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Effect of Loading Duration on the Parameters Obtained from Consolidation Test

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ABSTRACT

Consolidation properties of clay soils are evaluated in the laboratory using the one-dimensional consolidation test. The one-dimensional consolidation testing procedure was first suggested by Terzaghi (1925). In this procedure, the load on the specimen is applied and usually kept for 24 hours. After that, the load is doubled. Therefore, the duration of this test may continue at least 1 week and this duration is unpreferable for traditional purposes if the work is huge.

In this paper, decreasing of applied loading test time has been studied through a new proposed time for applied loading. The results of a new time procedure have been compared with standard (conventional) Oedometer tests that they have been carried out on remolded samples of clay to investigate the difference percentage if quick tests are adopted instead of long tests.

The comparison shows that the compression index increases with the increase test time, therefore, the compression index must be modified (use 1.1 Cc) when employed to calculate the settlement of soil. Also, the elapsed time of test is significant to the determination of swelling index. So, the test time of applied load should be not less than 2hrs.

The results show that two hours are enough to reach 90 % consolidation (t90). The values of pre-consolidation pressure predicted depending on the results of quick test are always smaller than those predicted depending on the results of conventional test results. Finally, two hours LID is enough for calculating the coefficient of permeability depending on the parameters obtained from consolidation test.

Keywords: Consolidation test, Quick test, LID.

تأثير وقت التحميل على المحددات المستخرجة من فحص الانضمام

الخلاصة

تعين خصائص الانضمام للترب الطينية في المختبر باستخدام فحص الانضمام الاحادي المحور .
في هذا الفحص يسلط الضغط1925تبعاً لطريقة العمل المقترحة من قبل العالم ترزاكي عام

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لمدة 24 ساعةٍ، بعد ذلك يضاعف الحمل، لذا فإن مدّة هذا الفحص قد تستغرق على الأقل إسبوعَ وهذه المدّةِ غير مفضّلةٌ للأغراض ِ التجارية خصوصاً إذا كان العمل ِ ضخماً.

في هذا البحث، تمت دراسة تأثير تقليل فترة التحميل لفحص الانضمام باستخدام وقت مقترح جديد لفترة التحميل على نماذج من التربة المقولبة . قورنت النتائج المستحصلة من الطريقة المقترحة مع تلك النتائج المستحصلة من فحص الانضمام التقليدي؛ لبيان مدى الاختلاف في النتائج.

بينت نتائج المقارنة بأن مؤشر الانضغاط يزداد مع اطالة فترة التحميل لذلك من الضروري تعديله قبل استخدامه في حساب هبوط التربة (زيادتة بمقدار 10%). كذلك فقد وجد بان مؤشر الانتفاخ يتأثر ايضاً بزيادة وقت التحميل ، لذا فان فترة التحميل يجب ان لا تقل عن ساعتين.

اشارت النتائج بان ساعتين من التحميل كافية للوصول الى 90% من الانضمام. كذلك وجد بان قيمة الاجهاد المسبق المسلط على التربة اقل في الفحص السريع اذا ما قورنت قيمته مع الفحص التقليدي. اخيراً فان ساعتين من التحميل كافية لتعيين قيمة معامل النفاذية.

INTRODUCTION

Laboratory testing of soils is a fundamental element of geotechnical engineering. The geotechnical engineer should recognize the project's issues ahead of time so as to optimize the test program, particularly strength and consolidation testing, since test can be expensive and time consuming.

Deformation of a saturated soil is more complicated than that of dry soil as water molecules, which fill the voids, must be squeezed out of the sample before readjustment of soil grains can occur. The more permeable, soil, the faster deformation under load will occur. However, when the load on a saturated soil is quickly increased, the increase is carried entirely by the pore water until drainage begins. Then more and more load is gradually transferred to the soil grains until the excess pore pressure has dissipated and the soil grains readjust to a denser configuration. This process is called "consolidation". (NHI, 2002).

In sandy soils that are highly permeable, the drainage caused by the increase in the pore water pressure is completed immediately. Pore water drainage is accompanied by a reduction in the volume of the soil mass, resulting in settlement. Because of the rapid drainage of the pore water in sandy soils, immediate settlement and consolidation take place simultaneously. This is not the case, however, for clay soils, which have low hydraulic conductivity. The consolidation settlement is time dependent. (Das, 2009).

