Journal of Al-Azhar University Engineering Sector

Vol. 18, No. 68, July 2023, 555 - 565

EFFECT OF DRAINAGE STATES ON CONSOLIDATION OF COHESIVE SOIL WITHIN PLASTICITY RANGE

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Citation:

N. S. Ahmed, M. Abo Bakr, and M. Saad Eldin, “Effect of drainage states on consolidation of cohesive soil within plasticity range”, Journal of Al-Azhar University Engineering Sector, vol. 18, pp. 555 - 565, 2023.

Received: 5 December 2022

Accepted: 1 June 2023

ABSTRACT

The behavior of soil consolidation on cohesive soil through the plasticity range was studied on cohesive soil taken from Tanta in Egypt. Index properties soil testes were carried out in soil laboratory at Al-Azhar University to determine the (liquid limit-plastic limit- specific gravity) this soil was divided into five samples with different water content between liquid and plastic limit ,so that the water content of the samples (22%- 31%-39%-47%-55%).Then three cases of the odometer test were done (single drainage-double drainage-triple drainage),and each case was performed five times on five sample . From the results of the tests, relationships were drawn between the consolidation coefficients and different stresses at different drainage. The relationships showed that ,the time of consolidation for triple drainage decreased than double drainage by about 26% , at water content 39%to 55% the coefficient of volume change in three dimension drainage is identical at stress 4kg/cm2 and The average values of the coefficient of volume change (mv) for three dimensions are more than one dimension and two dimension drainage about 22.5% and 13.6% under the same applied stress.

KEYWORDS: Consolidation, One Dimensional consolidation, Two Dimensional consolidation, Three Dimensional consolidation, Coefficient of Consolidation.

تأثير حالات التصرف على تصلد التربة المتماسكة خلال مدى اللدونه

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الملخص

تم دراسة سلوك تصلد التربه على التربه المتماسكه خلال مدى اللدونه وتم ذللك على تربه متماسكه مأخوذه من طنطا بجمهورية مصر العربيه .تم إجراء إختبارات خصائص التربه عليها بمعمل التربه بجامعه الازهر لتحديد (حد السوله- حد اللدونه- الوزن النوعى) ثم تقسيم هذه التربه على خمس عينات بمحتوى مائى مختلف بحيث يكون بين حدى اللدونه والسيوله حيث يكون المحتوى المائى للعينات(22%, 31%, 39%, 47%, 55%) ثم تم إجراء ثلاث حالات للادوميتر (تصرف المياه من اتجاه واحد- تصرف المياه من إتجاهين- تصرف المياه من ثلاث إتجاهات) وكل حاله تم إجراءها خمس مرات على خمس عينات ومن نتائج الإختبارات تم رسم علاقات بين معاملات التصلد والإجهادات المختلفه عند حالات التصرف المختلفه واوضحت العلاقات أن وقت التصلد في التصرف من خلال ثلاث إتجاهات

يقل عن التصرف الثنائى بنسبه 26%, وتطابق قيم التغير الحجمى في حالات التصرف الثلاثه للمحتوى المائى 39%الى 55% بدأ من اجهاد 4كجم/سم2 وتزيد القيمه المتوسطه للتغير الحجمى فى التصرف الثلاثى عن التصرف الأحادى و الثنائى الإتجاه بنسبه 22.5%-13.6% تحت نفس الإجهاد.
الكلمات المفتاحية: التصلد، تصلد احادي التصرف ، تصلد ثنائي التصرف ، تصلد ثلاثي التصرف ، معامل التصلد.

1. INTRODUCTION

The settlement is the most serious problem of cohesive soil. This settlement is caused by a phenomenon called soil consolidation. Most previous studies were concerned with studying one (1-D) [1] and two-dimensional (2-D) consolidation. That in some cases does not give a simulation of reality representation. It was necessary to study the three-dimensional (3-D) consolidation to simulate what happens to the cohesive soil in nature. A lot of research and studies have been done to study the consolidation of cohesive soil. We will present some of them, and this research's important results and objectives.

