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Rapid Determination of Soil Consolidation Parameters

Study SD92-08
Final Report

Prepared by
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16. Abstract

This work developed, installed and verified a system to accelerate incremental consolidation testing on soils. The final system meets the requirements of AASHTO T-216. The completed system reduces elapsed time required to run an incremental consolidation test from ±3 weeks to ±3 days and the man time from ±20 hours to ±2 hours.

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Table of Contents

Problem Statement

The South Dakota Department of Transportation Geotechnical Laboratory has several pneumatic consolidometers used to measure the consolidation characteristics of soils. These devices require considerable man time and elapsed time to run tests. A typical test might require 10 to 20 man hours and 2 to 3 weeks of elapsed time to complete. Due to limitations in man power and available time for projects, the Geotechnical Lab is unable to perform the desired amount of testing required for good highway design procedures.

SDDOT Geotechnical Lab desired to develop an accelerated consolidation test procedure that provides results with eight hours, or less, of man power. This system should provide results that correlate with the AASHTO T-216 standard.

The final research product should be a self-contained system that SDDOT Geotechnical Lab staff could use to perform accelerated consolidation tests. The purpose of this research was to develop and provide a working system to meet SDDOT's requirements.

Background Summary

The conventional consolidation test is widely used in highway engineering to obtain data with which to predict the magnitude and rate of settlement for foundations of highway facilities. The conduct of this test has changed little in the 60 years since its original conception by Terzaghi (1927) and refinement by Casagrande. The conventional test requires two to three weeks of elapsed time to run and 10 to 20 man hours to obtain, reduce and report the test results.

In the conventional consolidation test, a technician applies a small vertical stress to an undisturbed sample of soil that is 1 inch high and 2 to 4 inches in diameter placed inside a rigid ring. The load causes water to be squeezed out of the soil and the sample decreases in thickness at a gradually diminishing rate. Readings of vertical displacement are taken with time to an accuracy of 0.0001 inch. When the rate of displacement becomes small, another load increment is applied and displacement readings are taken. This process is repeated through 6 to 10 increments of increasing load, followed by 2 to 5 increments of decreasing load. Displacement readings are plotted versus time to determine soil parameters that characterize the magnitude and rate of consolidation.

Most consolidation testing performed today closely follows this process. The only significant variation is the mechanism for applying the load. Most devices use weights and various lever mechanisms to apply a constant vertical stress to the specimen. In recent years new devices which use air pressure acting on a piston to apply a constant vertical stress have appeared. One such device is the Karol Warner Model 350 consolidometer presently used by SDDOT.

These variations do not change the man time and elapsed time required to run the test. One must still wait for consolidation to finish for each load increment. Even though consolidation for an increment may be completed in a few hours, it is not feasible to have a person available to record data outside the standard 8 hour work day. As a practical procedure, most laboratories have standardized on a 24 hour time period for each load increment. This standardized procedure results in 5 load increments per week.

The elapsed time and man time required by the test can be reduced significantly by using an automatic data recorder to record readings. Adding this equipment allows one to record data during night time and weekends without having personnel available. The elapsed time required for the test can be reduced by 50 to 75%. Similar savings in man time are achieved. Such systems have been employed by the Departments of Transportation for North Carolina, Florida, Wyoming, Washington, California and others. Commercial systems are available from Wykeham Farrance, ELE, GEOCOMP Corporation and others to add automatic data recording and reduction to existing consolidation equipment.

An automatic data recorder and reporting system based on a personal computer together with instrumentation could be added to SDDOT's existing Karol Warner consolidometers in a turnkey fashion for $20,000 to $30,000. The resulting system would automate data collection and processing for all existing consolidometers. A technician would still add each load increment but two to three load increments could be added each day. However this system would still require several days to complete each test. Therefore adding a data acquisition system to the existing consolidometers would not meet the research objective of completing a test in a much shorter elapsed time.

Completing a consolidation test very rapidly requires a departure from the conventional incremental consolidation test procedure where load increment durations are typically 24 hours each. One must employ some system which constantly changes the vertical load so as to increase the rate at which consolidation occurs over the duration of the test. One of the first such systems was the constant rate of strain consolidation test developed by Hamilton and Crawford (1959). In this test, the specimen is compressed at a constant rate of deformation. Excess pore pressures are generated in the sample because insufficient time is allowed for complete consolidation. These excess pore pressures are measured and used in a theory to calculate consolidation properties for the specimen. This approach requires use of a cell to contain the sample which can be pressurized because reliable excess pore pressures must be measured.

Another rapid consolidation test is the constant gradient test developed by Lowe et. al. (1969). In this test, vertical load is applied at a rate to maintain a constant gradient across the sample. Consolidation theory allows one to use data from this test to obtain the conventional soil parameters for design.

Other systems employing constant rate of vertical loading and constant ratio of excess pore pressure to total vertical stress have been developed and demonstrated (see Armour and Drnevich (1985), von Fay and Cotton (1985), Silvestri, et al (1985), Crawford (1964), Wissa et al (1971), Gorman et al (1978), Leroueil et al (1983) and Janbu et al (1981)). Each of these approaches has the potential to meet SDDOT's objective of completing a consolidation test in a much shorter time.

Constant rate of consolidation systems are somewhat more complex and require more equipment than incremental consolidation tests. Their routine application was hindered for many years by the large expense of the automatic loading systems and the need for an automatic data recording system, both of which were quite expensive and unreliable. Recent developments in microcomputers and associated electronics have greatly reduced the cost of automatic loading and data recording systems.

In 1985 GEOCOMP Corporation contracted with the US Army Corps of Engineers to provide them with an automated incremental consolidation test system. The objectives of this system were to reduce the man-time required to run a consolidation test, automate the data processing of the test results and improve the reliability of the testing system. This system is based on moving a platen up and down by a computer driven motor to develop and maintain the required stress on the sample. Vertical displacements are monitored. When the displacements decrease to a small value, the load is automatically changed by the system. One of these LoadTrac systems can complete an incremental consolidation test on most soils in one to two days of elapsed time.

This same system has since been modified to perform constant rate of strain, constant gradient and constant rate of loading consolidation tests. Experience with this system has shown that a complete consolidation test can be completed in 6 to 12 hours after the specimen has been saturated by backpressuring.

We proposed that the SDDOT objective of reducing the man time required per consolidation test to less than 8 hours and performing the test according to AASHTO standards could be best met by modifying a standard LoadTrac unit for incremental consolidation testing. These modifications would consist primarily of changing the existing system to make it conform to the AASHTO standard.

Objectives

The objective of this research was to develop, verify and install one accelerated consolidation test system at the SDDOT Geotechnical Lab and familiarize the Lab personnel with its use. This system should have the potential of completing a standard consolidation test on most soils with less than 8 hours of man time. The delivered system should include provisions to automatically compute conventional consolidation test parameters. It should give results which agree with those obtained with the AASHTO T-216 standard test.

Research Results

SDDOT's research objective could be most easily and economically met by adapting one of GEOCOMP's standard LoadTrac units for incremental consolidation testing. The standard system required the following modifications:

- Change portions of control software to conform exactly to AASHTO T 216-83 standard.
- Modify reporting software to meet requirements of AASHTO T 216-83 and SDDOT.

Running an incremental consolidation test in which the load is automatically changed shortly after complete primary consolidation (e_{100}) is reached may produce a different result than one obtains with tests than use a fixed time interval of 24 hours per increment. AASHTO T 216-83 procedure allows the more rapid procedure. In fact, AASHTO T 216-83 describes in detail steps to remove secondary compression from tests that are run with load increment durations greater than required for primary consolidation. For operational reasons, many laboratories use a fixed time interval of 24 hours. As a part of our effort, we have run a series of tests on three soils provided by SDDOT and tests on several other soils using both approaches to determine the difference produced by the two procedures. The results from these tests together with other published data are discussed in this report to demonstrate the validity of data obtained with shorter load increment durations.

We have completed seven tasks to accomplish the research objectives. The activities and results for each task are summarized in the following.

Task 1: Summarize literature and DOT experience related to rapid consolidation testing

The primary difference between the test procedure used in the new equipment and the previously used procedure is in the duration of each load increment. Conventional practice is to maintain each load increment for 24 hours. The new equipment changes the load increment at some short time after the completion of primary consolidation (i.e., e_{100} is reached). This typically leads to durations for each load increment of 1 to 4 hours.

Several engineers have examined the effect of duration of load increment on results of incremental consolidation tests. In the earliest study of this effect, Newland and Allely (1960) found that e_{100} did not depend on whether loads were applied at e_{100} or at 24 hr. Hansen and Inan (1969); Walker (1969); and Andersland and Mathew (1973) reached the same conclusion. Bjerrum's (1967) model for long-term settlement implicitly assumes that the primary compression curve is independent of the time allowed for secondary compression in any load increment.

Olson (1985) in his state-of-the-art review of consolidation testing stated that his experience has shown e_{100} to be independent of earlier secondary compression, provided that secondary compression under one pressure does not exceed primary compression under the next load. Figure 1 reproduces one of his figures for consolidation tests on Atchafalaya Clay. It shows no significant difference between a test run with 24 hour load increments and one loaded at the end of primary consolidation. Olson (1993) reports that it has been standard practice in his laboratory class for several tests to have students run tests of this type to demonstrate that no practical difference results from the different loading times.

Crawford (1985) states that variations in test procedure in incremental tests can have a considerable effect on maximum past pressure, especially for soft sensitive clays. The compression index appears little effected by these test variations. His conclusion seems in conflict with that of others and he doesn't cite particular data or references to support this conclusion. In fact one of his figures for Olga Clay, recreated in Figure 2, shows no practical difference. Our assessment is that Crawford's conclusion may have been overly influenced by his experience with soft sensitive clays where there is evidence of load increment duration affecting the value of maximum past pressure.

Mesri and Choi (1985) conclude that there is a unique end of primary e-log p' curve for any soft clay and the rate of compression is of no consequence.

Jamiolkowski et al (1985) in their general report to the 11th International Conference on Soil Mechanics and Foundation Engineering concluded that standard 24 h incremental consolidation tests yield values of maximum past pressure generally 10% lower than end of primary curves due to the increased strains resulting from secondary compression. They concur with Mesri (1984) that it is conceptually more correct to use end of primary consolidation rather than 24 hr curves from oedometer tests, even though the difference is generally less than 10 to 20%. Their statement seems to accurately reflect the currently accepted view with a possible exception of some sensitive clays.

