OCW

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FUNDAMENTALS OF GEOTECHNICAL ENGINEERING

ASSIGNMENTS

LESSON 7
BEARING CAPACITY

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EXERCISE 1

A square footing 3 m long is located 1.5 m below the ground surface. This foundation rests on a 10-m stratum of sand, which lies over a gravel stratum.

The bulk unit weight of sand is 18.3 kN/m^3 and the water table is well below the depth of influence of the foundation.

The average number of blows in the SPT along the sand stratum was 15. Also, it has been estimated that the friction angle is 30º.

Taking into account that the allowable settlement is 25 mm, it has been determined the maximum load the soil will carry: 219 kN/m^2.

Determine the allowable bearing capacity of soil and interpret the result.

Answer: q_{allow} = **169.40 kN/m^2**.

EXERCISE 2

The figure below shows the soil profile at a construction site, where a foundation is to be constructed 2 m below the ground surface using square footings 3 m long (flexible type). These footings will carry a uniform load q = 150 kN/m^2.

During the geotechnical survey, several soil samples were taken. From these samples, after completing a series of tests in the laboratory, the following data were obtained:

Sand stratum

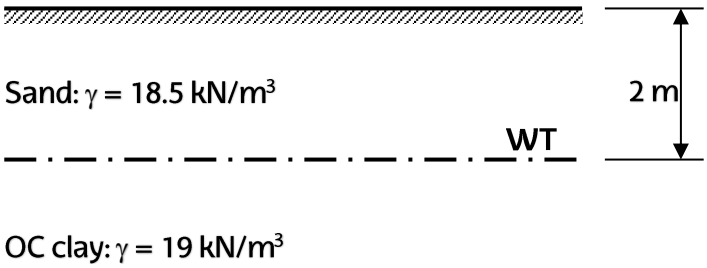
- Coefficient of earth pressure at rest, K_0: 0.5.

Clay stratum

- Coefficient of earth pressure at rest, K_0: 0.9.
- Undrained elastic modulus, E_u: 15 MPa.
- Undrained shear strength: 30 kPa.
- Effective cohesion: 10 kPa.
- Effective friction angle: 19º.

Determine:

1. Mohr circles of total and effective stresses at the pre-construction phase, at a point located at 4 m depth.
2. Vertical stress at a point located 2 m below the centre of the footing, at the post-construction phase.
3. Immediate settlement of the soil under the foundation. Explain the results obtained.
4. Allowable bearing capacity of soil. Interpret the result.



Answers: 2) σ_{vfinal} = 136.92 kN/m^2; 3) s_i = 25.20 mm; 4) q_{allow} = 61.68 kN/m^2.

EXERCISE 3

At a construction site where sands are predominant, a mat square foundation 18 m long is to be constructed on the ground surface. This foundation will carry a uniform load q = 75 kN/m^2. The water table is located at a depth of 5 m.

1. Determine whether the bearing capacity of soil is enough to support the applied load.
2. Verify the bearing capacity of the soil if foundation is changed to square footings 3 m long that will carry a uniform load of 150 kN/m^2.
3. Explain the results obtained.

Additional data:

γ= 18.5 kN/m^3, γ_{sat} = 20 kN/m^3, ϕ = 32º

Answers: 1) q_{allow} = 545.74 kN/m^2; 2) q_{allow} = 134.62 kN/m^2.

EXERCISE 4

At a planned construction site, which lies on a thick deposit of sand, a foundation is to be constructed 2 m below the ground surface using rectangular footings 3 m by 3.5 m. These footings will carry a uniform load q = 185 kN/m^2.

During the geotechnical survey, the water table was not found. Also, several soil samples were taken and, after completing a series of tests, the following data were obtained:

- Bulk unit weight: 18 kN/m^3.
- Coefficient of earth pressure at rest, K_0: 0.5.
- Average number of blows in SPT: 15.
- Friction angle: 31º.

Taking into account that the allowable settlement is 25 mm, determine:

1. Mohr circles of total and effective stresses at the pre-construction phase, at a point located at 4 m depth.
2. Vertical stress at a point located 2 m below the centre of the footing, at the post-construction phase.
3. Total settlement of the soil under the foundation. Explained the results obtained.
4. Allowable bearing capacity of soil. Interpret the result.

Answers: 2) σ_{Vfinal} = 161.4 kN/m^2; 3) s = 21.32 mm; 4) q_{allow} = 177.14 kN/m^2.

