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INTERPRETATION OF THE CONSOLIDATION TEST

BY

CARL B. CRAWFORD

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INTERPRETATION OF THE CONSOLIDATION TEST[a]

By Carl B. Crawford[1]

SYNOPSIS

Undisturbed specimens of a sensitive clay are loaded in increments of short and long duration and at a constant rate of strain. The preconsolidation pressure and the proportion of primary and secondary consolidation, as determined by pore pressure measurements, are shown to be a function of test procedure. Comparison with field rates of loading shows that the laboratory rates are quite unrealistic.

INTRODUCTION

Consolidation of saturated soil is a process of volume reduction due to the expulsion of water from the void space. If the process is slow, it can occur without the creation of significant pressures in the pore water; if it is rapid, the compression is inhibited by the inability of the water to drain away quickly

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Note.—Discussion open until February 1, 1965. Separate discussions should be submitted for the individual papers in this symposium. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. This paper is part of the copyrighted Journal of the Soil Mechanics and Foundations Division, Proceedings of the American Society of Civil Engineers, Vol. 90, No. SM5, September, 1964.

[a] Presented at the June 16-19, 1964, ASCE Soil Mechanics and Foundations Conference on Design of Foundations for Control of Settlement, at Evanston, Ill.

[1] Head, Soil Mechanics Sect., Div. of Building Research, Natl. Research Council, Ottawa, Canada.

enough, and this results in a temporary increase in the pressure of the pore water. The build-up and the dissipation of pore water pressures is related to the magnitude and rate of loading, the distance the draining water must travel, the permeability of the soil, and the compressibility of the soil structure.

K. Terzaghi[2] recognized the important influence of hydrodynamic time lag in the consolidation of relatively impermeable soils. Using certain simplifying assumptions, Terzaghi was able to develop a mathematical expression for the rate at which consolidation could occur during the release of water under pressure. This is called "primary consolidation," in order to distinguish it from a further compression, called "secondary consolidation," which occurs without appreciable pressure in the pore water. Considerable laboratory work has been conducted in recent years to investigate the relative contributions of primary and secondary consolidation.[3,4,5,6] This work has contributed considerably to the understanding of soil compressibility, especially of test techniques.

It can be shown that both primary and secondary consolidation are simple empirical divisions of a continuous compression process. There is ample evidence that the relative contribution of each is largely a function of the laboratory test procedure, particularly the rate of loading.[4,7] Furthermore, the prediction of actual consolidation in the field has not been generally satisfactory. Terzaghi,[8] drawing on his vast knowledge of case records, stated, "These records disclose a remarkable variety of secondary time effect." Terzaghi quoted cases of measured secondary effect varying directly with time, and others in which it varied with the log of time. Terzaghi also described a subsidence problem in which the predicted settlement was twenty times the actual value; he could only account for this discrepancy as a time effect.

The tests reported herein illustrate how completely unrealistic the rates of compression are in the standard laboratory test, compared to field com-

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[2] Terzaghi, K., "Principles of Soil Mechanics—Settlement and Consolidation of Clay," Engineering News-Record, November, 1925, pp. 874-878.

[3] Newland, P. L., and Allely, B. H., "A Study of the Consolidation Characteristics of a Clay," Geotechnique, London, England, Vol. 10, No. 2, 1960, pp. 62-74.

[4] Leonards, G. A., and Girault, P., "A Study of the One-Dimensional Consolidation Test," Proceedings, 5th Internatl. Conf. on Soil Mechanics, London, Vol. 1, 1961, pp. 213-218.

[5] Lo, K. Y., "Secondary Compression of Clays," Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 87, No. SM4, Proc. Paper 2885, August, 1961, pp. 61-87.

[6] Wahls, H. E., "Analysis of Primary and Secondary Consolidation," Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 88, No. SM6, Proc. Paper 3373, December, 1962, pp. 207-231.

[7] Hamilton, J. J., and Crawford, C. B., "Improved Determination of Preconsolidation Pressure of a Sensitive Clay," Special Technical Publication No. 254, ASTM, 1959, pp. 254-271.

[8] Terzaghi, K., "Discussion," Proceedings, 3rd Internatl. Conf. on Soil Mechanics, Zurich, Switzerland, Vol. 3, 1953, pp. 158-159.

pression. It is suggested that this is a much more influential factor than many of the other known errors of testing.

SOIL

The soil used for these tests has been generally considered a marine deposit, but recent geological work has cast doubt on earlier interpretations.[9] Its engineering properties are similar to those of the extensive deposits of "Leda" clay in the St. Lawrence and Ottawa River valleys.[10]

Uniform block samples of clay were cut from a small tunnel, in the city of Ottawa, at a depth of 33 ft. The soil on which the tests were made had a natural water content averaging 58.4%, a liquid limit of 54%, and a plastic limit of 25%. It had approximately 65% clay sized particles (< 0.002 mm), approximately 2 grams per liter of salts in the pore water, and a field vane strength of 0.5 kg per sq cm; the sensitivity was approximately 50.