ONE – DIMENSIONAL LABORATORY CONSOLIDATION TEST

The most common laboratory method is the incremental load (IL) oedometer (ASTM D 2435). High-quality undisturbed samples using thin-walled tubes (ASTM D 1587), piston samplers, or other special samplers are required for laboratory consolidation tests.

The one-dimensional consolidation testing procedure was first suggested by Terzaghi (1925). This test is performed in a consolidometer (sometimes referred to as an Oedometer). The soil specimen is placed inside a metal ring with two porous stones. The specimen is kept under water during the test. Each load is usually kept for 24 hours. After that, the load is usually doubled, thus doubling the pressure on the specimen, and the compression measurement is continued. At the end of the test, the dry weight of the test specimen is determined. The effective pressures ($\sigma = \sigma'$) and the corresponding void ratios (e) at the end of consolidation are plotted on semi logarithmic graph paper.

Consolidation test results are dependent upon the duration of each load increment. Traditionally, the load duration is the same for each increment and equal to 24 hrs. For some soils, the rate of consolidation is such that complete consolidation (dissipation of excess pore pressure) will require more than 24 hrs. The apparatus in general use does not have provisions for formal verification of pore pressure dissipation. It is necessary to use an interpretation technique which indirectly determines that consolidation is complete. This test method specifies two techniques; however the requesting agency may specify an alternative technique and still be in conformance with this test method (Sabatini et al., 2002).

AIM OF RESEARCH

The duration of consolidation test may continue at least 1 week and this duration is unpreferable for traditional purposes if the work is huge. Therefore, the effect of the decrease loading time will be studied through a new proposed time for applied loading. Then, the results of a new time procedure will be compared with standard (conventional) Oedometer tests that they have been carried out on remolded samples of clay to clarify the effect of the decrease in load duration on the consolidation parameters if quick tests are adopted instead of long tests.

RAPID LOADING TEST

Macfalane (1969) recommended that if a thin specimen is used, it may be possible to complete all the loading stages within one day, and to unload and remove the specimen on the second day.

Fattah et al., (2006) showed that a primary consolidation may occur in less than 3 hours for loads less than the pre-consolidation pressure $\sigma p'$. If the time period is too short for a given load increment (i.e., the sample is not allowed to achieve approximately 100 percent consolidation before the next load increment is applied), then values of the compression index, cc, or swelling index, cs may be underestimated and the values of the coefficient of consolidation, cv, may be overestimated.

According to the above studies, this paper proposed a new procedure and approved its validity to use in consolidation test instead of the conventional procedure.

In this research, fine grained soil samples are selected to clarify the effect of applied loading throughout the consolidation test on the parameters obtained from this test. Table (1) shows the series of standard and quick consolidation procedures that have been followed in this work.

IDENTIFICATION OF SOIL PROPERTIES

Standard tests were followed to identify the physical and chemical properties of the soils. Table (2) gives a detail of the tests results.

The grain size distribution refers that both soils are silty clay with little amount of fine sand. Figure (1) presents the grain size distribution of soils studied. According to Unified soil classification system the soil (S1) is clay with low plasticity (CL) and (S2) is Clay with high plasticity (CH).

CONSOLIDATION RESULTS

To identify the effect of applied loading time on the soil samples tested in Oedometer apparatus, the soil samples are prepared and tested in the same time using different applied loading time. The first one has been tested using with standard procedure (24 hrs for each load increment). The second has been tested using load increment time equals (2 hrs) while in the last one, the load increment time is (1 hr).

Figure (2) and (3) show the (e – Log p) curves for S1 and S2 respectively. From these figures, it can be seen that the trend of curves is the same but the values of void ratio at the same load are different.

Figure (4) shows the effect of load increment time on compression index (Cc) for the soil studied. It can be concluded that the higher value of compression index is marked at the LID equals (24 hr), while the lower value at LID (1 hrs). Therefore, the compression index obtained from the quick test must be modified when used to calculate the settlement of soil.