Coefficient of dilatancy of clays is shown to be linearly to their plasticity index . undrained test results on twelve soils comprising natural reconstituted clays and clay sand mixtures from the basis of the proposed correlation. Different correlations are obtained with variation in either consolidation history or stress path during undrained shear. Results of undrained test on reconstituted natural clays and clay-sand mixtures show that the coefficient of dilatancy is linearly related to plasticity index. Separate linear correlations apply to clays with a given consolidation history and shear under a given stress path (compression or extension) [2].

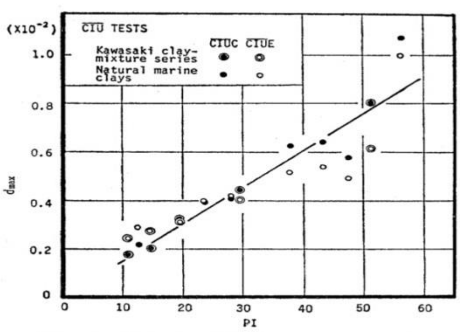

Fig. 1: Relationship between the d(max) and PI in CIU (isotropically consolidated undrained test) tests

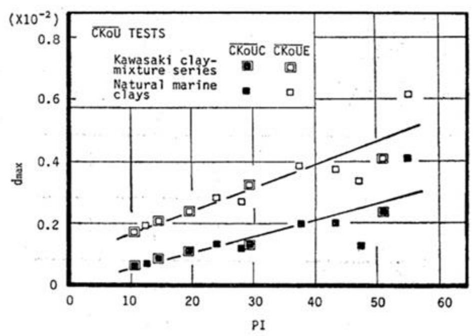

Fig. 2: Relationship between the d(max) and PI in CK_0U(consolidated undrained test) tests

Studied Conventional 1-dimensional consolidation tests on three clay minerals (kaolinite, illite and montmo - rillonite). According to the study's findings, the coefficient of consolidation for clay minerals fluctuates with consolidation pressure. The apparently contradictory trends in variation of C_v (coefficient of consolidation) with consolidation pressure seen in the literature can be reconciled on the basis of the virgin compression behavior. There is an increase of C_v with pressure for kaolinite, illite and powdered quartz, whose behavior in compressibility is controlled by mechanical factors. For montmorillonite with water as the pore fluid, the compression behavior is controlled by physicochemical factors and C_v is found to decrease with increase in pressure. When pressure is increased, it is observed that the coefficient of consolidation in clays either rises or falls, depending on whether mechanical or physicochemical factors dominate the virgin consolidation behavior. The mechanical and physicochemical parameters that control the compressibility of clays hence control how much of a response the coefficient of consolidation to pressure rise [3].

The consolidation behaviour of clay slurries has been determined. A fine-grained clay with high consistency limits (Wl = 180% ,Wp = 120%) was investigated using conventional oedometer and bench-top centrifuge tests. Results indicated that the slurry had an apparent preconsolidation (due to initial conditions, electrochemical interactions, tortuous drainage, and thixotropic strength) from void ratio (e) = 5.7 to 5.5 followed by virgin compression. Likewise, the low hydraulic conductivity (10-10 -10-12m/s) was due to low porosity (small pore throats) and high tortuosity (long flow paths) of the clay slurries. Unlike consolidation of soils, the C_v and mv of the clay slurry decreased with increasing σ` but increased with increasing e and k [4].

This study examines how specimen size affects the consolidation qualities of soft Bangkok clays by comparing test findings for two distinct specimen sizes: d60 (60 mm in diameter and 20 mm in height, which complies with ASTM D2435); and d35 (35 mm in diameter and 20 mm in height; newly developed in this study). The test results of this study, the reported 1D consolidation parameters in terms of coefficient of consolidation (cv), compression index (cc), swelling index (cs), and preconsolidation stress were not significantly altered when the specimen diameter was reduced from 60 mm to 35 mm while the height was maintained at 20 mm [5].

