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Determination of Compression Index and Coefficient of Permeability of the Soils

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Abstract
The main objectives of this study are determination of compression index, coefficient of permeability and over consolidation ratio of the soils. The undisturbed soil samples were prepared from four study area locations at 3m depth. The one dimensional consolidation tests were conducted in the laboratory using oedometer apparatus.
The results obtained from this research shown that, the compression index value of clay is 0.26 and silt soil ranges from 0.3 to 0.4, the coefficient of permeability values ranges from 10^{-8} to 10^{-9} cm/sec. The over consolidation ratio values ranges from 2.0 to 3. This shows that, the study area over loaded in the past with maximum effective stress.
Keywords: Coefficient, Permeability, Over consolidation ratio, Compression, Index

1. Introduction

The process whereby soil particles are packed more closely together over a period of time under the application of continued pressure. It is accompanied by drainage of water from the pore spaces between solid particles [2]. The compressibility characteristics of a soil mass might be due to any or a combination of the following factors [3]:

- Compression of the solid matter.
- Compression of water and air within the voids.
- Escape of water and air from the voids.

1.1 Objective of the study

- Determination of the compression index and coefficient of permeability of soil
- Determination of the over consolidation ratio of study area

2. Materials and methods

2.1 Soil samples

The identification of sampling area was done by observation and eleven test pits were selected. The test pit excavations were conducted at 3m depth and undisturbed soil samples were collected. And then, preparations of samples have done to conduct tests in the laboratory. Index properties laboratory tests and soil classification were done for all test pits. According to [1] soil classification, four test pits were selected for one dimensional consolidation test.

Then after, these tests have been determined using one dimensional oedometer laboratory equipment shown in [Fig.2.1]. The compressibility and permeability tests were conducted for samples TP1, TP2, TP4 and TP10. The easting and northing coordinates of test pits were tabulated in Table 3.1. After the results obtained from oedometer test, the analysis were done using Microsoft excel.

Figure 2.1 Consolidation apparatus [1].

3. The study area

The study area is found in Kemise town. It is the administrative center of the Oromiya Zone of the Amhara Region, northeastern Ethiopia. The town is located with latitude and longitude of 10°43'N 39°52'E respectively. The elevation of this town is 1450 meters above sea level.

Table 3.1 Test pit location and coordinates.

Test Pit Location	Test Pit	Northing	Easting
Zone Administration office	TP1	10°43'01"	39°52'03"
Gelma Abageda Adarash	TP2	10°43'08"	39°52'05"
Green Area	TP4	10°42'42"	39°52'01"
Garagadous (around high school)	TP10	10°42'52"	39°52'41"

4. Data analysis and discussion

The result obtained from laboratory tests were used for analysis of settlements. The standard test method used for One-Dimensional Consolidation is based on ASTM D 2435 [1].

4.1 Pre-consolidation pressure

The pre-consolidation stress,P_c, is the maximum effective stress to which the soil has been exposed in its past geological history. The Casagrande [4] method of obtaining the pre-consolidation pressure from consolidation tests is shown in Figure 4.1.

