SSC-N-577

A PLAN FOR
STARTUP GEOTECHNICAL CHARACTERIZATION
OF THE TEXAS SSC SITE

Office, field, and laboratory-based geotechnical studies will begin at the Texas SSC site in early 1989. These Startup Geotechnical Studies will have the immediate objective of gathering sufficient data to support concurrent efforts to (1) determine the final footprint --thereby helping the start of Land Acquisition-- and (2) begin the Site-Specific Conceptual Design. Both Land Acquisition and Conceptual Design must begin in the first quarter of CY89. Because of the obviously short time period for the supporting geotechnical studies, planning and preparing for them must begin now.

1. WHY GEOTECHNICAL?

Underground works are notorious for the regularity with which the unexpected occurs. Most large underground contracts will encounter some unforeseen "problem ground" which may necessitate new or modified excavation/support techniques, and changes that in all probability will have a direct impact on schedules and costs. Proof of this can be seen in the frequency with which "extra-contractual" claims are made by contractors based on "unexpected geological" or "differing" site conditions.

A&E Responsibility

A clear and detailed description of the site ground conditions should be produced before the design is completed and the construction contract is awarded. The margin of confidence with which the geological nature and geotechnical properties are known should be high enough to allow design, planning, and contract costing to be done with a minimum of risk from geological surprises.

The geotechnical characterization strategy described below is a necessary first step toward this desired geological understanding of the SSC site.

2. PRIORITIES

#1 The Footprint:

The most immediate priority of the geotechnical studies will be to indicate whether individual components of the collider footprint, or indeed the entire footprint, need to be relocated because of geotechnical constraints. Recommended shifts in locations of access shafts, interaction halls, and injector to avoid flood hazards, difficult ground (e.g. weak rock caused by faulting), or sources of unacceptable vibration will have obvious impacts on the already short-fused land acquisition process.

#2 Global Data:

The next priority is the development of a broadly based, broadly distributed geotechnical database for the site and its immediate environs. This global or systematic data set should have three attributes; (1) uniform geographic distribution over the site footprint, (2) complete coverage of all of the strata through which the SSC tunnels and shafts will pass, and (3) consistency of the data from sampling site to sampling site throughout the site. Geological, geohydrological, and geotechnical tests in the near vicinity of the E and F access shaft sites, for example, will provide this global data set in adequate strength for conceptual design. For collider tunnel design, the shaft site data will be extrapolated along the ring alignment by geological stratigraphic correlations.

#3 Structure-Specific Data:

The final short-term priority is to begin to assemble SSC structure-specific geotechnical data by focusing field tests on the locations of experimental halls and the injector. Backed by the global data set, these geotechnical and geohydrological data will support conceptual designs of construction methods and structural supports for key underground structures.

These three priorities, and the data needs they engender, are obvious drivers in the characterization plan described in Section 5, below.

3. PROPOSAL DATA

The Texas site proposers selected their site for its good general construction characteristics and host formations that are relatively consistent throughout the site region (among other factors). To demonstrate this, geological, geohydrological, and geotechnical data were assembled from a number of published and unpublished sources for the proposal (and subsequent amendments). This included sinking numerous proposal-specific boreholes to establish the large-scale structural competence and ground characteristics of the region.

During the planning phase, it will be important to identify proposal data that can make a valid contribution to the design process. All of the proposal data will help to form a context within which new geotechnical characterizations can be interpreted. Additionally, the proposal data have frequently been important in identifying geotechnical issues that need further evaluation.

Kick-off Geotechnical Workshop

Clearly, the geoscientists and geoengineers of the Texas proposer team have done an heroic job in characterizing and understanding their site. Volumes of site-specific data and interpretations now reside in state agencies, and many more interpretations exist most lucidly in the minds of key individuals. It would be most appropriate to tap this wealth of data and understandings before beginning the site field work. Workshops and field trips are the usual methods among geoscientists and geoengineers for effecting such data transfers.

