Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Fundamentals of Geotechnical Engineering II (CEng2142) Fx Examination

Name	
ID No.	
Signature	
Section	
Exam Date:	07.10.2019

Instruction:

1) This examination is closed book and constitutes 100% of your final grade.
2) The time allowed for this exam is 3 hours.
3) Please read the questions carefully and make sure you understand the facts before you begin answering. Write legibly and be concise as possible.
4) Use the provided space properly to present you answer.

Question #	**Weight** [marks]	**Score** [marks]
1	15	
2	25	
3	10	
4	20	
5	20	
6	10	

QUESTION 1: On Genesis of Soils & Soil Mechanics

1.1 What engineering geology features can you look for when you visit a site for a geotechnical engineering project?

Geologic structures (faults, synclines, anticlines) [1 mark]
Floodplains and river deposits (alluviums, meander migration) [1 mark]
Glacial deposits (glacial till and boulders left behind after glacier melting) [1 mark]
Arid landforms (dunes, collapsible soils, shrink-swell soils) [1 mark]
Coastal process (shoreline erosion, sea level changes) [1 mark]

1.2 How can geologic maps be useful to the geotechnical engineer?

Geologic maps help geotechnical engineers to evaluate the soil and rock in an area and to find specific geologic features such as faults. [2 marks]

1.3 Mention peculiar features of soil as an engineering material.

Particulate material [1 mark]	**Multi-phase material** [1 mark]
Water affected [1 mark]	**Dilatancy** [1 mark]
Stress-dependent stiffness [1 mark]	**Memory capacity** [1 mark]
Variability / Erratic nature [1 mark]	**Creep** [1 mark]

QUESTION 2: On Simple Soil Properties & Soil Characterization

2.1 A sample of clay is brought back from the field, extruded from the Shelby tube, and trimmed to the following dimensions: height = 150 mm, diameter = 75 mm.
It weighs 13.2 N. The water content has been determined to be 25%.
Find the following parameters for the clay:

a. Natural unit weight
b. Degree of saturation
c. Porosity
d. Void ratio
e. Dry unit weight
f. Saturated unit weight

Volume of the sample: $V_T = \frac{\pi D^2}{4} * h = \frac{\pi * 0.075^2}{4} * 0.15 = 6.62 * 10^{-4} m^3$ [1 mark]

The weight of the solid: $W_s = \frac{W_t}{1+\omega} = \frac{13.2*10^{-3}}{1+0.25} = 10.6 * 10^{-3}\ kN$ [1 mark]

The weight of the water:

$$W_w = W_T - W_s = 13.2 * 10^{-3} - 10.6 * 10^{-3} = 2.64 * 10^{-3}\ kN$$ [1 mark]

Assuming that the unit weight of the solids is $\gamma_s = 27\ kN/m^3$, the volume of the soild:

$$V_s = \frac{W_s}{\gamma_s} = \frac{10.6*10^{-3}}{27} = 3.91 * 10^{-4}\ m^3$$ [1 mark]

The volume of water: $V_w = \frac{W_w}{\gamma_w} = \frac{2.64*10^{-3}}{9.81} = 2.69 * 10^{-4}\ m^3$ [1 mark]

The volume of void:

$$V_V = V_T - V_s = (6.62 - 3.91) * 10^{-4} = 2.71 * 10^{-4}\ m^3$$ [1 mark]

a. Natural unit weight: $\gamma_T = \frac{W_T}{V_T} = \frac{13.2*10^{-3}}{6.62*10^{-4}} = 19.92\ kN/m^3$ [2 marks]

b. Degree of saturation: $S = \frac{V_w}{V_V} * 100\% = \frac{2.69*10^{-4}}{2.71*10^{-4}} * 100\% = 99.3\%$ [2 marks]

c. Porosity: $n = \frac{V_V}{V_T} * 100\% = \frac{2.71*10^{-4}}{6.62*10^{-4}} * 100\% = 40.9\%$ [2 marks]

d. Void ratio: $e = \frac{V_V}{V_s} = \frac{2.71*10^{-4}}{3.91*10^{-4}} = 0.694$ [2 marks]

e. Dry unit weight: $\gamma_d = \frac{\gamma_T}{1+\omega} = \frac{19.92}{1+0.25} = 15.94\ kN/m^3$ [2 marks]

f. Saturated unit weight:

$$\gamma_{sat} = \frac{W_s + (V_V * \gamma_w)}{V_T} = \frac{10.6*10^{-3} + (2.71*10^{-4}*9.81)}{6.62*10^{-4}} = 19.95\ kN/m^3$$ [2 marks]

2.2 The following data were recorded in a liquid limit test using the Casagrande apparatus.

Number of blows	Mass of can (g)	Mass of wet soil + can (g)	Mass of dry soil + can (g)
8	11.80	36.05	29.18
16	13.20	34.15	28.60
27	14.10	36.95	31.16
40	12.09	33.29	28.11

Determine the liquid limit of the soil.

