Engineering Standard

SAES-A-113 30 November, 2003

Geotechnical Engineering Requirements

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1 Scope

This standard covers mandatory geotechnical engineering requirements for onshore structures and earthworks. This standard does not address offshore geotechnical requirements, which are described in SAES-M-005 and SAES-Q-004, nor does it address any environmental related investigation or analysis.

All geotechnical investigations for onshore structures and earthworks for Saudi Aramco facilities must comply with this standard, including those investigations conducted directly for design and/or construction Contractors.

2 Conflicts and Deviations

2.1 Any conflicts between this standard and other applicable Saudi Aramco Engineering Standards (SAESs), Materials System Specifications (SAMSSs), Standard Drawings (SASDs), or industry standards, codes, and forms shall be resolved in writing by the company or buyer representative through the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

2.2 Direct all requests to deviate from this standard in writing to the company or buyer representative, who shall follow internal company procedure SAEP-302 and forward such requests to the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

3 References

The selection of material and equipment, and the design, construction, maintenance, and repair of equipment and facilities covered by this standard shall comply with the latest edition of the references listed below unless otherwise noted.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

SAEP-302	*Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement*

Saudi Aramco Engineering Standards

SAES-A-100	*Surveying Coordinates and Datums*
SAES-A-112	*Meteorological and Seismic Design Data*
SAES-A-114	*Excavation and Backfill*
SAES-L-440	*Anchors for Buried Pipelines*

SAES-M-005	*Design and Construction of Fixed Offshore Platforms*
SAES-M-009	*Design Criteria for Blast Resistant Buildings*
SAES-Q-001	*Criteria for Design and Construction of Concrete Structures*
SAES-Q-004	*Installation Specification Piles of Offshore Structures*
SAES-Q-005	*Concrete Foundations*
SAES-Q-006	*Asphalt Concrete Paving*
SAES-Q-007	*Foundations & Supports for Heavy Machinery*
SAES-Q-009	*Concrete Retaining Walls*

Saudi Aramco Construction Safety Manual

Saudi Aramco Sanitary Code

SASC-S-02	*Sanitary Wastewater and Sewerage Systems*

3.2 Industry Codes and Standards

American Association of State Highway and Transportation Officials

AASHTO T26	*Standard Specification for Quality of Water to be used in Concrete*
AASHTO T290	*Standard Method of Test for Determining Water Soluble Sulfate Ion Content in Soil*
AASHTO T291	*Standard Method of Test for Determining Water Soluble Chloride Ion Content in Soil*

American Society for Testing and Materials

ASTM D420	*Standard Guide to Site Characterization for Engineering, Design, and Construction Purposes*
ASTM D698	*Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort [12,400 ft-lbf/ft³ (600kN-m/m³)]*
ASTM D1556	*Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method (AASHTO T191)*

ASTM D1557	*Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort [56,000 ft-lbf/ft³ (2,700kN-m/m³)]*
ASTM D1883	*Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils*
ASTM D2166	*Test Method for Unconfined Compressive Strength of Cohesive Soil*
ASTM D2435	*Test Method for One-Dimensional Consolidation Properties of Soils*
ASTM D2487	*Test Method for Classification of Soils for Engineering Purposes*
ASTM D2850	*Test Method for Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression*
ASTM D2922	*Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth) (AASHTO T238)*
ASTM D4253	*Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table*
ASTM D4254	*Standard Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density*
ASTM D4318	*Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils*
ASTM D4428	*Standard Test Method for Crosshole Seismic Testing*
ASTM D5334	*Standard Test Method for Determination of Thermal Conductivity of Soil and Soft Rock by Thermal Needle Probe Procedure*
ASTM D5434	*Guide for Field Logging of Subsurface Explorations of Soil and Rock*
ASTM G57	*Standard Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method*

British Standards

BS 4550	*Methods of Testing Cement*

International Society of Soil Mechanics and Foundation Engineers

ISSMFE (1989) *International Reference Test Procedure for Cone Penetration Test (CPT)*

4 Site-Specific Geotechnical Information

4.1 Site-specific geotechnical information is required for all onshore structures, including existing foundations which undergo a change in loading conditions, prior to the commencement of detailed design. Geotechnical information is also required for significant earthworks such as fills in excess of 3 m, earth or rock dams, and cut slopes.

