Professional Engineering Exam

Geotechnical Engineering

Study Guide

Education and Training Evaluation Commission (ETEC)
National Center for Assessment (NCA)

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1. Aim:

The objective of this Instruction Manual is to provide guidelines for the NCA proposed Professional Engineers Exam. These guidelines cover the eligibility conditions, the grading and passing conditions, the structure of the exam and the distribution of exam questions among various areas. In essence, this Instruction Manual represents a "bridge" between the developed exam standards and the actual phrased questions. It is designed to help item writers prepare questions in Geotechnical Engineering Discipline Exam as well a study guide for the examinees.

2. Exam Structure:

2.1 Exam Type

The exam is initially paper-based with questions being a combination of multiple-choice questions (MCQ) and essays.

2.2 Exam Organization

The exam will be conducted in two sessions during one day. The duration of the first session is 2.5 hours while the second section is 4 hours long. There is one-hour break between the two sessions.

2.2.1. Session #1

The first session is the common part to be taken by all the examinees from all disciplines. This part includes seven topics: (Ethics – Professionalism - Laws for Professional Practice, Professional Laws and Regulation - Environment and Natural Resources - Engineering Management - Engineering Economics - Health, Safety & Security (HSS)).

The total duration of this session is 2.5 hours and the total number of questions is 30 MCQ and 2 essays.

2.2.2. Session #2

The second session is the Discipline Part. The following engineering disciplines are considered:

Code	Discipline
STE	Structural Engineering
GTE	Geotechnical Engineering
TRE	Transportation Engineering
WREE	Water Resources and Environmental Engineering
PE	Power Engineering
HVAC	Heating, Ventilation, and Air Conditioning (HVAC) and Refrigeration Engineering
TFSE	Thermal and Fluids Systems Engineering
CHE	Chemical Engineering
FPE	Fire Protection Engineering
ARCH	Architecture

The total duration of this session is 4 hours and the total number of questions is 30 MCQs and 7 essays. The examinee must answer all the MCQs and two essays (one compulsory and one to be chosen out of six essays).

2.3 Eligibility for the Exam

The eligibility to register for the exam is according to the Saudi Council of Engineers (SCE) requirements.

2.4 Grades

Each part (common part and discipline part) carries a total grade of 100. The MCQs carry a grade of 60% while the essays carry a grade of 40%. Each MCQ has 4 choices for the answer. There is no negative marking for wrong answers.

2.5 Passing Rules

- The eligible candidate must take in his/her first sitting the two exam parts (common part and discipline part).
- In order to pass the exam, the candidate must obtain a grade of 60% or above in each part of the exam.
- If the candidate fails both parts of the exam (by receiving in each part a grade less than 60%), he/she can take the two parts of the exam but only when one full year has passed.
- If the candidate fails only one part of the exam (common part or discipline part), he/she must repeat only the part he/she failed, but he/she must pass this part within one year.
- If a year passed and the candidate did not succeed in passing the part he/she failed, then he/she has to take both parts of the exam.

2.6 Exam Rules

- No printed or electronic material is allowed during the exam. All necessary reference materials will be provided by NCA
- Calculators approved by NCA are allowed.
- Comprehensive exam rules will be provided by the examination authority, NCA, in a separate manual.

3. Table of Specifications for Geotechnical Engineering Exam:

Topic Code	Major Area	Multiple Choice Questions (MCQs)		Number of Essay Questions	Standard Code
		%	Number of Questions		
T1	Site Investigation	10%	3	1	GTE–T1
T2	Laboratory Testing and Analysis of Test Results	13.33%	4	1	GTE–T2
T3	Field Procedures and Testing	6.67%	2	1	GTE–T3
T4	Shallow and Deep Foundations	23.33%	7	1 (compulsory)	GTE–T4
T5	Earth Retaining Structures	10%	3	1	GTE–T5
T6	Earth Structures	6.67%	2	1	GTE–T6
T7	Groundwater and Seepage	6.67%	2	1	GTE–T7
T8	Problematic Soil and Rock Conditions	6.67%	2	None	GTE–T8
T9	Seismic and Vibratory Loadings	6.67%	2	None	GTE–T9
T10	Tunneling	3.33%	1	None	GTE–T10
T11	Forensic Geotechnical Engineering Investigation	3.33%	1	None	GTE–T11
T12	Codes and Standards	3.33%	1	None	GTE–T12
	Total	100%	30	1 Compulsory and choose 1 out of 6	

4. Standards for Architecture:

The Engineering Standards for the Geotechnical Engineering Discipline is structured around 12 major areas. Seven areas (Site Investigation, Laboratory Testing and Analysis of Test Results, Field Procedures and Testing, Shallow and Deep Foundations, Earth Retaining Structures, Earth Structures, and Groundwater and Seepage) are considered prominent and practiced in the Geotechnical Engineering field worldwide and Professional Engineers in Geotechnical Engineering are expected to possess and demonstrate command of these areas. They account for more than 75% of the total number of MCQs and all of the seven possible essay questions are relevant to these areas. The remaining five areas (Problematic Soil and Rock Conditions, Seismic and Vibratory Loadings, Tunneling, Forensic Geotechnical Engineering Investigation, and Codes and Standards) account for about 25% of the MCQs and no essay question is given in these areas. Each of the twelve areas is composed of a number of indicators that cover the main areas of practice in Geotechnical Engineering. However, there is no correlation between number of indicators and number of set questions for each area. For Laboratory Testing and Analysis of Test Results, there are ten indicators and four MCQs, whereas Tunneling area has 13 indicators, yet only one MCQ.

GTE-T1 Site Investigation. (3 MCQ)

GTE-T1-1	Ability to understand and interpret data concerning aerial photographs; geologic, seismologic, hydrologic, and geomorphologic maps; topographic maps, hazard maps, and GIS.
GTE-T1-2	Recognize basic geological formations of Saudi Arabia and their distribution and identify geologic features, including faults in rock masses, karst, subsidence, and sand dunes.
GTE-T1-3	Decide based on information available of the site and the type and size of the project the need and extent of site investigation.
GTE-T1-4	Develop and evaluate site investigation programs of a good standard satisfying project scope, the Saudi Building Code requirements and other relevant geotechnical guides; this involves phasing of investigation into preliminary and detailed phases and identifying location, depth and number of subsurface investigations (i.e., boreholes, probes, down-hole testing, etc.), groundwater level monitoring wells, and test pits.
GTE-T1-5	Analyze and interpret factual and interpretive geotechnical reports, evaluate and consider the quality and adequacy of the reports and derive design parameters.
GTE-T1-6	Analyze and interpret reports describing geophysical surveys, including ground penetrating radar (GPR), electrical resistivity and seismic methods, and identifying limitations and advantages of each procedure.

GTE-T1-7 Understand techniques for excavating, logging, and sampling of test pits.

GTE-T1-8 Understand drilling techniques, including auger, rotary, wireline, and percussion methods, and select the appropriate method based on site conditions and limitations and advantages of each technique.

GTE-T1-9 Set the relevant type of in situ tests, including standard penetration test, static cone penetration, vane shear, pressuremeter/dilatometer tests, borehole permeability, and recognize the range of applications in geotechnical design.

GTE-T1-10 Identify problems that could be encountered during drilling of boreholes.

GTE-T1-11 Set sampling technique from amongst split-spoon or thin-walled tube, coring of rocks, and other available and relevant sampling methods.

GTE-T1-12 Understand and apply guidelines for transporting and storing soils and samples rock cores.

GTE-T1-13 Recognize and understand boring log data, including descriptions of stratification, including soil or rock units and their classifications and measurements of groundwater elevation.

GTE-T1-14 Describe and characterize rocks based on rock quality (e.g., Recovery Ratio, Rock Quality Designation (RQD), Rock Mass Rating (RMR)), the degree of weathering and joint conditions, spacing, and orientations.

GTE-T1-15 Assess the overall rock mass condition based on the Geomechanics RMR-System, the Norwegian Geotechnical Institute (NGI) Q system, and the Geological Strength Index (GSI).

GTE-T1-16 Select and recommend geotechnical parameters for design and construction.

GTE-T2 Laboratory Testing and Analysis of Test Results. (4 MCQ)

GTE-T2-1 Recognize physical and engineering properties of soils and rocks, and ability to express weight and volume relationships.

GTE-T2-2 Understand Atterberg limits and their associated indices and their reflection on soil behavior characteristics.

GTE-T2-3 Classify soils according to the unified soil classification system (USCS) (as required in the Saudi Building Code 303) or AASHTO.

GTE-T2-4 Interpreting the results of compaction tests, identifying the moisture content that provides the maximum dry density, and specifying soil compaction criteria for field applications.

GTE-T2-5 Establish one-dimensional behavior and stress history and find the associated compressibility parameters for cohesive soils, including coefficient of volume compressibility, compression index, swelling index, over-consolidation ratio, secondary compression index, laboratory as well as field pre-consolidation pressure, and the coefficient of consolidation.