Three-dimensional (3-D) consolidation has been studied to simulate what happens to the cohesive soil in nature. The final results showed that the average values of the coefficient of volume change for three dimensions consolidation are more than one dimension consolidation and two-dimension consolidation about 11.40% and 5.85% under the same applied stress. The application of consolidation test results shows a good correspondence with the decay times of the consolidation phenomenon. The case of Three-dimensional consolidation needed less time to arrive complete consolidation (U = 100%) than one dimensional consolidation and two-dimensional consolidation. The average values of Coefficient of consolidation for Three-dimensional consolidation are more than one dimensional consolidation and two-dimensional consolidation about 32.8% and 22.15% under the same applied stress [6].

2. Soil Samples

Samples were taken from the soil located in Tanta in Egypt. Then the samples were moved to the soil laboratory at Al-Azhar University to start laboratory tests on them. These tests were conducted on the soil after drying, grinding, and sifting through a 40 sieve.

3. Soil Properties

A Soil specific gravity test was performed on the soil, to calculate the density of the soil. Liquid limit and plastic limit tests were also performed According to (ASTM:D4318-05, 2005) as shown in table (1) [7].

Table 1: Properties of tested Clay

Property	Value
Specific gravity (G_S)	2.631
Liquid limit (L.L)	55%
Plastic limit (P.L)	22.489%
Plasticity index (PI)	32.15%

Table 2: No. of sample

No. of sample	W_C
Sample 1(S_1)	22%
Sample 2 (S_2)	31%
Sample 3 (S_3)	39%
Sample 4 (S_4)	47%
Sample 5 (S_5)	55%

4. EXPERIMENTAL WORK

For experimental work, we carried out the consolidation tests as one-dimensional drainage, two-dimensional drainage and three-dimensional drainage. We performed tests by using oedometer apparatus [8, 9].

4.1 consolidation apparatus and testing

In case single drainage two perforated aluminum plates were used the first permeable plate and the second impermeable plate. Two perforated aluminum plates were used as permeable plates in case double drainage. In case triple drainage Two perforated aluminum plates were used as permeable plates and sand around the sample were placed.

5. RESULTS AND DISCUSSIONS

Consolidation parameters were determined according to consolidation test data of the studied soil samples; these consolidation parameters were determined using consolidation theory. Finally, every sample has a relationship between consolidation coefficient and different stress at (3D) drainage consolidation .

5.1 Relationship between the coefficient of volume change and stresses

Fig. 3 shows the relation between the coefficient of volume change (m_v) and stress for S_1 The test results were the average values of m_v for three dimensions drainage are increased than one dimension and two-dimension drainage about 23.4% and 14.9% respectively.

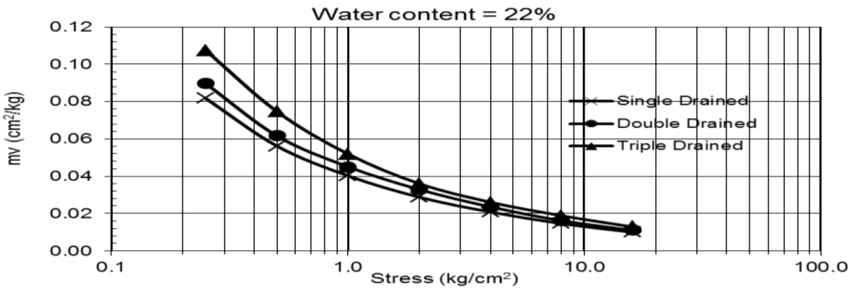

Fig. 3: Relationship between the coefficient of volume change (m_v) and stresses for different drainage at water content 22%

Fig. 4 shows the relation between the coefficient of volume change (m_v) and stresses for S_2 The test results were the average values of m_v for three dimensions drainage are increased than one dimension and two-dimension drainage about 21.5% and 12.5% respectively.