The relationship between the increment time of applied loading test and swelling index for the two soils is presented in Figure (5). This figure indicates refers that the behaviour of the swelling index with elapsed time of consolidation test is the same as the compression index behaviour under the same conditions.

Figure (6) shows the effect of load duration on the pre-consolidation pressure for the two soils. It was noticed that the value of pre – consolidation pressure decreases with the increase in loading time. It can be concluded that the values of pre-consolidation pressure predicted depending on the results of quick test are always smaller than those predicted depending on the results of conventional test results.

This behaviour may be attributed to that the increase in loading time leads to more compression of soil particles

It is important to ensure that 90 % consolidation takes place after each load increment (1, 2 and 24 hours). This can be seen in Figures (7 and 8) in which relationships between dial gauge reading and time are drawn for two soils tested by the standard and quick methods. Both figures show that time for 90 % consolidation (t90) is always the same by the two methods with time equals 24 hr or 2 hr only as shown in Figure (9). This result is in agreement with result obtained by Fattah et al., (2006).

Finally, it has been founded that the coefficient of permeability approximately is unchanged for both soils studied when the LID decreases from 24 hrs to 2 hrs as shown in Figure (10) which has been drawn depending on the parameters obtained by the quick and conventional procedures and applying the following formula.

$$k = c_v.\ m_v.\gamma_w \qquad \ldots(1)$$

CONCLUSIONS

From the results presented in this research, the following conclusions may be drawn;

1. Compression index increases with the increase in test time, therefore, the compression index must be modified (use 1.1 Cc) when employed to calculate the settlement of soil.
2. The swelling index is affected by elapsed time of consolidation test. So, the test time of applied load should be not less 2hrs.
3. Two hours are enough to reach 90 % consolidateon (t90).
4. Values of pre-consolidation pressure predicted depending on the results of quick test are always smaller than those predicted depending on the results of conventional test results, therefore pre-consolidation pressure must be increased by 15% before using.
5. Two hours of load duration is enough for calculating coefficient of permeability depending on the parameters obtained from consolidation test.

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Table (1) Testing procedures.

Load (kg)		1	2	4	8	16	32	8	2	1	Total time (hrs)
Standard test	Testing time(min.)	LID = 1440 for each						LID = 120 for each			150
Quick 1		LID = 120 for each						LID = 60 for each			15
Quick 2		LID = 60 for each						LID = 30 for each			7.5

* LID = load increment duration.

Table (2) Properties of the soils under study.

Soil	GS	LL %	PL %	PI %	Passing #200	USCS	Wc (%)	Dry Unit Weight(kN/m^3)	SO_3 %	Gypsum Content %
S1	2.69	37	20	17	98	CL	25.8	15.6	3.25	7.00
S2	2.69	52	21	31	99	CH	31.5	14.5	2.32	5.01

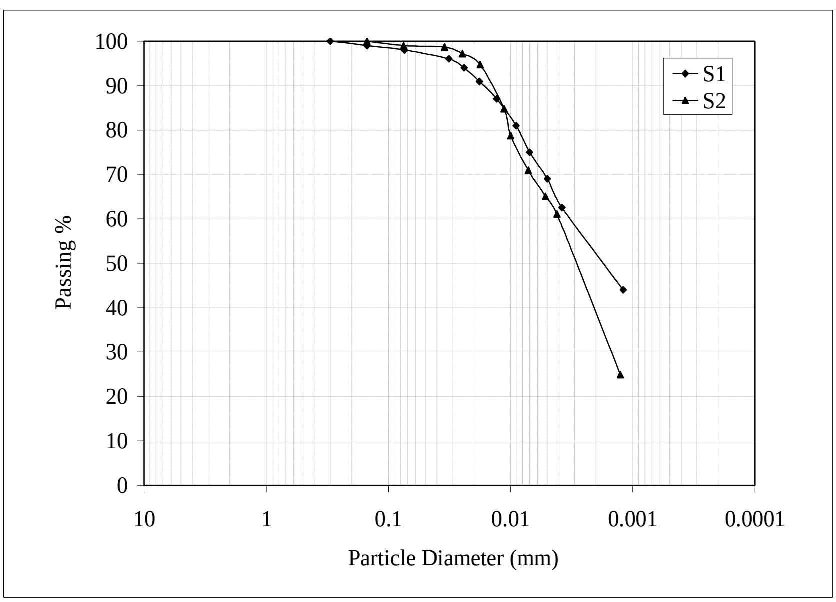

Figure (1) Grain size distribution for the soil studied.