TEST PROCEDURE AND APPARATUS

Most of the tests were made with vertical pressures of 0.5, 1, 2, 4, 8, and 16 kg per sq cm. Departures from this loading schedule were slight and had no apparent effect on the results. Previous tests on a similar soil, in which the load increment ratio was varied substantially, have been published.[7] Variations in procedure included daily load increments (Series A), weekly increments (Series B), and increments at the end of primary consolidation (Series C). A fourth set of tests (Series D) involved controlled rate of loading. All tests except Series B were conducted during winter at room temperature, which normally varies from 72°F to 78°F. The long term tests (Series B) were made in a controlled temperature room at 68 ± 1/4°F.

All specimens were tested in "teflon" coated stainless steel consolidation rings (with an area of 20 sq cm and either 1 cm or 2 cm high). All tests except those of Series B were done with the ring sealed to a base plate, in the center of which a 1/2-in. diameter Alundum disc was flush mounted and connected to a no-flow pressure measuring system. The top surface of the specimen was covered with a free-draining Alundum disc. In the Series B tests, pore pressures were not measured; the consolidation ring was floated between two free-draining discs. Therefore, only in Series B was the maximum length of drainage path equal to one-half the height.

Incremental loading tests were conducted in the normal manner, with an 11 to 1 lever ratio consolidation press and a load increment ratio of $\Delta p/p = 1$. The controlled rate of loading tests were made in a standard gear-driven soil compression machine with a proving ring to measure the vertical load.

Pore pressures were measured manually, using the Norwegian null-indicator device.[11] All pore pressure lines were of copper tubing, and care

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[9] Gadd, N. R., "Surficial Geology of Ottawa Map-Area Ontario and Quebec," Geological Survey of Canada, 1963, Paper 62-16.

[10] Crawford, C. B., "Engineering Studies of Leda Clay," Soils in Canada; Special Publication No. 3, Royal Soc. of Canada, 1961, pp. 200-217.

[11] Andresen, A., and Simons, N. E., "Norwegian Triaxial Equipment and Techniques," Proceedings, ASCE Research Conf. on Shear Strength of Cohesive Soils, Boulder, Colo., 1960, pp. 695-709.

was taken to flush air out of the system before each test. Because of the flexibility of the pore pressure measuring system, the maximum pore pressure was not recorded until approximately 1/2 min after each load had been applied. This apparatus characteristic limits the accuracy of measured values of pore pressure, especially the low pressures developed in the recompression range.

TEST RESULTS

As in most research with undisturbed soils, the quantity of uniform material was limited, and preliminary tests were done in order to plan the testing program. In this case, twelve tests are available on almost identical soil specimens, and each type of test proved to be satisfactorily reproducible. Test results are given in Table 1, in which the best estimate of preconsolidation pressure using the common empirical procedure[12] is indicated. Details of typical test results are shown in the illustrations presented subsequently.

TABLE 1.—TEST RESULTS

Test Series	Specimen No.	Initial Height, H, in centimeters	Length of Drainage Path	Nat. Water Content, in %	Nat. Void Ratio	Preconsol. Pressure, in kilograms per square centimeter	Loading
A	96-1-12	2	H	60.1	1.71	1.80	Daily increments
	96-1-16	2	H	57.8	1.63	1.80	
	96-1-18	2	H	57.0	1.63	1.85	
	at end of primary					2.65	
	96-1-19	1	H	59.9	1.67	2.20	
	96-1-21	1	H	59.0	1.67	1.7[a]	
B	96-1-13	2	H/2	59.4	1.69	1.40	Weekly increments
	96-1-20	2	H/2	57.3	1.63	1.33	
C	96-1-22	2	H	56.1	1.60	3.00	At end of primary
	96-1-23	1	H	57.5	1.64	2.62	
D	96-1-24	1	H	58.8	1.67	2.20	Constant rate
	96-1-25	1	H	59.0	1.67	2.47	
	96-1-27	2	H	58.5	1.67	2.47	

[a] By chance, the pressure of 2 kg per sq cm was allowed to act for 4,300 min. The additional secondary compression deflected the pressure-void ratio curve more than normal, causing a lower interpretation of preconsolidation pressure.

NORMAL INCREMENTAL LOADING (TEST SERIES A)

Specimens were loaded daily, pore pressures were measured at the lower surface, and free drainage was allowed at the top. Typical time-compression

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[12] Casagrande, A., "The Determination of the Preconsolidation Load and Its Practical Significance," Proceedings, 1st Internatl. Conf. on Soil Mechanics, Cambridge, Mass., Vol. 3, 1936, pp. 60-64.