Calculation →

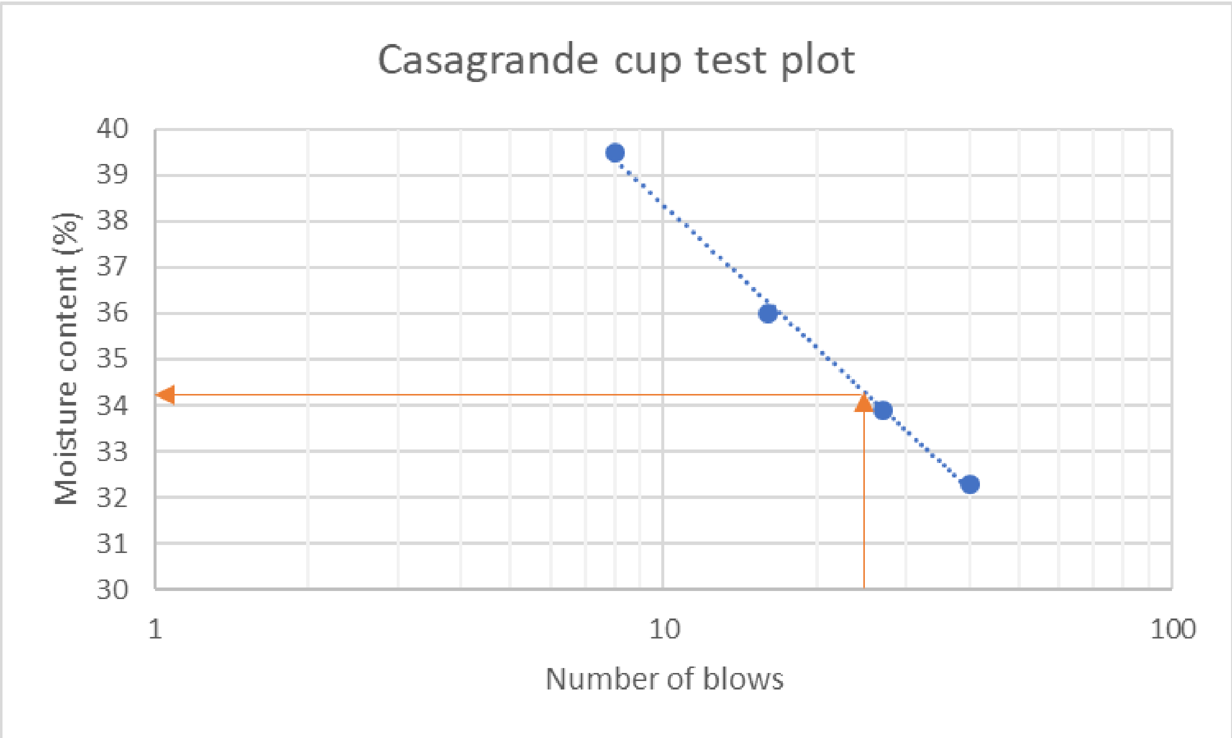
$$\omega = \frac{M_w}{M_s} * 100\% = \frac{(\text{Mass of wet soil } + \text{ can}) - (\text{Mass of dry soil } + \text{ can})}{(\text{Mass of dry soil } + \text{ can}) - (\text{Mass of can})} * 100\%$$

[1 mark]

Number of blows	Moisture content (%)
8	39.5
16	36
27	33.9
40	32.3

[4 marks]

Plot→



[1 mark]

Final answer →

LL=34.2%

[1 mark]

QUESTION 3: On Soil Classification & Field Identification

3.1 Upon retrieval of the soil aforementioned in question 2.2, the geotechnical engineer in charge has noted that the soil does not exhibit any signs of the presence of organic matter.