Figure 3 shows an idealized portrayal of consolidation behavior in clay. This portrayal was first presented by Bjerrum (1967). Vertical strain is shown as a function of log of effective vertical stress. The vertical axis could be void ratio instead of strain and the description would be the same. The upper most curve shows the relationship between vertical strain and vertical effective stress for the end of primary consolidation. If we consolidated different specimens of this clay to different vertical stresses, at the end of primary consolidation all points should fall on the end of primary line. With time after the end of primary consolidation, secondary consolidation (consolidation under a constant effective stress) occurs. This increases the vertical strain for the same vertical stress. If after finishing primary consolidation, we left our test specimens for 24 hours, we would find strains corresponding to those on the line labeled "24 hr increments" in Figure 3. The longer we allow secondary compression to occur, the lower the line relating stress and strain goes.

Figure 4 illustrates how this idealized consolidation behavior is manifested in an incremental consolidation test. Suppose we apply a vertical stress of 2 tsf. At the end of primary consolidation, we will be at point A. But we wait for 24 hours. The specimen undergoes secondary consolidation to come to point A'. Bjerrum (1967) showed that when we apply the next load, the sample first moves along a reloading curve until the end of primary curve is reached. Then it continues along the end of primary curve. The sample reaches the end of primary curve at 4 tsf at point B, regardless of whether it started the increment from point A or point A'. The recompression that occurs is a function of the rate of secondary consolidation. The amount of recompression will have some effect on the plots of consolidation versus time for each load increment. However, for practical purposes, this effect is small unless the soil has an unusually high rate of secondary consolidation or load increments are left for unusually long durations.

Figure 4 shows that we will get the same compression ratio whether we use durations of "end of primary" or 24 hours or any other value greater than end of primary. The key point is that we should be consistent among the load increments.

Some engineers argue that data for all consolidation tests should be plotted as the strain at the end of primary consolidation versus log of vertical stress. For load increments which last longer than end of primary, the strain resulting from secondary compression should be removed. The result is a relation between primary consolidation strain and vertical stress that is used to predict primary consolidation. Strain from secondary consolidation is then computed separately.

Turning to the effect of duration of load increment on the rate of consolidation, the literature shows that effects do exist. Leonards and Girault (1961), Leonards and Altschaeffl (1964), and Raymond (1966) looked at the effect of duration of secondary compression under one pressure on the shape of the primary time-settlement curve for the next pressure. The reduction in void ratio under one pressure lowers the e-p' point below the virgin compression curve. The next load initially involves a nearly horizontal reloading portion with a correspondingly high c_v. For a small load increment ratio, primary compression may conclude almost at once and nearly all the settlement may appear to be due to secondary effects. For a larger load increment ratio, where the soil strains out onto the virgin curve, one obtains the more usual primary consolidation time curves. Olson (1985) reported that when considerable secondary compression was permitted under one pressure, the settlement versus square root of time curve for the next load was often concave downwards, whereas when they loaded quickly, the settlement versus square root of time curve was always linear and fitted Terzaghi's theory well. The earliest observations of such behavior date back to the 30s. Olson concludes that it is clear that secondary compression under one pressure influences the primary compression curve for the next load.

From our review of the literature we conclude the following:

Except for some sensitive clays, the duration of load increment will affect computed maximum past pressure by less than ±10-20%. The effect on compression ratio (C_c / $1+e_0$) and recompression ratio (C_r/ $1+e_0$) will be even less. Considering the natural variation in maximum past pressure and compressibility indices, these effects are relatively unimportant.

Duration of load increment may affect time rate of settlement curves. When determining rate of consolidation from incremental consolidation tests, consideration must be given to the possible effects of load duration on the computed rates of primary and secondary compression.

Task 2: Modify LoadTrac system to follow AASHTO T216-83 procedure.

This task involved modifications to existing test control software so that a test can be run according to the specific requirements of the AASHTO test standard. The modifications were relatively minor. They were primarily surficial changes to indicate that the test was performed according to AASHTO standards and provisions to record data for each increment at the times specified in the AASHTO standard.

Task 3: Modify software to process and report test results following AASHTO guidelines and SDDOT requirements.

Sample outputs of the software were provided to SDDOT for their review and comment. No substantive changes were required. Changes requested by SDDOT were made to step-by-step instructions for running a test and to instructions for reporting test results.

Task 4: Run consolidation tests to verify system

GEOCOMP proposed to run up to 6 sets of tests on samples provided by SDDOT. Each set would consist of 2 tests. One test would use 24 hours per load increment. The other test will automatically change to the next load 1 hour after primary consolidation was complete.

During the course of the research SDDOT engineers raised the question of how results from the new equipment would compare with those they obtained in the Karol Warner equipment. Together, we decided to run the tests with 24 hour duration in the Karol Warner equipment. SDDOT shipped us one of their KW cells and four tubes containing undisturbed samples. One of the tubes contained a very stiff, dessicated sample with gravel that was very difficult to trim for consolidation tests. After several attempts to trim test specimens, we abandoned this tube.

We also performed comparison tests on two tubes from a Maine marine clay and obtained other comparison tests on two Midwest clays. A total of 23 tests using different load increment durations and test equipment were examined. Table 1 summarizes these tests. Four tests were discarded because of considerable differences in initial void ratio from other tests in the test series. An equipment failure occurred in one test.

Figures 5-11 show compression curves for tests on the same sample. Figure 5 shows two tests performed on tube #1 from SDDOT. The test with 24 hour duration shows more compressibility than the one loaded one hour after the end of primary; however the difference in the two compression curves is more like one would expect for differences in the specimens rather than differences in load increment duration.

Figure 6 shows the compression curves for tests performed on tube #2 from SDDOT. Tests C3 and C5 compare LoadTrac results to Karol Warner results with both using 24 hour durations. The results are essentially the same as we would expect. Test C6 used a short duration and gave slightly less compression; however note that its initial void ratio was also less than the other two samples.

Figure 7 shows the compression curves for tests performed on tube #3 from SDDOT. All tests were run in LoadTrac. Tests NC-2 and NC-3 have similar load increment durations but give somewhat different compression curves. The test specimens have different initial void ratios. These three samples were adjacent to each other from the same tube. Given the different initial void ratios, we believe that the different compressibilities are due to sample variation and not to load increment duration.

Figure 8 shows the compression curves for tests performed on a marine silty clay from southern Maine. This material consolidates relatively quickly. One test was run with loads increased two hours after the end of primary consolidation. The other was loaded within minutes after the end of primary consolidation in a SoilTest dead weight device. The results are similar for practical purposes. The difference in the two results is the opposite of what one would expect if there was an effect of load increment duration. The difference is more consistent with differences in the two samples as suggested by the difference in the initial void ratio.

Figure 9 shows the compression curves for tests performed on a deeper sample of the marine silty clay from southern Maine. One test was run in LoadTrac with 24 hour durations and the other was loaded two hours after completion of primary consolidation. There is a difference in the compression curves at intermediate stresses but similar strains by the time the stress reaches 16 tsf. This behavior is most likely sample differences as well, even though the specimens are within inches of each other.

Figure 10 shows the compression curves for tests on a stiff clay from the midwest. All tests were performed on specimens from the same tube. The relatively small difference in results is better correlated to differences in initial void ratio than to load increment duration.

Figure 11 shows the compression curves for tests on another stiff clay from the midwest. Again all tests were performed on specimens from the same tube. Here the results for three different load increment durations are virtually identical.

Table 2 summarizes compression data for all tests, except the discarded ones. Appendix A gives detailed data for these tests. Table 2 shows compression ratio, recompression ratio, and maximum past pressure. Compression ratio is the slope of the strain versus log of vertical stress curve in virgin compression. Recompression ratio is the slope of the strain versus log of vertical stress plot for unloading. In this report we use the rebound for one log cycle of stress to determine the recompression ratio. Maximum past pressure was determined by Casagrande's method. Table 2 also contains columns labeled "Difference, %." These values are the difference of a particular measurement from the average of all measurements determined on the sample, except the discarded tests. If there is an effect of load increment duration, one would expect a consistent trend in the % Difference columns, i.e. the maximum past pressure for 24 hour durations would always be higher or lower than those for short durations. No such trends are evident in Table 2. The maximum past pressure for 24 hour durations seems as likely to be higher than that from tests with short durations as it is to be lower.

One can also examine these data more directly by comparing changes in strain for a fixed change in stress. This avoids the extra discrepancies introduced by the fitting techniques used to determine consolidation parameters. Table 2 shows the strain that developed for increasing the vertical stress from 1 tsf to 4 tsf. This increase corresponds approximately to placing 50 ft of fill over each of these soils. As with the compression parameters, there is no consistent effect of load increment duration on strain.

It is our opinion that sample variation, and not load increment duration, accounts for most of the variability shown in Table 2. This is illustrated with tests C3, C5 and C7. There is more difference in C3 and C5, which have the same load increment duration, than there is between C3 and C7. Similarily for Midwest Clay #1, there is scatter amoung the various tests on samples from the same tube. There is clearly a correlation of compressibility with initial void ratio but no clear effect of load increment duration.

With the exception of maximum past pressure for tests NC-1 and NC-3, CR for M1-7, and RR for M1-4, all measures of compressibility are within ±20% of the mean values. This is consistent with the scatter one would expect from differences in test specimens.

Tables 3 to 6 examine the time compression curves for several of the test sets. These tables give the time for 50% primary consolidation obtained from curve fitting using the square root of time method and the log of time method.

Table 3 gives results for tests on tube #1. The limited data indicate the usual result that T_{50} from the square root of time fitting method is less than that obtained from the log of time fitting method. While the T_{50} values for the shorter duration are less than those for the 24 hr test, the difference is no more than one would expect from soil variability.

Table 4 gives results for tests on tube #2. Comparing results for the three tests at any common stress, we obtain quite good agreement for practical purposes. Comparing data for C3 and C6, we see no more difference in the times from fitting than we might expect to see on two identical samples.

Table 5 gives results for tests on tube #3. The question marks indicate that a good fitting could not be obtained from the data. The consolidation times for the shorter duration are significantly less than those for the 24 hr duration. This is also the test series with the largest difference in maximum past pressure. Since the direction of the difference in maximum past pressure is just the opposite of what is expected if load duration has an effect, we conclude that the differences in the two tests are due to sample variation.

Table 6 gives results for tests on Maine #2. These two tests had virtually identical initial void ratios and water contents. The compression parameters were very similar for two different load increment durations. Table 6 shows that the consolidation times are also quite similar with no consistent effect of duration.