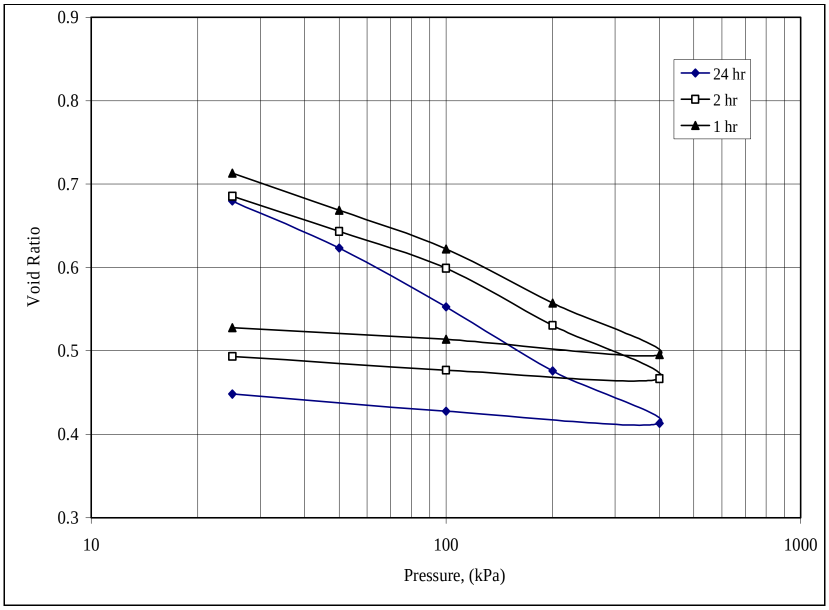

Figure (2) e – Log p Curve for S1 at different LID.

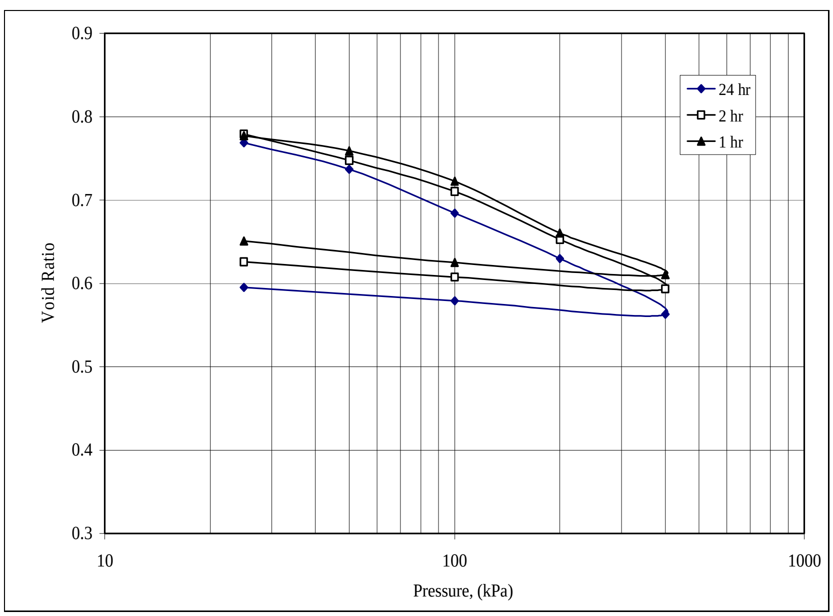

Figure (3) e – Log p Curve for S2 at different LID.

