Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Fundamentals of Geotechnical Engineering II (CEng2142)
Test 1 – Solution Set

Name	
ID No.	
Signature	
Section	
Exam Date:	18.04.2019

Instruction:

1) This examination is closed book and constitutes 15% of your final grade.
2) The time allowed for this exam is 1hour.
3) Please read the questions carefully and make sure you understand the facts before you begin answering. Write as legibly and concisely as possible.
4) Use the provided space properly to present you answer.

Question #	Weight [marks]	Score [marks]
1	10	
2	70	
3	20	

Examination paper set checked by: Henok Fikre (Dr.-Ing.)

Signature:

QUESTION 1: On Genesis of Soils & Soil Mechanics [10%]

1.1 Mention and briefly explain at least 5 peculiar features of soil as an engineering material. (5 marks)

Particulate material [1 mark]	made up of countless particles of a variety of shapes and sizes with little or no bonding between them.
Multi-phase material [1 mark]	As an immediate outcome of its particulate nature, soil can exist in solid, liquid, gas phases simultaneously.
Erratic material [1 mark]	Variability – spatial and depth wise
Water affected [1 mark]	water within pores of the soil contributes to the stress transfer in the soil; may also be flowing with respect to the granular particles, which creates friction stresses between the fluid and the solid material.
Stress dependent stiffness [1 mark]	not governed by Hooke's Law and the stiffness and strength of a given soil is not fixed but depends on the confining pressure.
Shear strength [1 mark]	critical than compressive strength and the virtually zero tensile strength.
Dilatancy [1 mark]	volume change as a result of shear deformation
Creep [1 mark]	secular deformation continuing through long ages practically forever
Memory capacity for stress history [1 mark]	Past maximum vertical stress experienced by the soil is stored in the mineral grain.

1.2 Karl von Terzaghi once wrote the following statement about civil engineering.

"*The development of every aspect of civil engineering passes through three stages: the EMPIRICAL, wherein precedent is the dominant influence; the SCIENTIFIC, wherein great strides are made and overconfidence in the power of science occasionally leads to failures; and the MATURE, wherein precedent and science combine into a judgment that permits the highest expression of the engineer's calling.*"

Write what you understand after reading the excerpt. (5 marks)

> *Terzaghi wanted to highlight the importance of balancing two approaches in problem solving in civil engineering. Although at its core, civil engineering uses principles of physics for analysis and design purposes, the role of empiricism is also significant. For every recommendation that bases itself using derived theoretical equations, one can find an intuition-driven, experiment-based empirical equation that is just as important. The role of empiricism is even more pronounced in geotechnical engineering, where one has relations such relations as connecting settlement with bearing-capacity, internal friction with bearing capacity, net imposed load with consolidation, etc. which are obtained from a series of systematic experimentations.* [5 marks]

QUESTION 2: On Simple Soil Properties [70%]

2.1 An embankment, with a total fill of 20,000 m^3, expected to be compacted up to a bulk density of 20kN/m^3 and a water content of 22% is about to be constructed. In order to carry out the construction work, three borrow quarries (with site conditions as presented in the following table) were identified based on their engineering quality. If you are in charge of the construction works which one would you choose based on economic advantage? (20 marks)

Hint: Use dry unit weight for final economic comparisons.

	Borrow site A	Borrow Site B	Borrow Site C
Simple soil properties	$\gamma_{d_{max}} = 20$ kN/m^3 $\gamma_{d_{min}} = 16$ kN/m^3 $D_r = 0.7$	$\gamma_{bulk} = 19$ kN/m^3 LI=-0.5 LL=50% PL=30%	$G_s = 2.65$ $e = 0.7$
Cost of production and hauling	50ETB/m^3	45 ETB/m^3	55ETB/m^3

In order to find the required amount of soil from each borrow site, the dry density from each sites shall be calculated.