4.2 Required Geotechnical Services

4.2.1 A site-specific geotechnical investigation is required for all new structures, foundations, major roads, pipelines, and significant earthworks, unless exempt by paragraph 4.2.2 or indicated in writing from the Supervisor, Civil Engineering Unit, Mechanical & Civil Engineering Division, Consulting Services Department. The Supervisor, Civil Engineering Unit, shall determine the suitability of existing soils data for use in design.

4.2.2 Geotechnical investigations are not required when all of the conditions below have been met:

4.2.2.1 The footprint of the structure is less than 4m x 4m (i.e., guard houses, sun shelters, etc.).

4.2.2.2 The net applied bearing pressure on the footing does not exceed 100 kPa (2000 psf).

4.2.2.3 The foundation will not be subjected to vibratory or dynamic loads.

4.2.2.4 The supported equipment or structure is not settlement sensitive.

4.2.2.5 Unusual soil conditions, such as subkha or expansive clay, are not present or observed in nearby borings.

4.2.2.6 No other special considerations apply.

4.2.3 A risk assessment study, for potential underground cavities is required for grass-root plants in the areas of predominately limestone geology.

5 Quality Control Requirements

5.1 Geotechnical Investigation Scope of Work

5.1.1 The Scope of Work shall include the following items:

- A description of the project
- The purpose and objectives of the geotechnical investigation
- Type of structures to be constructed
- Approximate loads
- Final grade and/or anticipated cut or fill
- Depth of basements, utility trenches, pits, ponds, etc.
- Information on site access, ID and work permit requirements
- Proponent contact and phone number
- The number, type, and depths of field tests to be conducted
- The objectives of the laboratory test program (specific number and type of laboratory tests need not be specified)
- A description of any special tests or requirements
- A location plot plan including the locations of the existing and proposed facilities and the locations of the field tests
- The completed checklist of "Required Geotechnical Services" (attached as Appendix A of this Standard).

5.1.2 The geotechnical investigation Scope of Work shall be approved by the Supervisor, Civil Engineering Unit, Mechanical & Civil Engineering Division, Consulting Services Department, prior to initiation of any field work. The Geotechnical File Number is assigned by Consulting Services Department at this time.

5.2 Geotechnical Contractor

5.2.1 The geotechnical investigation must be conducted by a Contractor on Industrial Development Unit's list of Saudi ARAMCO-Approved Independent Civil Testing Laboratories, with specific approval in the Geotechnical Category.

5.2.2 The Geotechnical Contractor shall submit a statement endorsing the adequacy of the proposed investigation program or submit suggested modifications.

5.3 Field Supervision

The Geotechnical Contractor shall provide an engineer or geologist in the field full time during exploration activities. The engineer/geologist shall supervise and observe all subsurface exploration operations, classify samples and prepare logs of borings, soundings, pits, etc.

5.4 Geotechnical Engineering and Reports

5.4.1 All engineering calculations and the draft final geotechnical investigation report must be peer-reviewed internally by the Contractor prior to submittal to Saudi Aramco for review. Both the primary engineer and the peer-reviewer must be practicing geotechnical engineers. The signatures of both the primary engineer and the peer-reviewer must appear in the report.

5.4.2 Two copies of the draft final geotechnical report, all engineering calculations, and the geotechnical investigation Scope of Work shall be submitted for review and approval to the Supervisor, Mechanical & Civil Engineering Division, Civil Engineering Unit, Consulting Services Department.

5.5 Sample Retention

All soil and rock samples shall be retained for a minimum 2 months after completion of the geotechnical investigation.

