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FUNDAMENTALS OF GEOTECHNICAL ENGINEERING

ASSIGNMENTS

LESSON 3
SOIL AND ROCK CLASSIFICATION

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EXERCISE 1

An undisturbed soil sample has been used to perform a series of tests. The mass of the soil sample was 2117.0 g, and after oven drying, its mass was reduced to 1837.7 g. Then, a particle-size distribution analysis by sieving was performed (see table).

ASTM sieve	Opening (mm)	Retained (g)
3″	75	0
¾″	19.0	248.56
No. 4	4.75	311.58
No. 10	2.00	345.21
No. 40	0.425	524.14
No. 200	0.075	324.87
Pan		83.34

From these data:

1. Determine the initial water content of the soil sample.
2. Plot the particle-size distribution curve of the soil.
3. Calculate the coefficient of uniformity, C_U, and the coefficient of curvature, C_C.
4. Explain if the soil is uniform.

Answers: w = 15.2%; C_U = 23.90; C_C = 1.07; Non-uniform

EXERCISE 2

A soil sample from a test pit has been taken to the laboratory to perform different tests. Its initial mass was found to be 2028.0 g.

Firstly, the soil sample was oven dried and the water content was obtained as w = 18.4%. Using this information:

1. Calculate the mass of the dried soil sample.

Secondly, a particle-size distribution analysis by sieving was performed and the results are shown in the table.

ASTM sieve	Opening (mm)	Retained (g)
¾"	19.0	70.25
No. 4	4.75	82.68
No. 10	2.00	733.4
No. 20	0.850	421.48
No. 40	0.425	189.46
No. 200	0.075	139.13
Pan		76.40

From these data:

2. Plot the particle-size distribution curve of the soil.
3. Determine the effective size.
4. Calculate the coefficient of curvature and the coefficient of uniformity.
5. Explain if the soil is uniform.

<u>Answers</u>: M_S = 1712.8 g; D_{10} = 0.245 mm; C_U = 10.35; C_C = 1.81; Non-uniform

EXERCISE 3

The water content of a certain fine-grained soil sample is w = 10.3%.

In addition, a plastic limit test was performed on a mass of 8.67 g of this soil. After oven drying, its mass was reduced to 7.94 g.

Finally, using the Casagrande cup device to perform the liquid limit test, the following data were obtained:

No of blows	Wet mass (g)	Dry mass (g)
27	12.94	10.11
23	13.39	10.38
16	13.65	10.49

From these data:

1. Calculate the plastic limit, w_P.
2. Calculate the liquid limit, w_L.
3. Calculate the plasticity index, I_P.
4. Determine the liquidity index and the consistency index. From the last one, indicate the consistency of the soil.
5. Using the Plasticity Chart, find the soil symbol.

Answers: w_P = 9.2 %; w_L = 28.5 %; I_P = 19.3; I_L = 0.06; I_C = 0.94; OL or CL

EXERCISE 4

An undisturbed soil sample has been used to perform a series of tests. The mass of the soil sample was 2986.1 g, and after oven drying, its mass was reduced to 2178.1 g.

After the sieve analysis, 1764.0 g were collected in the pan, so that it was concluded that it was a fine-grained soil.

Then, a plastic limit test was performed on a mixture of dry soil and water up to a mass of 8.35 g. After oven drying, its mass was reduced to 6.25 g.

Later, using the Casagrande cup device, a liquid limit test was performed. In the first trial 26 blows were needed. A specimen of soil was extracted to determine the water content (see table), and then a new trial was done. In this case, 27 blows were needed. The water content was also obtained:

No of blows	Wet mass (g)	Dry mass (g)
26	14.84	10.35
27	14.65	10.18

Table. Data recorded from the liquid limit test.

From these data:

1. Determine the water content of the soil.
2. Calculate plastic and liquid limits.
3. Calculate the plasticity index, the liquidity index and the consistency index. From the last one, indicate the consistency of the soil.
4. Using the Plasticity Chart, find the soil symbol.

Answers:

w = 37.1 %; w_P = 33.6 %; w_L = 44.0 %; I_P = 10.4; I_L = 0.34; I_C = 0.66; OL or ML

EXERCISE 5

Classify the following soils according to the Unified Soil Classification System (USCS).