Mention at least two signs of the presence of organic matter? (4%)

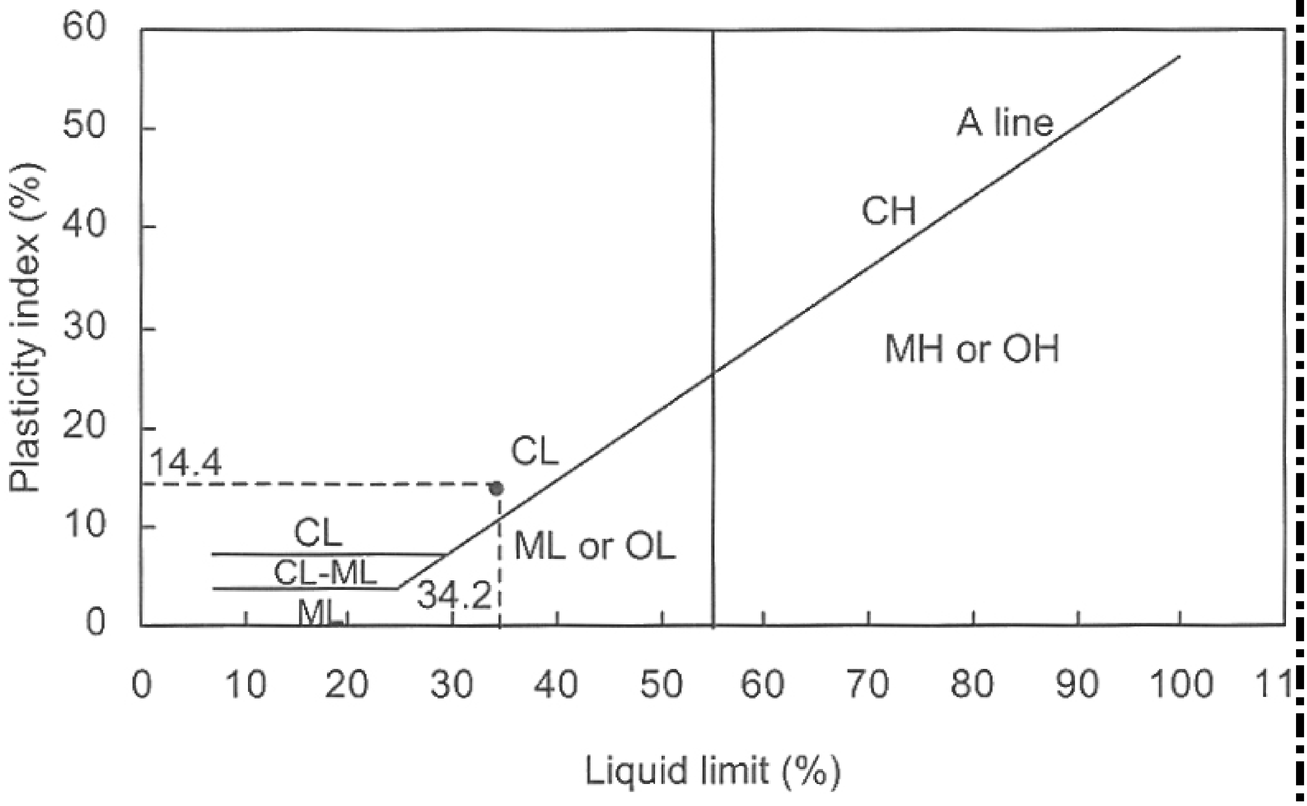
- The soil is not very dark [2 marks]
- The soil does not smell foul [2 marks]

3.2 Classify the soil in question 2.2 according to USCS assuming plastic limit PL=19.8%

Plasticity index (4%) →

PI= LL - PL = 34.2 - 19.8 = 14.4 [2 marks]

Plasticity chart (4%) →



[1 mark]

Final answer (3%) →

CL or OL [2 marks]

But no organic matter as reported. Therefore, CL. [1 mark]

QUESTION 4: On Stress in Soils

A wastewater treatment aeration tank of diameter 40m and gross weight 286.5 MN is to be constructed on one of the 40-60 Housing Project sites in Addis Ababa as shown below (left figure). To construct the tank, 6m of the top dense sand layer will be excavated, and the tank will be built as shown in below (right figure).