We conclude that the effect of load increment duration on time for primary consolidation is insignificant compared to the effects of sample variation. Coefficients of consolidation computed from tests run to the end of primary are as reliable as those determined from tests with 24 hour load increment durations.

Task 5: Prepare user's guides and draft final report

A user's guide was prepared which describes the mechanical and electrical aspects of the system. It also provides step-by-step instructions for operating the system, setting up a sample for testing and performing a test.

A draft final report was prepared and submitted to SDDOT for review. This final report incorporates comments received from that review.

Task 6: Provide training session and follow-on technical support

The final system was shipped to SDDOT in late November. A one day training session was given to SDDOT personnel in its use. The final system included the following items:

- One LoadTrac incremental consolidation system including force transducer, displacement transducer, analog-to-digital conversion card and associated electronics, installed and operational to include Speed Ware 486 33 MHz computer with math coprocessor and 4 MB of RAM, 120 MB hard disk, 5.25" floppy disk, 3.5" floppy disk, super VGA graphics card and color monitor, Logitec tracball.
- Uninterruptable power supply to provide 30 minutes of backup power for entire system.
- One consolidation cell to fit the LoadTrac load frame with a sample diameter of 2.5 inches and a sample height of 1 inch.
- Accessories to consolidation cell to accommodate sample with 2 inch diameter and 1 inch height.

Task 7: Provide final report

This final report incorporates comments from SDDOT's review as well as additional information gained from Task 6.

Implementation

Implementation of the results of this research will be primarily through the use of the equipment by SDDOT personnel to run tests and provide data for better foundation design. Based on our prior experience with equipment of this type and the results from the comparison tests we have run on soils provided by SDDOT, we believe the delivered system will provide quality results in less time with less man-time. We have found from experience that this success generally increases the use of the laboratory facilities by highway engineers once they realize they can obtain quality results in a short time.

Success on this project will be helpful to other state DOTs who have similar consolidation equipment and shortage of manpower. Many states have geotechnical laboratories which are presently under-utilized because of manpower limitations.

The delivered system meets the AASHTO standard T-216 for incremental consolidation testing. In fact using LoadTrac to add the next load at the end of primary consolidation is consistent with the principle method described in the standard for reporting test results. Results for twenty three consolidation tests on different types of soil with different load increment durations show that the delivered system gives similar results to those obtained with Karol Warner equipment and those obtained using load increment durations of 24 hours.

Benefits

The equipment resulting from this research will allow SDDOT staff to provide important foundation design data in a more timely fashion with less manpower than presently required. This improved capability can result in better design compared to present procedures because:

☞ use of overly conservative empirical correlations to estimate consolidation settlements can be avoided

☞ more accurate predictions of consolidation magnitude and rate can be obtained allowing better forecasting of behavior during construction and operation.

- less man-time (approximately ±18 man hours based on comparisons of the time required to run tests in standard equipment and times required for LoadTrac) will be required per test resulting in lower costs.

- more data can be collected for each test allowing more detailed and thorough analysis of the test results.

- human errors associated with data collection, reduction and reporting can be reduced because these operations are performed by computer

- immediate availability of test results shortly after completion of the test

- availability of data during the test that allows an engineer to alter the test conditions to meet his specific project needs means better utility of test results

Conclusions

A new automated device was provided to SDDOT that will decrease the elapsed time and man time required to perform an incremental consolidation test. This device determines when primary consolidation is completed and proceeds to the next load increment after a delay time set by the user. The final system meets the requirements of AASHTO T-216.

Tests on three samples provided by SDDOT indicated testing times as short as two hours per load increment for sample #1, four hours per load increment for sample #2 and six hours per load increment for sample #3 were sufficient. For standard tests consisting of 10 load increments, these times translate to required testing times of 20 hours for sample #1, 40 hours for sample #2 and 60 hours for sample #3. This represents a reduction of eight to ten days (including two weekend days) achieved by automation.

A review of the literature indicated that the shorter load durations used in the new equipment should not materially affect the compression parameters computed from the test data. Results for twenty three consolidation tests on different types of soil with different load increment durations show that the delivered system gives similar results to those obtained with Karol Warner equipment and those obtained using load increment durations of 24 hours.

Standard practice at SDDOT was to run twelve load increments per test with each load increment lasting 24 hours. Data were recorded and calculations were performed by hand. Final results were drafted and typed. We estimate that this procedure required three weeks of elapsed time to run a test and an additional week to obtain the test result in final form. It required approximately one hour to set up the test, ±15 hours to take readings, and four hours to reduce and report test results. We estimate the total man time per test was ±20 hours.

The new system saves elapsed time and man time. The new system requires 2 to 3 days to run a test on typical South Dakota soils. It requires one hour to set up the test, no man time to run the test and approximately one hour to prepare the test report.

The new system will reduce the elapsed time from the start of a test to availability of the test report from ±4 weeks to ±3 days. It will reduce the man time required by each test from ±20 hours to ±2 hours.

Besides reduced elapsed time and reduced man time, the new system offers other benefits. These include the ability to collect as much data as desired for a test, ability to collect data consistently throughout each load increment, ability to examine detailed test results while the test runs, ability to modify test conditions as the test runs, and a variety of options to examine and evaluate test data to obtain engineering parameters.

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Table 1: Summary of Consolidation Tests

Test Number	Sample ID	Equipment	Duration	Initial Void Ratio	Initial Water Content, %	Comments
C1	SD #1	Karol Warner	24 hr	1.19	45.4	
C4		Karol Warner	24 hr	1.23	48.2	equipment failure
C2		LoadTrac	T_{100} + 1 hr	1.14	41.9	
C3	SD #2	LoadTrac	24 hr	1.22	44.2	
C5		Karol Warner	24 hr	1.20	44.4	
C6		LoadTrac	T_{100} + 1 hr	1.11	40.5	
NC-1	SD #3	LoadTrac	24 hr	0.93	31.4	
NC-3		LoadTrac	T_{100} + 4 hr	0.89	31.4	
NC-2		LoadTrac	T_{100} + 2 hr	0.77	26.9	void ratio lower than others
NC-5	Maine #1	LoadTrac	T_{100} + 2 hr	0.93	34.5	
G-1		SoilTest	T_{100} + 6 min	1.05	38.8	
NC-6	Maine #2	LoadTrac	24 hr	1.34	50.7	
NC-4		LoadTrac	T_{100} + 2 hr	0.90	33.6	void ratio lower than others
NC-7		LoadTrac	T_{100} + 2 hr	1.35	50.6	
M1-6	Midwest Clay #1	Karol Warner	24 hr	0.810	26.4	void ratio higher than others
M1-7		Karol Warner	24 hr	0.767	24.2	
M1-3		LoadTrac	12 hr	0.697	23.7	
M1-1		LoadTrac	6 hr	0.877	27.9	void ratio higher than others
M1-2		LoadTrac	6 hr	0.709	23.0	
M1-4		LoadTrac	1 hr	0.658	18.9	
M2-3	Midwest Clay #2	LoadTrac	24 hr	0.576	19.5	
M2-1		LoadTrac	2 hr	0.586	19.2	
M2-2		LoadTrac	6 hr	0.577	19.1	

T_{100} time required for 100 percent primary consolidation

Table 2: Comparison of Consolidation Tests

Test Number	Sample ID	Equipment	Duration	Initial Void Ratio	Initial Water Content, %	Max. Past Press., tsf	Diff. %	CR	Diff. %	RR	Diff. %	Strain 1-4 tsf	Diff. %
C1	SD #1	Karol Warner	24 hr	1.19	45.4	1.1	-8	.23	7	NM	—	.132	16
C2		LoadTrac	T_{100} + 1 hr	1.14	41.9	1.3	8	.20	-7	.024	---	.095	-16
C3	SD #2	LoadTrac	24 hr	1.22	44.2	3.3	-14	.22	-3	.043	-15	.038	-3
C5		Karol Warner	24 hr	1.20	44.4	4.1	7	.24	6	.061	21	.043	7
C6		LoadTrac	T_{100} + 1 hr	1.11	40.5	4.1	7	.22	-3	.047	-7	.038	-4
NC-1	SD #3	LoadTrac	24 hr	0.93	31.4	1.92	35	.145	2	.036	13	.060	-6
NC-3		LoadTrac	T_{100} + 4 hr	0.89	31.4	0.9	-35	.138	-2	.027	-13	.068	6
NC-5	Maine #1	LoadTrac	T_{100} + 2 hr	0.93	34.5	3.1	0	.186	0	.016	-19	.046	-2
G-1		SoilTest	T_{100} + 6 min	1.05	38.8	3.1	0	.187	0	.022	19	.048	2
NC-6	Maine #2	LoadTrac	24 hr	1.34	50.7	0.93	-8	.25	-9	.021	0	.128	-11
NC-7		LoadTrac	T_{100} + 2 hr	1.35	50.6	1.1	8	.302	9	.021	0	.158	11
M1-7	Midwest Clay #1	Karol Warner	24 hr	0.767	24.2	?	---	.093	24	.022	26	.026	18
M1-3		LoadTrac	12 hr	0.697	23.7	?	---	.061	-18	.019	9	.020	-11
M1-2		LoadTrac	6 hr	0.709	23.0	?	---	.065	-13	.016	-9	.020	-12
M1-4		LoadTrac	1 hr	0.658	18.9	?	---	.080	7	.013	-26	.024	5
M2-3	Midwest Clay #2	LoadTrac	24 hr	0.576	19.5	?	---	.065	3	.014	0	.016	1
M2-1		LoadTrac	2 hr	0.586	19.2	?	---	.057	-10	.014	0	.016	1
M2-2		LoadTrac	6 hr	0.577	19.1	?	---	.067	6	.014	0	.015	-2

C_c compression index = slope of line relating void ratio and log of vertical stress in virgin compression region
CR compression ratio = slope of line relating vertical strain and log of vertical stress in virgin compression region. Also = $C_c / (1+e_0)$
C_s swell index = slope of line relating void ratio and log of vertical stress in unloading region
RR recompression ration = slope of line relating vertical strain and log of vertical stress in unloading region. Also = $C_s / (1+e_0)$
? value for maximum past pressure could not be determined from the data

