Project Field Model Pile Load Test, Hamilton Air Force Base Test Site, Novato, California. Prepared for Amoco Production Company by Woodward-Clyde Consultants, Clifton, N.J., 1980.
21. J.M. Konrad. Contribution Au Calcul de Frottement Lateral des Pieux Flottants Fonces dans des Argiles Molles et Sensibles. M.S. thesis. The Graduate School of the University of Laval, Quebec, Canada, 1977.
22. M. Roy, R. Blanchet, F. Tavenas, and P. LaRochelle. Behavior of a Sensitive Clay During Pile Driving. Canadian Geotechnical Journal. Vol. 18, July 1981, pp. 67-85.
23. American Petroleum Institute. Recommended Practice for Planning, Designing, and Constructing Offshore Platforms. API RP 2A. 9th ed., Washington, D.C., 1978.
24. M.W. O'Neill, R.A. Hawkins, and L.J. Mahar. Field Study of Pile Group Action, Appendix D. FHWA RD-81-006. FHWA, U.S. Department of Transportation, March 1981, pp. D14-D17.
25. L.J. Mahar and M.W. O'Neill. Geotechnical Characterization of Desiccated Clay. Journal of Geotechnical Engineering. ASCE, Vol. 109, No. 1, Jan. 1983, pp. 56-71.
26. R.P. Aurora, E.H. Peterson, and M.W. O'Neill. Model Study of Load Transfer in Slender Pile. Journal of the Geotechnical Engineering Division. ASCE, Vol. 106, Aug. 1980, pp. 941-945.

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*Abridgment*

# Large Observation Borings in Subsurface Investigation Programs

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ABSTRACT

The West Papago/I-10 Inner Loop Freeway alignment in Phoenix, Arizona is underlain by up to ±20 ft of surficial silty clay, sandy clay, clayey sand overburden, and ±200 ft of dense sand-gravel-cobbles (S-G-C) with occasional ±18-in boulders. Conventional, small-diameter borings are used for disturbed and undisturbed sampling in the overburden. Atterberg Limits, mechanical analyses, consolidation, collapse-potential, direct shear, and triaxial compression tests are performed on the overburden material. Refusal to helical-auger penetration usually occurs at or near the top of the S-G-C deposit. Local practice is to utilize percussion drilling to penetrate the S-G-C deposit. This procedure does not produce representative specimens of the foundation material and laboratory testing is not attempted. This paper contains a description of the composition of the subsurface materials, current drilling-sampling techniques for the S-G-C deposit, and the use of large observation borings as a supplementary means for conducting visual examination of the S-G-C material. This examination aids in the assessment of the S-G-C material as a foundation material for bridges and retaining walls, as a tunneling medium, and in the slopes of a depressed roadway.

The final link of Interstate 10 (I-10) is under design and construction by the Arizona Department of Transportation. This ±9 mi segment of the West Papago/I-10 Inner-Loop Freeway through downtown Phoenix will involve major multi-level interchanges, a depressed I-10 roadway in highly developed areas with multi-level buildings, and historic properties immediately adjacent to the alignment. The depressed roadway will intercept the surface drainage of the Phoenix Basin and separate the watershed into two regions. Storm runoff collected from the northern half of the drainage area must be conveyed through tunnels to its natural outlet at the Salt River. Subsoils through which the tunnels must be driven, and that will support structure foundations and form the depressed section side slopes, have been extensively investigated. The primary exploration method has been conventional, small-diameter drill holes with limited in-hole testing and, where feasible, acquisition of samples for use in laboratory testing.

The variation of particle sizes from clay to boulders, and material desiccation and cementation, prevents acquisition of samples suitable for laboratory testing. The absence of suitable test informa-

tion for assessing soil strength and deformation characteristics of the sand-gravel-cobbles (S-G-C) deposit has resulted in greater than normal use of engineering judgment in predicting soil structure interaction and performance of slopes and structure foundations. Large observation borings were drilled to supplement the information obtained through small-diameter borings.

## SUBSURFACE CONDITIONS

The project lies within an intermontane basin that is drained by the Salt, Gila, and Colorado Rivers into the Gulf of California. The surficial deposits consist of alluvial fan material composed of silty clay, sandy clay, and clayey sand with lesser amounts of silty sand and sand. This overburden is often highly stratified, moderately-to-strongly calcite-cemented, and generally possesses scattered gravel and calcareous concretions. Its thickness varies from less than approximately 10-20 ft along much of the east-west freeway alignment and decreases to less than approximately 2 ft in the area of the Salt River. The overburden is underlain by S-G-C deposits.

The rapid washing of eroded material from the nearby mountain ranges into the broad Phoenix Basin resulted in massive S-G-C deposits, which, as indicated in well logs, extend to a depth of several hundred feet in many areas of the Salt River Valley. The gravel- and cobble-size particles are subrounded, hard, and durable; and are composed of quartzite, granitics, volcanics, and other metamorphics. These S-G-C deposits contain numerous cobbles with nominal diameters of up to approximately 12 in. and occasional boulders with maximum diameters of up to 18 in. The upper 20-30 ft of the S-G-C deposits are generally weakly or uncemented and are relatively clean. Below 30 ft, the S-G-C deposits contain more silt and traces of clay and are locally weakly cemented.