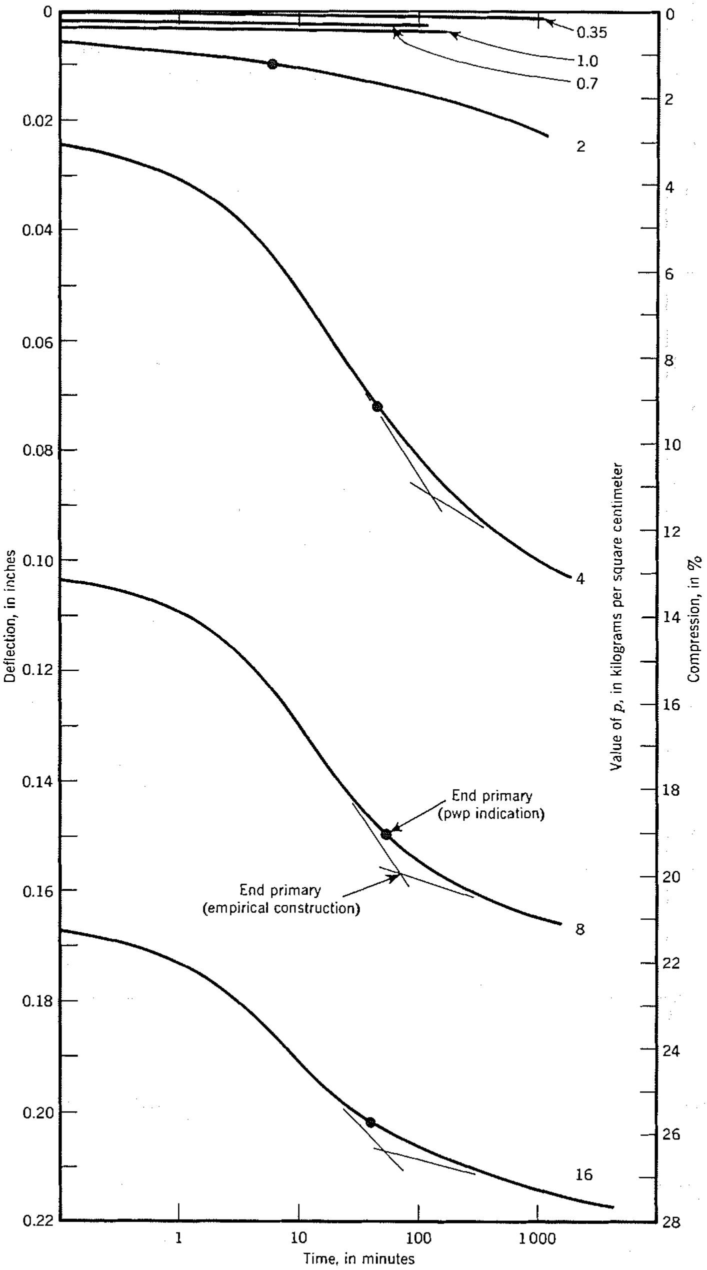

FIG. 1.—TIME-COMPRESSION CURVES: SPECIMEN 96-1-18

curves are shown in Fig. 1. In Fig. 2, the ratio of pore pressure to applied pressure is plotted in relation to deflection for the last four loading increments on specimen 96-1-18. This proves to be a linear relationship over most of the range, and by extrapolating to zero pore pressure, it is possible

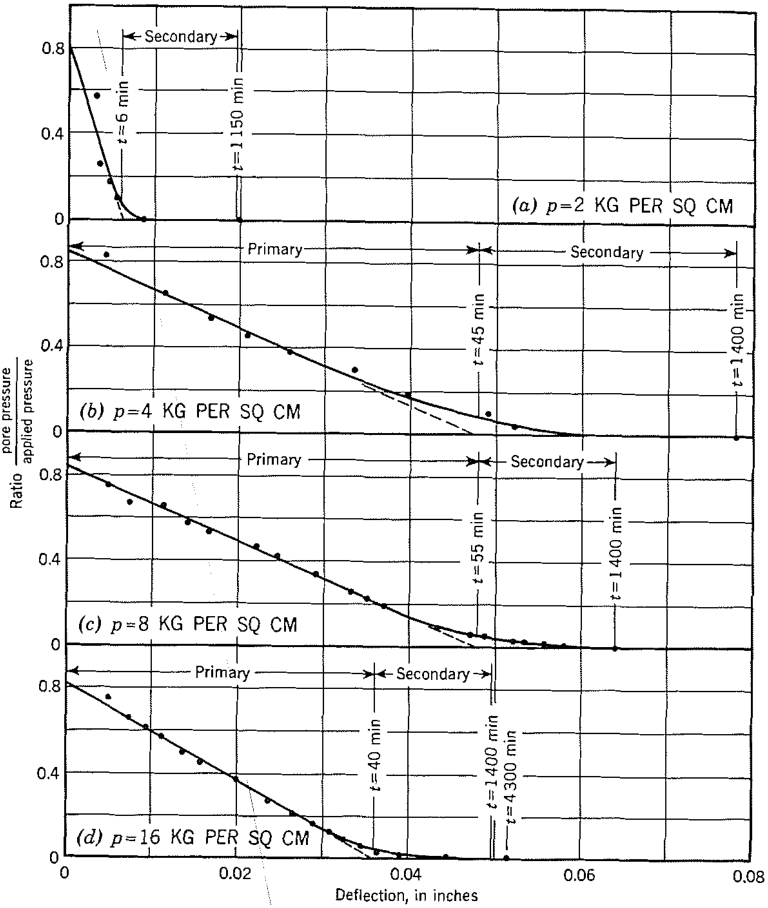

FIG. 2.—RELATIONSHIP BETWEEN PORE PRESSURE AND DEFLECTION UNDER INCREMENTAL LOADS: SPECIMEN 96-1-18

to establish a well-defined end of primary consolidation. The end of primary consolidation arbitrarily obtained in this manner is shown as a solid circle on each of the time curves of Fig. 1. It occurs somewhat earlier than that determined by the usual approximation.