Table 3: Tests on Tube #1

Test	Average Stress, tsf	T_{50}, log fit min	T_{50}, sqrt fit min
C1 Karol Warner 24 hour increments	.26	5.5	7
	.52	12	8
	.99	19	12
	3.05	18	?
C2 LoadTrac T100 + 1 hr	.19	1.1	.8
	.38	1.6	.8
	.75	3.2	1.7
	1.5	9.1	7.8
	3	11	10
	6	11	10

? value could not be determined from the data

T_{50} sqrt fit = time for 50% consolidation determined from the square root of time fitting method
T_{50} log fit = time for 50% consolidation determined from the log of time fitting method

Table 4: Tests on Tube #2

Test	Average Stress, tsf	T_{50}, log fit min	T_{50}, sqrt fit min
C5 Karol Warner 24 hour increments	.75	3.6	1.2
	1.5	9	4
	3	19	14
	6	31	23
	12	42	38
C3 LoadTrac 24 hour increments	1.5	5.2	2.0
	3.0	17	14
	6.0	25	25
	12	33	30
C6 LoadTrac T100 + 1 hour increments	0.75	3.1	1.7
	1.5	5.0	2.5
	3.0	14	6.0
	6.0	22	21
	12	30	28

Table 5: Tests on Tube #3

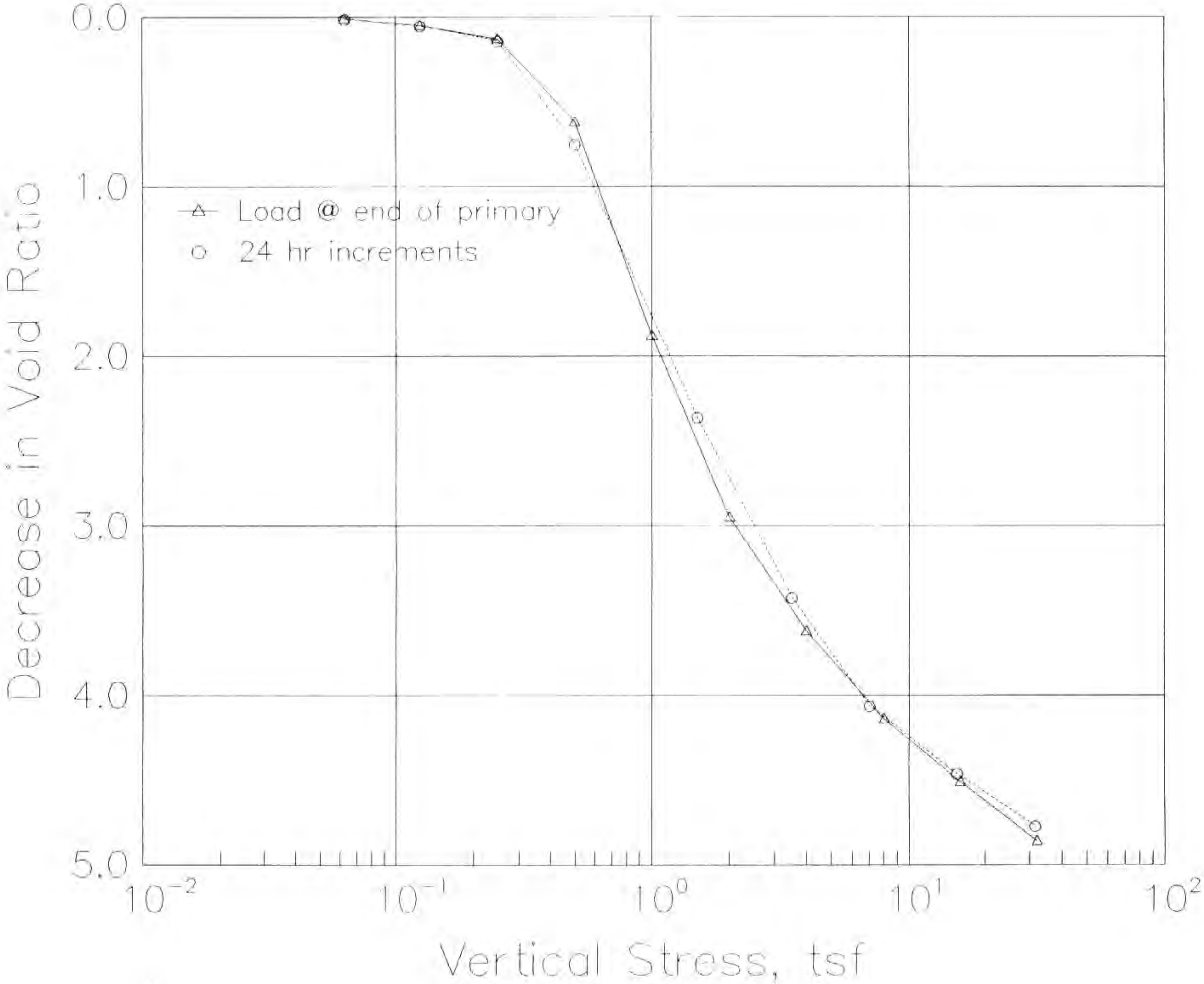
Test	Average Stress, tsf	T_{50}, log fit min	T_{50}, sqrt fit min
NC-1 LoadTrac 24 hour increments	.375	30	15
	.75	50	?
	1.5	76	?
	3.0	140	?
	6.0	174	160
	12	182	169
NC-3 LoadTrac T_{100} + 4 hr increments	.375	25	?
	.75	17	?
	1.5	20	?
	3.	26	?
	6.	28	24
	12	33	28

? trend of test data do not allow reliable curve fitting to obtain consolidation times

Table 6: Tests on Maine #2

Test	Average Stress, tsf	T_{50}, log fit min	T_{50}, sqrt fit min
NC-6 LoadTrac 24 hour increments	.063	5	3
	.19	7	4
	.375	6	3
	.75	17	7
	1.5	11	8
	3.0	6	4
	6.0	4	3
	12	2	1
NC-7 LoadTrac T_{100} + 2 hr increments	.063	4	3
	.19	2	2
	.38	2	2
	.75	2	2
	1.5	28	13
	3.	9	9
	6.	5	4
	12	3	2

Atchafalaya Clay from Olson (1985)



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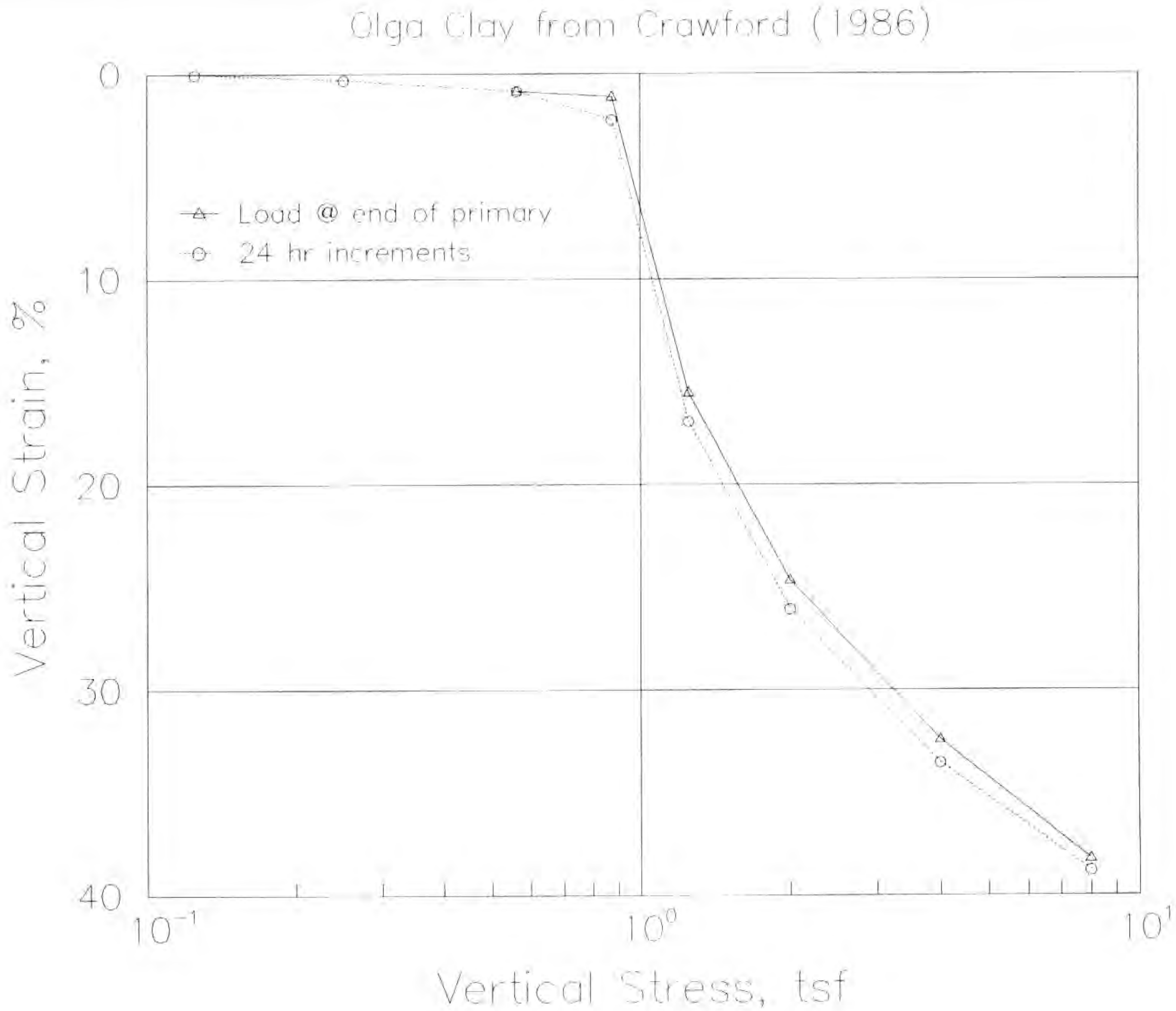