## CONVENTIONAL SUBSURFACE INVESTIGATIONS

The methods usually employed to drill the overburden will permit the taking of disturbed and undisturbed samples that can be used for establishing soil strength and deformation characteristics. The percussion drilling procedures required for S-G-C penetration produce degraded specimens that are unsatisfactory for any meaningful testing in the laboratory.

The drilling, sampling, and field testing of the overburden and S-G-C materials currently include the procedures discussed in the following paragraphs.

### Auger Boring--Overburden

Drilling in overburden is performed with a 6.5-in. outer diameter (O.D.), 3.25-in. inner diameter (I.D.), hollow-stem auger, or a ±4-in. solid-stem, continuous flight auger. The point of refusal to auger penetration is usually coincident with the top of the S-G-C deposits. Grab samples may be taken from auger cuttings and standard penetration tests, or 2.42-in. diameter ring (liner) samples may be taken to provide disturbed and undisturbed samples for testing.

### Becker Drill--S-G-C

Drilling with the Becker Hammer Drill is accomplished by advancing a double-walled drive casing with a Link-Belt, 180-diesel, pile hammer having a rated energy of 8,100 ft-lb per blow, or 12,000 ft-lb per blow when equipped with a supercharger. Cuttings are removed with compressed air by reverse circulation and collected at the surface in a cyclone, from which grab samples are taken.

### Odex System--S-G-C

The Overburden Drilling with Eccentric System, or ODEX, is also referred to as a "down-the-hole hammer system." The system consists of a pneumatic rotary-percussion, down-the-hole hammer operating at the bottom of the hole, being drilled through a 5-in. diameter steel casing. The eccentric button percussion bit underreams the bore hole and allows advancement of the casing. The same compressed air or air-detergent that operates the hammer also serves to expel the cuttings from the bore hole.

### Schramm Rotadrill--S-G-C

The Schramm T605 H, truck-mounted drill rig is a top-drive, rotary rig that is capable of up to 85,500 in.-lb of torque with a pull-down capacity of 35,000 lb. Drilling is performed with either 8-in. or 5.625-in.-diameter tricone roller bits. Cuttings are removed by compressed air or an air-water mixture. Grab samples are taken from the cuttings. When casing is required to stabilize the bore hole, a Hammerhawk drill-thru casing hammer is used, permitting simultaneous rotary-tricone drilling and driving of casing.

## LARGE OBSERVATION BORINGS

Since early 1983, the Arizona Department of Transportation has utilized large observation borings to supplement small-diameter explorations and testing. This procedure was first used in value engineering studies for the tunnel drainage system when a 36-in.-diameter boring was drilled to a depth of 65 ft to permit in-situ examination of the material. A 36-in. auger was selected for access purposes (Figure 1). Repeated entry and withdrawal of the auger resulted in actual hole dimensions varying from 42 to 66 in.

The boring was logged and bag samples were taken during drilling. A 60-ft section of 36-in.-diameter, steel safety casing with approximately 8 x 8-in. viewing ports at approximately 5-ft intervals, was positioned in the boring. The sidewalls of the boring were examined, the material visually classified, and color photographs taken (Figure 2). The following conditions were reported:

1. Side walls stood unsupported at full depth even in sand layers for approximately 24 hr.
2. The size of the hole varied from 42 to 66 in.
3. Cobbles and boulders were primarily flat, thin, and rounded in approximately the same way as the exposed materials from the Salt River Channel.
4. The largest boulder observed in the excavated material was 18 x 18 x 6-in.
5. In the sidewall, large boulders greater than 10 in. were observed to be scattered throughout the profile rather than concentrated at particular depths.
6. Cobbles and boulders were observed to be rather flat-lying, (i.e., with the greatest surface exposure along a horizontal plane).
7. Roots were observed to exist as deep as 33 ft. Large trees were growing adjacent to the boring.
8. S-G-C deposits appeared to be cemented for the full depth, from their first appearance at 20 ft

FIGURE 1 A 36-in. helical auger for large observation borings.

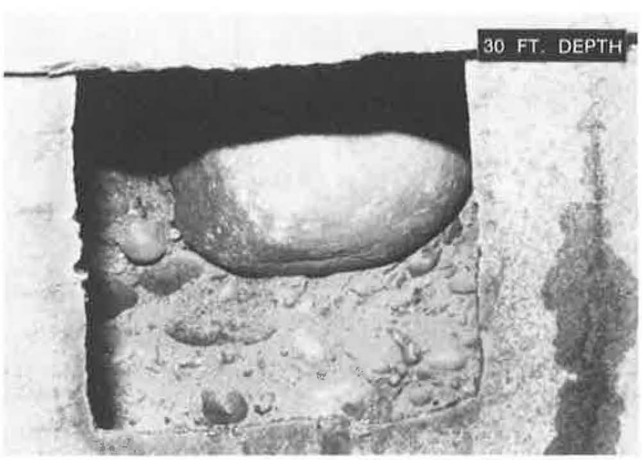


FIGURE 2 Sand-gravel cobbles (S-G-C) as viewed through 8 x 7-in. hole at 30-ft depth.

down to 65 ft. The amount of cementation increased with depth as noted by an increase in the whitish coating on particles. This was particularly noticeable below 48 ft. There may not be a significant cementation effect, however, because materials still crumbled easily with hand pressure at all depths. The cementing material did not react with HCL.