The linear relationship shown in Fig. 2 resembles that reported by D. W. Taylor,[13] but recent tests of a similar soil (with pore pressure measurements by transducer) indicate more curvature and longer periods of pore pressure dissipation. This leads to greater difficulty in separating primary and secondary consolidation, but is not thought to affect the general conclusions resulting from the work reported herein. The present equipment is sufficient to suggest (by extrapolation) that 80% to 85% of each applied stress increment above the preconsolidation pressure is transmitted immediately to the pore water. This is not an unreasonable value in view of the probability of the presence of gas in the specimen and the influence of side friction.

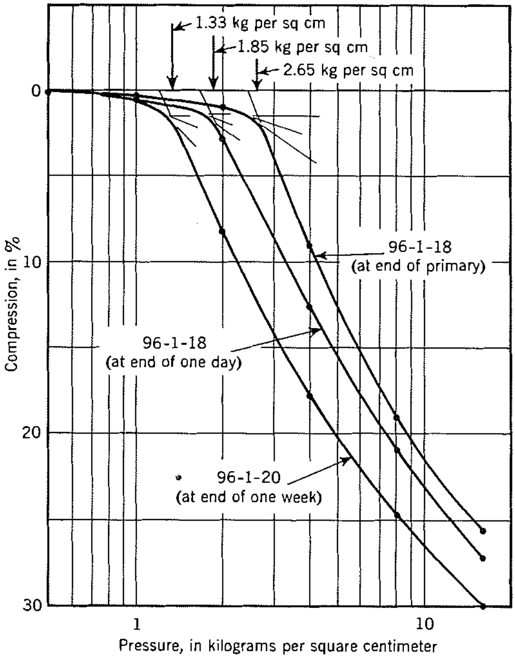

FIG. 3.—COMPRESSION-LOG PRESSURE CURVES FOR NORMAL AND LONG TERM INCREMENTAL LOADING

For comparison of tests, the percentage compression (rather than the void ratio) is plotted against the logarithm of pressure in Fig. 3. Two separate curves are shown for specimen 96-1-18. The upper curve indicates the compression at the end of primary consolidation (Fig. 2) for each pressure

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[13] Taylor, D. W., "Research on Consolidation of Clays," Serial 82, Massachusetts Inst. of Tech., 1942.

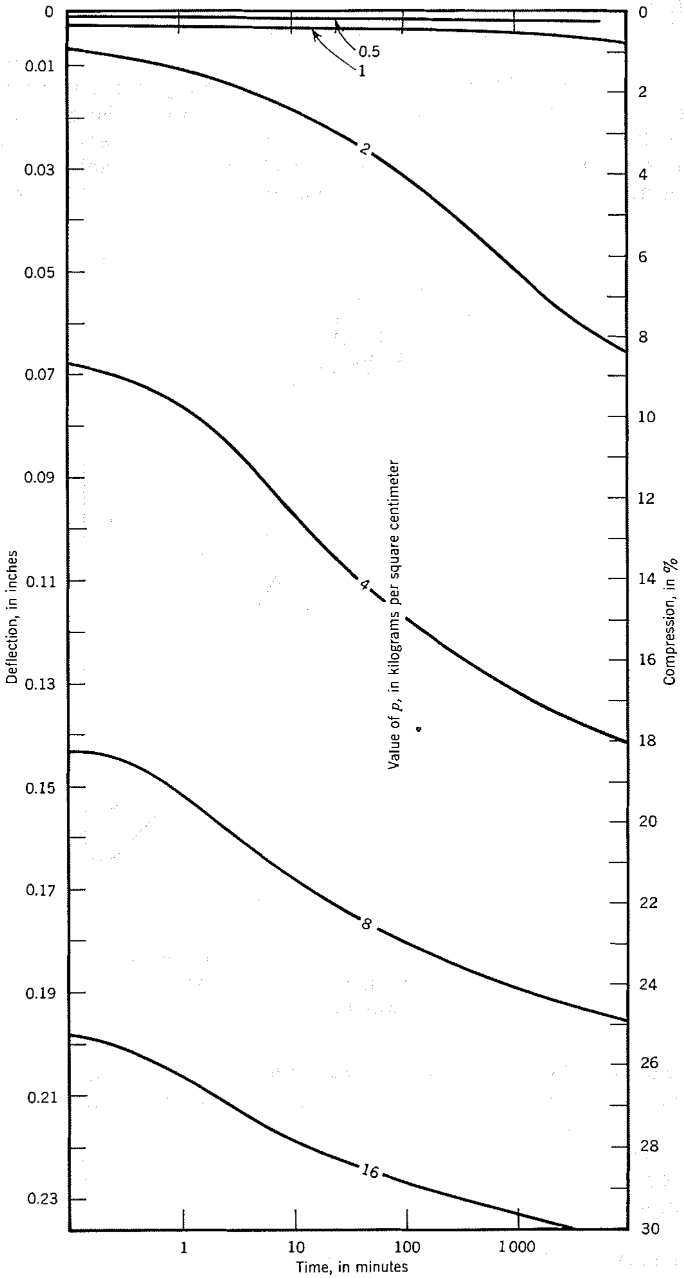
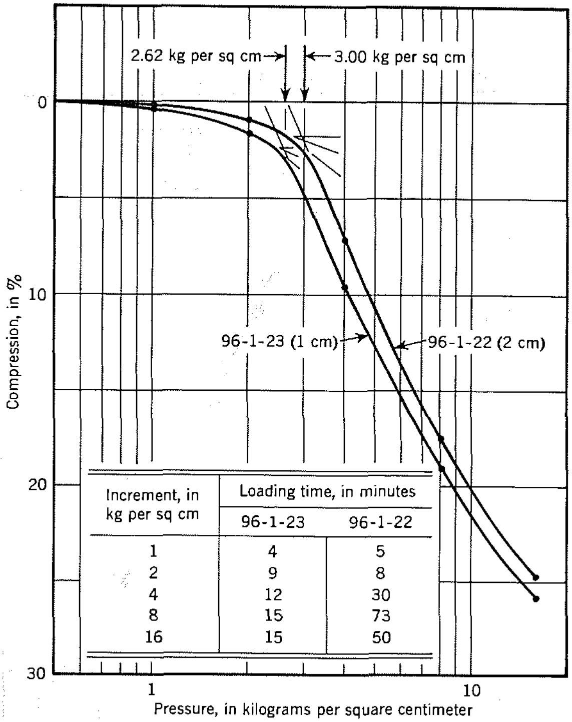