The workshop agenda should include discussions of both discipline-specific and interdisciplinary topics. Discipline-specific (i.e. geology, geophysics, groundwater, surface-water, soil engineering or rock engineering) agendas should cover: data and sample availability; acquisition and analysis procedures and criteria; region-scale overviews; and site-specific issues and uncertainties. Interdisciplinary topics will cover: local geoenvironmental issues and concerns; local geohazards; local geotechnical construction practices; and local regulations and regulating agencies. It will also be important to learn of other federal, state and academic groups in the region who also have pertinent data.

4. STRATEGY AND TECHNIQUES FOR CHARACTERIZATION

Footprint Studies

Footprint-delimiting geotechnical studies, as highest priority, will be the first begun. Items that need to be identified are as follows:

- Floodplains (100-year) that encroach on the locations of surface facilities (including facilities related to underground operations)

- Zones of poor rock quality and potentially high water inflow due to faults and sheared zones in the rock that should be avoided for the experimental hall excavations

- Areas where the tunnel placement is shallow and there are nearby sources of vibration such as major highways and railroads that may represent a problem due to unacceptable vibrations at tunnel depth.

These studies will begin in the office using topographic maps, flood-hazard maps, and, importantly, stereo aerial photographs to identify spots for field checking. Flood hazard locations will be surveyed in the field and studied by computer simulations. Poor rock areas are delimited by geologic mapping and geophysical techniques, then drilled and hydrologically tested. Areas where vibrations may be a problem are monitored to measure actual background noise at tunnel depth. Recommendations to move a structure because of any of these geological conditions can be made based on field data alone.

Global Data

Because of the short time available for field efforts, conceptual design-supporting geotechnical studies will be performed by concurrent development of both the global database and the structure-specific database.

For the global set, drilling at each access shaft will assure geographically well-distributed data. Drillholes to and beyond the depth of the collider tunnel will give a basic stratigraphic characterization; the strata may be correlated from drill site to drill site. A geophysical characterization of the drill-hole stratigraphy will be performed at the same time for later use in tracing formations along the ring profile. Hydrologic testing and monitoring will be conducted in the boreholes.

Samples of rock core and soil will be taken from the same hole for laboratory geomechanical tests. In this manner, geological, geophysical, geohydrological, and geotechnical data will be tied to the same stratigraphy. The next step will be to tie these point-specific data together along the collider tunnel profile by tracing the strata from hole to hole using surface-based geophysical methods. Faults and shear zones to be crossed by the tunnel will be identified by geologic mapping and probed by drilling and testing.

Structure-Specific

At the same time, a similar, but more focused suite of field activities will be performed at the locations of specific structures. The most complex of these will center on the experimental halls. Several holes will be drilled, logged, and hydrologically tested at each hall site to depths below the planned floor of the excavation. Rock samples will be laboratory-tested. Geophysical techniques will be used, but the emphasis will be on cross-hole geophysics to probe the excavation site in three dimensions. Studies for the injector will be, in effect, an extension of the global database into a new area of the site. Drill-hole-based geological, geohydrological, geophysical, and geotechnical tests will add new control points on the side of the injector facing away from the ring, with several tie-lines crossing the injector area.

The following section expands on this basic strategy; it also gives more details on how the techniques are applied, and how their application might vary for a particular preferred site.

5. PLAN FOR GEOTECHNICAL CHARACTERIZATION

The startup geotechnical activities at the Texas SSC site should allow the geologist and engineer to build their level of knowledge and confidence about the geological structures and geotechnical properties of the site materials to the point where there remains only a realistically small risk of encountering a geologic surprise. The objectives of this phase are:

- To confirm the site's suitability and optimize the ring and hall positions within it
- To permit the right construction technique to be selected and the right TBM to be designed
- To support structural design work
- To provide a rational framework within which construction contracts and schedules can be formulated.

A program of geotechnical activities to meet these objectives, as well as the priorities described above, is outlined in the tables that follow. These tables cover the following:

- Table 1 Footprint Location
- Table 2 Global Data
- Table 3 Structure-Specific Data - Experimental Halls
- Table 4 Structure-Specific Data - Injector Complex.

In each table, the basic investigative program is explained first, then the techniques to be used are described.