EXERCISE 5

The figure below shows the soil profile at a construction site, where a foundation is to be constructed 1.5 m below the ground surface using rectangular footings 3 m by 3.5 m (flexible type). These footings will carry a uniform load q = 165 kN/m^2.

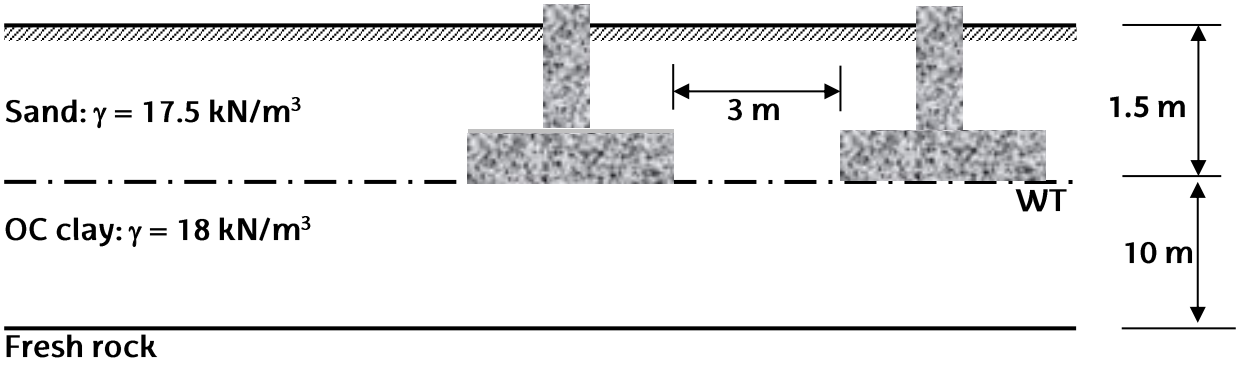
During the geotechnical survey, several soil samples were taken and, after completing a series of tests, the following data were obtained:

Clay stratum

- Undrained elastic modulus, E_u: 14 MPa.
- Undrained shear strength: 25 kPa.
- Effective cohesion: 8 kPa.
- Effective friction angle: 18º.

Taking into account that the allowable settlement is 25 mm, determine:

1. Vertical stress at a point located 1 m beneath the centre of the left footing, taking into account the influence of both footings, at the post-construction phase.
2. Immediate settlement of the soil under one foundation. Explained the results obtained.
3. Allowable bearing capacity of soil. Interpret the result.



Answers: 1) σ_{Vfinal} = 167.19 kN/m^2; 2) s_i = 24.9 mm; 3) q_{allow} = 50.11 kN/m^2.

EXERCISE 6

At a planned construction site, which lies on a thick deposit of normally consolidated clay, a foundation is to be constructed on the ground surface using square footings 15 m long. These footings will carry a vertical force of 20.000 kN. The water table is also on the ground surface.

During the geotechnical survey, several soil samples were taken and, after completing a series of tests, the following data were obtained:

- Bulk unit weight: 18 kN/m^3.
- Undrained shear strength, c_U: 60 kPa.
- Effective friction angle: 20º.

1. Verify whether that soil will fail. Also, indicate what the most unfavourable situation is: in a short-term or in a long-term.

Due to the result obtained, it is decided to locate the foundation at a depth of 1 m. In this new situation

2. Verify whether that soil will fail and explain the result obtained.

Answers: Failure occurs in both cases.

EXERCISE 7

A wall foundation is carrying the following internal forces: V = 100 kN, H = 25 kN and M = 8 m·kN (these internal forces are applied on the centre of gravity of the foundation base).

This soil is constituted by gravel particles; its unit weight is 19 kN/m^3 and the friction angle is 34º. The water table was not found.

The foundation is located at a depth of 1 m and its dimensions are: B = 1.5 m, L = 10 m. If the maximum gross pressure transmitted to the soil is 88 kN/m^2, verify whether the soil will fail.

Answer: q_{allow} = 162.00 kN/m^2. No failure occurs.

EXERCISE 8

A material coming from an excavation has been accumulated on a construction site that lies on a thick deposit of sand. This material takes up a rectangular area 10 m by 50 m and its height reaches 3 m. Due to these conditions, it has been estimated that the gross pressure applied on the ground surface is $q = 66\ kN/m^2$.

The following information about the soil is known:

- Water table is on the ground surface.
- Bulk unit weight = $18\ kN/m^3$.
- Friction angle = 32º.
- Average number of blows in SPT = 16.