GTE-T2-6 Estimate soil permeability (saturated hydraulic conductivity) from index properties, borehole permeability tests, laboratory testing, or other appropriate methods.

GTE-T2-7 Identify type of shear tests best suited to estimate shear strength for proposed applications, set the relevant testing conditions required for the determination of the drained and undrained strength of effective or total stress conditions, as appropriate.

GTE-T2-8 Ability to represent test results graphically, establish the failure envelope, interpret test results to obtain analytically or graphically shear strength parameters for soils.

GTE-T2-9 The capability of interpreting results of laboratory and field tests to evaluate elasticity parameters including Young's modulus, shear modulus, and secant modulus required in the estimation of the immediate settlement, design for dynamic loads, or in numerical computations.

GTE-T3 Field Procedures and Testing. (2 MCQ)

GTE-T3-1 Identify suitable techniques for improvement of in-situ materials, including compaction, vibroflotation, preloading, grouting, dynamic compaction, use of geotextiles and geogrids, sand columns, and stone columns.

GTE-T3-2 Set specification required for quality assurance processes and quality control for ground improvement.

GTE-T3-3 Understand shoring methods and design and selection of appropriate support systems, including sheet piles, soldier pile and lagging, soil nailing, tie-back walls, and anchoring systems.

GTE-T3-4 Consider the impact of excavation and construction of the foundation and underground part of the project on adjacent structures and utilities from dewatering, excavation, pile driving, or other construction activities.

GTE-T3-5 Design and evaluate geotechnical construction and post-construction monitoring instrumentation, including piezometers, inclinometers, settlement plates, or vibration sensors.

GTE-T3-6 Select and evaluate the appropriateness of sites for borrowing earth fill based on material characteristics and cost of transportation.

GTE-T3-7 Familiarity with categories of conduit installation, soil-pipe interaction solutions, and backfill selection.

GTE-T3-8 Ability to estimate the load on ditch conduits and positive and negative projecting conduits due to surface loads.

GTE-T4 Shallow and Deep Foundations. (7 MCQ)

GTE-T4-1 Selection of constructional and economic foundation system based on structure type and site investigation data concerning geological, geotechnical, and hydrogeological characteristics of the project site.

GTE-T4-2 Evaluate ultimate and allowable bearing capacities analytically, empirically, or from field tests such as the standard penetration test, cone penetration test, and plate load test.

GTE-T4-3 Ability to estimate bearing capacity for rock formation based on the results of the field characterization program of the rock mass, including the approach of using the value of Rock Quality Designation (RQD) directly to assess the allowable bearing stress or using Rock Mass Rating Procedure (RMR).

GTE-T4-4 Estimate expected immediate, primary consolidation, and secondary consolidation settlements for different supporting grounds, including evaluation of stresses induced within soil masses by different loaded areas.

GTE-T4-5 Ability to quantify the rate of settlement for various loading, ground, and drainage conditions, including the analysis and design of sand or wick drains system to expedite settlement of preloaded soft soil formations.

GTE-T4-6 Analyze and design shallow foundations for homogeneous or stratified medium, concentric or eccentric loads, vertical or inclined loads, and lateral loads.

GTE-T4-7 Establish tolerable, total and differential settlements, and angular distortion of foundation system. Develop monitoring systems for verification of performance.

GTE-T4-8 Analyze and design combined footings (i.e., rectangular, trapezoidal, and strap) and mat foundations employing either flexible or rigid approaches.

GTE-T4-9 Analyze and design ring foundations for tower superstructures comprising water and transmission towers.

GTE-T4-10 Recommend applicable values for the coefficient of subgrade reaction for different soil formations.

GTE-T4-11 Structural design of isolated, combined, and mat foundations comprising setting of footing depth and steel reinforcement.

GTE-T4-12 Ability to design foundations of both shallow and deep embedment, subjected to uplift loads.

GTE-T4-13 Ability to estimate the allowable axial bearing capacity of deep foundations considering end bearing, skin resistance and where applicable negative skin friction.

GTE-T4-14 Evaluate potential settlement of single pile, pile groups, drilled shafts, and other deep foundation systems.

GTE-T4-15 Ability to estimate the allowable lateral load capacity and lateral deflection for single piles and pile groups.

GTE-T4-16 Select and design deep foundations whether conventional piles, drilled shafts, caissons or group of piles, and give reasons for the selection.

GTE-T4-17 Recognize techniques and procedures for static and dynamic pile load testing.

GTE-T4-18 Recommend methods for inspection and integrity testing (e.g., low-strain impact integrity testing, ultrasonic cross-hole testing, and thermal integrity testing) of deep foundations.

GTE-T4-19 Selection of factor of safety or load and resistance factors for foundation design considering type of structure, complexity of the geology and variability of the ground conditions, extent and quality of performed site investigations, and type of structural loading.

GTE-T4-20 Design and evaluate instrumentation programs to monitor settlement, pore water pressure, groundwater variations, and stress and strains in foundation structures.

GTE-T4-21 Recognize measures to protect against aggressive conditions to concrete and steel, including a selection of cement type, cover thickness, water/cement ratio and steel type.

GTE-T4-22 Recognize commonly used geotechnical software for shallow and pile foundations and the limitations and assumptions behind each of these software.

GTE-T4-23 Ability to assess the condition of existing foundations and propose methods for rehabilitation of foundations using constructible and economical techniques.

GTE-T5 Earth Retaining Structures. (3 MCQ)

GTE-T5-1 Select the appropriate type of retaining wall system from feasible options, including gravity, semi-gravity, cantilever, buttressed, counterfort, mechanically stabilized earth, and crib or gabion walls.

GTE-T5-2 Analyze external stability of rigid walls against sliding, overturning and bearing capacity, including estimation of lateral active and passive earth pressures using conventional Rankine or Coulomb failure theories.

GTE-T5-3 Analyze the internal stability of mechanically stabilized earth walls.

GTE-T5-4 Analysis and design of retaining walls where the width of the retained soil behind the retaining walls is narrower than the active wedge and backed by the vertical cut of rock.

GTE-T5-5 Design drainage systems for the wall and backfill.

GTE-T5-6 Analysis and design of flexible walls such as soldier pile and lagging, sheet pile, secant pile, tangent pile, diaphragm walls, braced and anchored walls, and walls supported on drilled shafts, for temporary or permanent situations.

GTE-T5-7 Understand design requirements for separation, filtration, and drainage and then apply appropriate measures, including the use of geosynthetic materials.

GTE-T6 Earth Structures. (2 MCQ)

GTE-T6-1 Design of earth fill dams employing characteristics of the construction materials for the dam body and dam core, recommend necessary measures for preparation of the foundation and identify geotechnical considerations for dam auxiliary structures.

GTE-T6-2 Evaluate the stability of natural or manmade slopes using either mass procedures or methods of slices for both homogeneous or layered mediums, and quantify the effects of seepage and pore water pressures on the stability of slopes.

GTE-T6-3 Identify and design a stabilization system for soils and rock slopes.

GTE-T6-4 Be able to apply commonly available commercial programs for slope stability analysis and realizing limitations and assumptions behind each of these software.

GTE-T6-5 Setting the requirements for flexible or rigid pavement structures, including preparations for subgrade and quality control testing.

GTE-T6-6 Evaluate resilient modulus and other design parameters relevant to the design of pavements.

GTE-T6-7 Recognition and understanding of repetitive Static Plate Load Tests of Soils and Flexible Pavement Components.

GTE-T7 Groundwater and Seepage. (2 MCQ)

GTE-T7-1 Analytical or graphical quantification of seepage, including gradients, flow velocities, and flow quantities under or through earth fill dams, underneath concrete dams, around sheet piles, and into excavation.

GTE-T7-2 Estimate the pore water pressure and total and hydraulic head at points within the seepage medium.

GTE-T7-3 Evaluate uplift pressure due to seepage and assess its effect on the stability of structures.

GTE-T7-4 Evaluation of critical and exit hydraulic gradients and check for the possibility of piping.

GTE-T7-5 Design of filters or drainage blanket as required.

GTE-T7-6 Select and propose approaches to prevent or minimize seepage using grouting, geomembrane, or cutoff walls.

GTE-T7-7 Design of a proper dewatering system during the temporary works, including a long-term risk assessment and its impact on neighboring facilities with a proper mitigation strategy.

GTE-T8 Problematic Soil and Rock Conditions. (2 MCQ)

GTE-T8-1 Identify and classify expansive soils and assess and quantify heave and swelling pressure.

GTE-T8-2 Recommend soil treatment methods and/or foundation systems to accommodate shrinking and swelling of expansive soils that consider soil characteristics, building type and loads, and local construction practice.

GTE-T8-3 Identify and classify collapsible soils based on collapse potential and predict collapse settlement.

GTE-T8-4 Devise improvement techniques or recommend a suitable foundation system that accommodates the loss of support due to collapse.

GTE-T8-5 Recognize sabkha formation as well as loose coastal saline silty sands and its potential geotechnical and structural problems.