Soil	Passing #200	Passing #40	Passing #10	Passing #4	C_U	C_C	w_L^+	w_L^-	w_P
1	3 %	45 %	65 %	75 %	7.5	0.5	-	-	-
2	15 %	30 %	85 %	95 %	-	-	80	-	60
3	10 %	30 %	40 %	50 %	5	2	60	-	28
4	65 %	70 %	80 %	90 %	-	-	45	50	23
5	65 %	70 %	80 %	90 %	-	-	32	45	23
6	82 %	85 %	90 %	95 %	-	-	35	40	28
7	55 %	60 %	65 %	70 %	-	-	82	90	58
8	55 %	60 %	65 %	70 %	-	-	60	82	58

Answers:

Soil 1: SP, Poorly graded sand with gravel.

Soil 2: SM, Silty sand.

Soil 3: GW-GC, Well-graded gravel with clay and sand.

Soil 4: CL, Sandy lean clay.

Soil 5: OL, Sandy organic clay.

Soil 6: ML, Silt with sand.

Soil 7: MH, Gravelly elastic silt with sand.

Soil 8: OH, Gravelly organic silt with sand.

EXERCISE 6

An undisturbed soil sample has been used to perform a series of tests. The mass of the soil sample was 4628.6 g, and after oven drying, its mass was reduced to 3757.0 g.

Then, a particle-size distribution analysis by sieving was performed and the results are shown in table 1.

ASTM sieve	Opening (mm)	Retained (g)
1.5″	37.5	0
¾″	19.0	71.41
No. 4	4.75	161.52
No. 10	2.00	604.9
No. 40	0.425	368.19
No. 200	0.075	139.08
Pan		2411.9

Table 1. Data recorded from the sieve analysis.

After this analysis, it was concluded that the soil was fine-grained. So, it was necessary to determine the plastic limit, using the corresponding test, and was found to be w_P = 19.2 %.

Finally, using the Casagrande cup device to perform the liquid limit test, the following data were obtained:

No of blows	Wet mass (g)	Dry mass (g)
34	14.82	10.90
24	14.56	10.36

Table 2. Data recorded from the liquid limit test.

From these data:

1. Determine the water content of the soil sample.
2. Plot the particle-size distribution curve.
3. Calculate the liquid limit, w_L.
4. Calculate the plasticity index, the liquidity index and the consistency index. From the last one, indicate the consistency of the soil.
5. Classify the soil according to the Unified Soil Classification System (USCS).

Answers: w = 23.2 %; w_L = 38.5 %; I_P = 19.3; I_L = 0.21; I_C = 0.79; CL.

EXERCISE 7

An undisturbed soil sample has been used to perform a series of tests. The mass of the soil sample was 2317.2 g, and after oven drying, its mass was reduced to 1823.1 g.

Then, a particle-size distribution analysis by sieving was performed and the results are shown in table 1.

ASTM sieve	Opening (mm)	Retained (g)
¾"	19.0	225.13
No. 4	4.75	408.56
No. 10	2.00	335.45
No. 20	0.850	298.12
No. 40	0.425	215.87
No. 200	0.075	80.04
Pan		259.93

Table 1. Data recorded from the sieve analysis.

Due to the percentage passing through #200 sieve, it was necessary to determine the plastic limit and the liquid limit of this soil. A plastic limit test was performed on a mass of 9.24 g. After oven drying, its mass was reduced to 8.57 g.

Finally, using the Casagrande cup device to perform the liquid limit test, the following data were obtained:

No of blows	Wet mass (g)	Dry mass (g)
32	12.15	9.29
18	12.46	9.23

Table 2. Data recorded from the liquid limit test.

From these data:

1. Determine the water content of the soil.
2. Plot the particle-size distribution curve of the soil.
3. Calculate the liquid limit, w_L, and the plastic limit, w_P.
4. Calculate the plasticity index, the liquidity index and the consistency index. From the last one, indicate the consistency of the soil.
5. Classify the soil according to the Unified Soil Classification System (USCS).

Answers: w = 27.1 %; w_L = 32.7 %; w_P = 7.8 %; I_P = 24.9; I_L = 0.78; I_C = 0.22; SC.