FIG. 4.—TIME-COMPRESSION CURVES: SPECIMEN 96-1-20

increment. The lower curve represents the compression at the end of loading period, in this case after one day. The difference between the two (curves) represents the secondary consolidation under each increment.

SLOW INCREMENTAL LOADING (TEST SERIES B)

Specimens were loaded in weekly increments. Because pore pressures were not measured, the specimens were allowed to drain at the top and bottom of a floating ring. Time-compression curves for one of the tests (96-1-20) are shown in Fig. 4. The other long term test (96-1-13) departed from the usual loading schedule. It was compressed under increments of 0.4, 0.8, 1.6, 3.3, 6.6, and 13.2 kg per sq cm, but the pressure-void ratio curve was almost identical to that for 96-1-20, which is plotted in Fig. 3. Comparison with 96-1-18 illustrates the increasing contribution of secondary consolidation with long increments of loading. This probably has an exceptional influence on the interpretation of preconsolidation pressure, because the 2 kg per sq



Increment, in kg per sq cm	Loading time, in minutes	
	96-1-23	96-1-22
1	4	5
2	9	8
4	12	30
8	15	73
16	15	50

FIG. 5.—COMPRESSION-LOG PRESSURE CURVES FOR SPECIMENS LOADED AT END OF PRIMARY CONSOLIDATION

cm load is near the probable preconsolidation pressure. Another feature of the Series B test is that it compressed much more, even during the first day, than did the Series A test under the same pressure of 2 kg per sq cm. The reason for this is not evident, but it may be due to the long duration of the preceding increment.

RAPID INCREMENTAL LOADING (TEST SERIES C)

Specimens were loaded in the usual increments, but, in these cases, the pressure-deflection curves were extrapolated (as in Fig. 2), and the next increment was applied at the anticipated end of primary consolidation. The pressure-compression curves are shown in Fig. 5 in which the duration of load application for each increment is noted. Below the preconsolidation load, the time required for pore pressure dissipation seems to be unrelated to thickness. For the first increment above the preconsolidation pressure (i.e., 4 kg per sq cm), the time required is approximately directly proportional