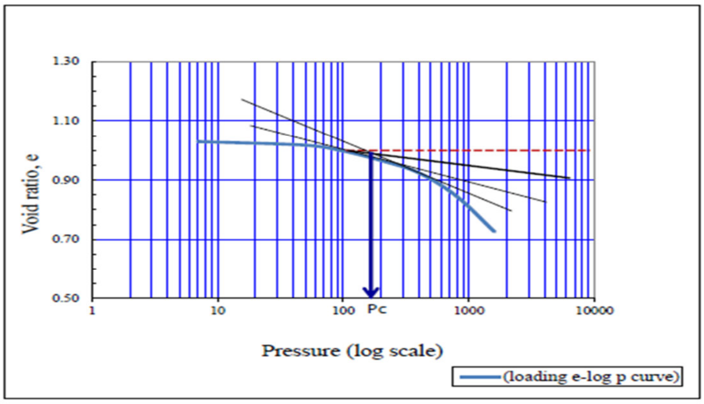

Figure 4.1. Typical curve (TP1, 3m) void ratio Vs log pressure to determine P_c

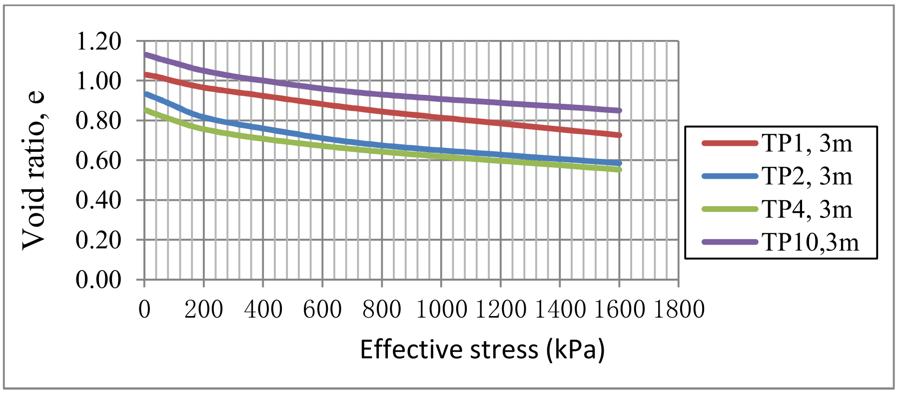

Figure 4.2 Consolidation test results; void ratio Vs pressure (linear scale)

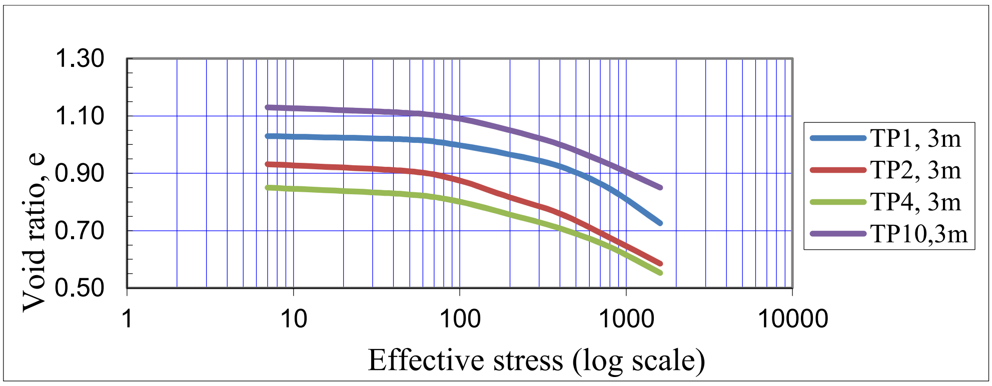

Figure 4.3. Consolidation test results, void ratio vs Effective stress (log scale)

4.2 Compression Index (C_c)

In fact, the assessment of the compression index (C_c) for a clayey soil (which is determined by laboratory oedometer tests) is highly influenced by the soil state. Another parameter that affects the compression behavior of clays is the sampling procedure [8]. The value of C_c (Table 4.2) is the slope of the linear portion of the e Vs log P curve. Thus: The results were tabulated in Table 4.1.

$$C_c = \frac{e_1 - e_2}{\log P_2 - \log P_1}$$

4.3 Coefficient of consolidation (C_v)

The similarity between the laboratory curve and the theoretical curve is used for the determination of the coefficient of consolidation (C_v) of the soil. The methods are known as the fitting methods [5]. The square-root-of-time fitting method used for the determination of C_v and typical Square-root-of-time versus dial reading curve for TP1, 3m, 200Kpa loading was done.

$$C_v = \frac{0.848 * H^2}{t_{90}}$$

4.4 Over consolidation ratio (OCR)

Over consolidation ratio is the relationship between current over burden pressure and pre-consolidation pressure in the history of the area. So, it is the ratio of pre-consolidation pressure to over burden pressure. The results obtained from laboratory test analysis shows, the ratios are greater than one. This clearly shows that, the study area soils were over loaded in the past history.