Site A

Using the relative density equation, i.e

$$D_r = \frac{(\gamma_d)_{max}}{\gamma_d}\left[\frac{(\gamma_d - (\gamma_d)_{min})}{((\gamma_d)_{max} - (\gamma_d)_{min})}\right]$$

[4 marks]

$$\gamma_d = 18.6\ kN/m^3$$

[1 marks]

Site B

$$\boldsymbol{\gamma_d = \frac{\gamma_{bulk}}{1+\omega}}$$

[2 marks]

And to find the water content use the Liquidity index equation

$$LI = \frac{\omega - PL}{PI}$$

[2 marks]

So the water content is $\omega = 20\,\%$ [1 mark]
And the dry density is $\boldsymbol{\gamma_d} = 15.833\ kN/m^3$ [1 mark]

Site C

$$\boldsymbol{\gamma_d} = \frac{G_s\,\boldsymbol{\gamma_w}}{\mathbf{1}+\boldsymbol{e}}$$

[2 marks]

The dry density is $\gamma_d = 15.588\ kN/m^3$ [1 mark]

At the construction site

$$\boldsymbol{\gamma_d} = \frac{\boldsymbol{\gamma_{bulk}}}{\mathbf{1}+\boldsymbol{\omega}}$$

The dry density is $\gamma_d = 16.399\ kN/m^3$ [1 mark]

Id no	**Description**	**A** [3 marks]	**B** [3 marks]	**C** [3 marks]	**Construction site**
1	Dry density(kN/m^3)	18.6	15.833	15.588	16.399
2	Required volume (Per /m^3 of the construction site)	0.88167	1.03575	1.05203	
3	Total volume required	17,633.33	20,714.96	21,040.54	
4	Cost of production and hauling per m^3	50	45	55	
5	Total cost	881,666.67	932,173.31	1,157,229.92	

Hence Borrow Site A is the most Economical site [1 mark]

2.2 A soil sample from an **old landfill** site was taken to the laboratory for testing. The results of sieve analysis are presented as follows. (18% + 7% + 5% = 30 marks)

Sieve opening (mm.)	Weight of sieve (gm.)	Weight of sieve and soil, after shaking (gm.)	Percentage retained on each sieve [6 marks]	Cumulative percentage retained [6 marks]	% Finer [6 marks]
9	244	244	0	0	100.0
4.75	246	248	0.4	0.4	99.6
2.36	250	266	3.2	3.6	96.4
2	248	255	1.4	5	95.0
1.18	248	255	1.4	6.4	93.6
0.6	248	272	4.8	11.2	88.8
0.425	249	269	4	15.2	84.8
0.3	246	248	0.4	15.6	84.4
0.15	251	301	10	25.6	74.4
0.075	250	370	24	49.6	50.4
PAN	300	552	50.4	100	0.0

Carry out the necessary calculations and plot the grain size distribution on semi-log paper provided in the next page. Also determine uniformity coefficient and coefficient of gradation.