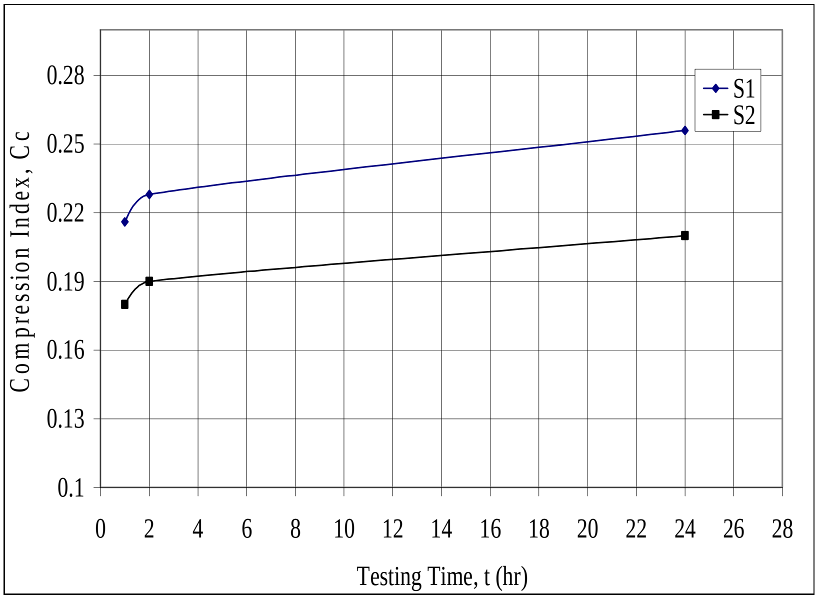

Figure (4) Effect of LID on the values of compression index (Cc).

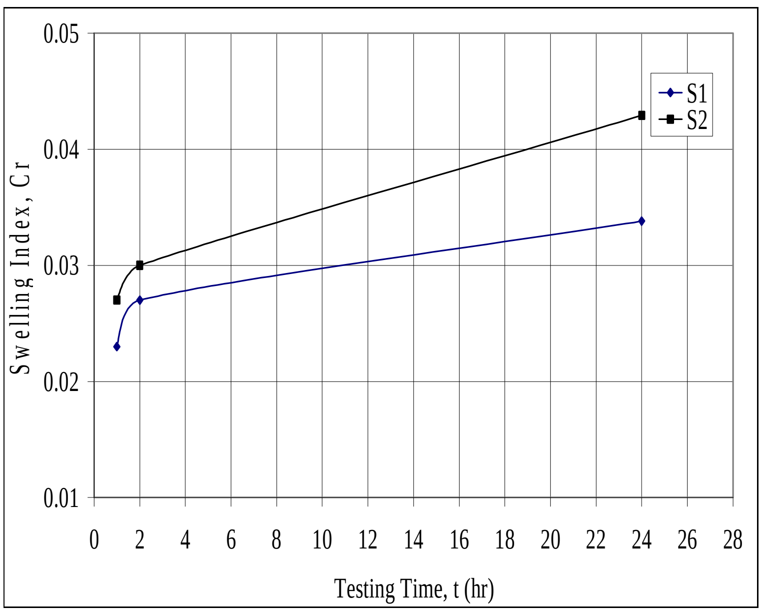

Figure (5) Effect of LID on the values of swelling index (Cr).

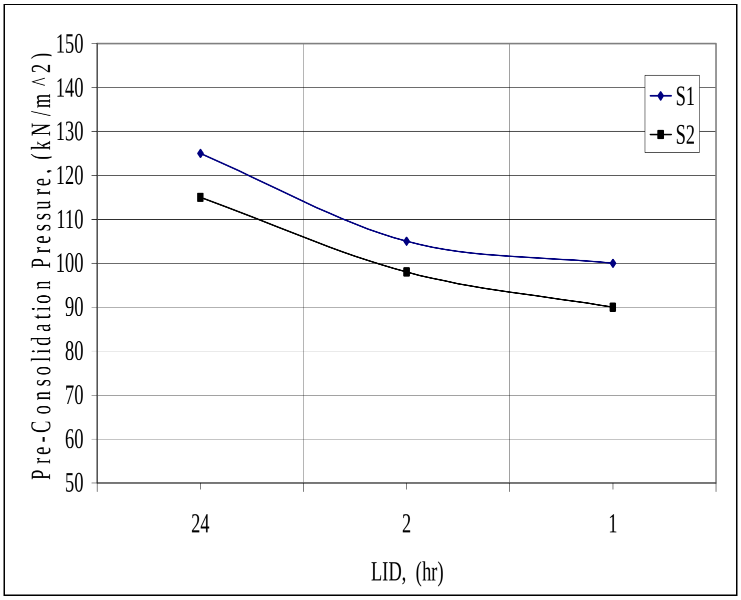

Figure (6) Effect of load duration on the Pre-consolidation pressure.