For the values provided in the figures:

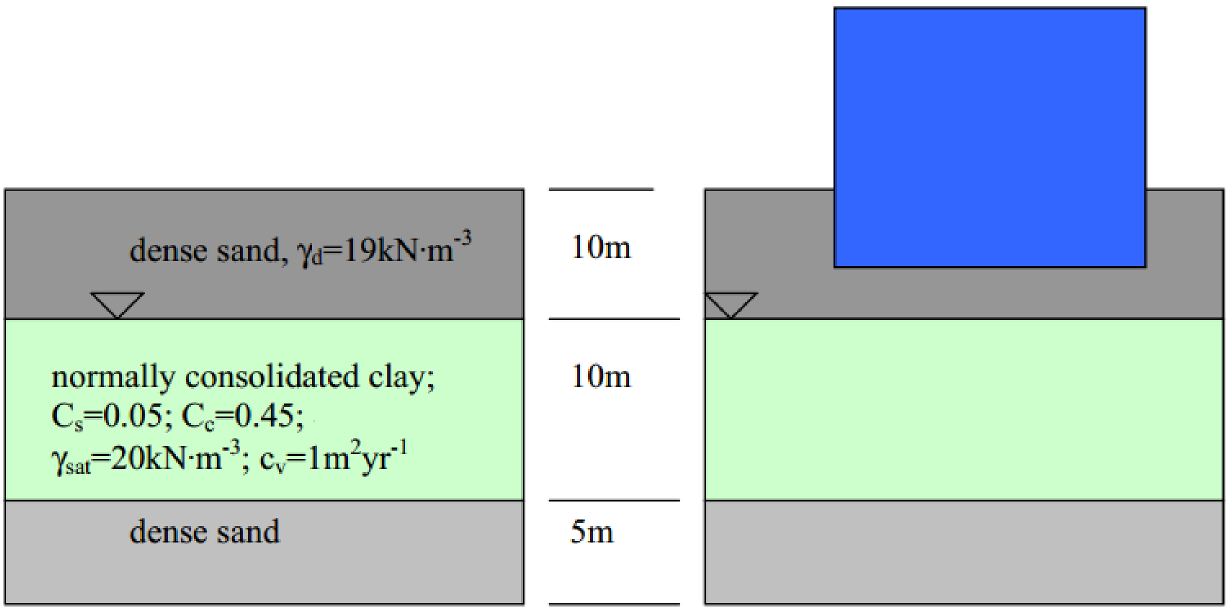
4.1 Compute the geostatic stresses at the middle of the silty-clay layer. Use $\boldsymbol{\gamma_w = 10\ kN/m^3}$

4.2 Compute the increase in vertical stress due to the construction of the tank at the middle of the silty-clay layer directly beneath the center of the tank.

4.3 If the nearest building imposes a total structural load of 900MN and is supported by 30X30m square mat foundation situated at a depth of 12m from the surface, at what minimum horizontal distance (edge clearance) should the tanker be constructed from the building to avoid stress overlap in the middle of the silty-clay layer? Use 3V:1H Method.

Note: The vertical stress increase directly beneath the center of a circular, uniformly loaded area is given by the following relation in which q is the magnitude of the uniform load; R is the radius of the circular area; and z is the depth of interest beneath the loaded area:

$$\Delta\sigma_v = q\left[1 - \frac{1}{\left[\left(\frac{R}{z}\right)^2 + 1\right]^{3/2}}\right]$$



Answer Q#4 here ↓

a) Geostatic stresses (9%)

Total stress: $\sigma = \gamma * z = 19 * 10 + 20 * 5 = 290\ kPa$ [3 marks]

Pore pressure: $u = \gamma_w * z_w = 10 * 5 = 50$ [3 marks]

Effective stress: $\sigma' = \sigma - u = 290 - 50 = 240\ kPa$ [3 marks]

b) Additional stress (6%)

$$q = \frac{W}{A} = \frac{286.5*10^3}{\pi*\left(\frac{40}{2}\right)^2} = 228\ kPa$$ [1 mark]

Net bearing stress just below the tank

$$q = 228 - 19 * 6 = 114\ kPa$$ [1 mark]

R=20m [1 mark]