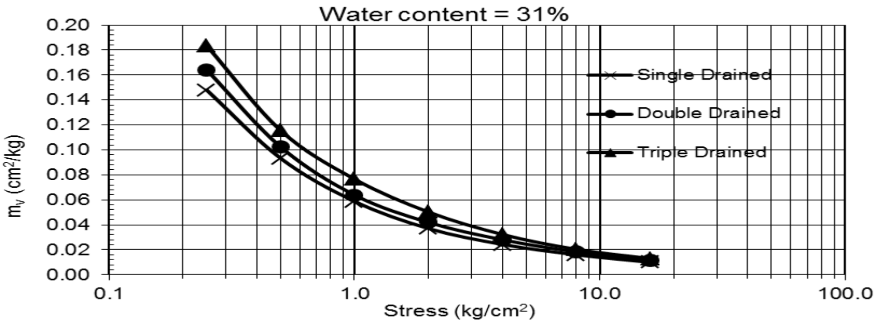

Fig. 4: Relationship between the coefficient of volume change (m_v) and stresses for different drainage at water content 31%

Fig. 5 shows the relation between the coefficient of volume change (m_v) and stresses for S_3 The test results were the average values of m_v for three dimensions drainage are increased than one dimension and two-dimension drainage about 21.9% and 13.4%, respectively .

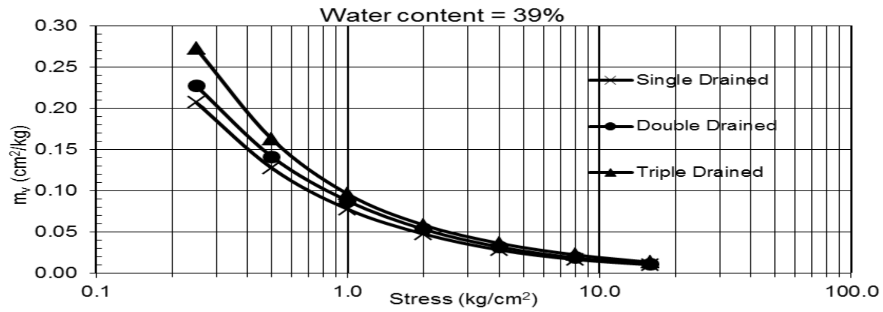

Fig. 5: Relationship between the coefficient of volume change (m_v) and stress for different drainage at water content 39%

Fig. 6 clears the relation between the coefficient of volume change (m_v) and stresses for S_4 The test results were the average values of m_v for three dimensions drainage are increased than one dimension and two-dimension drainage for S_4 about 23% and 12.2% respectively .

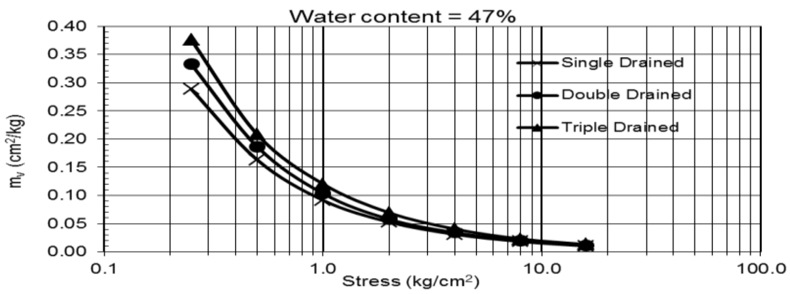

Fig. 6: Relationship between the coefficient of volume change (m_v) and stresses for different drainage at water content 47%

Fig.7 shows the relation between the coefficient of volume change (m_v) and stresses for S_5 The test results were the average values of mv for three dimensions drainage are increased than one dimension and two-dimension drainage for S_5 about 22.8% and 14.9%, respectively.