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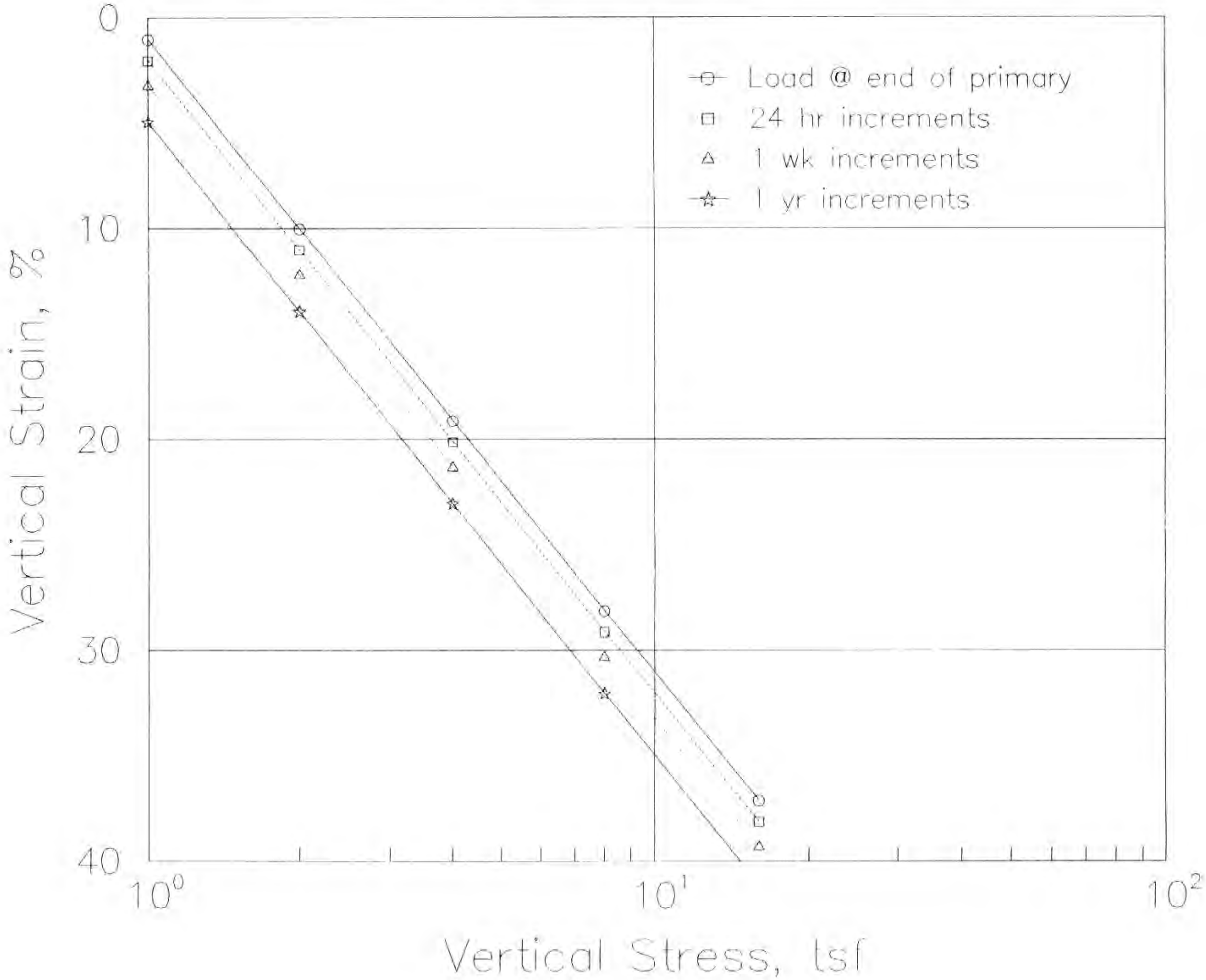
Idealized Consolidation Behavior



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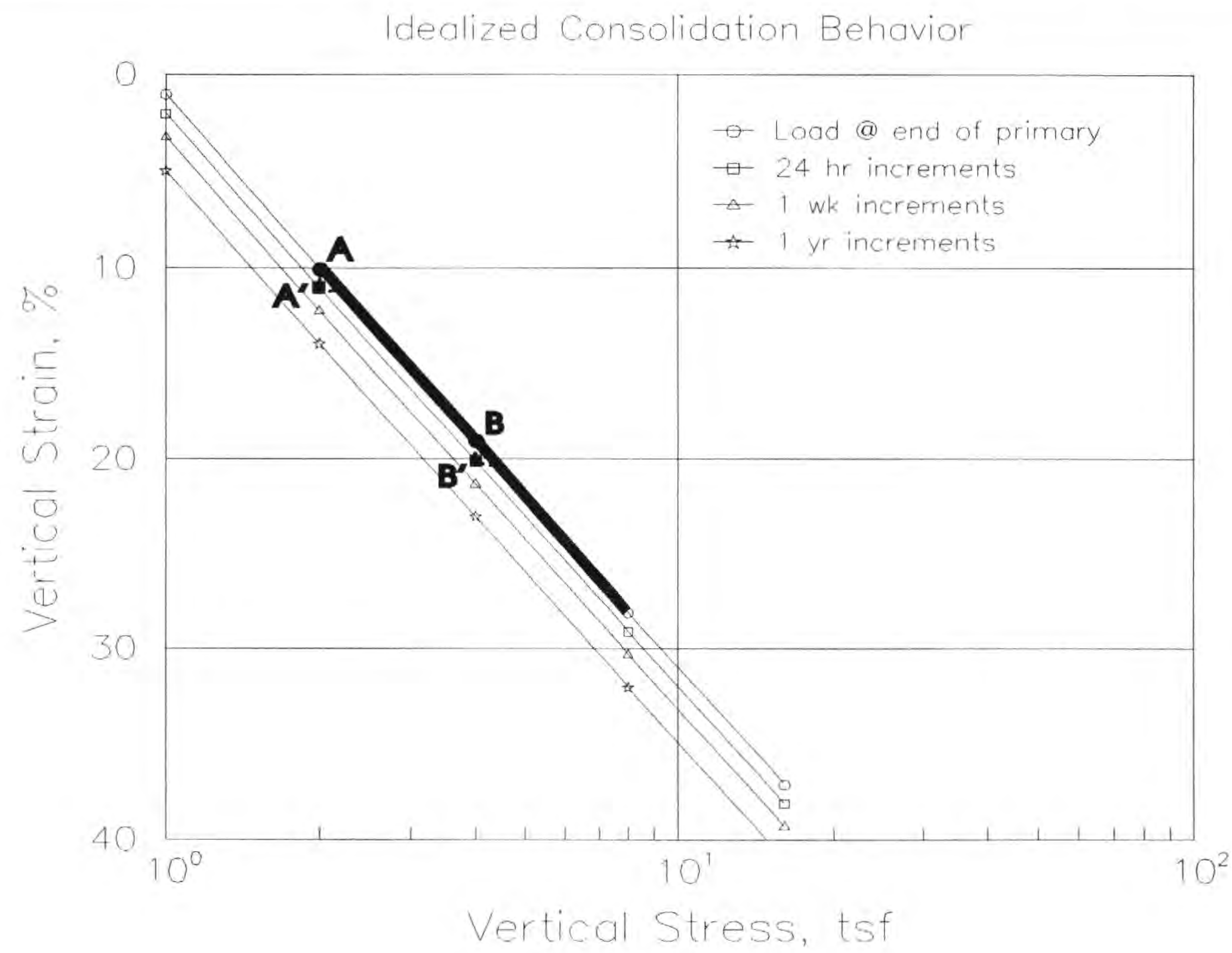

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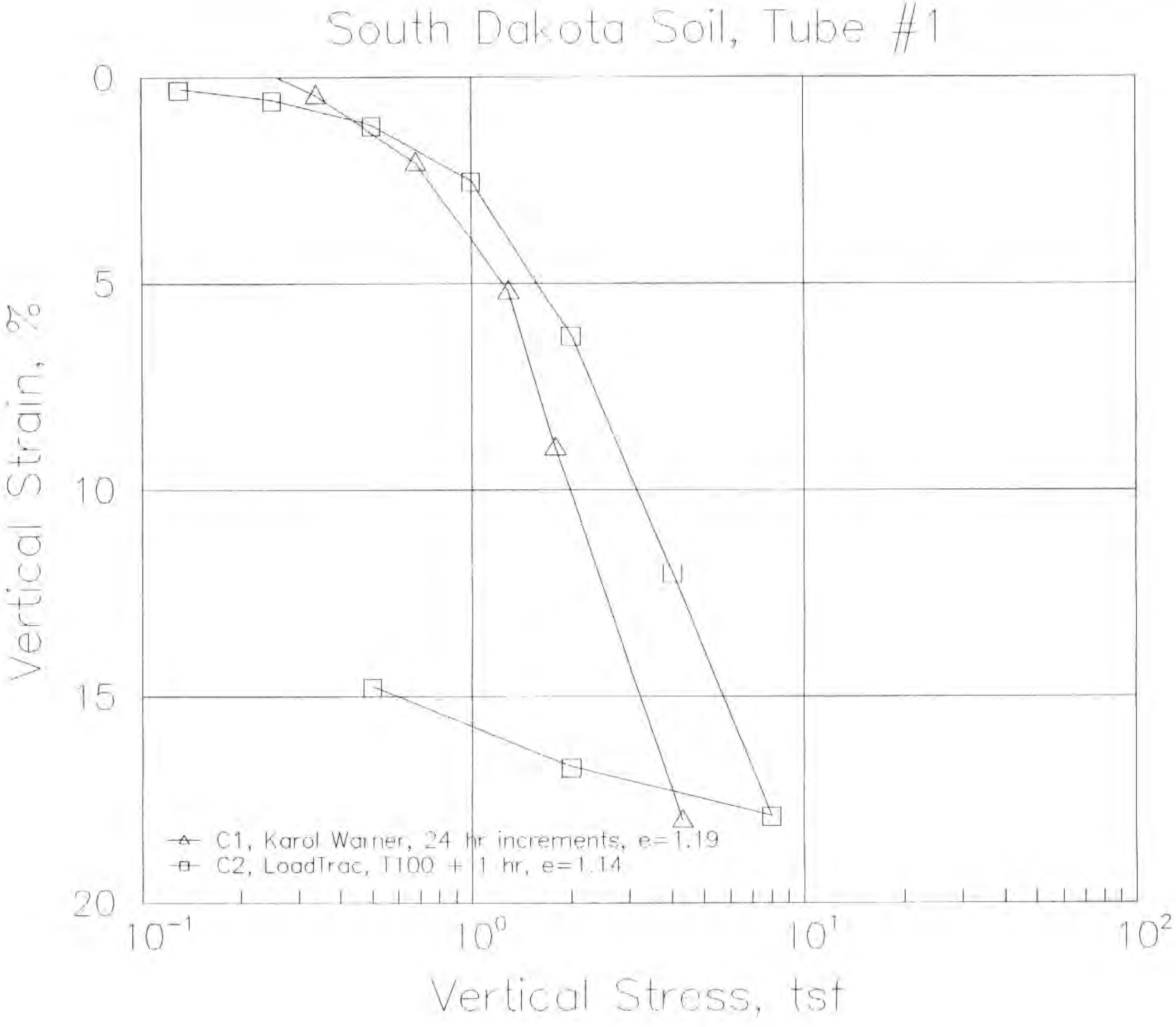