GTE-T8-6 Propose appropriate geotechnical and structural provisions required for safe construction on sabkha soils.

GTE-T8-7 Identify the appropriate investigation, design, and monitoring techniques relevant to construction sites suspected to have cavities, including steps to be considered at the phase of site investigation, treatment approaches, foundation selection, and construction provisions.

GTE-T9 Seismic and Vibratory Loadings. (2 MCQ)

GTE-T9-1	Identify seismic zones of Saudi Arabia and potential seismic hazards.
GTE-T9-2	Interpret the results of probabilistic seismic hazard analyses to establish baseline design ground motions, including deaggregation to establish a representative magnitude.
GTE-T9-3	Account for the effect of local soil conditions on strong ground motions.
GTE-T9-4	Assess the susceptibility of a given soil formation to liquefaction.
GTE-T9-5	Estimate liquefaction-induced lateral spreading and settlement and; assess their effects on the integrity of engineered facilities at the site.
GTE-T9-6	Propose measures for stabilizing subsurface soils disposed to liquefaction.
GTE-T9-7	Evaluate and select soil dynamic properties and seismic design parameters for geotechnical design.
GTE-T9-8	Recognize general considerations in designing dynamic bases.
GTE-T9-9	Evaluate dynamic bearing capacity of foundations and select representative values for the lumped system parameters, including shear modulus and damping ratio at small and large strains.
GTE-T9-10	Analyze and design retaining structures for seismic loads, including evaluation of dynamic active and passive earth pressure force and consideration of liquefied soils.
GTE-T9-11	Assess the performance of earth fill dams and the foundation and abutment stability of concrete dams subject to seismic loading.
GTE-T9-12	Analyze and design foundations subjected to cyclic loading, induced by waves, wind, and sources other than earthquake loads.
GTE-T9-13	Design of foundations subjected to impact, or vertical, rocking, sliding, or torsional oscillation, including selection and design of proper foundation-isolation systems.

GTE-T10 Tunneling. (1 MCQ)

GTE-T10-1	Setting techniques for investigating and characterizing subsurface conditions for soft ground and rock formations.
GTE-T10-2	Selection of geotechnical parameters for tunnel design.
GTE-T10-3	Recognize soft ground and rock tunneling systems and appropriate technology and machinery used in practice.
GTE-T10-4	Identify typical cross-sections applicable per function.

GTE-T10-5 Identification of risk and recognizing OSHA (or equivalent Saudi Arabian) regulations for protecting the safety and health of underground construction workers.

GTE-T10-6 Recognize ground conditions that pose special problems for underground construction, including squeezing ground, running or flowing sands, the presence of large obstructions and fault and shear zones.

GTE-T10-7 Recognize tunneling methods and their applicability to the subsurface ground conditions, including drill and blast, new Austrian method, TBM or shield, and cut-and-cover method.

GTE-T10-8 Analysis of stresses and deformations for unlined tunnels as well as for single-or double-lined tunnels.

GTE-T10-9 Evaluate the potential for ground deformations (e.g., surface settlements) associated with tunneling and their potential impacts on adjacent and overlying structures and facilities (e.g., utilities).

GTE-T10-10 Recognize different measures used to support tunnel openings prior to installation of the permanent lining, including shotcrete, rock bolts, wire mesh, and steel arches.

GTE-T10-11 Recommend rock or soil loads for design of different types of permanent linings.

GTE-T10-12 Identify methods of handling groundwater in tunnels (grouting, freezing etc.).

GTE-T10-13 Fire life safety and ventilation requirements, i.e., number of ventilation and egress shafts.

GTE-T11 Forensic Geotechnical Engineering Investigation. (1 MCQ)

GTE-T11-1 Recognize process of data collection, laboratory and field diagnostic tests, instrumentation and monitoring, and development of failure hypotheses.

GTE-T11-2 Diagnose and assess geotechnical failures and carry out distress characterization and back analysis, and recognize the role of reliability.

GTE-T11-3 Identify through forensic analysis failure of foundations, retaining walls, slope and excavation, as well as damages due to expansive and collapsible soils.

GTE-T11-4 Develop and advise rehabilitation approaches and remedial actions upon identifying geotechnical risks from collected data.

GTE-T12 Codes and Standards. (1 MCQs)

GTE-T12-1 Exhibit general knowledge of building codes, specifications, and standards requirements and limitations, especially the Saudi Building Code (SBC).

12.1 Code Documents.

12.2.1 SBC 201 - Saudi Building Code - General (Equivalent to International Building Code – IBC 2015).

12.2.2 SBC 301 - Loading (Equivalent to Minimum Design Loads for Buildings and Other Structures (ASCE 7).

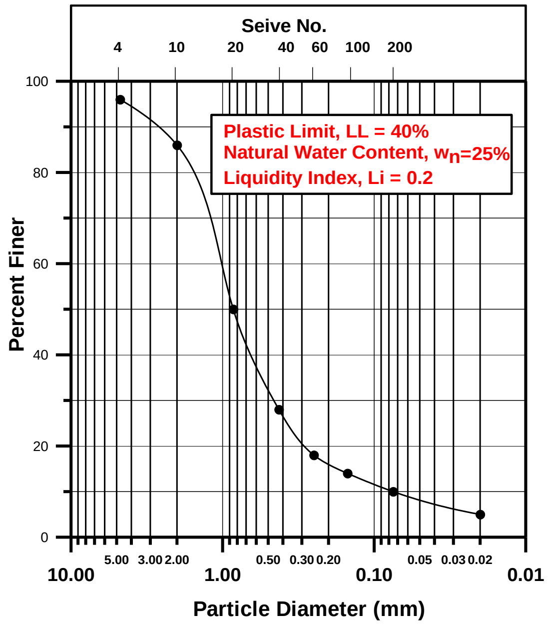
12.2.3 SBC 302 – Construction (Equivalent to various ACI Technical Specifications and covering part of Occupational Safety and Health Administration (OSHA) Regulations - OSHA 1926 Construction Safety Standards).

12.2.4 SBC 303 – Soils and Foundations (Equivalent in part to Chapter 18 in the International Building Code, IBC 2015).

12.2.5 SBC 304 - Concrete Structures (Equivalent to American Concrete Institute (ACI 318, 530).

5. Samples of Questions

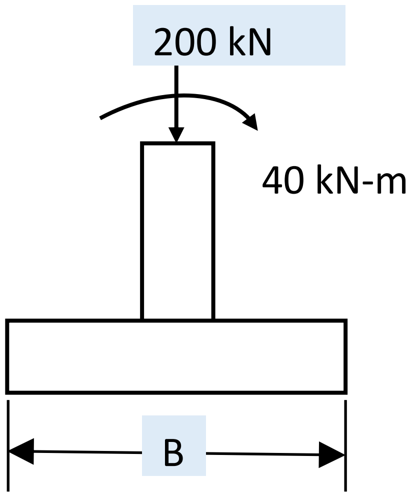
Q. No.	Major Area	EA Code	Question Statement (Answer's Choices)	Key Answer	Expected Time (min.)	Supplied Reference
1	**Site Investigation**	GTE-T1-4	Which of the following statements is incorrect? a) The results from a single borehole can be misleading. b) The required minimum depth of the borings cannot be changed during the drilling operation. c) In practical terms, once drilling equipment has been mobilized to a site, the cost of an additional one or two boreholes is usually not significant. d) After if an adequate exploration has been carried out, then conservative recommendation made by the consultant is considered not ethical.	(B)	2.0 – 3.0	None
2	**Laboratory Testing and Analysis of Test Results**	GTE-T2-1	From a borrow pit where the natural moisture content is 15% and the unit weight is 17 kN/m^3, soil with 2000 m^3 in volume is excavated. The soil is used in an embankment compacted at a void ratio of 0.3. If the specific gravity is equal to 2.70 and assuming that no change in dry mass and moisture content of the soil, the volume of the compacted embankment is most nearly: a) 1510 m^3 b) 1450 m^3 c) 1340 m^3 d) 1280 m^3	(B)	3.0 – 4.0	None
3	**Laboratory Testing and Analysis of Test Results**	GTE-T2-3	As part of site exploration, a soil sample was collected from the site of a proposed project. Mechanical and consistency tests were carried out. The grain size distribution curve, natural water content, liquid limit, and liquidity index are shown in the figure. According to the AASHTO Classification System, the soil is classified as: a) A-1-a (0) b) A-3 (0) c) A-7-5 (20) d) A-2-6 (0)	(D)	4.0 – 5.0	AASHTO chart