TABLE 1

FOOTPRINT LOCATION

BASIC PROGRAM: Evaluate whether locations of shafts, experimental halls, campus, or injector should be moved to avoid surface geohazards, problem ground conditions, or high level of vibrations. Identify impacting flood zones, and sheared zones on stereo aerial photos and topographic maps; and field-verify by mapping, drilling, and surface geophysical studies. Fly current stereo aerial photographic coverage. Measure ambient vibrations at tunnel depth beneath major highways and railroads.

TECHNIQUES:

1. Preparation

Identification of Hazards: Use existing data, stereo aerial photos (1:24,000 to 1:60,000, several vintages) and topographic maps to identify floodplains, and major lineaments that could be fault zones; review flood hazard maps and historical accounts of floods; review and prepare bedrock structure contour maps; focus on footprint vicinity.

Aerial Photography: Fly stereo aerial photography at a scale of 1:24,000 or better, with sufficient surveyed-in ground targets to support preparation of topographic maps with 2-foot contour interval. Coverage should extend 1 mile beyond footprint.

2. Flood Plains

Flood Hazard Assessment: Review stream height records and precipitation, records; field verify indications of flooding at locations of facilities; observe roughness and land use patterns; survey floodplain cross-sections and longitudinal profile; conduct flood routing simulations with backwater effects. Presently, flood hazard assessments are expected to be needed near J2, E1, J6, L2, J3, and J4 (see map in pocket).

3. Structural Zones

Structural Zone Studies: Field verify locations of possible sheared zones relative to locations of experimental halls; use roll-along refraction spreads to delimit zone; drill zone (with N-coring) to 25 feet below excavated invert, logging core and hole as for shaft borings; packer-test whole zone or several intervals to measure permeability. Presently, such studies are expected to be needed near J5/K2, K4, and K5; study during initial identification of hazards may eliminate these concerns, or identify additional areas to be studied.

4. Vibration

Ambient Vibration: Measure vibrations at tunnel depth caused by cultural noise such as road and railroad traffic. Where the tunnel is shallow, holes will be bored to tunnel depth immediately adjacent to rail lines and major highways where they intersect the tunnel alignment. Triaxial accelerometers, positioned in the borehole at tunnel depths and one or two shallower depths, will monitor the frequency and displacement characteristics of the vibrations, and will give an indication of the local vibration-attenuation characteristics. Presently, these studies are expected to be needed at 5 locations around the ring (see map and profile in pocket).

TABLE 2

GLOBAL GEOTECHNICAL DATA

BASIC PROGRAM: Sample E and F shaft locations by drilling (with sampling and coring), logging, hydro-testing, and laboratory testing. The drill holes will be control points for collider tunnel characterization. Tie tunnel stratigraphy between access-shaft borings using surface-based geophysics. Add surficial stratigraphic control and faults and folds by geologic mapping and aerial photo interpretation. Probe fractured and permeable zones with angle drilling and in-situ hydrologic testing. Field-verify water wells.

TECHNIQUES:

1. Drilling

Sample Curation: For logistical reasons, it will be desirable for DOE to take custody of some existing site cores --say particularly good reference stratigraphic sections for correlation purposes-- in a storage area near the site.

Drilling: Drill 13 holes, at shaft locations, each providing 100% coverage of the tunnel strata between it and the next adjacent shaft location, on both sides (see map and tunnel profile). Seven shaft locations probably will not need a boring during this phase because adequate proposer borings exist nearby.

Soil Sampling: Sample every 10 feet with drive sampler (ring or tube sampler) or Pitcher sampler; use standard geotechnical soil logging. It is presently expected that only 4 of the 13 borings will need soil sampling.

Rock Coring: Continuously N-core; use standard lithologic, RQD, and fracture logging; special preservation of Taylor Marl for laboratory tests.

Borehole Logs: Use SP, R(short), R(long), natural gamma, compensated density, Vp, Vs, and caliper.

2. Hydrology

Bedrock Air-Lift Test: Test all holes; ream soil portion to 6-inches, install 6-inch blank casing, clean N-hole in rock, and perform air-lift test.

Bedrock Packer Tests: Test 7 holes; guarded straddle packers; test 2 intervals near tunnel depth plus one additional interval (fractured zone or weathered rock) in each hole; collect water samples; complete hole as single or multiple-point piezometer; and monitor water levels.