This large observation boring presented an opportunity to study the drilling effort and excavated material, and to examine the in-situ subsurface materials, which was more beneficial in the design process than reviewing the results of many small-diameter percussion borings required to penetrate the S-G-C deposits.

Two 28-ft-deep large observation borings were drilled specifically for access by geotechnical engineers representing the FHWA, the Arizona Department of Transportation, and the management and design consultants. The objectives were to

1. Compare the in-situ condition of the overburden with the results of a small-diameter auger hole drilled nearby;
2. Examine the gradational changes at the interface of the overburden and S-G-C deposits;
3. Witness the effort required to drill the S-G-C;
4. Make a personal assessment of the S-G-C with respect to adopted end-bearing and side-resistance parameters for drilled shafts; and
5. Take samples of the S-G-C deposits for use in laboratory corrosivity testing.

A final design exploration program was developed for the tunnel alignments and included auger borings to establish the top of the S-G-C deposits along the alignment, and ODEX holes through the tunnel envelope and for installation of groundwater observation wells. Four large observation borings were planned as part of the tunnel bidding procedure. Subsurface information acquired through conventional, small-diameter explorations was furnished with the bidding plans. The prospective bidders were advised of the drilling of the large observation borings. A prebid conference was set for the afternoon of April 10, 1984. Early April 9, two large observation borings were started simultaneously at the west and east tunnel alignments.

Representatives of the contractors, their consultants, equipment manufacturers, suppliers, and construction engineers observed the drilling process with intermittent examination of the side walls during drilling (Figure 3). The borings were planned to penetrate the full depth of the tunnel envelope. Some holes achieved this while others were terminated at groundwater level, but, in all cases, the borings penetrated into the tunnel envelope. A 36-in. corrugated metal pipe (CMP), 16-gauge, protective casing having approximately 8 x 10-in. viewing ports cut at approximately 5-ft centers, staggered at 180 degrees, was positioned in the boring with viewing ports along the tunnel alignment.

FIGURE 3 S-G-C drilling with a Texoma Tarus holedigger.

On April 9 and 10, 1984, 122 representatives of 52 firms entered the four large observation borings for personal examination of overburden and S-G-C deposits, and a pre-bid conference was held on April 10. Logs of these boring and water depths were subsequently included in an addendum to the bidding documents and provided to all bidders. The concept and execution of these large observation borings as a part of the bidding package were well received.

Two rigs have been used to date to drill the large observation borings on the West Papago/I-10 Freeway in Phoenix--A Watson Model 3000 and a Texoma Tarus. The Watson Model 3000 is equipped with a 318-in.$^3$ diesel engine, a sliding frame permitting clearance for 7-to-14.5-ft-diameter tools and 46 in. of travel. A telescoping kelly permits drilling to approximately 105 ft. It develops 100,000 ft-lb of rotary torque and 24,000 lb of positive crowd. Full-stroke crowd and quick hoist speed results in a reduced cycle time, allowing greater production rates. Two hundred rpm of the drilling tool allows for quick spinoffs and increased production.

The Texoma Tarus Hole digger is equipped with a 426-in.$^3$ diesel engine that develops 83,741 ft-lb of rotary torque and 51,200 lb of positive crowd pressure. A telescoping kelly permits drilling to 100 ft. A spinoff speed of 281 rpm allows for quick spinoff.

## CONCLUSIONS

The following conclusions are presented:

1. Geologic conditions in the Salt River Valley at Phoenix require special drilling and sampling techniques in the acquisition of subsurface information for design and construction. Some of these techniques involve percussion drilling that does not produce the quality of results desired.
2. Large observation borings were a valuable supplement to the conventional subsurface investigation program, particularly in the S-G-C materials. It was possible to observe the in situ composition of the S-G-C materials, and the distribution and concentration of sand, gravel, cobbles, and boulders, which had not been possible with small-diameter percussion borings.
3. The in-situ visual examination of the S-G-C materials aided considerably in the formulation of judgments relative to the acceptability of end-bearing and side-resistance values adopted for deep foundation design, and potential problems associated with construction of temporary earth support systems within the S-G-C materials.
4. The random, heavy concentration of cobbles and boulders within much of the S-G-C deposits is a deterrent to in-situ testing within large observation borings in the S-G-C material.
5. In a different geologic environment, large observation borings may provide opportunity for in-situ testing as well as visual examination of critical subsurface materials.

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