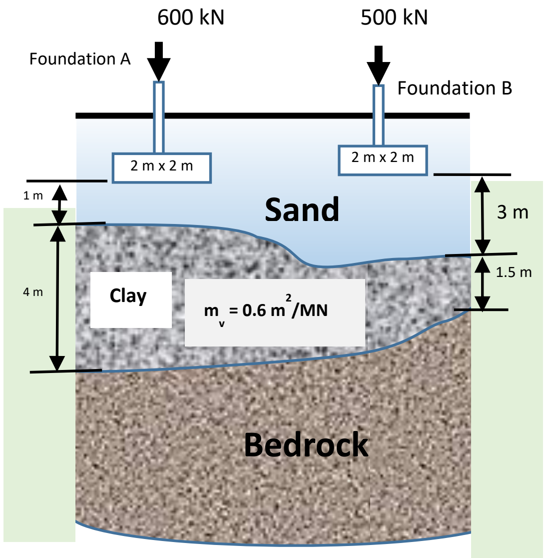
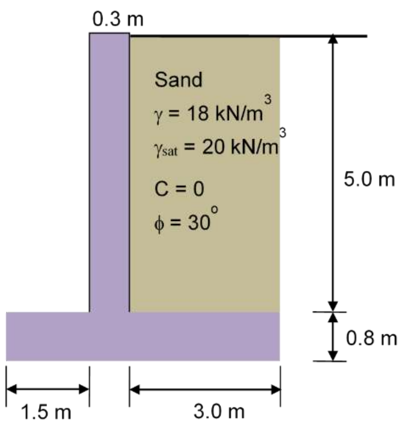
<table>
<tr><th>Q. No.</th><th>Major Area</th><th>EA Code</th><th>Question Statement (Answer's Choices)</th><th>Key Answer</th><th>Expected Time (min.)</th><th>Supplied Reference</th></tr>
<tr><td></td><td></td><td></td><td>
</td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Field Procedures, Testing and Safety</td><td>GTE-T3-1</td><td>Of the coast of the city of Dammam, an artificial island is constructed through dredging of soil from the bed of the Arabian Gulf. The best technique for compacting the fill materials is:

(a) Pneumatic rubber-tired rollers.
(b) Smooth-wheel rollers.
(c) Vibroflotation.
(d) Sheepsfoot rollers.</td><td>(C)</td><td>1.0 – 2.0</td><td>None</td></tr>
<tr><td>5</td><td>Field Procedures, Testing and Safety</td><td>GTE-T3-6</td><td>A proposed embankment fill requires 5000 m^3 volume to be constructed with a soil having a void ratio of 0.7. The soil can be obtained from one of three borrow pits marked as Site A. Site B and Site C. The void ratios and cost per cubic meter for transportation to the construction site are provided in the below table. The most economical borrow pit is:

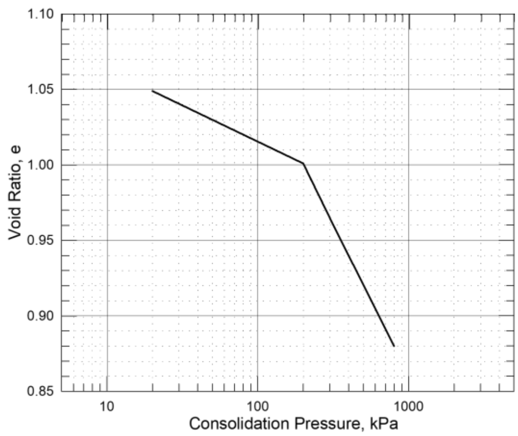
<table>
<tr><th>Borrow Pit</th><th>Void ratio</th><th>Cost (SR/m^3)</th></tr>
<tr><td>Site A</td><td>0.8</td><td>38</td></tr>
<tr><td>Site B</td><td>1.2</td><td>45</td></tr>
<tr><td>Site C</td><td>1.5</td><td>32</td></tr>
</table>

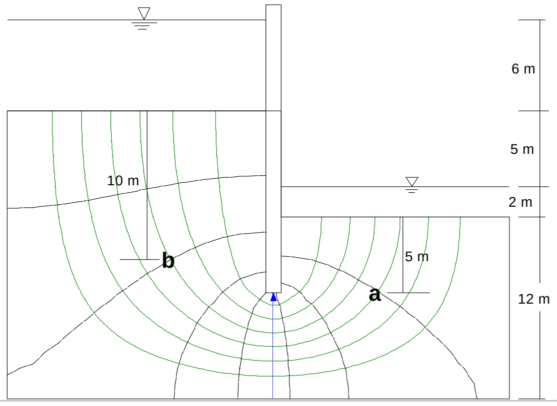
a) Site A followed by Site B
b) Site A followed by Site C
c) Site B followed by Site A
d) Site C followed by Site B</td><td>(B)</td><td>3.0 – 4.0</td><td>None</td></tr>
</table>

Q. No.	Major Area	EA Code	Question Statement (Answer's Choices)	Key Answer	Expected Time (min.)	Supplied Reference
6	**Shallow and Deep Foundations**	GTE-T4-5	A clay layer 25 mm thick (drained at both top and bottom) in the laboratory reached 50% consolidation in 2 minutes. If a clay layer of the same clay in the field having a thickness of 3 m and underlain by a rock layer is subjected to the same pressure increment, it is most nearly take the clay layer to reach 50% consolidation: a) 95.3 days b) 86.4 days c) 80.6 days d) 78.5 days	(C)	3.0 – 4.0	Taylor's Isochrones chart
7	**Shallow and Deep Foundations**	GTE-T4-6	The least width, B, for the footing to ensure positive contact pressure on the supporting soil is most nearly;  a) 1.8 m b) 1.5 m c) 1.2 m d) 1.0 m	(C)	2.0 – 3.0	None
8	**Shallow and Deep Foundations**	GTE-T4-7	Two square footings supporting two columns of a residential building are shown. Only one borehole was carried out under foundation B and based on that, the width of the clay layer was taken to be uniform and equal to 1.5 m. Two years after construction, the building settles, with a differential settlement of 15 mm. A subsequent soil investigation showed that the thickness of the clay layer is as shown in the figure. It will most nearly take additional	(B)	4.0 – 6.0	None

Q. No.	Major Area	EA Code	Question Statement (Answer's Choices)	Key Answer	Expected Time (min.)	Supplied Reference
			time for the differential settlement to reach 25 mm: e) 12 years f) 10 years g) 8 years h) 7 years  			
9	**Earth Retaining Structures**	GTE-T5-2	If the drain behind the shown cantilever retaining wall becomes clogged and groundwater rises to the top of the horizontal backfill, using Rankine's theory, the total active resultant (kN/m) acting on the retaining wall is most nearly increases by: a) 97% b) 112% c) 117% d) 122%  	(D)	4.0 – 5.0	None

Q. No.	Major Area	EA Code	Question Statement (Answer's Choices)	Key Answer	Expected Time (min.)	Supplied Reference
10	**Codes and Standards**	GTE-T12-1	The Saudi Building Code set the allowable differential settlement as: a) The least of maximum allowable total settlement and maximum allowable angular distortion. b) The greater of maximum allowable total settlement and maximum allowable angular distortion. c) The maximum allowable settlement and the ratio of the length to the height of the building. d) The maximum allowable angular distortion and the ratio of the length to the height of the building.	(A)	2.0 – 3.0	None
Essay (1)	**Shallow and Deep Foundations**	GTE-T4-4 GTE-T4-5	A two-story building was built at a site where a 4-m thick clay is overlaid by a 3 m stratum of permeable sand is underlain by impermeable bedrock. The building adds pressure of 400 kPa to the already existing overburden pressure and causes an initial excess pore pressure of 400 kPa throughout the entire depth of the clay layer. Geotechnical investigation revealed that the initial void ratio for the clay layer is equal to 1.07 and the unit weights for the sand and clay layers are 15 kN/m^3 and 17.5 kN/m^3, respectively. A standard oedometer test was conducted on an undisturbed sample taken from the middle of the clay layer. The sample thickness was 19 mm and drainage was allowed from both the top and bottom of the sample. For the first load increment, the sample reached 60% consolidation in 2 min. The relationship between the void ratio and the logarithm of consolidation pressure is shown. For the clay layer, required: a) How many days will it take for 50% of the expected total settlement to take place b) The amount of consolidation settlement that will occur in two years. c) How many years will it take for a consolidation settlement of 11 cm to take place?		30.0 – 40.0	Table of the relationship between Time Factor and Average Degree of Consolidation & Taylor's Isochrones chart

Q. No.	Major Area	EA Code	Question Statement (Answer's Choices)	Key Answer	Expected Time (min.)	Supplied Reference
			d) How many years will it take for a consolidation settlement of 11 cm to take place if instead of the bedrock there was a gravely sand layer, and calculate the excess pore water pressure at the middle of the clay layer six months after the application of building load? 			
Essay (2)	**Groundwater and Seepage**	GTE-T7-1 GTE-T7-2	At a construction site, a sheet-pile wall of the section shown was installed. The permeability for the soil at the site is equal to 5 × 10^{-2} cm/sec. Required: a) The seepage quantity per meter of the sheet-pile wall width per day. b) The pore water pressure at points (a) and (b). c) The effective stress at point (a) if the unit weight of soil is 18 kN/m^3. d) What would be the pore water pressure at point (a) if the water level in front of the wall rises 11 m such that it reaches the same present water level behind the wall? e) To what level should water be allowed to rise above the downstream ground surface so that the existing rate of seepage is reduced by 25%?		30.0 – 40.0	None

Q. No.	Major Area	EA Code	Question Statement (Answer's Choices)	Key Answer	Expected Time (min.)	Supplied Reference
						

6. Solutions of Samples Questions

Multiple Choice Questions (MCQs)

Question # 1

Indicator GTE-T1-4: Develop and evaluate site investigation programs of a good standard satisfying project scope, the Saudi Building Code requirements and other relevant geotechnical guides; this involves phasing of investigation into preliminary and detailed phases and identifying location, depth and number of subsurface investigations (i.e., boreholes, probes, down-hole testing, etc.), groundwater level monitoring wells, and test pits.