Soil Pump Tests: Test 4 holes; plug-back hole in rock, pull 6-inch casing, ream hole to 6-inch, install 4-inch steel casing with up to 10 feet of screen, filter-pack annulus, and conduct 8-hour pump test;

collect water samples; complete hole as piezometer and monitor water level.

Water Wells: Review files of local and state water and health agencies for location, ownership, depth and yield. Visit homesteads and farms to verify location, depth and status and identify unrecorded wells. Measure static water level. Survey-in location if necessary. Focus on footprint and on wells in alluvial deposits intersected by the collider alignment.

3. Laboratory

Laboratory Soil Tests: Test all samples; sieve, Atterburg, moisture density, specific gravity, permeability, unconfined compressive strength, direct shear, triaxial strength, soil chemistry, and swell potential.

Laboratory Rock Tests: Test 130 samples; tests will include density, moisture content, swell potential, slake durability, abrasion, hardness, permeability, unconfined compressive strength, triaxial strength, Brazilian tensile strength, bulk mineralogy, clay mineralogy, cement petrography, and discontinuity shear tests.

Water Chemistry: Test Eh, pH, TDS, sulfate, chlorinity, major anions, and TOC for 20 samples.

4. Mapping

Photographic Mapping: Pre-map collider ring swath using 1:24,000 to 1:60,000 scale stereo air photos, preferably of several vintages. Delimit soil cover, geomorphic units and features, structural trends, faults, folds, fractured and sheared zones, and bedrock outcrops. Identify likely points of water use.

Surface Mapping: Visit key outcrops with local experts. Use air photos or topographic maps as mapping base. Map surface soil deposits and morphostratigraphic units. Identify and trace key rock-stratigraphic horizons and note strike and dip. Trace-out faults and estimate throw. Characterize and trace shear and fracture zones. Do statistical sampling of fracture trends and density. Cover 3-mile-wide swath along ring.

5. Geophysics

Geophysics Control: Use uphole velocity, refraction profile and resistivity sounding (all to depth of boring).

Refraction Surveys: Perform 100 profiles with spreads adequate to penetrate to the depths of nearby shaft borings (see map and profile in pocket for desired depth of penetration. Field-process results to verify tie to profiles at shaft sites. If necessary, revise spread and reshoot to focus on top of weathered rock. Conduct surveys along tunnel centerline.

Resistivity Surveys: Perform 100 soundings (co located with refraction profiles) with spreads arranged to achieve the same penetration as refraction profiles. Field-process results to tie interpretation of top-of-sound-rock and water table to refraction surveys and nearby water wells. Conduct surveys along tunnel centerline.

6. Structural Zones

Structural Zones Studies: Locate structural zone on ground by field mapping and roll-along refraction spreads. Angle-drill (N-cored in rock) to intercept structure at tunnel depth. Log core and hole as for access shaft holes. Perform packer-test sheared zone with guarded straddle-packer to assess permeability. It is presently expected that 11 locations along the tunnel will require these studies; geologic mapping may eliminate concerns for some of these, or others may be found that need to be studied. See the map and profile in the pocket for locations of studies.

TABLE 3.

STRUCTURE SPECIFIC DATA FOR EXPERIMENTAL HALLS

BASIC PROGRAM: Prove-out the experimental hall locations -- roof, side-walls, and subfloor -- by drilling (with sampling and coring), logging, in-situ hydrologic tests, up-hole and cross-hole geophysics, and laboratory testing. Roof strata will receive special attention for underground excavations.

TECHNIQUES:

1. Drilling

Full-Depth Drilling: Drill 3 holes at each hall location (K1, K2, K5, and K6) to depths 20 to 35 feet below planned excavation invert. See map and profile in pocket for typical layout and depth of borings.

Roof Strata Drilling: Drill 3 additional holes at halls K1 and K2 for which wholly underground excavation is being considered; drill to the depth of the planned excavated crown.

Soil Sampling: Sampled every 10 feet with drive sampler (ring or tube sampler) or Pitcher sampler; standard geotechnical soil logging; only expected to be needed at halls K5 and K6.