Table 4.1. One dimensional consolidation test results.

Test pit	Depth (m)	Natural moisture content (%)	Wet Density, gm/cm^3	Pressure (kPa)	Void ratio (e_f)	coefficient of consolidation,(c_v)(cm^2/sec)	Compression Index, (C_c)	Pre-consolidation pressure, P_c(kPa)	Over burden pressure, kPa	OCR, (%)
TP1	3	32.74	1.75	50	1.02	0.85	0.4	170	51.50	3.3
				100	1	1.71				
				200	0.97	1.01				
				400	0.92	0.55				
				800	0.85	0.33				
				1600	0.73	0.23				
TP2	3	22.45	1.7	50	0.91	0.44	0.3	105	50.03	2.1
				100	0.87	0.83				
				200	0.82	0.53				
				400	0.76	0.33				
				800	0.67	0.26				
				1600	0.59	0.36				
TP4	3	31.99	1.88	50	0.83	0.33	0.3	110	55.33	2.0
				100	0.8	1.21				
				200	0.76	0.31				
				400	0.71	0.33				
				800	0.64	0.17				
				1600	0.55	0.38				
TP10	3	36.67	1.79	50	1.11	0.88	0.26	120	52.7	2.3
				100	1.09	1.35				
				200	1.05	0.7				
				400	1.00	0.31				
				800	0.93	0.23				
				1600	0.85	0.22				

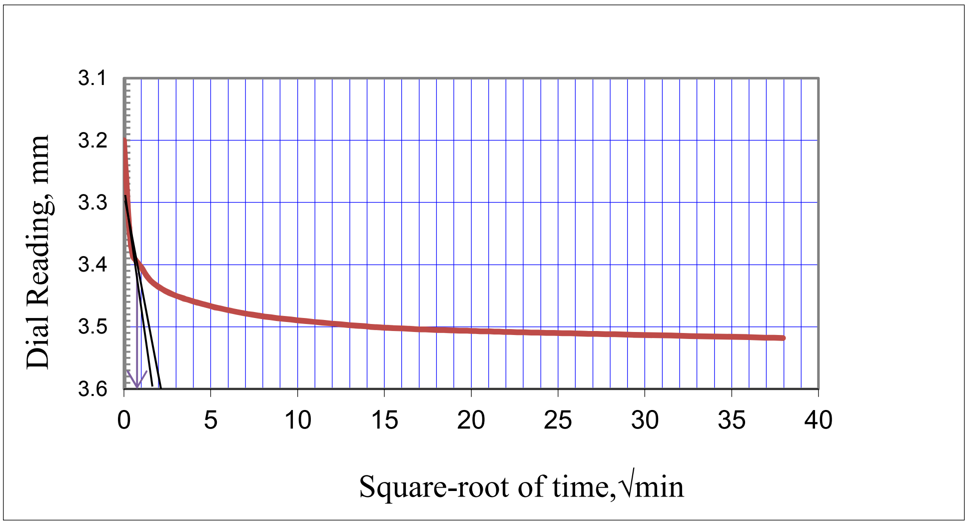

Figure 4.4. Typical Square-root-of-time Vs dial reading curve for TP1, 3m (200Kpa loading).

4.5 Determination of permeability Coefficient (k)

The greater the value of the coefficient of permeability, the greater is the flow [6]. The coarse grained soils have high permeability than fine grained soils. The coefficient of permeability can be obtained from the following relationship [7]:

$$k = \frac{c_v a_v \gamma_w}{1+e}$$

Where: c_v = coefficient of consolidation, a_v = coefficient of compressibility, γ_w=unit weight of water and e= void ratio.

Figure 4.6. show that, consolidation pressure has a direct impact on permeability of soil and the value of 'k' decreases with increasing consolidation pressure.

Table 4.2. Relationship between void ratio and coefficient of permeability.