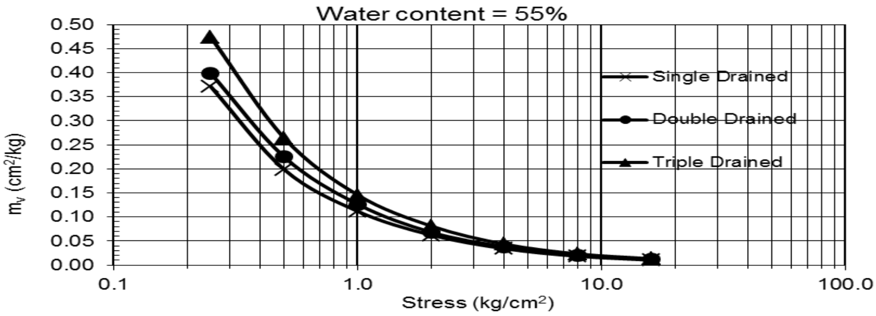

Fig. 7: Relationship between the coefficient of volume change (m_v) and stresses for different drainage at water content 55%

From w_c 39% to w_c 55%, the coefficient of volume change (m_v) in the three-dimension drainage is identical at stress 4kg/cm^2.

5.2 Relationship between Coefficient of consolidation and stresses

Fig. 8 shows the relation between the coefficient of consolidation (c_v) and stresses for S_1 The test results were the average values of (c_v) for three dimensions are decreased than one dimension and two-dimension drainage by about 62.9% and 26.5%, respectively.

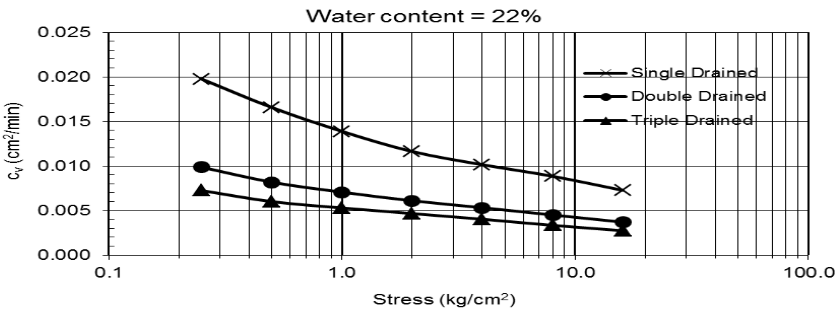

Fig. 8: Relationship between coefficient of consolidation (c_v) and stresses for different drainage at water content 22%

Fig. 9 shows the relation between the coefficient of consolidation (c_v) and stresses for S_2The test results were the average values of (c_v) for three dimensions drainage are decreased than one dimension and two-dimension drainage about 51.6% and 14.5%, respectively.

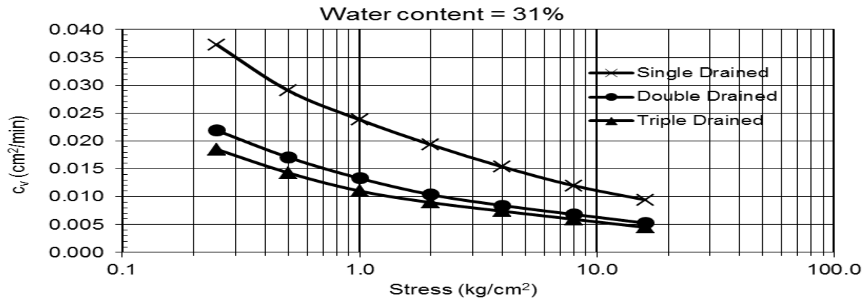

Fig. 9: Relationship between coefficient of consolidation (c_v) and stresses for different drainage at water content 31%

Fig. 10 shows the relation between the coefficient of consolidation (c_v) and stresses for S_3 The test results were the average values of (c_v) for three dimensions drainage are decreased than one dimension and two-dimension drainage about 50.1% and 11.4%, respectively .