EXERCISE 8

An undisturbed soil sample has been used to perform a series of tests. The mass of the soil sample was 2244.1 g, and after oven drying, its mass was reduced to 1941.3 g.

Then, a particle-size distribution analysis by sieving was performed and the results are shown in table 1.

ASTM sieve	Opening (mm)	Retained (g)
1.5"	37.5	0
¾"	19.0	107.01
No. 4	4.75	225.48
No. 10	2.00	511.69
No. 40	0.425	689.15
No. 200	0.075	230.56
Pan		177.41

Table 1. Data recorded from the sieve analysis.

Due to the percentage passing through #200 sieve, it was necessary to determine the plastic limit and the liquid limit of this soil. A plastic limit test was performed on a mass of 7.50 g. After oven drying, its mass was reduced to 6.75 g.

Finally, using the Casagrande cup device to perform the liquid limit test, the following data were obtained:

No of blows	Wet mass (g)	Dry mass (g)
33	14.11	10.84
26	14.88	11.18
20	12.04	8.86

Table 2. Data recorded from the liquid limit test.

From these data:

1. Determine the water content of the soil.
2. Plot the particle-size distribution curve and estimate C_U and C_C.
3. Calculate the liquid limit, w_L, and the plastic limit, w_P.
4. Calculate the plasticity index, the liquidity index and the consistency index.
5. Classify the soil according to the Unified Soil Classification System (USCS).

<u>Answers</u>: w = 15.6 %; w_L = 33.1 %; w_P = 11.1 %; I_P = 22.0; I_L = 0.20; I_C = 0.80; SW-SC.

EXERCISE 9

An undisturbed soil sample has been taken from a construction site to identify and classify it. After splitting it into subsamples, one of them was oven drying, and its mass was found to be 3545.2 g. This sample was used to perform a particle-size distribution analysis by sieving in two stages, because in the laboratory the sieve shaker could only hold 6 sieves. Tables 1 and 2 show the results of this test.

Sieve	Opening (mm)	Retained (g)
1.5″	37.5	0
¾″	19.0	105.81
3/8″	9.5	184.92
No. 4	4.75	216.33
No. 10	2.00	616.8
Pan		2421.4

Table 1. Sieve analysis (1st stage)

Sieve	Opening (mm)	Retained (g)
No. 20	0.850	985.6
No. 40	0.425	400.57
No. 70	0.212	354.48
No. 100	0.150	177.29
No. 200	0.075	140.20
Pan		363.20

Table 2. Sieve analysis (2nd stage)

Due to the percentage passing through #200 sieve, it was necessary to determine the plastic limit and the liquid limit of this soil. A plastic limit test was performed on a mass of 8.39 g. After oven drying, its mass was reduced to 7.90 g.

Finally, using the Casagrande cup device to perform the liquid limit test, the following data were obtained:

No of blows	Wet mass (g)	Dry mass (g)
32	12.72	7.43
18	14.23	7.92

Table 3. Data recorded from the liquid limit test.

From these data:

1. Plot the particle-size distribution curve of the soil.
2. Estimate the coefficient of uniformity, C_U, and the coefficient of curvature, C_C.
3. Calculate the liquid limit, w_L, the plastic limit, w_P, and the plasticity index, I_P.
4. Classify the soil according to the Unified Soil Classification System (USCS).

Answers: C_U = 22.9; C_C = 1.79; w_L = 75.0 %; w_P = 6.2 %; I_P = 68.8; SW-SC.

EXERCISE 10

A soil sample has been taken from a test pit to identify and classify it. That sample was in turn divided in smaller samples.

A first sample was oven dried and then a sieve analysis was performed. After that it was found that gravel particles comprise 10 % of the sample and sand particles 35 %.

Then, a plastic limit test was performed, and the result was w_P = 10 %. Also, it was necessary to perform the liquid limit test (see table).

In addition, since there was a slight odour of organic material, it was decided to perform another test in the Casagrande cup device with another sample but without drying. In this test, the liquid limit was found to be 91 %.

From these data, classify the soil according to the Unified Soil Classification System (USCS).

No of blows	Wet mass (g)	Dry mass (g)
40		
30	10.55 g	6.39 g
26	10.49 g	6.31 g
20	11.11 g	6.65 g

Table. Data recorded from the liquid limit test.