5.5 Underground Cavity Risk Assessment Study

An assessment of the relative risk for underground cavities within the study area shall include, as a minimum, the following:

- Site-specific geologic formations, thicknesses, and depths
- Structural geologic features, such as fracture orientations and frequency
- Groundwater depths and flow patterns, both historical and present.
- Surface hydrology and topography
- Aerial photography showing collapse features
- A map of relative risk for the study area

6 Execution of Geotechnical Investigations

6.1 General Requirements

The Geotechnical Contractor shall:

6.1.1 Furnish all labor, equipment, tools, supervision, supplies and transportation required to perform the geotechnical investigation, exploration, testing, analyses and reporting in accordance with ASTM D420 and with this Standard, including requirements in Appendix A.

6.1.2 Comply with all aspects of the Saudi Aramco Construction Safety Manual and all safety programs and policies of Saudi Aramco.

6.1.3 Immediately notify Saudi Aramco if initial field work and/or testing indicate a need for modifications in the geotechnical investigation work scope.

6.2 Examination of Site

6.2.1 Prior to mobilization, the Geotechnical Contractor shall obtain all available information regarding the project, including types of structures to be constructed, loads, previous construction on the site, existing soils information which may be available, any problems experienced by near-by structures, and any special concerns to be addressed.

6.2.2 The Geotechnical Contractor shall examine the site and become familiar with all existing conditions and evaluate the conditions with respect to performance of the work and to the design/construction of the proposed facilities.

6.3 Survey Requirements

6.3.1 Survey coordinates and datum shall be in accordance with SAES-A-100.

6.3.2 UTM coordinates and Mean Sea Level (MSL) elevations must be provided for all field tests described in paragraphs 6.4.1, 6.4.2, 6.4.3, 6.4.4, and 6.4.5. MSL elevations and UTM coordinates must be shown on the field test log. If local coordinates and elevations are available, a table shall be included in the report showing both local and UTM/MSL data for each boring location.

6.4 Field Work

6.4.1 Boreholes (BH)

6.4.1.1 The location and depth of boreholes shall be specified in the geotechnical investigation Scope of Work.

6.4.1.2 In all boreholes, standard penetration tests are to be performed in soil at depths of 0.15, 0.75, 1.5, 2.25, 3.0, 3.75, 4.5 m, and at 1.5 m intervals thereafter, and at changes in soil strata. If the soil is cohesive, then undisturbed thin wall samples shall be obtained. Double-tube core barrels shall be used for rock coring.

6.4.1.3 If hand excavation is required to obtain work permits, the hand-excavated soils should be sampled and logged, including an estimation of the relative density (i.e., loose, medium-dense, or dense).

6.4.1.4 Groundwater measurements shall be made after stabilization of the water table in the borehole.

6.4.1.5 All boreholes shall be sealed with sand-cement mortar at the end of the groundwater measurements.

6.4.2 Cone Penetration Testing (CPT)

6.4.2.1 The location and depth of cone penetration soundings shall be specified in the geotechnical investigation Scope of Work.

6.4.2.2 Cone penetration testing shall include pore pressure measurements (i.e., piezocone). Where stiff/dense soils are encountered, the Piezocone should be replaced with a higher capacity electronic cone.

6.4.2.3 The International Reference Test Procedure for Cone Penetration Test (CPT), ISSMFE (1989), shall be followed for all Cone Penetration calibration, testing and data reporting.

6.4.3 Cross-hole Seismic Testing

6.4.3.1 The location and depth of cross-hole seismic tests shall be specified in the geotechnical investigation Scope of Work. The exact location should be determined by the Contractor's field geologist based on field conditions (underground utilities may exist in the area and the test must be located so as not to be affected by utilities).

6.4.3.2 Cross-hole seismic tests shall be as described in ASTM D4428 to determine design parameters of soil/rock as required in SAES-Q-007 for dynamically loaded foundations. One shot hole and two receiver holes shall be used. The tests shall be conducted at a minimum 0.75 m interval to a depth of 10 m

unless otherwise specified it the geotechnical Scope of Work. Only the shot hole should be sampled and logged as described above. The receiver holes need not be sampled and logged.