Example GTE-T1-4:

Which of the following statements is incorrect?

a) The results from a single borehole can be misleading.

b) The required minimum depth of the borings cannot be changed during the drilling operation.

c) In practical terms, once drilling equipment has been mobilized to a site, the cost of an additional one or two boreholes is usually not significant.

d) After if an adequate exploration has been carried out, then conservative recommendation made by the consultant is considered not ethical

Solution GTE-T1-4:

It is possible to change the depth of the boring during drilling as per the condition of the site. If the initial boreholes revealed complexities of soil strata, suspicion of poor soil at greater depth, the depth of some of the further boreholes could be increased.

The Answer is: (b)

Question # 2

Indicators

GTE-T2-1: Recognize physical and engineering properties of soils and rocks, and ability to express weight and volume relationships.

Example GTE-T2-1

From a borrow pit where the natural moisture content is 15% and the unit weight is 17 kN/m^3, soil with 2000 m^3 in volume is excavated. The soil is used in an embankment compacted at a void ratio of 0.3. If the specific gravity is equal to 2.70 and assuming that no change in dry mass and moisture content of the soil, the volume of the compacted embankment is most nearly:

a) 1510 m^3

b) 1450m^3

c) 1340 m^3

d) 1280 m^3

Solution GTE-T2-1

$\gamma = \frac{W}{V}$.......> $\quad 17 = \frac{W}{2000}$ ....>>>> $W = 34000\ kN$

$$\omega = \frac{W_w}{W_s} \quad \ggg> W = W_w + W_s \quad \ggg \quad W = (1+\omega)W_s$$

$$34000 = (1+0.15)W_s \ldots\ldots\ldots\ldots\ldots..> \quad W_s = 29565.2\ kN$$

$$\gamma_s = \frac{W_s}{V_s} \ldots\ldots\ldots\ldots..V_s = \frac{29565.2}{\gamma_w G_s} = \frac{29565.2}{9.81 \times 2.7} = 1116.2\ m^3$$

$$e_2 = \frac{V_{v2}}{V_s} = \frac{V_2 - V_s}{V_s} \ldots\ldots\ldots\ldots V_2 = (1+e_2)V_s$$

$$V_2 = (1+0.3)1116.2 \approx \mathbf{1451\ m^3}$$

Note:

- W = total weight of soil
- W_s = weight of solids
- W_w = Weight of water
- ω = water content

- γ = Moist (total unit weight)
- γ_s = Unit weight of solids
- V_s = Volume of solids
- V_v = Volume of voids
- V = Total volume
- V_2 = Volume of soil after compaction

Short solution:

$$\gamma = \frac{(1+\omega)G_s}{1+e}\gamma_w$$

$17 = \frac{(1+0.15)\times 2.7}{1+e} \times 9.81$ ....> $e_1 = 0.792$

$\frac{V_2}{V_1} = \frac{(1+e_2)}{(1+e_1)}$ >>> $\frac{V_2}{2000} = \frac{(1+0.3)}{(1+0.792)}$ $\ggg$ $V_2 = \mathbf{1451\ m^3}$

The Answer is: (b)

Question # 3

Indicator GTE-T2-3: Classify soils according to the unified soil classification system (USCS) (as required in the Saudi Building Code 303) or AASHTO.

Example GTE-T2-3

As part of site exploration, a soil sample was collected from the site of a proposed project. Mechanical and consistency tests were carried out. The grain size distribution curve, natural water content, liquid limit, and liquidity index are shown in the figure. According to the AASHTO Classification System, the soil is classified as:

a) A-1-a (0)

b) A-3 (0)

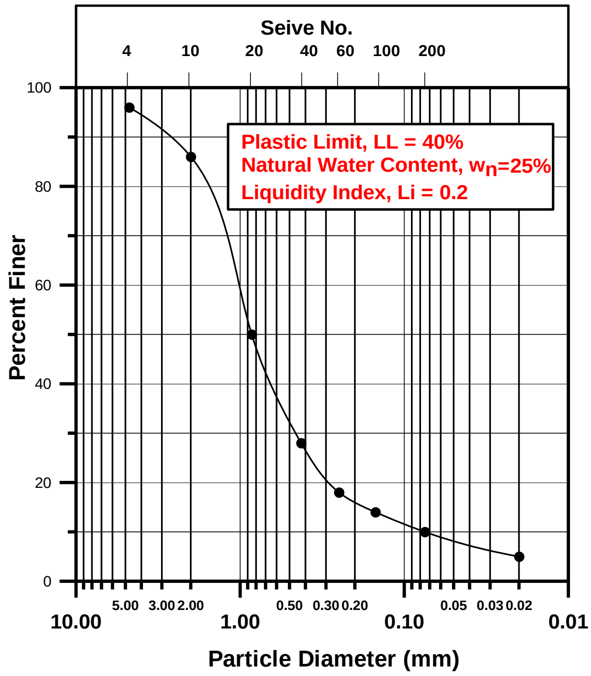
c) A-7-5 (20)

d) A-2-6 (0)

Solution GTE-T2-3

$$Li = \frac{w_n - PL}{PI} = \frac{w_n - PL}{LL - PL} = \frac{25 - PL}{40 - PL}$$

$0.2 = \frac{25-PL}{40-PL}$ PL = 21.25 %



Where

PI = Plasticity index

PL = Plastic limit

PI = LL – PL = 40 - 21.25 = 18.75 %

From the grain size distribution curve, the percentage passing sieves relevant to AASHTO Classification system are as follows:

Sieve #	% finer
No. 10	86
No. 40	28
No. 200	10

Based on these values and for LL = 40% and PI =19%, the group is A-2-6.

Group Index

$$GI = (F_{200} - 35)[0.2 + 0.005(LL - 40)] + 0.01(F_{200} - 15)(PI - 10)$$

Where F_{200} = % passing sieve # 200

Substituting the values of F_{200}, LL, and PI, the value of group index GI is –ve, therefore GI =0.

The soil is classified as A-2-6 (0).

The Answer is: (d)

Question # 4

Indicator GTE-T3-1: Identify suitable techniques for improvement of in-situ materials, including compaction, vibroflotation, preloading, grouting, dynamic compaction, use of geotextiles and geogrids, sand columns, and stone columns.

Example GTE-T3-1

Of the coast of the city of Dammam, an artificial island is constructed through dredging of soil from the bed of the Arabian Gulf. The best technique for compacting the fill materials is:

a) Pneumatic rubber-tired rollers

b) Smooth-wheel rollers

c) Vibroflotation

d) Sheepsfoot rollers

Solution GTE-T3-1

a and d are not applicable as machines. b is ineffective because of the thickness of the deposit to be compacted.

The Answer is: (c)

Question # 5

Indicator GTE-T3-6: Select and evaluate the appropriateness of sites for borrowing earth fill based on material characteristics and cost of transportation.

Example GTE-T3-6

A proposed embankment fill requires 5000 m^3 volume to be constructed with a soil having a void ratio of 0.7. The soil can be obtained from one of three borrow pits marked as Site A. Site B and Site C. The void ratios and cost per cubic meter for transportation to the construction site are provided in the below table. The most economical borrow pit is:

Borrow Pit	Void ratio, e	Cost (SR/m^3)
Site A	0.8	38
Site B	1.2	45
Site C	1.5	32

a) Site A followed by Site B

b) Site A followed by Site C

c) Site B followed by Site A

d) Site C followed by Site B

Solution GTE-T3-6

$$\frac{V_{natural}}{V_{compacted}} = \frac{1 + e_{natural}}{1 + e_{compacted}}$$

Volume of soil required from Site A = (1+0.8)/(1+0.7) X 5000 = 5294 m^3

Cost of soil from Site A = 5294 x 38 = 201172 SR.

Volume of soil required from Site B = (1+1.2)/(1+0.7) X 5000 = 6470 m^3

Cost of soil from Site B = 6470 x 45 = 291150 SR.

Volume of soil required from Site C = (1+1.5)/(1+0.7) X 5000 = 7353 m^3

Cost of soil from Site C = 7353 x 32 = 235296 SR.