Rock Coring: Continuously N-cored; use standard lithologic, RQD, and fracture logging; special preservation of Taylor Marl and Eagle Ford shale samples for laboratory tests.

Boreholes Logs: Use SP, R(short), R(long), natural gamma, compensated density, Vp, Vs, and caliper.

2. Geophysics

Geophysical Surveys: Use uphole velocity, cross-hole velocity, refraction profile, and resistivity sounding (all to the depth of the deepest boring).

3. Hydrology

Bedrock Packer Tests: Test 2 intervals in each full-depth borehole, including fractured zones in particular; guarded straddle packer; collect water samples; complete borehole as single- or multiple-point piezometer, and monitor water level.

Soil Pump Tests: Test in 2 boreholes at K5 and two at K6; plug-back hole in rock, pull any casing, ream hole to 6 inches, install 4 inch steel casing with up to 10 feet long screen, filter-pack annulus, and conduct 8-hour pump test; collect water samples; and complete borehole as piezometer and monitor water level.

4. Laboratory

Laboratory Soil Tests: Test all samples; sieve, Atterburg, moisture density, specific gravity, permeability, unconfined compressive strength, direct shear, triaxial strength, soil chemistry, swell potential.

STRUCTURE SPECIFIC DATA FOR EXPERIMENTAL HALLS (continued)

Laboratory Rock Tests: Test 10 samples per hole; density, moisture content, swell potential, slake durability, abrasion, hardness, permeability, unconfined compressive strength, triaxial strength, Brazilian tensile strength, bulk mineralogy, clay mineralogy, cement petrography, and discontinuity shear tests.

Water Chemistry: Test Eh, pH, TDS, sulfate, chlorinity, major anions, and TOC for 6 samples.

5. Engineering

Deflection of Experimental Hall Floors: Soft rocks, prone to heaving and squeezing, and soil foundations could result in troublesome deflections when the load of the detectors are applied; this can be evaluated by scoping-simulations using known or generic rock mass properties, and 2- or 3-dimensional numerical codes.

TABLE 4

STRUCTURE SPECIFIC DATA FOR THE INJECTOR COMPLEX AND TRANSFER TUNNELS

BASIC PROGRAM: Tie injector area stratigraphy with stratigraphy at nearby access shafts using drilling (with sampling and coring), logging, hydrotesting, and laboratory testing. Surface-based geophysics will be used to tie with shaft borings, and to assess near-surface conditions for cut-and-cover injectors.

TECHNIQUES:

1. Drilling

Drilling: Drill 3 holes, 2 on the side of the HEB alignment facing away from the near cluster and one between the HEB and the collider ring near the location of the transfer tunnels, providing 50% stratigraphic overlap with each other as well as with the boreholes at J1 and F10 --at a minimum of 25 feet deeper than the planned injector depth (see map in pocket for details).

Soil Sampling: Sample every 10 feet with drive sampler (ring or tube sampler) or Pitcher sampler; standard geotechnical soil logging.

Rock Coring: Continuously N-core; use standard lithologic, RQD and fracture logging; special preservation of slaking rocks.

Borehole Logs: Use SP, R(short), R(long), natural gamma, compensated density, Vp, Vs, and caliper.

2. Geophysics

Geophysics Control: Use uphole velocity, refraction profile and resistivity profile (both to depth of boring).

Geophysical Surveys: Survey lines to tie each injector boring to the other injector borings and both J1 and F10 (a total of 5 lines); both refraction and resistivity, with spreads long enough to penetrate to the depth of the tunnel; field-process results to verify tie to profiles at borings (see map in pocket for survey locations).

3. Hydrology

Bedrock Packer Tests: Test three holes; guarded straddle packers; test two intervals near tunnel depth; collect water samples, complete 2 holes as piezometers; and monitor water level.

4. Laboratory

Laboratory Rock Tests: Test 30 samples; density, moisture content, swell potential, slake durability, abrasion, hardness, permeability, unconfined compressive strength, triaxial strength, Brazilian tensile strength, discontinuity shear tests, bulk mineralogy, clay mineralogy, cement petrography.

Water Chemistry: Test Eh, pH, TDS, sulfate, chlorinity, major anions, and TOC for 4 samples.