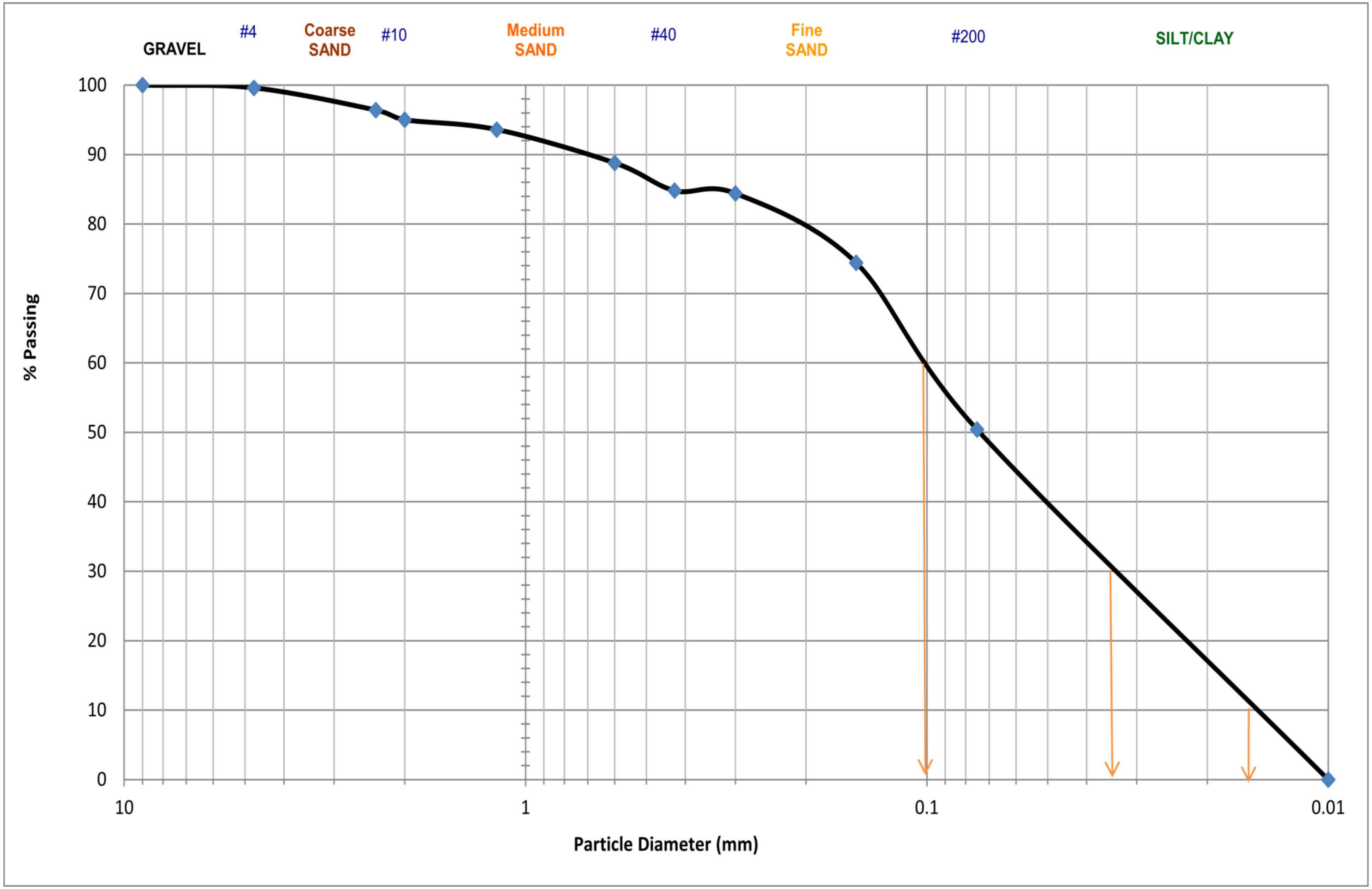
$D_{10} = 0.016$ [1 mark]

$D_{30} = 0.035$ [1 mark]

$D_{60} = 0.1$ [1 mark]

$C_u = \frac{D_{60}}{D_{10}} = 6.25$ [1 mark]

$C_c = \frac{{D_{30}}^2}{D_{10} \times D_{60}} = 0.76$ [1 mark]



GRAVEL
#4
Coarse SAND
#10
Medium SAND
#40
Fine SAND
#200
SILT/CLAY
100
90
80
70
60
50
40
30
20
10
0
% Passing
10
1
0.1
0.01
Particle Diameter (mm)

[7 marks]

2.3 On soil consistency (3% + 3% + 2% + 2% + 10% = 20 marks)

A) What is the rationale behind fixing 3mm as the diameter of the crumbling soil in plastic limit determination? Also how does one know this diameter achieved during the experiment? (3%)

-It has been determined that at 3 mm diameter, the moisture content distribution in the soil sample is uniform. [2 marks]

-By comparing the rolled sampled with that of a standard caliper. [1 mark]

B) What is the potential problem if we use less than 6g sample of soil that crumbled at 3mm diameter in plastic limit determination? And how do you make sure to achieve such mass requirement? (3%)

-The sample collectted will not be an accurate representative of the soil. [2 marks]

-Perform the test with an ample specimen in the first place. [1 mark]

D) How does one practically make sure to use saturated soil for linear shrinkage test? (2%)