Due to constructive requirements, it is necessary to increase the height of the material. It has been estimated that the increment of the gross pressure on the ground surface per meter of increased height will be $\Delta q = 22\ kN/m^2$.

Taking into account, solely, the bearing capacity of the natural soil, determine the maximum height that the accumulated material can reach. The final result should be obtained in meters, without decimals.

Answer: H_{max} = 12 m.

EXERCISE 9

At a planned construction site, which lies on a thick (30 m) deposit of overconsolidated clay, a foundation is to be constructed 3 m below the ground surface using a mat foundation (flexible type) 25 m by 50 m. These foundation will carry a vertical uniform load q = 116.2 kN/m^2. The water table has been found at 3 m depth.

During the geotechnical survey, several samples were taken and, after completing a series of tests, the following data were obtained:

a) Test to determine the density and unit weight of a soil.

Test result: bulk unit weight: 17.3 kN/m^3

b) Unconfined compression test.

Test result: unconfined compressive strength = 54.5 kPa.

c) CU triaxial compression test.

Test result: cohesion = 6.5 kPa

friction angle = 18º

Also, the undrained elastic modulus has been estimated to be 4.3 MN/m^2.

In addition, from a soil sample located above the water table, the bulk unit weight was obtained: 16.9 kN/m^3.

Finally, it has been found that the rock mass below the clay stratum is slightly weathered. Determine:

1. Total settlement of the soil under the foundation. Explain the results obtained.
2. Allowable bearing capacity of soil in a short-term and in a long-term. Also, verify whether that soil will fail. If it would fail, indicate whether it will be a short-term, medium-term or long-term failure.

Answers:

1) s_i = 314.16 mm; 2) q_{allow}(ST) = 51.36 kN/m^2; q_{allow}(LT) = 179.96 kN/m^2. ST failure.

EXERCISE 10

At a construction site, which lies on a thick deposit of sand, a building is to be constructed. The foundation of this building will be square footings 3 m long located at a depth of 1.5 m. These footings will carry a vertical uniform load of 165 kN/m^2.

During the geotechnical survey, the water table was not found. Also, several soil samples were taken and, after completing a series of tests, the following data were obtained:

a) Test to determine the density and unit weight of a soil.

Test result: bulk unit weight = 17.2 kN/m^3

b) Standard Penetration Test (SPT). Number of blows = 12

Also, due to constructive requirements, the allowable settlement has been set to 25 mm. Determine:

1. Total vertical stress at a point located 1 m below the geometrical centre of one footing, at the post-construction phase.
2. Total settlement of the soil under one foundation. Explain the results obtained.
3. Allowable bearing capacity of soil using both Terzaghi's expression as that based on SPT. Also, verify whether that soil will fail.

Answers:

1) σ_V = 162.71 kN/m^2; 2) si = 25.22 mm.

3) q_{allow}(Terzaghi) = 405.24 kN/m^2; q_{allow}(SPT) = 135.52 kN/m^2. Failure.

EXERCISE 11

An earth dam is to be constructed on a thick (15m) deposit of saturated clay which lies on a fresh rock. Due to the geographical location of the construction site, it has been assumed that this clay is a normally consolidated clay. Some of the most important properties of this soil have been determined by using the following laboratory tests:

a) Test to determine the density and unit weight of a soil.

Test result: bulk unit weight: 17.5 kN/m^3.

b) Unconfined compression test.

Test result: unconfined compressive strength: 75.2 kPa.

No more tests have been performed, so the remaining properties have been estimated from the bibliography. Thus, the friction angle has been taken from the TBC.Foundations. In this case, the selected value has been the minimum value assigned to clayey soils: 16º. Also, the undrained elastic modulus has been taken 5 MN/m^2.

In order to construct the earth dam, two projects are possible. In the first one, the earth dam will transmit to the soil a uniform load q_1 = 60 kN/m^2 through a rectangular area 25 m by 300 m. In the second project, the pressure will be q_2 = 50 kN/m^2 through another rectangular area 30 m by 350 m. These loads will be applied on the ground surface. In addition, this second project will cost a 20% more than the first project.

Using these data, select the most adequate project, taking into account, exclusively, the bearing capacity of the soil and the economic costs.

With the selected project, calculate the total settlement of the soils under the geometrical centre of the earth dam. Explain the result obtained.

Answers: 1) Project 2. 2) s_i = 45 mm.