6.4.4 Shallow Refraction Seismic Soundings

6.4.4.1 The location of refraction seismic tests shall be specified in the geotechnical investigation Scope of Work.

6.4.4.2 The geophone spread should be twelve geophones at 2 m intervals for a total 24 m spread. Soundings should be taken at least twice at each location, with the energy source at 0 m and again at 26 m (Reverse Spread). Additional soundings should be taken if the results do not clearly define the rock layers.

6.4.5 Test Pits

6.4.5.1 The location and depth of test pits shall be specified in the geotechnical investigation Scope of Work.

6.4.5.2 Unless otherwise specified in the Scope of Work, the pits should extend to a depth of 1 m and be logged. Density testing per ASTM D1556 or ASTM D2922 should be performed on the undisturbed soils at depths of 0.0, 0.3, 0.6, and every 0.3 m thereafter, and bulk samples representative of the soil layer(s) taken for California Bearing Ratio (CBR) testing as per ASTM D1883.

6.4.6 Percolation Testing

6.4.6.1 The location of percolation test area shall be specified in the geotechnical investigation Scope of Work.

6.4.6.2 Percolation testing shall be performed as described in SASC-S-02. The depth of the percolation test holes should be the same as the depth of the proposed trenches or seepage pits, and the test holes should be uniformly spread over the proposed soil absorption field.

6.5 Laboratory Testing

The Geotechnical Contractor shall perform laboratory testing on selected samples from the boreholes and test pits as necessary to determine relevant engineering properties.

6.5.1 Classification testing shall be in accordance with ASTM D2487.

6.5.2 Other soil properties shall be determined in accordance with ASTM D698, ASTM D1557, ASTM D1883, ASTM D2166, ASTM D2435, ASTM D2850, ASTM D4253, ASTM D4254 and ASTM D4318. Laboratory CBR tests should use the "three-point" method along with soil density results to estimate the in-situ CBR and the CBR at the recommended compaction density.

6.5.3 Representative chemical analyses of soil and groundwater samples, if required for determination of concrete design per SAES-Q-001 Table 1, shall be performed in accordance with AASHTO T26, AASHTO T290, and AASHTO T291. Water-soluble sulfate and chloride tests are required where concrete will be in contact with the soil.

7 Engineering and Report Requirements

7.1 The final geotechnical report shall address all items in the Scope of Work including the checklist of "Required Geotechnical Services" attached as Appendix A of this Standard.

7.2 A Geotechnical File Number must be obtained from Consulting Services Department for all geotechnical investigations. This Geotechnical File Number must appear on the report cover, the title page and on all field and laboratory test logs.

7.3 The draft final report submitted to Consulting Services Department for review and approval shall include the following in addition to the engineering report:

7.3.1 The geotechnical investigation Scope of Work.

7.3.2 All engineering calculations.

Calculations shall clearly state soil properties, factors of safety and assumptions used in the analyses.

7.3.3 Evidence of internal peer-review of the report and calculations.

7.4 The final report shall address Saudi Aramco's comments and questions on the draft final report. The final report shall have an Executive Summary, placed immediately after the Table of Content. The signatures of both the primary engineer and the peer-reviewer must appear in the report.

7.5 All boring logs must be prepared in Saudi Aramco Boring Log format.

7.6 Two copies of the final report shall be submitted to Consulting Services Department's geotechnical library. One electronic copy of the final report using

text-searchable Adobe Acrobat (latest edition) format shall also be submitted to Consulting Services Department.

Revision Summary

31 December, 2002	Revised the "Next Planned Update". Reaffirmed the contents of the document, and reissued with minor revision to clarify that the Scope includes geotechnical investigations performed for Contractors, to add the requirement for underground cavity risk assessments for grass root plants, to specify the contents of geotechnical investigation scopes of work and risk assessment methodology, to allow the use of high capacity electric cones in lieu of piezocones dense soils, and to remove the requirement for boring logs to be submitted in gINT electronic format.
29 January, 2003	Editorial Revision – added items to Section 5.1.1.
30 November, 2003	Minor Revision – Corrected referenced Standard numbers, and added requirement for electronic copy of final report.