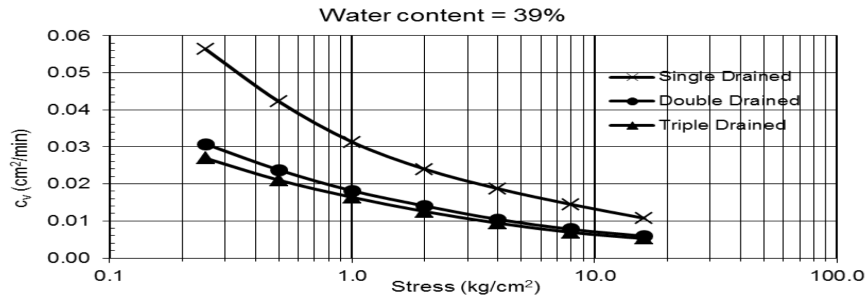

Fig. 10: Relationship between coefficient of consolidation (c_v) and stresses for different drainage at water content 39%

Fig. 11 shows the relation between the coefficient of consolidation (c_v) and stresses for S_4 The test results were the average values of (c_v) for three dimensions drainage are decreased than one dimension and two-dimension drainage about 59.5% and 11.6%, respectively .

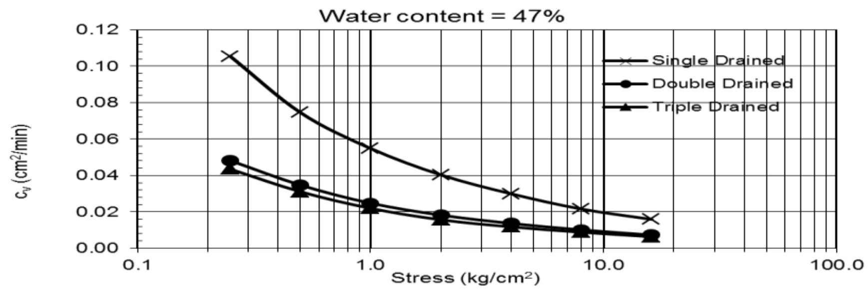

Fig. 11: Relationship between coefficient of consolidation (c_v) and stresses for different drainage at water content 47%

Fig. 12 shows the relation between the coefficient of consolidation (c_v) and stresses for S_5 The test results were the average values of (c_v) for three dimensions drainage are decreased than one dimension and two-dimension drainage about 44.2% and zero%, respectively .

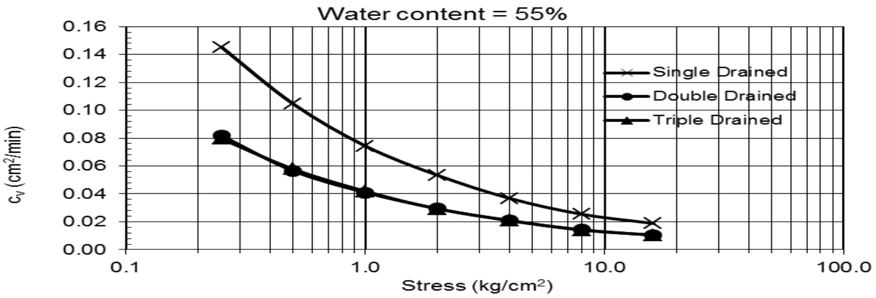

Fig. 12: Relationship between coefficient of consolidation (c_v) and stresses for different drainage at water content 55%

5.3 Relationship between time of consolidation and stresses

At degree of U_{50} for different drainage we obtain to T_{50} from casagrand method. The following figure Fig.13 obtain the relation between the time of consolidation (t_{50}) and stresses for S_1 The test results were the average values of (t_{50}) for three dimensions drainage are decreased than one dimension and two-dimension drainage about 67.7% and 14.27%, respectively.