Test pit	Depth (m)	Pressure P (kPa)	Void ratio e_f	Coefficient of consolidation c_v (10^{-3}cm^2/sec)	Coefficient of compressibility,a_v (10^{-5}cm^2/kN)	Coefficient of permeability k 10^{-9} cm/sec
TP1	3	100	1	1.71	39.55	33.82
		200	0.97	1.01	32.08	16.45
		400	0.92	0.55	20.78	5.95
		800	0.85	0.33	19.67	3.51
		1600	0.73	0.23	14.91	1.98
TP2	3	100	0.87	0.83	65.3	29
		200	0.82	0.53	58.4	17.01
		400	0.76	0.33	28.2	5.3
		800	0.67	0.26	21.2	3.3
		1600	0.59	0.36	11.2	2.54
TP4	3	100	0.8	1.21	50.62	34.03
		200	0.76	0.31	44.52	7.84
		400	0.71	0.33	24.2	4.67
		800	0.64	0.17	16.26	1.68
		1600	0.55	0.38	11.29	2.77
TP10	3	100	1.09	1.35	37.8	24.42
		200	1.05	0.7	35.94	12.3
		400	1	0.31	25.96	4.02
		800	0.93	0.23	17.19	2.05
		1600	0.85	0.22	9.71	1.16

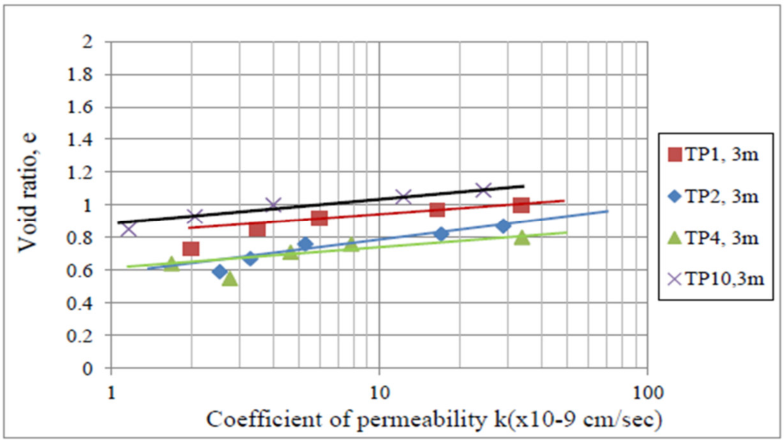

Figure 4.5. Void ratio Vs Log Coefficient of Permeability

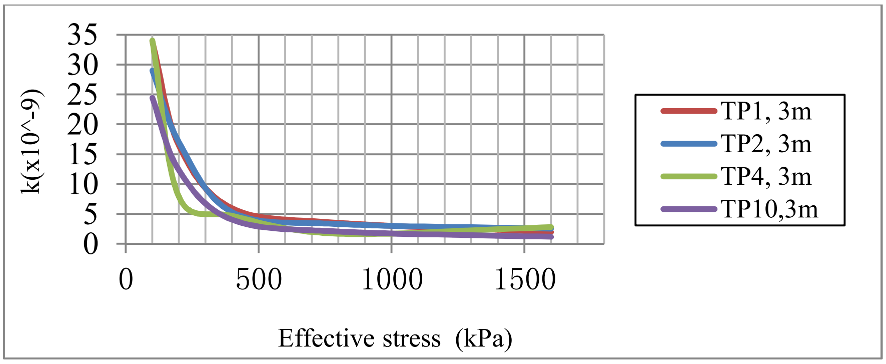

Figure4.6. Relationship between consolidation pressure and coefficient of permeability.

The e-log p relationship displays a distinct break at approximately the maximum past effective stress (P_c). The values of pre-consolidation pressure (P_c) are ranges from 105-170kPa.

4. Conclusion

The compressible nature of soils are used as an input for computation of settlment of foundation.

- The compression index (c_c) of clay soil found in the research area is 0.26. While the silt soils have compression index of 0.3 to 0.4.
- The coefficient of permeability (k) ranging from 10^{-8} to 10^{-9} cm/sec.
- Actually investigated values of OCR are greater than one, showing that the soil has been loaded in the past with maximum effective stress.

Acknowledgment

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