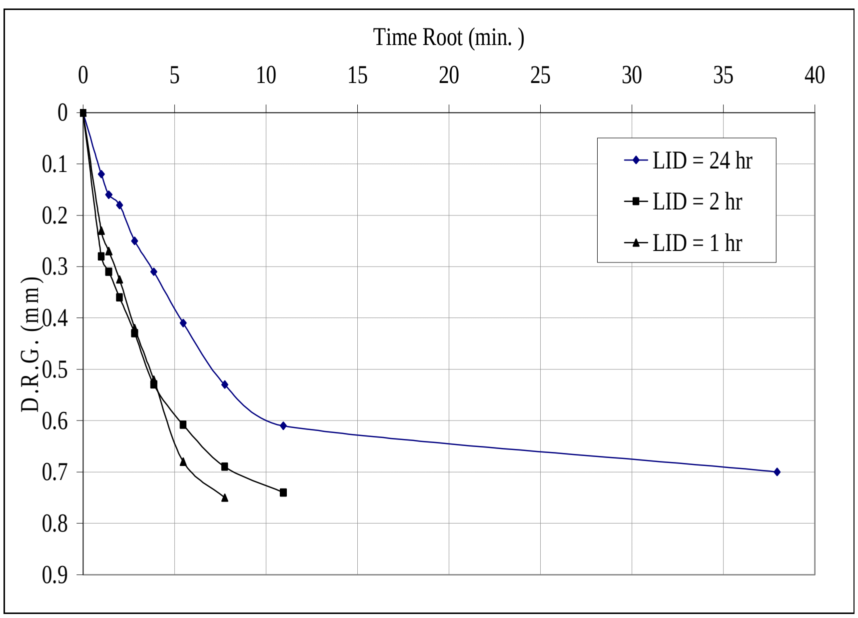

Figure (7) Determination of the coefficient of consolidation for soil 1.

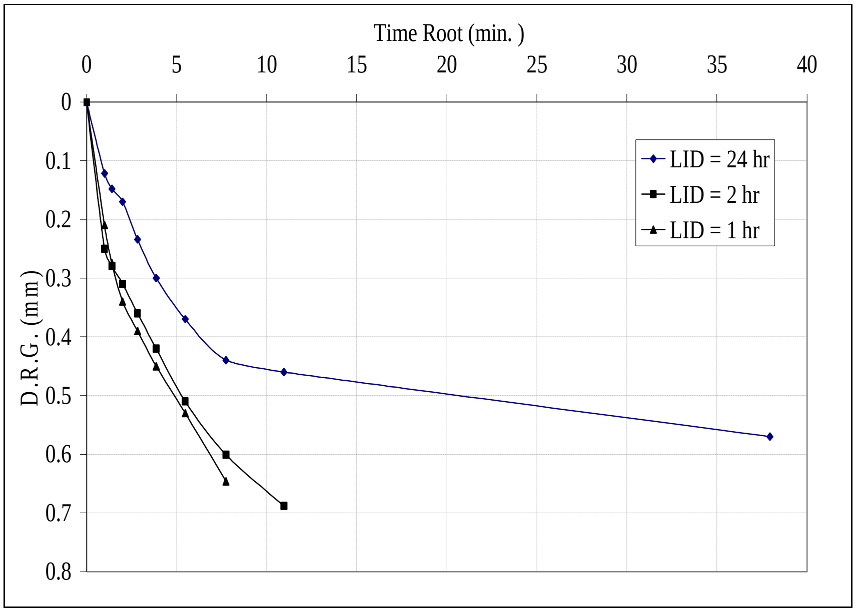

Figure (8) Determination of the coefficient of consolidation for soil 2.