-By taking a specimen with a moisture content very near to the liquid limit i.e. collect the sample from the Casagrande cup if the number of blows needed to close the gap is in the vicinity of 25 in that specific trial. [2 marks]

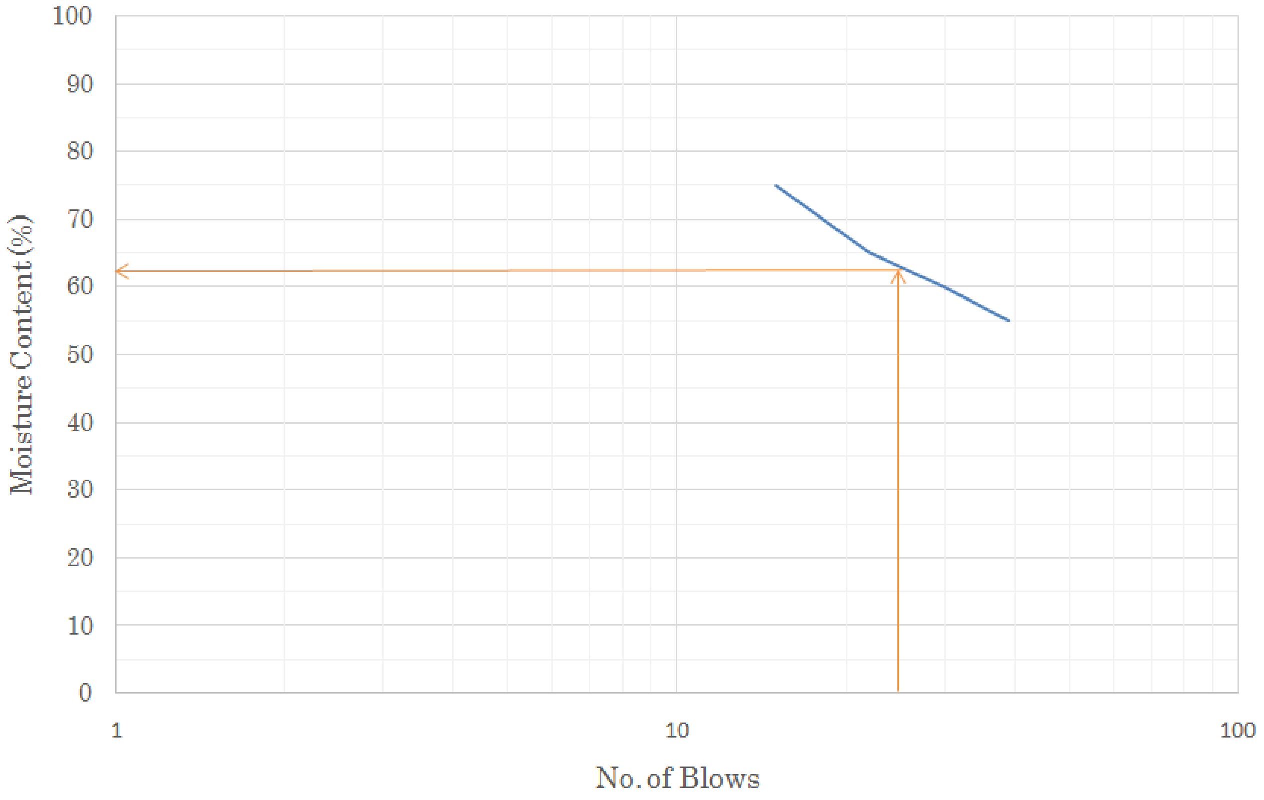
E) What is the major reason mercury is used in volumetric shrinkage determination experiment? (2%)

-Elemental or metallic mercury is a shiny, silver-white metal and is liquid at room temperature. It is used in older thermometers, fluorescent light bulbs and some electrical switches. When dropped, elemental mercury breaks into smaller droplets which can go through small cracks. This specific behavior along with its non-reactive nature towards soil makes it ideal to determine the irregular volume created in the container upon air & oven drying. [2 marks]

F) The following data is part of the investigation carried out on the soil referred to in question 2.2.