Appendix A – Required Geotechnical Services

The final report of the Geotechnical Contractor shall include information and recommendations on items marked in the following list.

1. Introduction

___ 1.1 Description of proposed construction, including final grade elevations

___ 1.2 Purpose and scope of investigation

___ 1.3 Abstract of findings and recommendations

2. Site Conditions

___ 2.1 Site local geology, general description

___ 2.2 Potential geologic hazards

___ 2.3 Site surface description

___ 2.4 Site topography (referenced to MSL-mean sea level), general description

___ 2.5 Description of above-ground obstructions

3. Subsurface Conditions

___ 3.1 Stratigraphy

___ 3.2 Subsurface material properties, general description

___ 3.3 Groundwater elevations (referenced to MSL-mean sea level) and expected variations

___ 3.4 Description of underground obstructions encountered or otherwise identified

4. Field Investigation

___ 4.1 Summary of operations

___ 4.2 Description of sampling procedures

___ 4.3 Description of field tests

___ 4.4 Logs of borings, soundings, pits, wells, etc. in accordance with ASTM D5434 and containing:

- 4.4.1 Complete descriptions and thicknesses of all strata, including near-surface materials such as paving, base course, topsoil, fill, etc.
- 4.4.2 Locations referenced to UTM coordinate system
- 4.4.3 Ground surface elevations referenced to MSL (mean sea level)
- 4.4.4 Standard penetration test values in blows per six-inch increment
- 4.4.5 Results of all field tests

___ 4.5 Percolation test results as per SASC-S-14

___ 4.6 Location plan, containing as a minimum

4.6.1 Scale plan with locations of borings, soundings, pits, wells, etc.

4.6.2 UTM and local plant coordinate systems

___ 4.7 A table showing both UTM/MSL data and local plant coordinates and elevations for each borehole, sounding, pit, etc.

5. Laboratory Tests

___ 5.1 Description of tests

___ 5.2 Test results

6. Soil and Groundwater Properties

___ 6.1 Confirmation of or proposed alternatives to coefficient of friction or adhesion values between soil and concrete as per SAES-Q-005