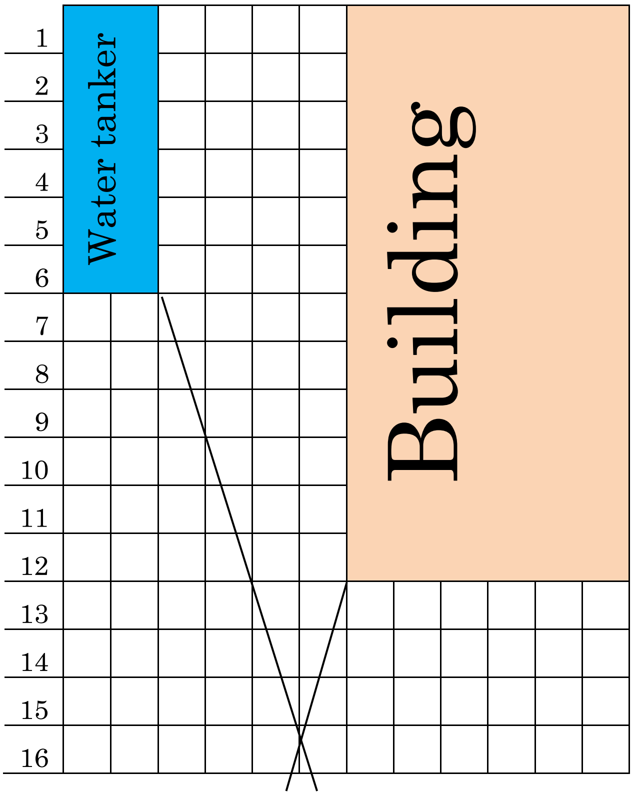
z= 4+5=9m [1 mark]

$$\Delta\sigma_v = q\left[1 - \frac{1}{\left[\left(\frac{R}{z}\right)^2 + 1\right]^{3/2}}\right] = 228\left[1 - \frac{1}{\left[\left(\frac{20}{9}\right)^2 + 1\right]^{3/2}}\right] = 106\ kPa$$

[2 marks]

C) Stress overlap (5%)

4m [3 marks]



[2 marks]

QUESTION 5: On Permeability & Seepage

4.1 The topmost layer is loose, clean sand, 1m thick. Its vertical permeability k_V can be estimated using Hazen's formula. The sieve analysis is showed that 10% of the materials pass through a sieve of aperture size 0.16mm. Its horizontal permeability k_H is known to be approximately 500% of the k_V. Below the sand stratum is a marine marl. 3 meters thick with $k_V = k_H = 10^{-6}\, m/sec$. What is the equivalent k_{Heq} for the upper 4 m of the soil mass?

Note: Hazen's empirical formula is given as $k_V = CD_{10}{}^2$ where C ranges from 0.8-1.5.

Sand:

H=1m [1 mark]

D_{10} = 0.16 mm [1 mark]

$k_H = 5 * k_V$ [1 mark]

$$k_{V1} = CD_{10}{}^2 = 1.5 * 0.16^2 = 0.0384\ cm/s \text{ [1 mark]}$$

$$k_{H1} = 5 * k_{V1} = 5 * 0.0384 = 0.192\ cm/s \text{ [1 mark]}$$

Marl:

H=3m [1 mark]

$k_V = k_H = 10^{-6}\, m/sec = 10^{-4}\, cm/sec$ [1 mark]

$$k_{Heq} = \frac{k_1 H_1 + k_2 H_2}{H_1 + H_2} = \frac{0.192 * 100 + 10^{-4} * 300}{100 + 300} = 0.0481 cm/s$$

[2 marks]

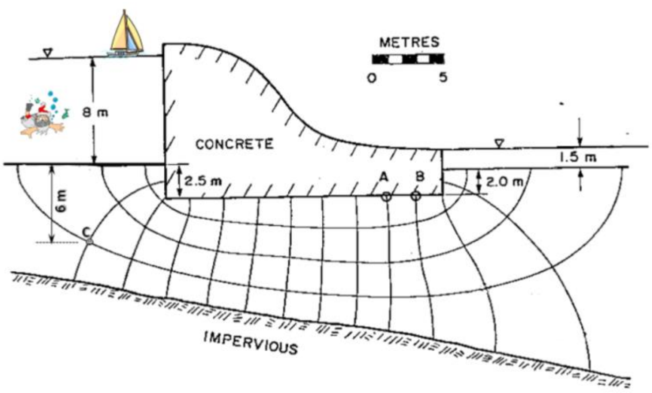
4.2 For the flow net shown below, the sand is isotropic having a permeability of $1\text{x}10^{-3}$ cm/sec, an average void ratio of 0.6 and Gs = 2.65. Determine the following:

a) The seepage loss in cubic meters per day per meter width of the dam perpendicular to the section shown.

b) The exit hydraulic gradient, the critical hydraulic gradient and the factor of safety against piping at the downstream toe of the dam.

c) How high would water rise in a standpipe situated at Point C?

d) What is the effective stress at Point C if sat=20 kN/m³? Use $\gamma_w = 10\ kN/m^3$