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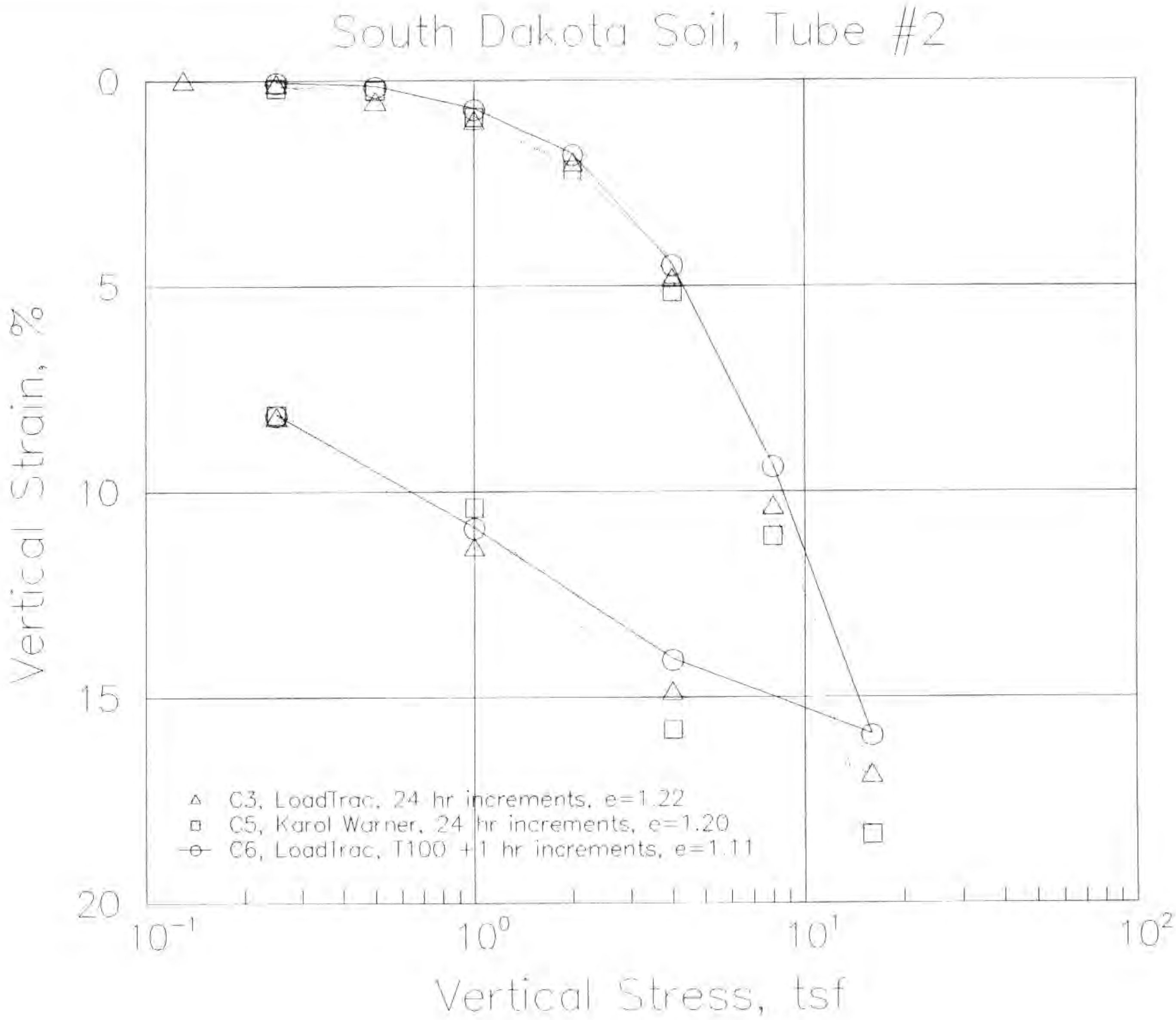

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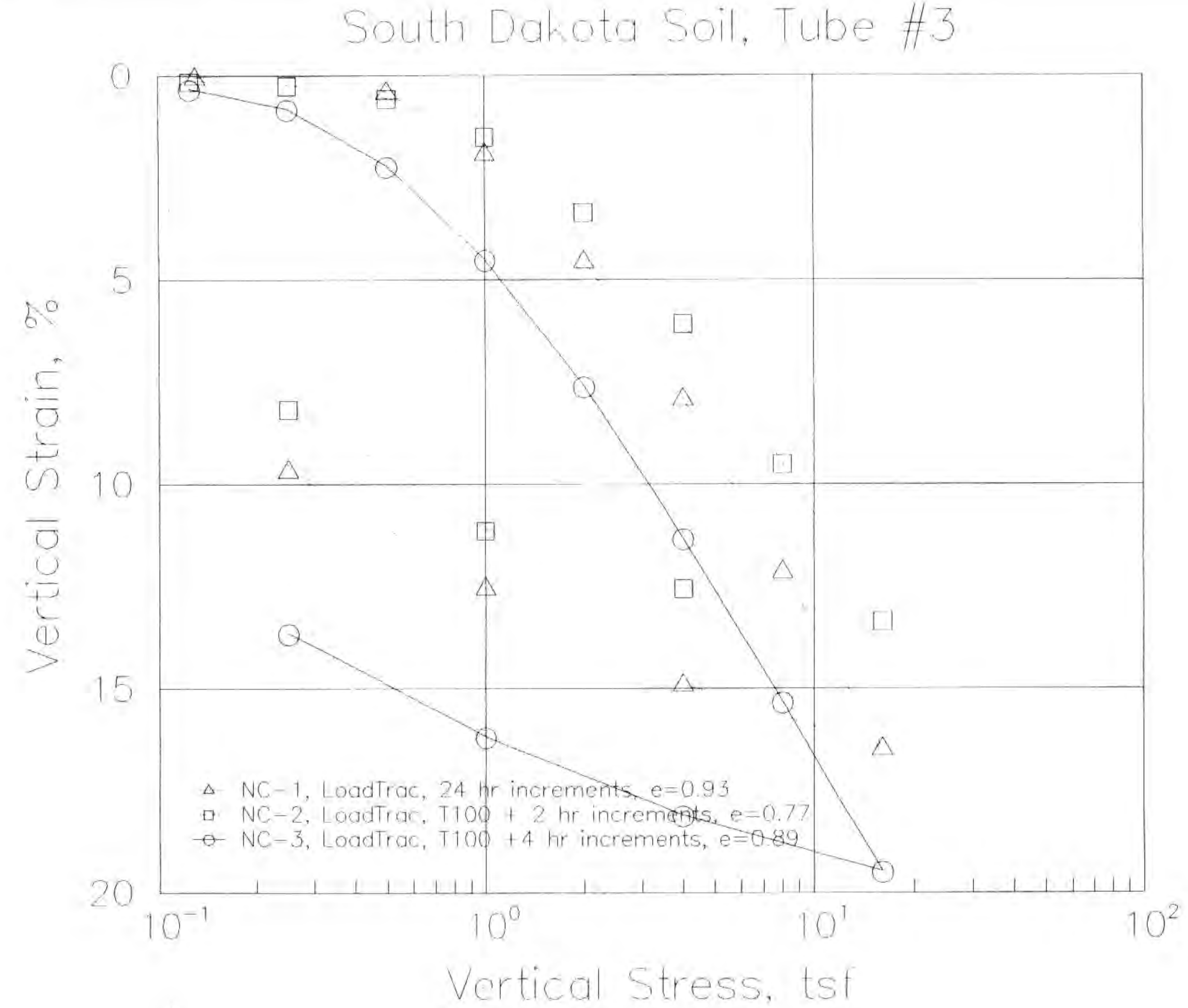

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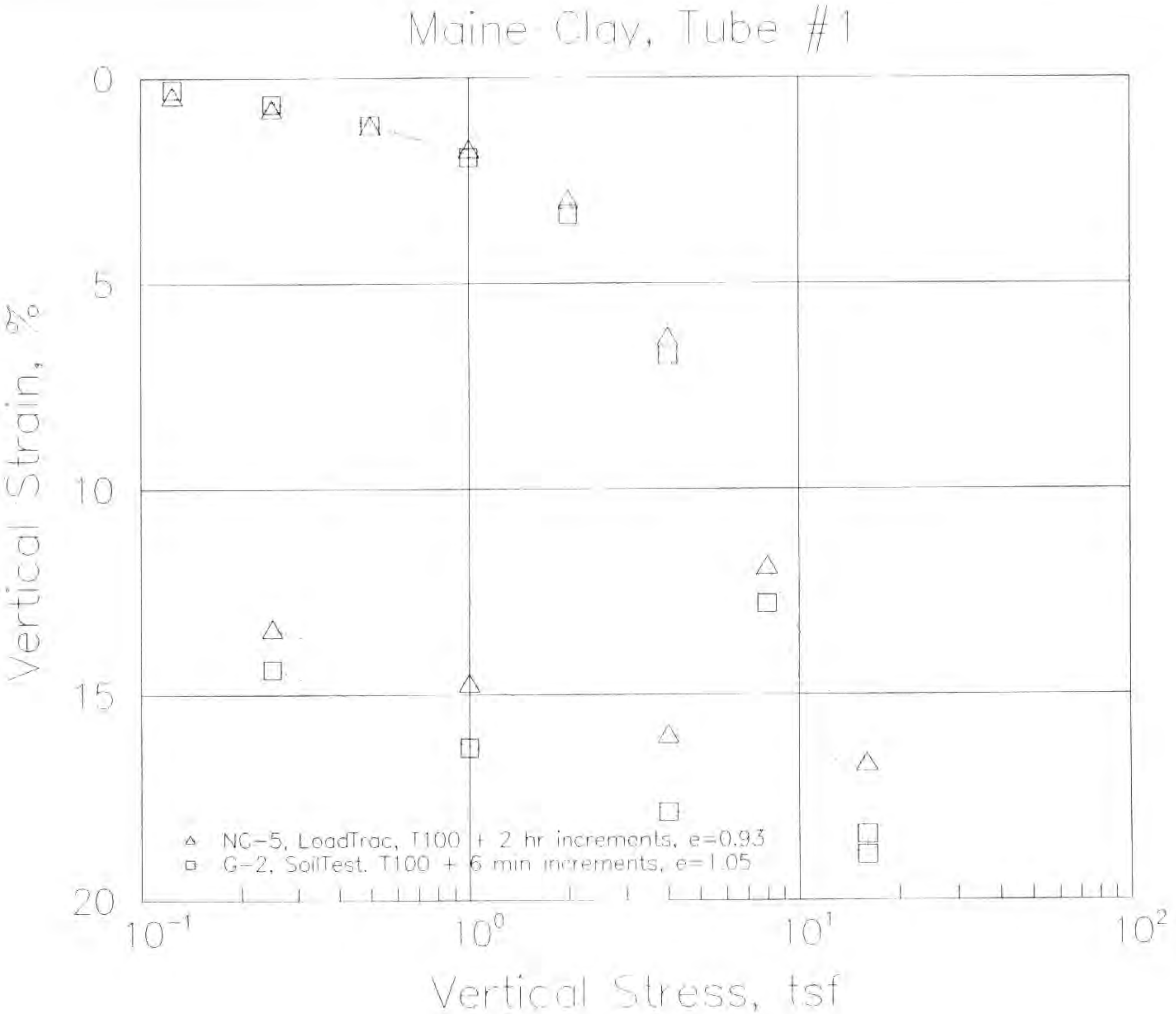