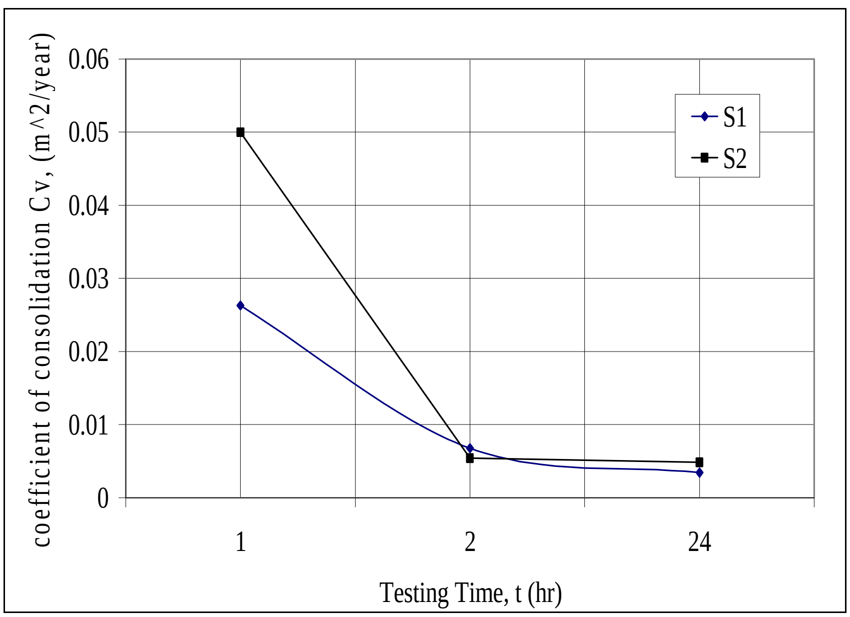

Figure (9): Effect of LID on values of the Coefficient of consolidation, Cv.

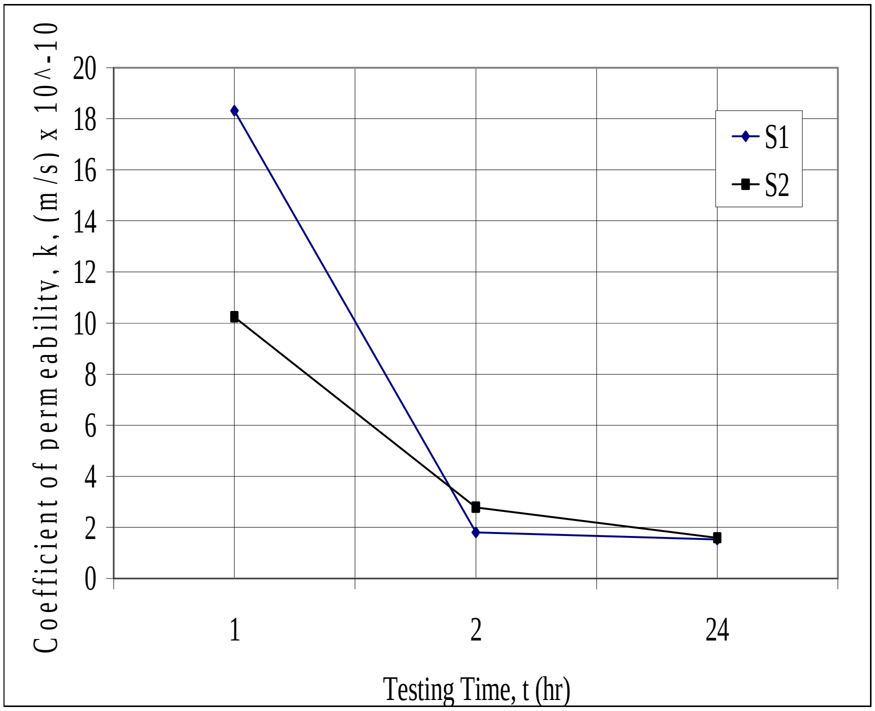

Figure (10) Effect of LID on values of the coefficient of permeability, k.