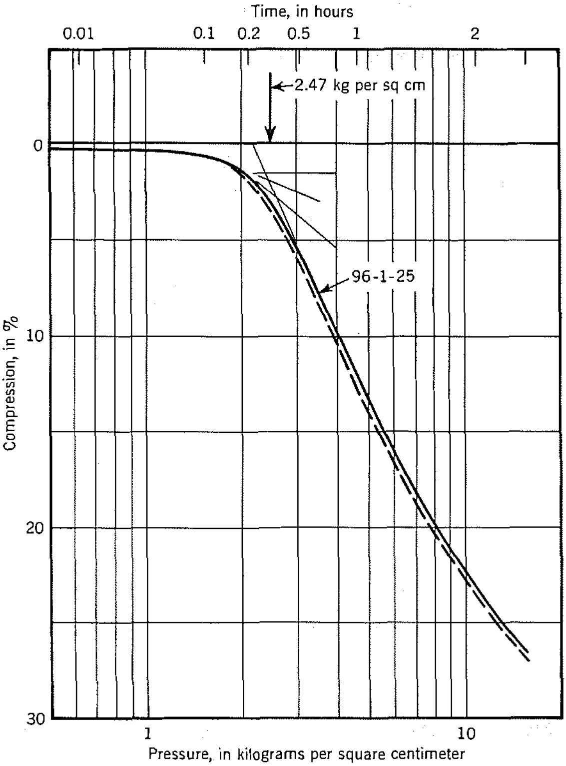


FIG. 6.—COMPRESSION-LOG PRESSURE CURVES FOR CONSTANT RATE OF LOADING

to the thickness. For the last two increments, the time for primary consolidation is approximately proportional to the square of the thickness.

CONTROLLED RATE OF LOADING (TEST SERIES D)

Test Series D was a special set of tests in which pore pressure was measured at the bottom of each specimen while it was being consolidated by continuous vertical loading. For all tests, the loading rate was set for 0.0009 in. per min, but, due to deflection of the proving ring, the specimens were compressed at approximately 4% per hr to the preconsolidation load, and then at a rate of 7% or 14% per hr, depending on specimen thickness.

The tests in this series gave almost identical pressure-deflection curves; the curve for specimen 96-1-25 is shown in Fig. 6. Maximum pore pressure at the base of the specimen was less than 5% of the applied pressure. If pore pressures are deducted from applied pressures, the broken curve in Fig. 6 is obtained. The two curves enclose the possible range of vertical effective stresses within the specimen. Specimen 96-1-27, which was twice as thick as 96-1-25, developed a maximum pore pressure equal to 8% of the applied pressure, but even this amount had little effect on the pressure-deflection curve.

In the range from 0% to 15% compression, it took specimen 96-1-27 (2 cm thick) twice as long as it took specimen 96-1-25 (1 cm thick) to compress the same amount. In other words, the specimens were forced to compress at a rate that varied directly with the thickness of specimen, and not with the square of the thickness, in accordance with classical theory; only slightly higher pore pressures were generated in the thicker specimen.

RATE OF COMPRESSION

It is difficult to compare rates of compression for specimens loaded in increments, because the rate varies greatly during the test. The virgin compression of specimen 96-1-20, for example, occurred during a 28-day period, or at an average rate of approximately 1% per day, but the actual rate varied from approximately 1% per min, during the first minute of each load application, to approximately 1% per week at the end of each loading period. The rate at the end of primary compression for this material averaged 1% per hr.

The rates of compression for the various types of test during loading from 2 to 4 kg per sq cm are shown in Fig. 7. The 1-cm thick specimen (96-1-23) has the highest rate, averaging more than 3% per min during the first minute of loading and approximately 40% per hr during the complete loading period. This high forced-rate of consolidation probably leads to an unusually high degree of disturbance. Specimen 96-1-27 was loaded at the slowest rate, a constant 7.4% per hr.

It is common practice to study the influence of compression rate by varying the size of load increment. In this manner, K. Langer[14] found that soil

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[14] Langer, K., "Influence of Speed of Loading Increment on the Pressure Void Ratio Diagram of Undisturbed Soil Samples," Proceedings 1st Internatl. Conf. on Soil Mechanics, Cambridge, Mass., Vol. 2, 1936, pp. 116-118.

was less compressible under small load increments. Langer attributed this to two factors: (1) Large increments caused a shock to the soil structure; and (2) the induced pore pressure gradients caused internal rupture of the structure. Taylor[13] reported that consolidation proceeded at a slower rate when load increments were small, and after extensive study, he concluded that predictions of settlement are likely to be seriously in error when load increments in the field and in the test are not similar. Field loading is seldom applied in increments, and a further study of this factor is warranted. It is necessary, however, to keep in mind that two properties, in particular, control the rate at which compression can occur; these are: (1) The permeability of the soil; and (2) the plastic resistance of the soil structure.