The Answer is: (b)

Question # 6

Indicator GTE-T4-5: Ability to quantify the rate of settlement for various loading, ground, and drainage conditions, including the analysis and design of sand or wick drains system to expedite settlement of preloaded soft soil formations.

Example GTE-T4-5

A clay layer 25 mm thick (drained at both top and bottom) in the laboratory reached 50% consolidation in 2 minutes. If a clay layer of the same clay in the field having a thickness of 3 m and underlain by a rock layer is subjected to the same pressure increment, it is most nearly take the clay layer to reach 50% consolidation:

a) 95.3 days

b) 86.4 days

c) 80.6 days

d) 78.5 days

Solution GTE-T4-5

Sample

$T_v = \frac{C_v t}{H_d^2}$

For degree of consolidation U = 50%, time factor T_v = 0.197

The sample is drained at both top and bottom; hence the drainage path is equal to half the thickness of the sample, H_d =25/2 = 12.5 mm

$0.197 = \frac{C_v \times 2}{(12.5)^2}$ $\qquad C_v = 15.39\frac{mm^2}{min} = 0.022m^2/day$

Clay layer

The layer is underlain by a rock layer, so the drainage path is equal to the entire thickness of the clay layer in the field, or H_d = 3 m.

$0.197 = \frac{0.022 \times t}{(3)^2}$.................. t = 80.6 days

The Answer is: (c)

Question # 7

Indicator GTE-T4-6: Analyze and design shallow foundations for homogeneous or stratified medium, concentric or eccentric loads, vertical or inclined loads, and lateral loads.

Example GTE-T4-6

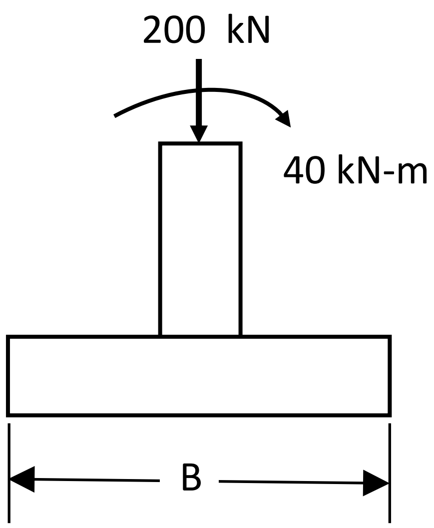
The least width, B, for the square footing to ensure positive contact pressure on the supporting soil is most nearly:

a) 1.8 m

b) 1.5 m

c) 1.2 m

d) 1.0 m



Solution GTE-T4-6

$$q = \frac{Q}{BL}\left(1 - \frac{6e}{B}\right)_{min}$$

L = B

$$e = \frac{M}{Q} = \frac{40}{200} = 0.2m$$

$$0 = \frac{200}{B^2}\left(1 - \frac{6\times0.2}{B}\right) \longrightarrow \text{B =1.2 m}$$

The Answer is: (c)

Question # 8

Indicators: GTE-T4-7: Establish tolerable, total and differential settlements, and angular distortion of foundation system. Develop monitoring systems for verification of performance.

Example GTE-T4-7

Two square footings supporting two columns of a residential building are shown. Only one borehole was carried out under foundation B and based on that, the width of the clay layer was taken to be uniform and equal to 1.5 m. Two years after construction, the building settles, with a differential settlement of 15 mm. A subsequent soil investigation showed that the thickness of the clay layer is as shown in the figure. It will most nearly take additional time for the differential settlement to reach 25 mm:

a) 12 years

b) 10 years

c) 8 years

d) 7 years

Solution GTE-T4-4

Vertical stress increase at the center of the clay layer under the foundation

$$\Delta\sigma_A = \frac{P}{(B+z)(L+z)} = \frac{600}{(2+3)(2+3)} = 24\ kN/m^2$$

$$\Delta\sigma_B = \frac{P}{(B+z)(L+z)} = \frac{500}{(2+3.75)(2+3.75)} = 15\ kN/m^2$$

Primary consolidation settlement = $m_v \Delta\sigma$ H

$S_{c(A)}$ = 0.6 x 10^{-3} x 24 x 4 = 0.0576 m = 57.6 mm

$S_{c(B)}$ = 0.6 x 10^{-3} x 15 x 1.5 = 0.0135 m = 13.5 mm

Differential settlement = 57.6-13.5 = 44.1 mm

Current differential settlement = 15 mm

Degree of consolidation U = 15/44.1 = 0.34

For U = 34% ....>>> T_v = 0.095

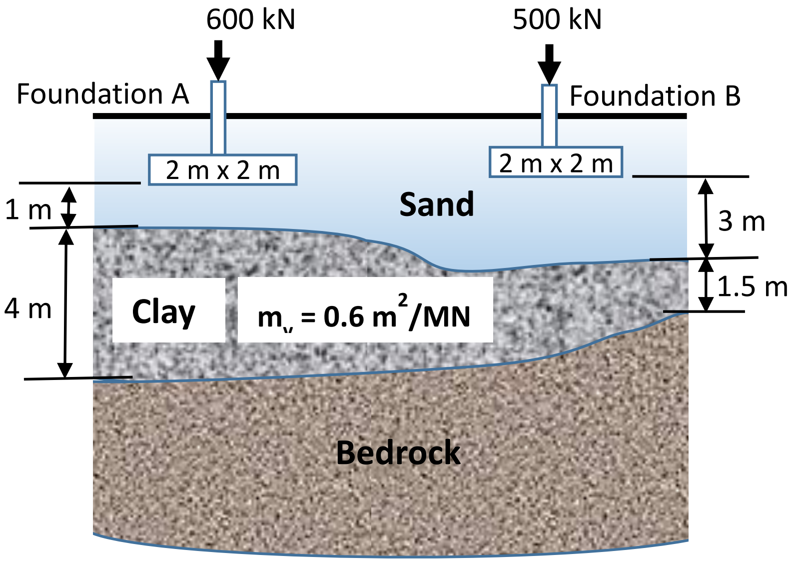
$T_v = \frac{C_v t}{H_d^2}$....>$C_v = \frac{T_v H_d^2}{t} =$

$\frac{0.095 \times 4^2}{2} = 0.76 m^2/year$

For 25 mm differential settlement:

$U = \frac{25}{44.1} = 0.57$ ....$T_V = 0.257$

$$t = \frac{T_v H_d^2}{C_v} = \frac{0.57 \times 4^2}{0.76} = 12\ years$$



Therefore, for the differential settlement to reach 25 mm will (12-2) = 10 years

The Answer is: (b)

Question # 9

Indicator GTE-T5-2: Analyze external stability of rigid walls against sliding, overturning and bearing capacity, including estimation of lateral active and passive earth pressures using conventional Rankine or Coulomb failure theories.

Example GTE-T5-2

If the drain behind the shown cantilever retaining wall becomes clogged and groundwater rises to the top of the horizontal backfill, using Rankine's theory, the total active resultant (kN/m) acting on the retaining wall is most nearly increases by:

a) 97%

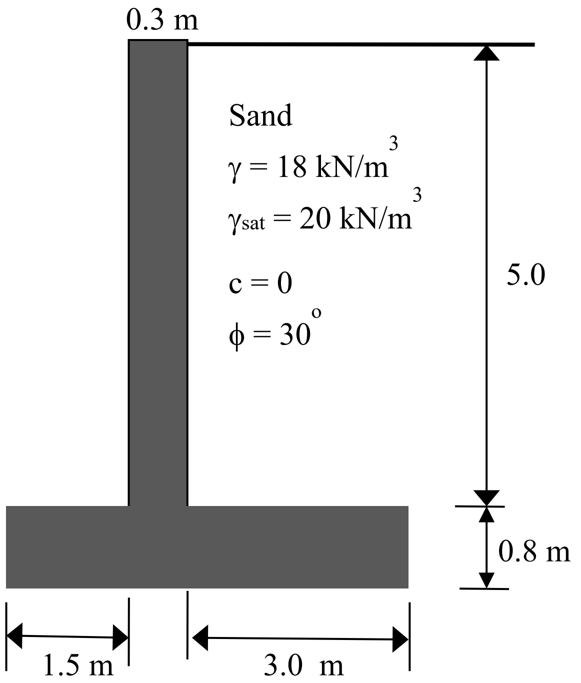
b) 112%

c) 117%

d) 122%

Solution GTE-T5-2

The active earth pressure coefficient is given by:



$$k_a = \frac{1 - \sin\varphi}{1 + \sin\varphi} = \frac{1 - \sin 30}{1 + \sin 30} = 0.33$$

Before clogging of drain

At the base of the footing (depth = 5.8 m)

the earth pressure, $P_a = k_a \gamma H$ = 0.33 x 18 x 5.8 = 34.45 kN/m^2

Total active resultant = 0.5 x P_a x H = 0.5 x 34.45 x 5.8 = 99.9 kN/m

After clogging of drain

At the base of the footing (depth = 5.8 m), the earth pressure, $P_a = k_a \gamma_{sub} H$

=0.33 x (20 – 9.81) x 5.8 =19.5 kN/m^2

At the base of the footing (depth = 5.8 m), the hydrostatic pressure, $P_w = \gamma_w H$ = 9.81 x 5.8 = 56.9 kN/m^2.