Answer 4.2 here ↓

a) $q = kh_L \frac{N_f}{N_d}$ [1 mark]

$k = 1 * 10^{-3}\, cm/sec$ [1 mark]

$h_L = 8 - 1.5 = 6.5m = 650\ cm$ [1 mark]

$N_f = 4$ [1 mark]

$N_d = 13$ [1 mark]

==> $q = 1 * 10^{-3} * 650 * \frac{4}{13} = 0.2\, cm^3/sec$ [1 mark]

b)

$i_{exit} = \frac{h_L/N_d}{L_{min}} = \frac{6.5/13}{2.0/2} = 0.5$ [1 mark]

$i_{crt} = \frac{G_s-1}{1+e} = \frac{2.65-1}{1+0.61} = 1.03$ [1 mark]

$F_{piping} = \frac{i_{crt}}{i_{exit}} = \frac{1.03}{0.5} = 2.06$ [1 mark]

c) Piezometric level for point C

$H_c = 8 - \frac{6.5}{13} = 7.5m$ [1 mark]

d) Effective stress = Total stress - Pore pressure

$$\sigma_v{}' = [8 * \gamma_w + 6 * \gamma_{sat}] - [(7.5 + 6) * \gamma_w]$$
$$= [8 * 10 + 6 * 20] - [(7.5 + 6) * 10$$
$$= 65\ kPa$$ [1 mark]

QUESTION 6: On Soil Compaction

6.1 The following results are obtained from a standard compaction test.

Mass of compacted soil (g)	1920.5	2051.5	2138.5	2147.0	2120.0	2081.5
Moisture content (%)	11.0	12.1	12.8	13.6	14.6	16.3

The specific gravity of the solids is 2.68, and the volume of the compaction mould is 1000 cm^3. Plot the compaction curve and obtain the maximum dry density and optimum moisture content.

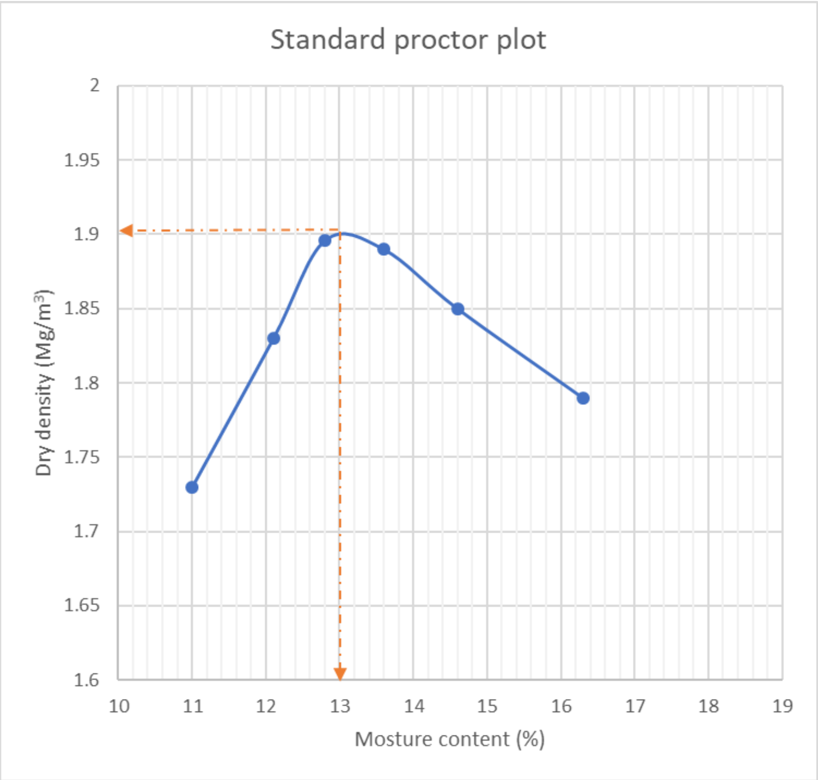
Calculation →

$\rho = \frac{M}{V}$ [1 mark] ; $\rho_d = \frac{\rho}{1+\omega}$ [1 mark]

ω (%)	$\rho_d (Mg/cm^3)$
11.0	1.730
12.1	1.830
12.8	1.896
13.6	1.890
14.6	1.850
16.3	1.760

[6 marks]

Plot→



[1 mark]

Final answer →

MDD: $\rho_{d,max} = 1.907\ Mg/cm^3$ [1 mark]

OMC: $\omega_{opt} = 13\%$ [1 mark]