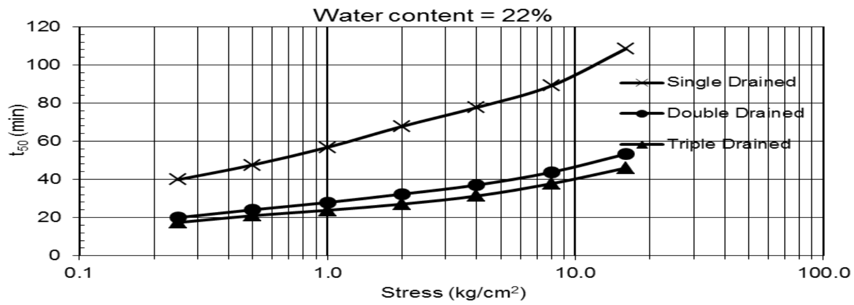

Fig. 13: Relationship between time of consolidation (t_{50}) and stresses for different drainage at water content 22%

Fig.14 shows the relation between the time of consolidation (t_{50}) and stresses for S_2 The test results were the average values of T_{50} for three dimensions drainage are decreased than one dimension and two-dimension drainage for S_2 about 66.7% and 25.3%, respectively.

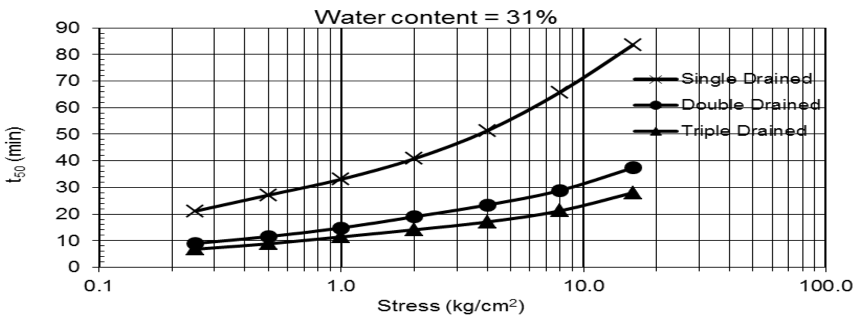

Fig. 14: Relationship between time of consolidation (T_{50}) and stresses for different drainage at water content 31%

Fig.15 shows the relation between the time of consolidation (t_{50}) and stresses for S_3 The test results were the average values of T_{50} for three dimensions drainage are decreased than one dimension and two-dimension drainage for S_3 about 67.7% and 28.1%, respectively.

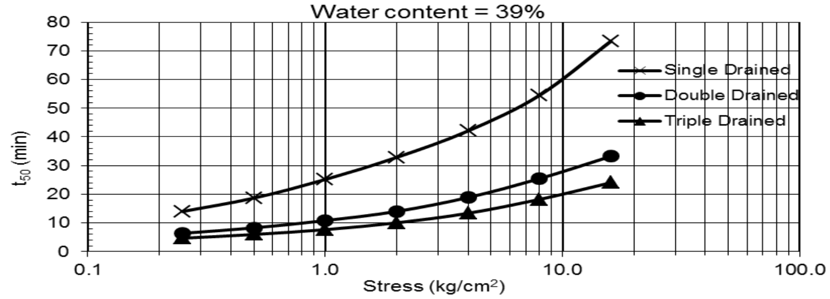

Fig. 15: Relationship between time of consolidation (T_{50}) and stresses for different drainage at water content 39%

Fig.16 shows the relation between the time of consolidation (t_{50}) and stresses for S_4 The test results were the average values of T_{50} for three dimensions are decreased than one dimension and two-dimension drainage for S_4 about 60% and 26.5% respectively.