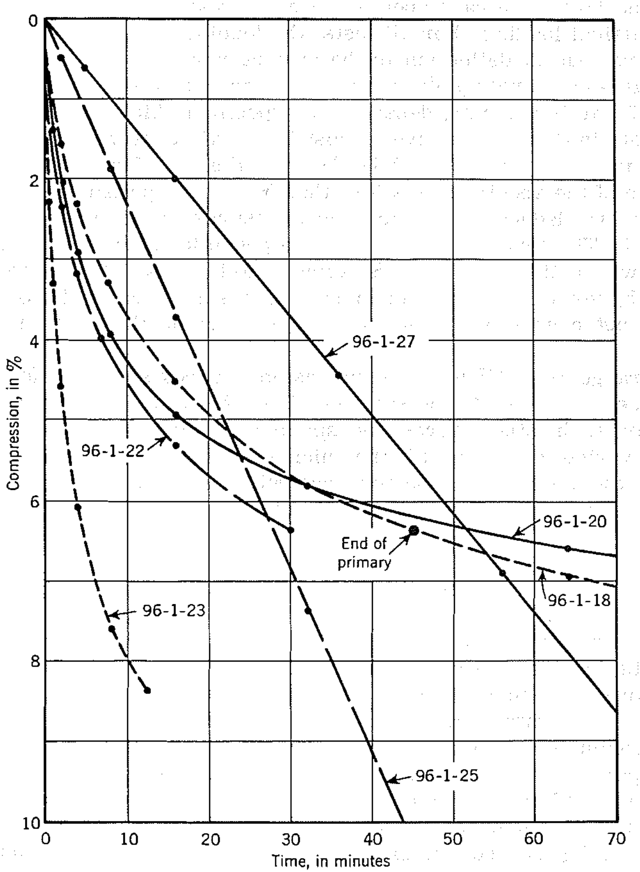

FIG. 7.—RATE OF COMPRESSION WITH VARIOUS METHODS OF LOADING WHEN LOADED FROM 2 TO 4 KG PER SQ CM

According to the Terzaghi theory, the coefficient of consolidation varies directly with the permeability and inversely with the compressibility of the structure. It follows that substantial pore pressures will be created by large load increments, and that hydrodynamic effects will control the rate of compression. When increments are small, however, the pore pressure gradients will be small, and the plastic resistance of the soil structure will have a relatively greater effect. G. A. Leonards and B. K. Ramiah[15] demonstrated this experimentally and concluded that ". . . the coefficient of consolidation obtained from any particular laboratory test is purely arbitrary and can vary significantly from the value that would obtain in the field."

The compression index and the empirical preconsolidation pressure do not depend on soil permeability; they depend only on the compressibility of the soil structure. For most clays, the structure continues to deform indefinitely under a constant effective stress, but as long as each load increment is maintained for the same time interval, the compression index appears to be relatively unaffected by this characteristic. R. D. Northey[16] found that specimens, reloaded at the end of primary consolidation, gave a satisfactory evaluation of the compression index, and similar tests reported herein (Series C) confirm this.

For the soil specimens described herein, the empirical preconsolidation pressure is greatly affected by the loading procedure. According to Table 1, the preconsolidation pressure based on normal test procedure (daily loading) is approximately 1.8 kg per sq cm, but, by varying the procedure, values ranging from 1.3 to 3.0 can be obtained. It is evident that the lower values are associated with large amounts of secondary consolidation. This may be due partly to structural damage caused by the shock of large load increments (as suggested by Langer), but the rate of loading is undoubtedly an important factor. Insufficient field observations have been made to establish which of the laboratory tests is correct, but field evidence is being gathered at every opportunity in order to assess these factors.

LABORATORY RATE COMPARED TO FIELD RATE

The laboratory rates of compression are all considerably faster than known field rates. The maximum for Leda clay, under the heavily loaded National Museum in Ottawa, for example, was only 1/2% per yr.[17] Compression of Leda clay under an earth fill[18] is occurring at the maximum known rate, approximately 1% per yr. When specimen 96-1-23 was loaded from 2 kg to 4 kg per sq cm, it compressed 1% in one tenth of a minute, or approximately

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[15] Leonards, G. A., and Ramiah, B. K., "Time Effects in the Consolidation of Clays," Special Technical Publication No. 254, ASTM, 1959, pp. 116-130.

[16] Northey, R. D., "Rapid Consolidation Tests for Routine Investigations," Proceedings, 2nd Australia-New Zealand Conf. on Soil Mechanics, Christchurch, N. Z., 1956, pp. 20-24.

[17] Crawford, C. B., "Settlement Studies on the National Museum Building, Ottawa, Canada," Proceedings, 3rd Internatl. Conf. on Soil Mechanics, Zurich, Vol. 1, 1953, pp. 338-345.

[18] Eden, W. J., "Field Studies on the Consolidation Properties of Leda Clay," Proceedings, 14th Canadian Soil Mechanics Conf., Assoc. Committee on Soil and Snow Mechanics, Natl. Research Council, Ottawa, Canada, 1960, No. TM 69, pp. 107-118.

five million times as fast as the maximum field rate. The maximum field rate is only approximately 1/50 of the rate of secondary compression after a load increment has been maintained for a week. Obviously, if rate of compression affects the compressibility of the soil, the risk of extrapolating laboratory test results to actual problems is great. The estimation of permeability from consolidation testing is particularly suspect, because of the rapidity of loading required to produce pore water pressure in a small element of soil.

The confusion that can result from the concept that primary and secondary consolidation are separate components of total compression is demonstrated by Figs. 5 and 6. The specimens shown in Fig. 5 have experienced primary consolidation only (positive pore pressure throughout the test); the test shown in Fig. 6 has, according to the usual definition, experienced secondary consolidation only (pore pressure virtually zero throughout). The two types of test were conducted at approximately the same average rate of strain, but the Series C tests (Fig. 5) were subjected to a wide variation in rate, and the compression curve appears to be less reproducible.

