The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Civil Engineering

Study Programme	: Bachelor of Science Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: CVX7346 Ground Improvement Techniques**
Academic Year	: 2024/2025
Date	: 22nd February 2026
Time	: 13.30 - 16.30 hours
Duration	: **3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of Seven (7) questions in Four (4) pages including the design tables.
3. Answer any **Five (5)** questions only.
4. All questions carry equal marks.
5. Answer for each question should commence on a new page.
6. This is a Closed Book Test (CBT).
7. Relevant tables / codes (if necessary) are provided in the last page of the exam paper.
8. Answers should be in clear handwriting.
9. Do not use Red colour pens.

(01) Stone Columns are an effective ground improvement technique used to increase soil bearing capacity, reduce settlement, and enhance drainage in weak or compressible soils.

(i) Briefly describe the concept of "Unit Cell Idealization" in the Design of Stone Columns. **(04 marks)**

(ii) The application of stone columns becomes ***ineffective*** in improving soils under certain subsurface conditions. Briefly discuss three (03) such situations in which stone columns may not perform effectively. **(06 marks)**

(iii) Stone columns with a diameter of 0.75 m are to be installed in a square grid pattern to achieve a shear strength improvement factor of 1.5 for a particular site. The shear strengths of the stone columns and the surrounding soil to be improved are estimated to be 120 kPa and 20 kPa, respectively. Determine the required spacing of the stone columns. **(05 marks)**

(iv) List three (03) advantages and two (02) disadvantages of Stone Columns as a ground improvement technique. **(05 marks)**

(02) Ground anchors are a ground improvement technique that enhances the stability and load-bearing capacity of soil or rock masses by transferring tensile forces from structures into competent subsurface strata through prestressed steel tendons bonded within drilled and grouted boreholes.

(i) List the different types of ground anchors used in ground improvement works and briefly describe their appropriateness for application under various ground conditions. **(04 marks)**

(ii) Briefly describe the installation procedure of ground anchors, and illustrate with a neat diagram showing the main components of a typical ground anchor. **(06 marks)**

(iii) A ground anchor system is to be designed for a shoring excavation to a depth of 12 m. The geotechnical properties of the retained soils and the parameters of the ground anchor system are provided in Table Q.2.

Table Q.2.

Parameter	**Value**
Properties of soil	
Soil Type	Granular
Unit weight of soil ( )	17.2 kN/m^3
Angle of internal friction (ø)	32^0
Groundwater Table	15.00m depth
Anchor Parameters	
Angle of inclination of the anchor	30^0 to the horizontal
Soldier Beam Interval	2.50m

With the given data, and assuming a vertical excavation face, and at-rest earth pressure conditions behind the wall, determine the design tie-back force to be resisted by each anchor. Assume that two anchors are installed at depths of 3.0 m and 9.0 m below the top of the retaining wall. [Clearly state any additional assumptions made in your analysis] **(06 marks)**

(iv) List eight (08) applications of ground anchors. **(04 marks)**

(03) Soil nailing is an effective ground improvement technique that enhances the stability of slopes and excavations by reinforcing in situ soil with closely spaced, passive steel bars grouted into predrilled holes, thereby increasing shear strength and reducing deformation through composite soil–nail interaction.

(i) Briefly describe the step-by-step construction sequence adopted in deep soil nailing, and support your explanation with suitable illustrations showing the main stages of the process. **(06 marks)**

(ii) Discuss the key considerations for (a) arrangement, (b) placement, (c) length, and (d) material selection of soil nails, with reference to varying ground conditions and specific engineering applications. **(08 marks)**

(iii) Provide a clearly labeled diagram of a soil nail, depicting a typical head plate arrangement and indicating both temporary and permanent facings. **(03 marks)**

(iv) List six (06) advantages of soil nailing compared to other lateral support mechanisms **(03 marks)**

(04) Grouting is an effective ground improvement technique that stabilizes weak soils by injecting cementitious or chemical materials into voids and fractures, thereby enhancing soil strength, increasing load-bearing capacity, reducing permeability, and controlling settlement.

(i) Explain six (06) different grouting techniques, accompanied by clear illustrations. **(08 marks)**

(ii) Propose the optimal grouting technique based on the intended purpose and the specific characteristics of the soil or rock. **(04 marks)**

(iii) Jet grouting can be effectively used to stabilize slopes by reinforcing the soil along potential failure surfaces, particularly in situations where instability is caused by embankment surcharge at the slope crest. Explain this statement with appropriate illustrations. **(04 marks)**

(iv) State the relationships used to estimate the cutoff wall thickness for single-row and double-row jet-grouted cutoff walls, with appropriate illustrations. **(04 marks)**

05) Compaction is a ground improvement technique that enhances the engineering properties of soil by mechanically increasing its dry density through the reduction of air voids, thereby improving shear strength, stiffness, and bearing capacity while decreasing compressibility and permeability.

(i) Identify the soil parameters that can be modified to achieve the required level of compaction. **(03 marks)**

(ii) Briefly describe the process of achieving the required level of compaction using the parameters identified in (05)(i), with appropriate illustrations. **(05 marks)**

(iii) Discuss the applications of the Modified Proctor Compaction Test and distinguish between the Standard and Modified Proctor Compaction Tests, with appropriate illustrations. **(05 marks)**

(iv) Propose four (04) compaction methods that are most appropriate based on the project type, site conditions, and soil type. **(04 marks)**

(v) Briefly describe how quality assurance of the compaction process is maintained. **(03 marks)**

(06) Preloading with vacuum consolidation improves soft soils by accelerating consolidation, increasing shear strength, and reducing settlements without excessive fill loading.

(i) Briefly explain how preloading and vacuum consolidation can be used to reduce settlement in a soft clay deposit subjected to applied loading, with the aid of graphical illustrations showing the relationship between void ratio and effective stress. **(06 marks)**

(ii) Illustrate, with appropriate diagrams, how vertical drains can be effectively used to accelerate the consolidation process in soft ground formations. **(06 marks)**

(iii) List four (04) advantages and four (04) disadvantages of preloading and vacuum consolidation. **(04 marks)**

(iv) Electro-osmosis is a commonly used ground improvement technique for accelerating soil consolidation; briefly outline the theoretical principles underlying its application in enhancing the consolidation process. **(04 marks)**

(07) Thermal stabilisation, biotreatment, and vegetation-based reinforcement improve problematic soils by enhancing strength and stability through physicochemical alteration, microbial bonding, and root reinforcement.

(i) Describe in detail on the following thermal stabilisation techneques with neat illustrations.
(a) Ground Heating. **(03 marks)**
(b) Ground Freezing. **(03 marks)**

(ii) Discuss how biological methods improve the engineering properties of soils. **(04 marks)**

(iii) What is meant by Microbiologically (or Microbially) Induced Calcite Precipitation (MICP). **(04 marks)**

(iv) List eight (08) effects of vegetation on erosion control and slope stability improvement. **(06 marks)**