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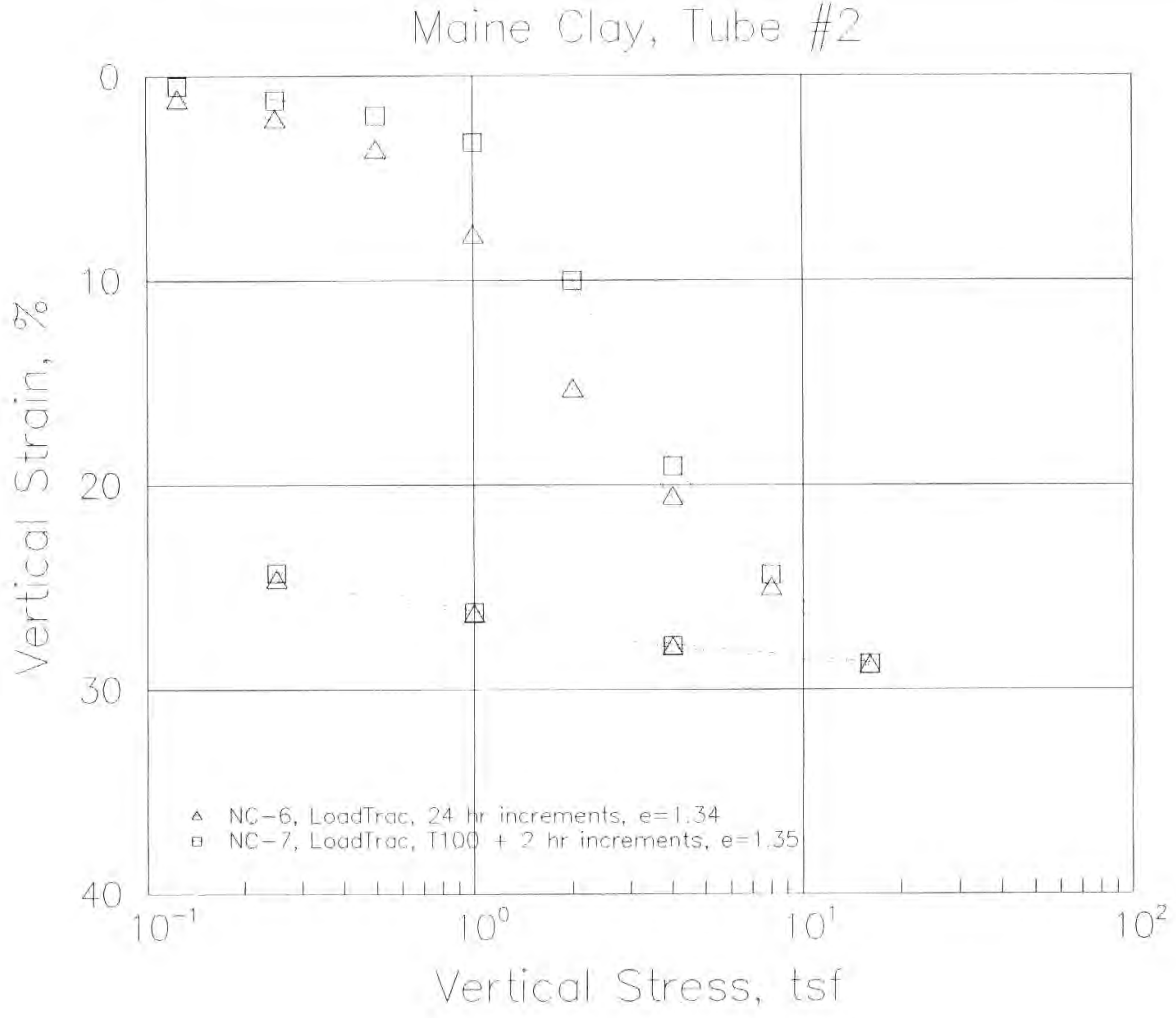

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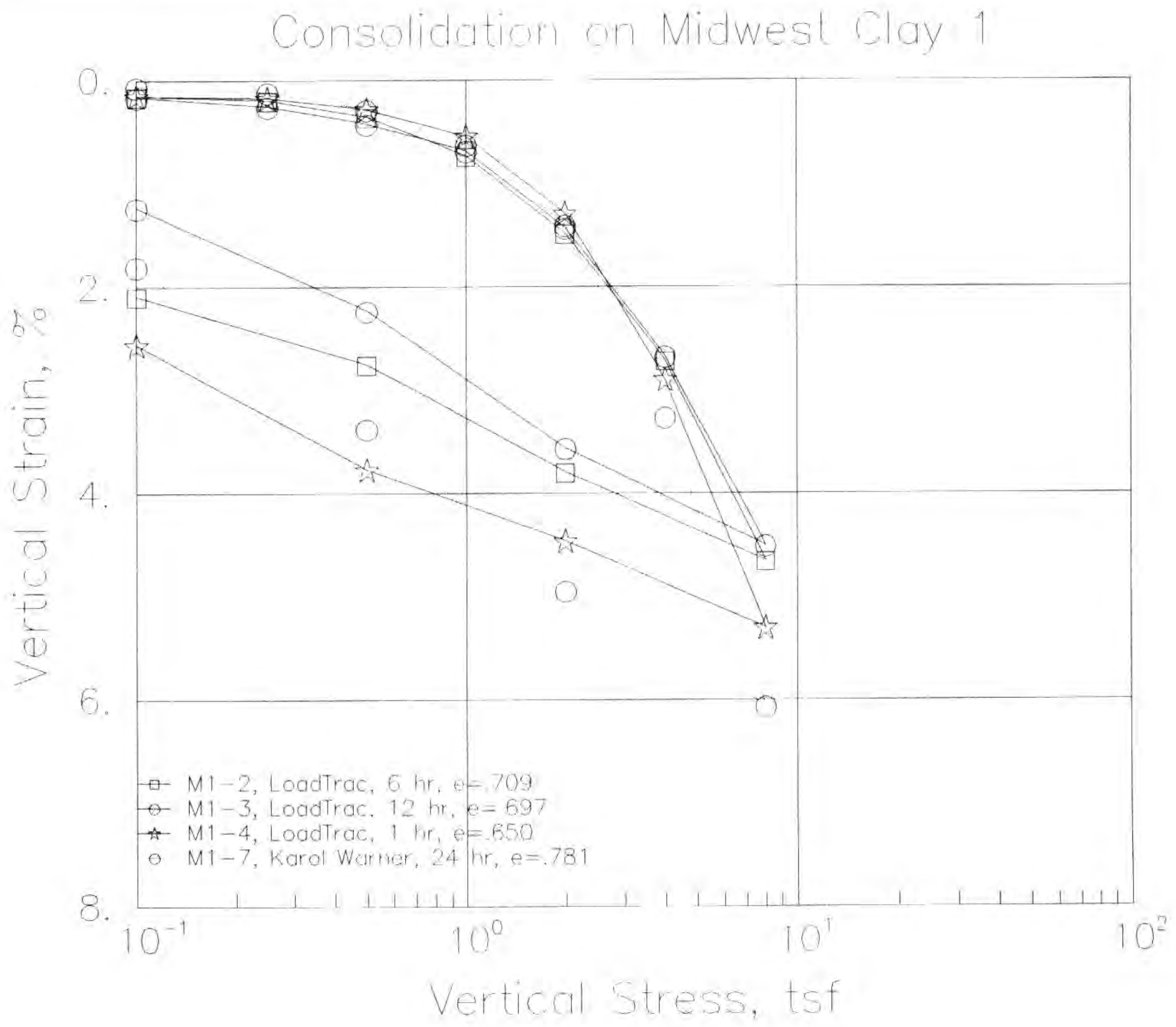