Total pressure at the base of the footing, $P_{total} = P_a + P_w$ = 19.5 + 56.9 = 76.4 kN/m^2

Total active resultant = 0.5 x P_{total} x H = 0.5 x 76.4 x 5.8 = 221.6 kN/m.

Percentage of increase in total active resultant = (221.6 – 99.9)/99.9 x 100 =121.8%

The Answer is: (d)

Question # 10

Indicator GTE-T12-1: Exhibit general knowledge of building codes, specifications, and standards requirements and limitations, especially the Saudi Building Code (SBC).

Example GTE-T12-1

The Saudi Building Code set the allowable differential settlement as:

a) The least of maximum allowable total settlement and maximum allowable angular distortion.

b) The greater of maximum allowable total settlement and maximum allowable angular distortion.

c) The maximum allowable settlement and the ratio of the length to the height of the building.

d) The maximum allowable angular distortion and the ratio of the length to the height of the building.

Solution GTE-T12-1

As per section 5.4.1.5 of SBC 303, the allowable differential settlement is the least of maximum allowable total settlement and maximum allowable angular distortion.

The Answer is: (a)

Essay Questions

Essay Question # 1

Indicators

GTE-T4-4: Estimate expected immediate, primary consolidation, and secondary consolidation settlements for different supporting grounds, including evaluation of stresses induced within soil masses by different loaded areas.

GTE-T4-5: Ability to quantify the rate of settlement for various loading, ground, and drainage conditions, including the analysis and design of sand or wick drains system to expedite settlement of preloaded soft soil formations.

A two-story building was built at a site where a 4-m thick clay is overlaid by a 3 m stratum of permeable sand is underlain by impermeable bedrock. The building adds a pressure of 400 kPa to the already existing overburden pressure and causes an initial excess pore pressure of 400 kPa throughout the entire depth of the clay layer.

Geotechnical investigation revealed that the initial void ratio for the clay layer is equal to 1.07 and the unit weights for the sand and clay layers are 15 kN/m^3 and 17.5 kN/m^3, respectively.

A standard oedometer test was conducted on an undisturbed sample taken from the middle of the clay layer. The sample thickness was 19 mm and drainage was allowed from both the top and bottom of the sample. For the first load increment, the sample reached 60% compression in 2 min.

The relationship between the void ratio and the logarithm of consolidation pressure is shown. For the clay layer, required:

a) How many days will it take for 50% of the expected total settlement to take place

b) The amount of consolidation settlement that will occur in two years.

c) How many years will it take for a consolidation settlement of 11 cm to take place?

d) How many years will it take for a consolidation settlement of 11 cm to take place if instead of the bedrock there was a gravely sand layer, and calculate the excess pore water pressure at the middle of the clay layer six months after the application of building load?

Answer to Essay Question #1

a) *For the laboratory sample*

For an average degree of consolidation, U = 60%, time factor, T_v = 0.286

$T_v = \frac{C_v t}{H_d^2}$ >>>>> $0.286 = \frac{C_v \times 2}{\left(\frac{19}{2}\right)^2}$ >>> C_v = 12.9 mm^2/min = 0.019 m^2/day

T_v = time factor

C_v = coefficient of consolidation

H_d = Length of drainage path

For the clay layer:

For an average degree of consolidation, U = 50%, time factor, T_v = 0.197

$0.197 = \frac{0.019t}{4^2}$ >>>>>>> t = 166 days

b) Taking the clay layer as a single layer

Overburden pressure at the center of the clay layer, σ_o'= 3 x 15 + 2 x 17.5 = 80 kN/m^2

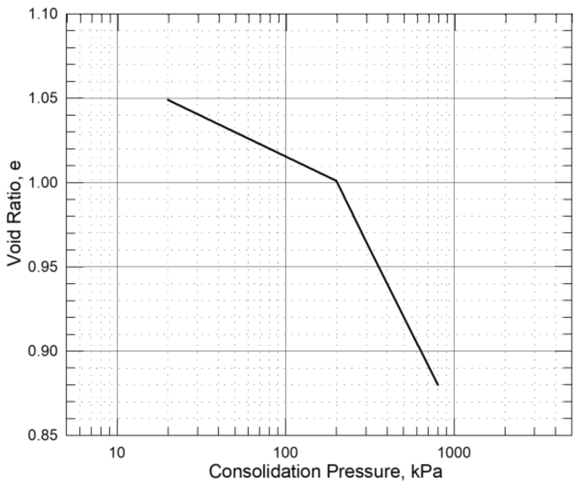
From the void ratio consolidation pressure relationship shown in the figure we get

Swell index C_s

$$C_s = \left(\frac{1.02-1}{log\left(\frac{200}{80}\right)}\right) = 0.05$$

Compression index C_c

$$C_c = \left(\frac{1.0 - 0.9}{log\left(\frac{600}{200}\right)}\right) = 0.21$$



$$S_c = \frac{C_s H}{1+e_0}\log\left(\frac{\sigma_c'}{\sigma_o'}\right) + \frac{C_c H}{1+e_0}\log\left(\frac{\sigma_o' + \Delta\sigma}{\sigma_c'}\right)$$

$$S_c = \frac{0.05\times4}{1+1.07}\log\left(\frac{200}{80}\right) + \frac{0.21\times4}{1+1.07}\log\left(\frac{80+400}{200}\right) = 0.193 \text{ m}$$

Therefore, consolidation settlement = 193 mm

$T_v = \frac{C_v t}{H_d^2}$ $T_v = \frac{0.019 \times(2 \times 365)}{4^2}$ T_v = 0.867

For T_v = 0.867 >>>> U = 90.3%

The settlement in two years = 0.903 x 193 = 174.3 mm

c) U = 110/193 x 100 = 57%

For U = 57 % >>>> T_v = 0.257

$T_v = \frac{C_v t}{H_d^2}$ $0.257 = \frac{0.019\times t}{4^2}$ t = 216 days

d) The layer will drain at both top and bottom (i.e., H_d = 2 m)

$T_v = \frac{C_v t}{H_d^2}$ $0.257 = \frac{0.019\times t}{2^2}$ t = 54 days

Excess pore water pressure at the middle of the clay layer.

$$T_v = \frac{C_v t}{H_d^2} = \frac{0.019 \times (6 \times 30)}{2^2} = 0.855$$

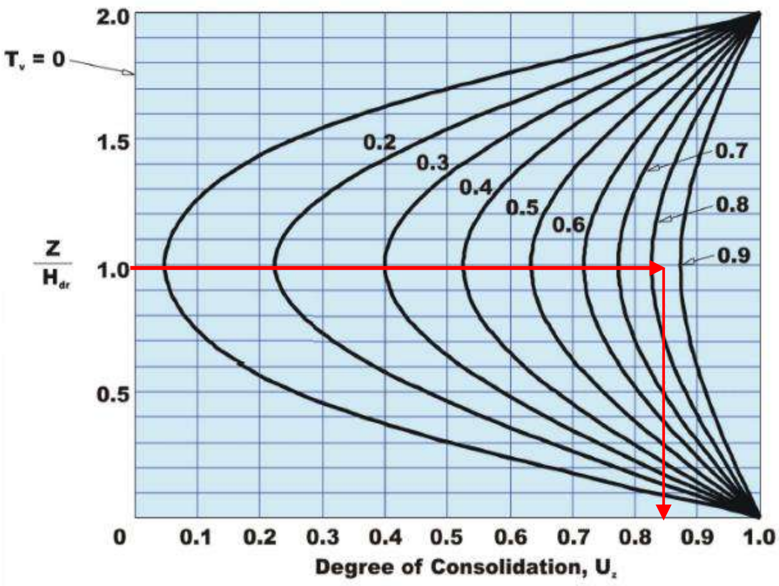
$z/H_d = 2/2 = 1$

From the isochrones chart, the degree of consolidation, U_z at the middle of the clay layer 6 months after the application of building load is equal to 0.85.

$$U_z = 1 - \frac{u_z}{u_0}$$

$$0.855 = 1 - \frac{u_z}{400}$$

u_z = 58 kN/m^2



Essay Question # 2

Indicators:

GTE-T7-1: Analytical or graphical quantification of seepage, including gradients, flow velocities, and flow quantities under or through earth fill dams, underneath concrete dams, around sheet piles, and into excavation.

GTE-T7-2: Estimate the pore water pressure and total and hydraulic head at points within the seepage medium.