These observations lead to the belief that further development of consolidation theory is being inhibited by preoccupation with an unrealistic primary consolidation, which is artificially induced in the laboratory and unrelated to that in nature. A change in experimental technique may lead to more fruitful research results.

SUGGESTED REVISION TO CONSOLIDATION ANALYSIS

Fundamentally, a saturated, undisturbed clay soil is a complex arrangement of solid particles, held together by interparticle forces, with its void spaces full of water. The structure so formed resists compression and deformation. According to Taylor,[13] it has a plastic resistance that depends, in magnitude, on the rate of compression. In the ordinary laboratory consolidation test, the relationship between deformation and applied load is masked by unknown pore pressures, which depend on certain test conditions.

The suggestion is made herein that the laboratory consolidation test be conducted at a steady rate of compression, sufficiently slow to prevent development of significant pore pressures. This would be similar to a drained triaxial compression test, except that lateral strain is prevented. Such a test should provide a more realistic evaluation of soil compressibility by avoiding the impact and the extremely rapid rates of strain caused by incremental loading. Research could then be extended into a more realistic range of loading rates.

This method will not permit direct estimations of field rates of consolidation, but the best predictions could probably be made by estimating the field pore pressures in the manner described by A. W. Skempton and A. W. Bishop[19] and by T. W. Lambe[20] or by the method of Skempton and L.

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[19] Skempton, A. W., and Bishop, A. W., "The Gain in Stability Due to Pore Pressure Dissipation in a Soft Clay Foundation," Proceedings, Cinquième Congrès des Grands Barrages, No. R. 57, Paris, France, 1955.

[20] Lambe, T. W., "Pore Pressures in a Foundation Clay," Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 88, No. SM2, Proc. Paper 3097, April, 1962, pp. 19-47.

Bjerrum,[21] and then estimating the rate of dissipation under field conditions. In this manner, the changes in effective stress could be computed and related to corresponding changes in volume and shearing resistance.

CONCLUSIONS

1. There is substantial field evidence that the prediction of consolidation settlement from laboratory tests is not always satisfactory.
2. Much of the difficulty in predicting consolidation settlement from laboratory tests may be due to the great differences between rates of compression in the laboratory and in the field. It is shown that, in order to create a hydrodynamic effect, the laboratory rate may be as much as several million times as fast as the field rate.
3. The measurement of the preconsolidation pressure of uniform undisturbed specimens of Leda clay is satisfactorily reproducible (± 10%) by each of several specific test methods.
4. The variation in the preconsolidation pressure, however, is from 1.3 kg to 3.0 kg per sq cm, depending on the loading procedure in each test. Much of the difference can be attributed to differences in secondary consolidation, according to the usual definition.
5. Pore pressure measurements, extrapolated to zero deflection, suggest that the maximum pressure developed in the specimen is 80% to 85% of the applied load, and that this pressure dissipates as a direct function of deflection. Primary consolidation, by direct measurement, is found to be completed a little earlier than suggested by empirical methods.
6. Ordinary laboratory specimens of this clay can be compressed by as much as 25% in a few hours, either with or without the development of substantial pore pressures. Pressure-void ratio curves in the two cases are similar, but, by the usual definitions, the compression in one case is all primary, and, in the other, it is all secondary.
7. The division of consolidation into primary and secondary components is shown to be an arbitrary separation of a continuous compression process, and the relative contribution of each depends on the method of loading.
8. It is suggested that more attention be given to measurement of the pressure-compression characteristics of a soil independent of hydrodynamic time lag. These characteristics should be investigated at rates more compatible with field cases.

The test results presented herein illustrate the substantial influence of rate of testing on the confined compression characteristics of an undisturbed clay. The great difference between laboratory and field rates of consolidation suggests the need for further study of this obviously important test

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[21] Skempton, A. W., and Bjerrum, L., "A Contribution to the Settlement Analysis of Foundations on Clay," Geotechnique, London, England, Vol. 7, No. 4, 1957, pp. 168-178.

variable. However, any consolidation theory developed in the laboratory must be evaluated by field observations.

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KEY WORDS: clay (materials); consolidation; settlement; soil mechanics; strains; testing

ABSTRACT: To create significant pore water pressure in a tiny test specimen of clay, it must be loaded with large increments. This causes the specimen to compress at rates to several million times the rate for an equivalent element of soil in the field. A laboratory investigation of compression rates, under incremental and continuous loading, showed that the compressibility of an undisturbed sensitive clay was greatly influenced by the rate of compression. These rapid tests gave pressure-compression curves similar to those for identical specimens, and demonstrated that the relative contributions of primary and secondary consolidation is a function of test procedure. When compared with long duration incremental loading tests, however, they revealed a much higher preconsolidation pressure and less compressibility. It was therefore concluded that the influence of compression rate may be important in the interpretation of consolidation tests and warrants more attention and research.

REFERENCE: Crawford, Carl B., "Interpretation of the Consolidation Test," Journal of the Soil Mechanics and Foundation Division, ASCE, Vol. 90, No. SM5, Proc. Paper 4056, September, 1964, pp. 87-102.