Gage Results: Based upon the results of the strain gage data, the following unit side shear values were applied during the load test:

Bottom of Casing to Strain Gage Level 2 1.77 tsf

Strain Gage Level 2 to Strain Gage Level 1 24.9 tsf

Strain Gage Level 1 to Bottom of O-cell 2.46 tsf "

(See Figure 2)

As might have been expected, the O-cell load test confirmed the design assumptions and provided important information for drilled shaft foundations that will now be used for future Iowa DOT highway bridge projects.

The Bulger Creek Replacement Bridge project began in March, 1997. The drilled shaft part commenced that August, and was completed in late September. The bridge went into service in December 1997.

Thanks to a forward thinking bridge division that was willing to consider drilled shafts, coupled with the design confirming use of the O-Cell, and the inherent performance, and cost effective characteristics of this foundation system, drilled shafts are finding a place in the State's deep foundation thinking. In fact, the Iowa DOT is engaged in further drilled shaft *(continued on page 18)* test projects intended to provide additional information upon which future designs will be based. One such project planned involves static and dynamic testing of drilled shafts, and includes cross hole sonic logging. This will generate data about drilled shaft performance in soils as well as socketed into rock. It is likely that the Iowa DOT will continue to call for drilled shafts whenever they feel the system provides the best solution.■