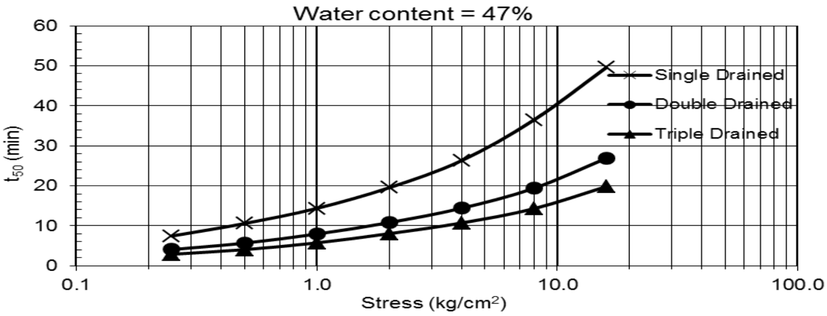

Fig. 16: Relationship between time of consolidation (T_{50}) and stresses for different drainage at water content 47%

Fig. 17 shows the relation between the time of consolidation (t_{50}) and stresses for S_5 The test results were the average values of T_{50} for three dimensions drainage are decreased than one dimension and two-dimension drainage for S_5 about 71.3% and 36.2%, respectively.

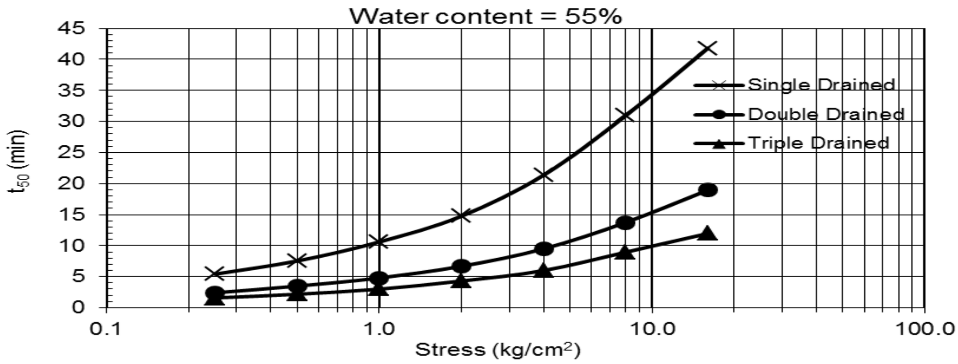

Fig. 17: Relationship between time of consolidation (T_{50}) and stresses for different drainage at water content 55%

SUMMARY AND CONCLUSIONS

In this study, the consolidation on cohesive soil through the plasticity range at 3D drainage was studied. Tests were performed on samples with water content (22% - 31% - 39% - 47% - 55%) and the results showed the following conclusions.

- The maximum values of the coefficient of volume change, the coefficient of compressibility, the coefficient of consolidation, the void ratio and the permeability are at stress ($\Delta\sigma$) 0.25 kg/cm^2 at the otherwise the minimum values for them at ($\Delta\sigma$) 16 kg/cm^2 in case of single, double and triple drainage .
- The coefficient of volume change , the coefficient of compressibility, the coefficient of consolidation and the void ratio increase gradually with the increase of water content at single, double and triple drainage .
- The time of consolidation increases gradually with the increase of applied stress. The maximum values of time of consolidation at stress ($\Delta\sigma$) 16 kg/cm^2 at the otherwise the minimum values for them at ($\Delta\sigma$) 0.25 kg/cm^2 at single, double and triple drainage .
- The time of consolidation decreases gradually with the increase of water content at single, double and triple drainage .
- The average values of time of consolidation for three dimensions drainage are less than one dimension and two-dimension drainage about 66.6% and 26% respectively under the same applied stress.
- The average values of the coefficient of volume change for three dimensions drainage are more than that for one dimension and two-dimension drainage about 22.5% and 13.6% respectively under the same applied stress.
- The average values of the coefficient of consolidation for three dimensions drainage are less than one dimension and two-dimension drainage about 53.7% and 12.8% respectively under the same applied stress.
- From wc 39% to wc 55%, the coefficient of volume change in the three-dimension drainage is identical at stress 4kg/cm^2.

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