___ 6.2 Unit weight of soil (in kN/m^3)

___ 6.3 Cohesion (in kN/m^2) and angle of internal friction

6.4 Chemical analysis and other properties of soil at depths of proposed structural elements and utilities, as follows:

___ 6.4.1 pH value

___ 6.4.2 Carbonate content

___ 6.4.3 Water soluble Chloride ion (Cl) concentration (in percent by weight of soil) (AASHTO T291)

___ 6.4.4 Water soluble Sulfate ion (SO_4) concentration (in percent by weight of soil) (AASHTO T290)

___ 6.4.5 Acid soluble Chloride ion (Cl) concentration (in percent by weight of soil) (BS 4550)

___ 6.4.6 Acid soluble Sulfate ion (SO_4) concentration (in percent by weight of soil) (BS 4550)

___ 6.4.7 Electrical resistivity of soil (ASTM G57)

___ 6.4.8 Thermal resistivity of soil (ASTM D5334)

6.5 Permeability (in cm/sec)

___ 6.5.1 Laboratory determination

___ 6.5.2 In situ determination

6.6 Chemical analysis of groundwater (AASHTO T26) at depths of proposed structural elements and utilities, as follows:

___ 6.6.1 pH value

___ 6.6.2 TDS (in ppm)

___ 6.6.3 Chloride ion (Cl) concentration (in ppm)

___ 6.6.4 Sulfate ion (SO_4) concentration (in ppm)

7. Absorption

___ 7.1 Suitability of site for use as an absorption field per SASC-S-02

___ 7.2 Recommended alternatives if site is unsuitable

8. General Foundation Recommendations

8.1 Foundation recommendations to be based on:

___ 8.1.1 Construction at existing grade

___ 8.1.2 Site modified to final grade different than existing grade

___ 8.1.3 Improved ground

___ 8.2 Type(s) of foundation recommended

___ 8.3 Basis for selecting recommended foundation type(s)

___ 8.4 Recommendations for foundation type(s) selected

___ 8.5 Recommendations for deep foundations regardless of foundation type selected

___ 8.6 Recommendations for shallow foundations regardless of foundation type selected

___ 8.7 Soil strength parameters used in determining design capacities

___ 8.8 Ground Improvement recommendations

9. Shallow Foundation Recommendations in accordance with SAES-Q-005 and SAES-Q-007

___ 9.1 Spread footings: Depth below grade, size and shape restrictions

___ 9.2 Mat foundations: Depth below grade, modulus of subgrade reaction (in kN/m^3)

___ 9.3 Tank foundations: Recommendations and restrictions, excavation and backfill, ringwall or mat considerations, extended water tests

___ 9.4 Vibratory equipment foundations: Dynamic shear modulus, Poisson's ratio, other considerations

___ 9.4.1 Based on correlations from published literature

___ 9.4.2 Based on in-situ testing

___ 9.5 Ultimate and allowable net soil bearing capacity (in kPa)

___ 9.5.1 As a function of the shape and size of foundation, depth of embedment, and soil strength

___ 9.5.2 Any increase in net allowable bearing capacity for hydrotest loads, and short term loads such as wind and earthquake

___ 9.5.3 Ultimate net soil bearing capacity for blast loading conditions (SAES-M-009)

___ 9.6 Foundation settlement (in mm)

___ 9.6.1 As a function of loading, shape, depth and size of foundations, and compressibility of sub-soils

___ 9.6.2 Immediate settlement during construction

___ 9.6.3 Long term settlement

___ 9.6.4 Time rate of settlement

___ 9.6.5 Adjacent foundation settlement

___ 9.6.6 Differential settlement for tanks, including

9.6.6.1 Along the perimeter

9.6.6.2 Center of tank to perimeter

9.6.6.3 Slope of tank bottom after anticipated settlement

9.6.6.4 Limitations or recommendations for hydrotest procedures to minimize differential settlement

9.6.6.5 Anticipated settlement and rebound during hydrotest and specific measurements during hydrotest

10. Deep Foundation Recommendations

___ 10.1 Type of pile or drilled pier and basis for recommendation

___ 10.2 Ultimate and allowable axial compression capacity through end bearing and skin friction (in kN)

___ 10.2.1 Capacity vs. length

___ 10.2.2 Any increase in capacity for hydrotest loads, or for short term loads such as wind and earthquake

___ 10.3 Minimum and maximum tip elevations, when applicable

___ 10.4 Ultimate and allowable axial uplift capacity (in kN)

___ 10.4.1 Uplift capacity vs. length

___ 10.4.2 Any increase in capacity for hydrotest loads, or for short term loads such as wind and earthquake

___ 10.5 Allowable lateral capacity (in kN)

___ 10.5.1 Applied lateral loading vs. deflection of pile head

___ 10.5.2 Pile moment vs. depth

___ 10.5.3 P-Y curves

___ 10.5.4 Recommendations for generation of P-Y curves and required parameters (cohesion, friction angle, E50)

___ 10.6 Downdrag considerations

___ 10.7 Spacing, group action, and use of batter piles

___ 10.8 Settlement considerations

___ 10.9 Vibratory equipment foundations, spring constants in each direction for recommended pile type

___ 10.10 Driven pile installation considerations

___ 10.10.1 Driving criteria, including refusal criteria

___ 10.10.2 Wave equation analysis

___ 10.10.3 Pre-drilling requirements/restrictions

___ 10.10.4 Potential problems and recommended solutions

___ 10.10.5 Pile installation near existing facilities

___ 10.11 (Non-driven) drilled pile and pier installation considerations

___ 10.11.1 Installation equipment requirements

___ 10.11.2 Casing/slurry considerations

___ 10.11.3 Installation criteria and recommendations

___ 10.11.4 Potential problems and recommended solutions

___ 10.12 Load test requirements, procedures, and acceptance criteria

11. Earth Pressures and Retaining Walls

___ 11.1 Active earth pressure, at-rest earth pressure and passive earth pressure coefficients

___ 11.2 Ultimate and allowable passive soil resistance (as allowed in SAES-Q-005, SAES-Q-009 and SAES-L-440) for on-site soils, and recommended fill and backfill material