At a construction site, a sheet-pile wall of the section shown is installed. The permeability for the soil at the site is equal to 5×10^{-2} cm/sec. Required:

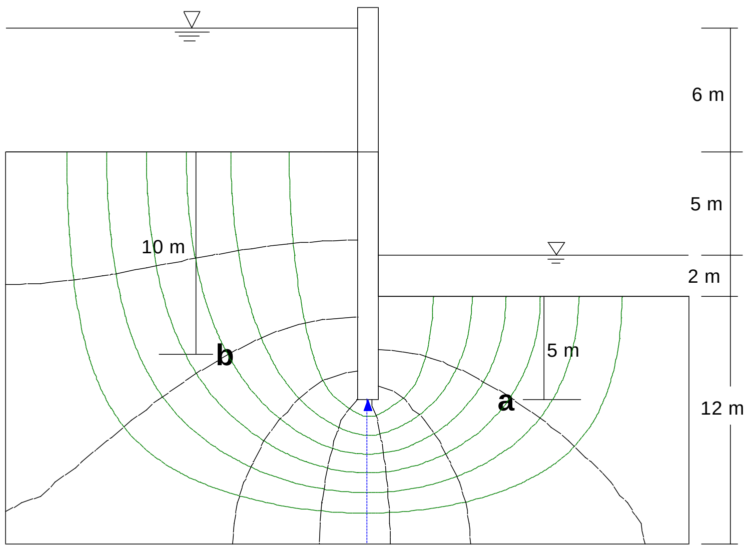
a) The seepage quantity per meter of the sheet-pile wall width per day.

b) The pore water pressure at points (a) and (b).

c) The effective stress at point (a) if the unit weight of soil is 18 kN/m^3.

d) What would be the pore water pressure at point (a) if the water level in front of the wall rises 11 m such that it reaches the same present water level behind the wall?

e) To what level should water be allowed to rise above the downstream ground surface so that the existing rate of seepage is reduced by 25%?



Answer to Essay Question #2

a)

$$k = 5 \times 10^{-2} cm/sec = 43.2\ m/day$$

$$q = k\Delta h \frac{N_f}{N_d} = 43.2\ \times 11 \times \frac{7}{8} = 415.8 m^3/\ \text{day}/m$$

b) Pore water pressure at point (a) and point (b):

Bernoulli's equation

$$\boldsymbol{h = \frac{u}{\gamma_w} + z}$$

Where h = total head

u = pore water pressure

z = elevation head

Take the datum at the discharge point

$\boldsymbol{h_a = \frac{u_a}{\gamma_w} + z_a}$

h_a = 11 – (7 x 11/8) = 1.375 m

z_a = - 7 m

$\boldsymbol{1.375 = \frac{u_a}{9.81} - 7}$ >>>>>>>> u_a = 82.16 kN/m^2

$\boldsymbol{h_b = \frac{u_b}{\gamma_w} + z_b}$

h_b = 11 – (2 x 11/8) = 8.25 m

z_a = - 5 m

$\boldsymbol{8.25 = \frac{u_b}{9.81} - 5}$ >>>>>>> u_b = 130 kN/m^2

c) Effective stress at point (a):
$\boldsymbol{\sigma' = \sigma - u}$ >>>>>>>> $\boldsymbol{\sigma' = (2 \times 9.81 + 5 \times 18) - 82.16 = 27.46 kN/m^2}$

d) If the water level in front of the wall rises 11 m such that it reaches the same present water level behind the wall, there will be no seepage and the pore pressure at point a will be hydrostatic, or

$$u_a = \gamma_w z = 9.81 \times (5 + 2 + 11) = 176.58\ kN/m^2$$

e) For reduction of seepage by 25% requires the reduction of head difference by 25%.

Therefore, the new head difference = 0.75 x 11 = 8.25 m.

The level of water in the downstream should rise by 2.75 m.

Reference Sheets

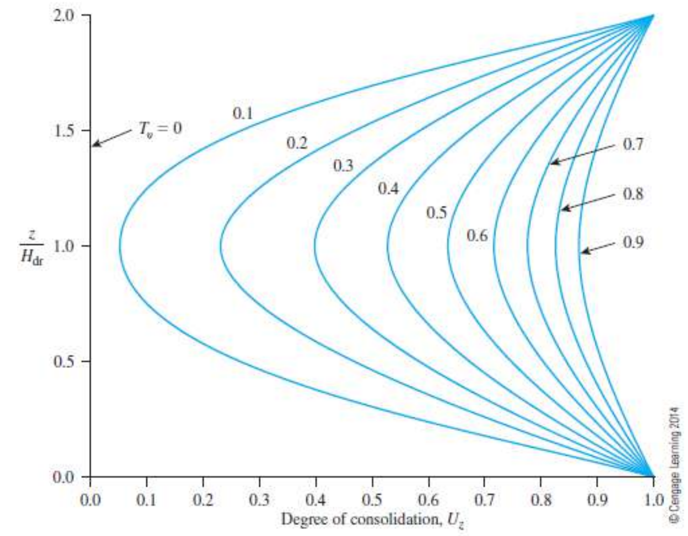
MCQ - Question #3

General Classification	***Granular Materials*** *(35% or less passing 0.075 mm)*							***Silty-Clay Material*** *(More than 35% passing 0.075 mm)*			
Group Classification	**A-1-a**	**A-1-b**	**A-3**	**A-2-4**	**A-2-5**	**A-2-6**	**A-2-7**	**A-4**	**A-5**	**A-6**	**A-7-5** **A-7-6** **
Sieve Analysis Percent passing:											
2.00 mm	50 max										
0.42 mm	30 max	50 max	51 min								
0.075 mm	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of Fraction passing 0.42 mm											
Liquid Limit				40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plastic Index	6 max	6 max	N.P.	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min
Usual types of significant constitutent materials	Stone Fragments - gravel and sand		Fine sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
General rating as subgrade	Excellent to good							Fair to poor			

** A-7-5 – PI <= LL - 30
A-7-6 – PI > LL - 30

$$GI = (F - 35)[0.2 + 0.005(LL - 40)] + 0.01(F - 15)(PI - 10)$$

Essay Question No.1


2.0
1.5
1.0
0.5
0.0
$\frac{z}{H_{dr}}$
$T_v = 0$
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Degree of consolidation, U_z
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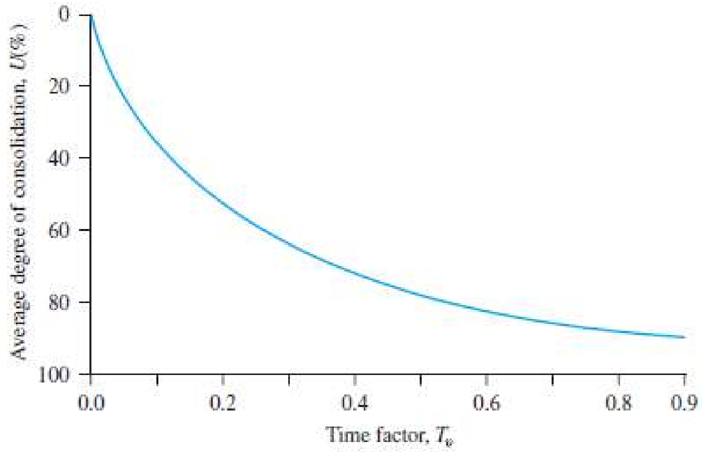
0
20
40
60
80
100
Average degree of consolidation, U(%)
0.0 0.2 0.4 0.6 0.8 0.9
Time factor, T_v

Table Variation of T_v with U

U (%)	T_v	U (%)	T_v	U (%)	T_v	U (%)	T_v
0	0	26	0.0531	52	0.212	78	0.529
1	0.00008	27	0.0572	53	0.221	79	0.547
2	0.0003	28	0.0615	54	0.230	80	0.567
3	0.00071	29	0.0660	55	0.239	81	0.588
4	0.00126	30	0.0707	56	0.248	82	0.610
5	0.00196	31	0.0754	57	0.257	83	0.633
6	0.00283	32	0.0803	58	0.267	84	0.658
7	0.00385	33	0.0855	59	0.276	85	0.684
8	0.00502	34	0.0907	60	0.286	86	0.712
9	0.00636	35	0.0962	61	0.297	87	0.742
10	0.00785	36	0.102	62	0.307	88	0.774
11	0.0095	37	0.107	63	0.318	89	0.809
12	0.0113	38	0.113	64	0.329	90	0.848
13	0.0133	39	0.119	65	0.340	91	0.891
14	0.0154	40	0.126	66	0.352	92	0.938
15	0.0177	41	0.132	67	0.364	93	0.993
16	0.0201	42	0.138	68	0.377	94	1.055
17	0.0227	43	0.145	69	0.390	95	1.129
18	0.0254	44	0.152	70	0.403	96	1.219
19	0.0283	45	0.159	71	0.417	97	1.336
20	0.0314	46	0.166	72	0.431	98	1.500
21	0.0346	47	0.173	73	0.446	99	1.781
22	0.0380	48	0.181	74	0.461	100	∞
23	0.0415	49	0.188	75	0.477		
24	0.0452	50	0.197	76	0.493		
25	0.0491	51	0.204	77	0.511		

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