Determine the liquid limit and plastic limit. (10%)

Liquid Limit			**Plastic Limit**	
Trial	No. of blows	Moisture Content (%)	Trial	Moisture Content (%)
1	15	75	1	28
2	22	65		
3	30	60	2	26
4	39	55		



[4 marks]

LL= 62.5 % [2 marks]

PL = (28+26)/2 = 27% [2 marks]

QUESTION 3: On Soil Classification [20%]

3.1

A) What are the two go-to parameters that a geotechnical engineer considers for classifying soils? Which of these two parameters is more relevant for

a. fine-grained soils, and
b. coarse-grained soils? Explain the why this is so. (6 marks)

Parameters	More relevant for	Reason
Soil consistency [2 marks]	*fine-grained soils* [2 marks]	*particles have high surface-area to volume ratio, the interaction between soil grains and water is considerable. Consequently, their behavior is significantly affected by the amount of available water within the voids.* [2 marks]
Soil gradation [2 marks]	*coarse-grained soils* [2 marks]	*Consistency is less relevant to coarse-grained soils due to small or little interaction with the particles. Major properties are affected by the size and proportion of particle grains.* [2 marks]

B) Classify the soil referred to in question 2.2 using Unified Soil Classification System. [Necessary charts are provided on last page] (14 marks)

% Coarse = 40.6 % < 50.4% = % Fine → FINE GRAINED SOIL [2 marks]

PI= PI - PL = = 62.5 - 27= 35.5% [2 marks]

LL=62.5%>50% → Soil is of high plasticity [2 marks]

Soil falls above the 'A' line → CH [2 marks]

But soil most probably has organic content as it is taken from a landfill site [4 marks]

- Final verdict, OH. [2 marks]

The CH outcome could be attributed to several factors one of which is error in Atterberg limits determination.

It is circumstances like this which highlight the need for *combining precedent and science into a judgment that permits the highest expression of the engineer's calling.*

Table 3.2 Unified Soil Classification System

Major divisions			Group symbols		Typical names		Laboratory classification criteria	
Coarse-grained soils (More than half of materials is larger than No.200 sieve size)	Gravels (More than half of coarse fraction is larger than No.4 sieve size)	Clean gravels (Little or no fines)	GW		Well-graded gravels, gravel-sand mixture, little or no fines.	Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows, Less than 5 percent ………… GW,GP,SW,SP More than 12 percent ………… GM,GC,SM,SC 5 to 12 percent ………… Borderline case requiring dual symbols **	Cu= $\frac{D60}{D10}$ greater than 4, Cc= $\frac{D30^2}{D10 \text{ X } D60}$ between 1and 3	
			GP		Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW	
		Gravels with fines (Appreciable amount of fines)	GM*	d	Silty gravels, gravel-sand silt mixtures		Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are boarder cases requiring use of dual symbols
				u				
			GC		Clayey gravels, gravel-sand-clay mixtures		Atterberg limits above "A" line with PI greater than 7	
	Sands (More than half of coarse fraction is smaller than No.4 sieve size)	Clean sands (Little or no fines)	SW		Well-graded sands, gravelly sands, little or no fines		Cu= $\frac{D60}{D10}$ greater than 6:,Cc= $\frac{(D_{30})^2}{D_{10} \text{ X } D_{60}}$ between 1 and 3	
			SP		Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM*	d	Silty sands, sand-silt mixtures		Atterberg limits below "A" line or PI less than 4	Limits plotting in hatched zone with PI between 4 and 7 are borderline cases requiring use of dual symbols
				u				
			SC		Clayey sands, sand-clay mixtures		Atterberg limits above "A" line or PI greater than 7	

Fine-grained soils (More than half of materials is smaller than No.200 sieve)	Silts and clays (Liquid limit less than 50)	ML	Inorganic silts and very fine sands, rock flour, silts or layer fine sands, or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
	Silts and clays (Liquid limit greater than 50)	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
	Highly organic soils	Pt	Peat and other highly organic soils