___ 11.3 Recommendations for retaining structure design

___ 11.3.1 Pressure diagrams for retaining wall design per SAES-Q-009

___ 11.3.1 Pressure diagrams for sheetpile design

___ 11.4 Groundwater considerations

___ 11.5 Drainage requirements

12. Pipeline Anchors

___ 12.1 Recommended type of anchor, concrete block or batter piles

___ 12.2 Design parameters for:

___ 12.2.1 Anchor block design in accordance with SAES-L-440

___ 12.2.2 Pile anchor

13. Seismic Analysis

___ 13.1 Seismicity based on SAES-A-112

___ 13.2 Confirmation of or proposed alternatives to Soil Profile Type(s) and Site Soil Coefficient(s) given in SAES-A-112

___ 13.3 Liquefaction potential of soils

___ 13.4 Site-specific seismic risk study

14. Earthwork

___ 14.1 Definition of select fill as per SAES-A-114

___ 14.2 Suitability of on-site material for select and non-select fill

___ 14.3 Special preparations or other requirements for use of on-site material

___ 14.4 Availability of imported fill

___ 14.5 Subgrade preparation

___ 14.6 Recommended compaction criteria and moisture content control in accordance with SAES-A-114 and SAES-Q-006

___ 14.7 Potential compaction difficulties and recommended solutions

___ 14.8 Final fill surface/wind erosion protection measures

15. Excavation Considerations

___ 15.1 Allowable excavation slope inclinations, temporary and permanent in accordance with SAES-A-114 and the Saudi Aramco Construction Safety Manual

___ 15.2 Groundwater control

___ 15.2.1 Recommended dewatering method

___ 15.2.2 Temporary versus permanent groundwater control

15.3 Foundation subgrades

___ 15.3.1 Heave control

___ 15.3.2 Protection/preserving integrity of subgrade

___ 15.4 Effects on existing facilities

___ 15.5 Potential excavation problems

___ 15.6 Pressure diagrams for shoring design

16. Rock excavation

___ 16.1 Rippability of rock based on Caterpillar Handbook of Ripping

___ 16.1.1 For mass-grading operations

___ 16.1.2 For trenches and small excavations

___ 16.2 Definition of rock for contract documents (see SAES-A-114)

17. Pavements and Slabs-on-Grade

___ 17.1 Natural soil and fill, subgrade suitability per SAES-Q-006

___ 17.2 Recommended CBR (California Bearing Ratio) value for pavement design

___ 17.2.1 Based on correlations from published literature

___ 17.2.2 Based on laboratory testing

___ 17.2.3 Based on in-situ testing

___ 17.3 Recommended modulus of subgrade reaction for slab design

___ 17.4 Treatment for improving subgrade, if required

___ 17.5 Base course and sub-base course recommendations per SAES-Q-006

___ 17.6 Base, sub-base, and subgrade drainage recommendations

18. Other Considerations

___ 18.1 Swelling potential of soils, including depth of zone of soil moisture content fluctuation and associated recommendations

___ 18.2 Erosion protection of slopes

___ 18.3 Collapsible or dispersive soils

___ 18.4 Effects of proposed construction on existing facilities or adjacent property

___ 18.5 Geologic or other potential hazards

19. Foundation Protection

___ 19.1 Concrete requirements per SAES-Q-001 (Table 1)

___ 19.2 Coatings or other protective measures if required

20. Underground Cavity Risk Assessment and Cavity Probing

___ 20.1 Risk Assessment Study for potential of underground cavities, including site-specific geologic formations, thicknesses, and depths; structural geologic features, such as fracture orientations and frequency; groundwater depths and flow patterns, both historical and present; surface hydrology and topography; aerial photography showing collapse features; and a map of relative risk for the study area.

___ 20.2 Results of cavity probing beneath specific foundations.

21. References and Glossary

___ 21.1 Major references used in the preparation of the report

___ 21.2 Glossary of the technical terminology used in the report