Answer: OH, Sandy organic clay

EXERCISE 11

The following data were obtained from a particle-size distribution analysis on a soil sample using ASTM sieves.

Particles	Size (ϕ)	Percentage
Coarse sand	No. 4 (4.75 mm) › ϕ › No. 10 (2 mm)	5 %
Medium sand	No. 10 (2 mm) › ϕ › No. 40 (0.425 mm)	15 %
Fine sand	No. 40 (0.425 mm) › ϕ › No. 200 (0.075 mm)	25 %
Silt and clay	ϕ ‹ No. 200 (0.075 mm)	55 %

Table 1. Percentage of the different particles (termed according the USCS).

1. Using these data, would it be possible to plot exactly the particle-size distribution curve? And approximately? Explain your answers and plot the curve.

Due to the percentage of fines, it was necessary to determine the plastic limit and the liquid limit of this soil. A plastic limit test was performed on a mass of 8.32 g. After oven drying, its mass was reduced to 7.56 g.

Also, using the Casagrande cup device to perform the liquid limit test, the following data were obtained:

No of blows	Wet mass (g)	Dry mass (g)
32	12.23 g	10.58 g
27	12.89 g	10.93 g
20	13.15 g	10.91 g

2. Calculate the plastic limit and the liquid limit of the soil.

In addition, since there was a slight odour of organic material, the liquid limit without drying was also determined, and was found to be 21%.

From these data:

3. Classify the soil according the Unified Soil Classification System (USCS).

Answers:

w_P = 10.1 %; w_L = 18 %; CL, Sandy lean clay

EXERCISE 12

A soil sample has been taken from a test pit to identify and classify it. That sample was in turn divided in smaller samples. The wet mass of the first one was 1523.87 g. The dry mass, after oven-drying, was 1452.31 g. This one was used to perform a particle-size distribution analysis.

After this analysis, the following data are known:

a) % passing #4: 85 %.

b) % passing #200: 55 %.

Then, the plastic limit test and the liquid limit test were performed on that dry soil sample. The first one, with 9.15 g of soil, that after oven drying, were reduced to 7.52 g. In the second one, using the Casagrande cup device, the following data were obtained:

No of blows	Wet mass (g)	Dry mass (g)
32	11.47	8.31
27	10.55	7.59
22	12.48	8.85

In addition, since there was a slight odour of organic material, using one of the initial soil samples, the liquid limit without drying was also determined by means of the Casagrande cup device. The following data were recorded:

No of blows	Wet mass (g)	Dry mass (g)
29	12.35	8.61
21	11.22	7.63

Using these data:

1. Calculate the consistency index of the soil, $\mathbf{I_C = \frac{w_L - w}{w_L - w_P}}$ and interpret the answer.

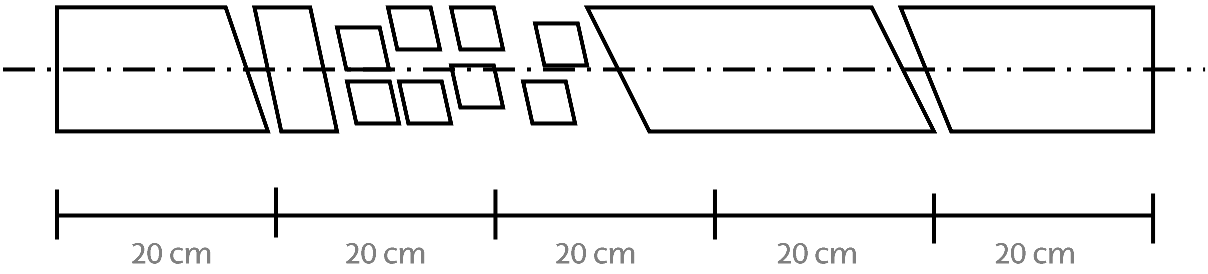
2. Classify the soil according the Unified Soil Classification System (USCS).

Answers:

I_C = 1.93; CL, Sandy lean clay with gravel.

EXERCISE 13

The following figure shows a rock core sample. Approximately calculate RQD, explaining clearly which values are necessary to take and the calculations to carry out.



Answer:

RQD ≅ 59 %