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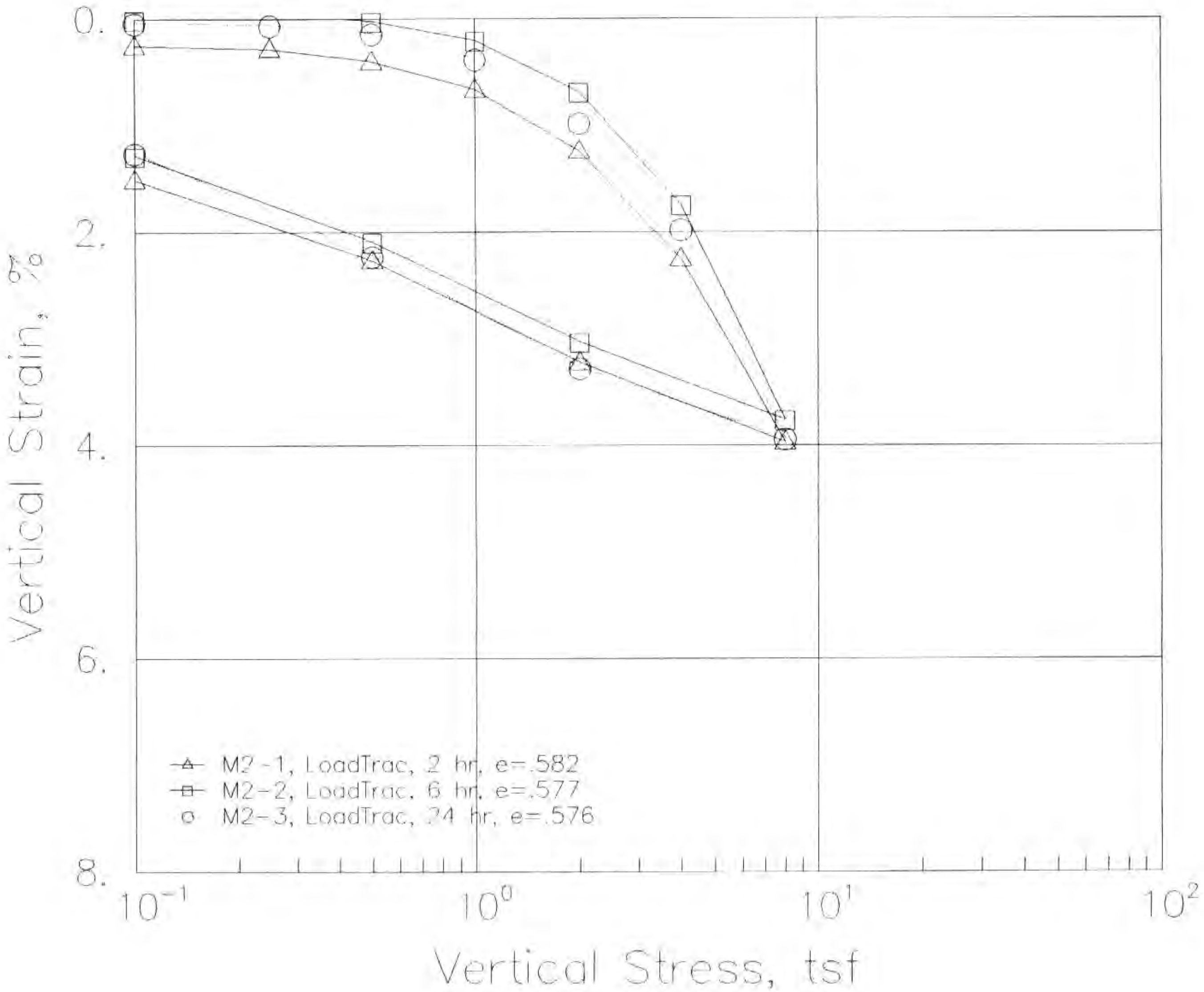
Consolidation on Midwest Clay 2



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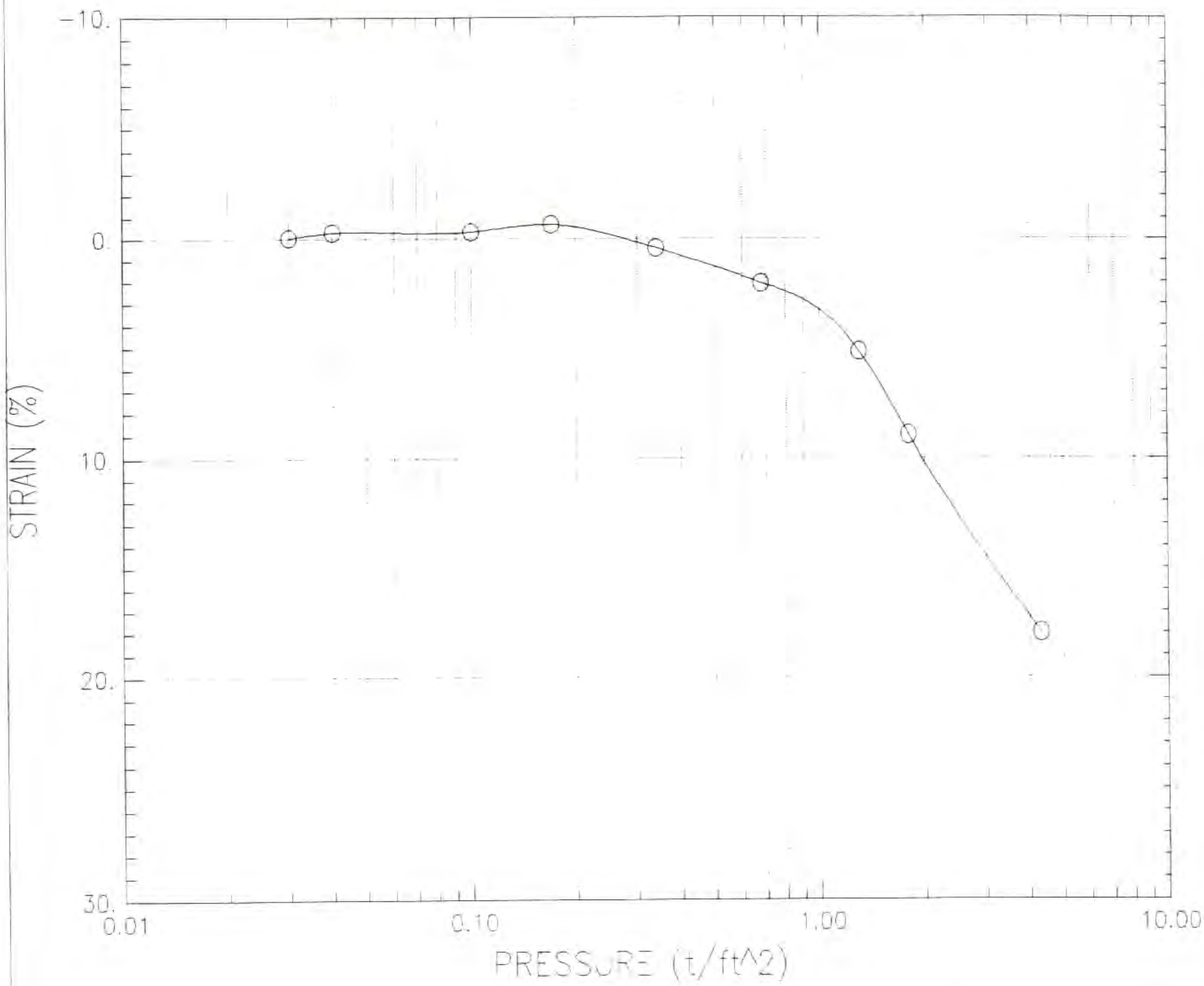
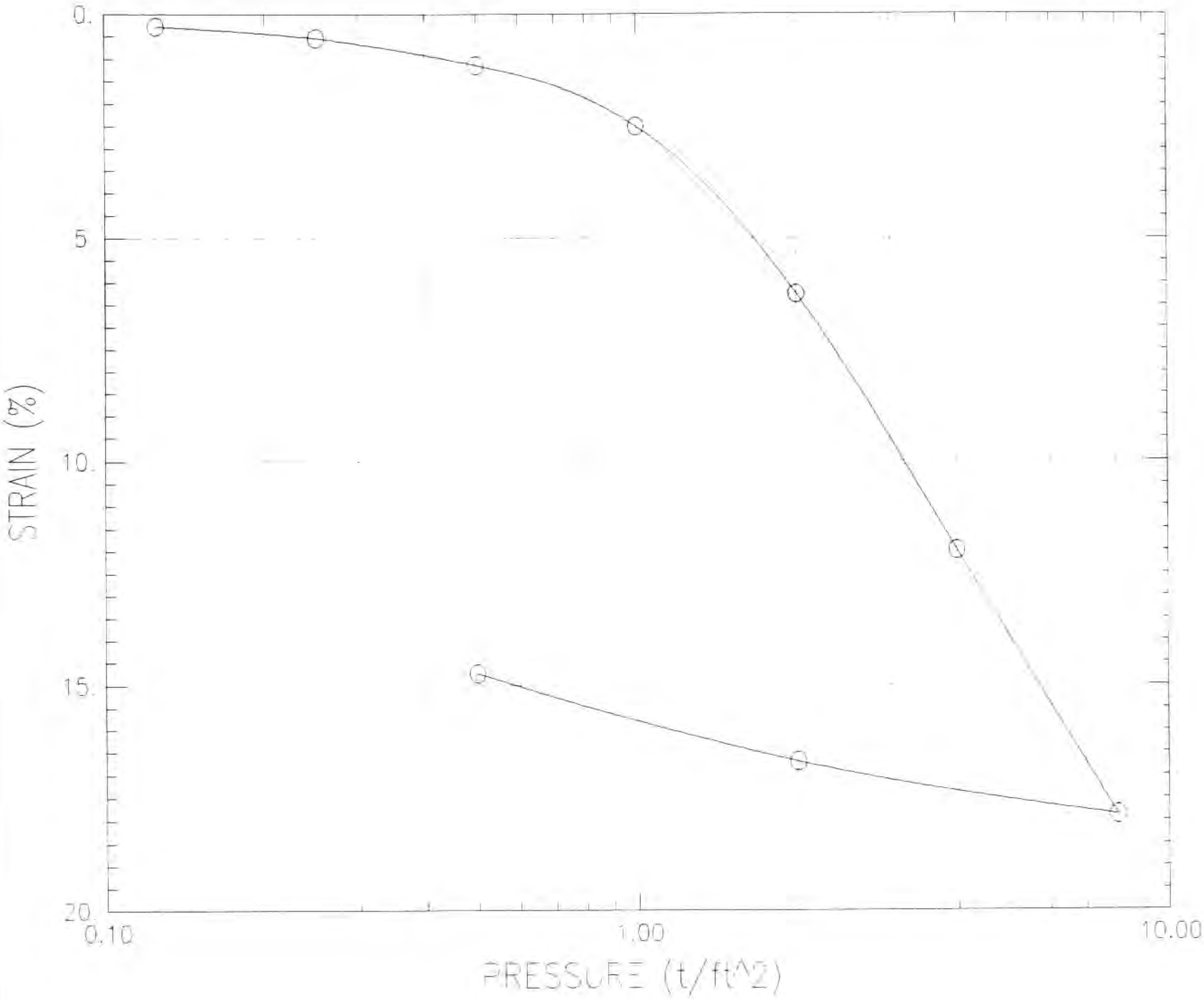
Appendix A

Incremental Consolidation Tests

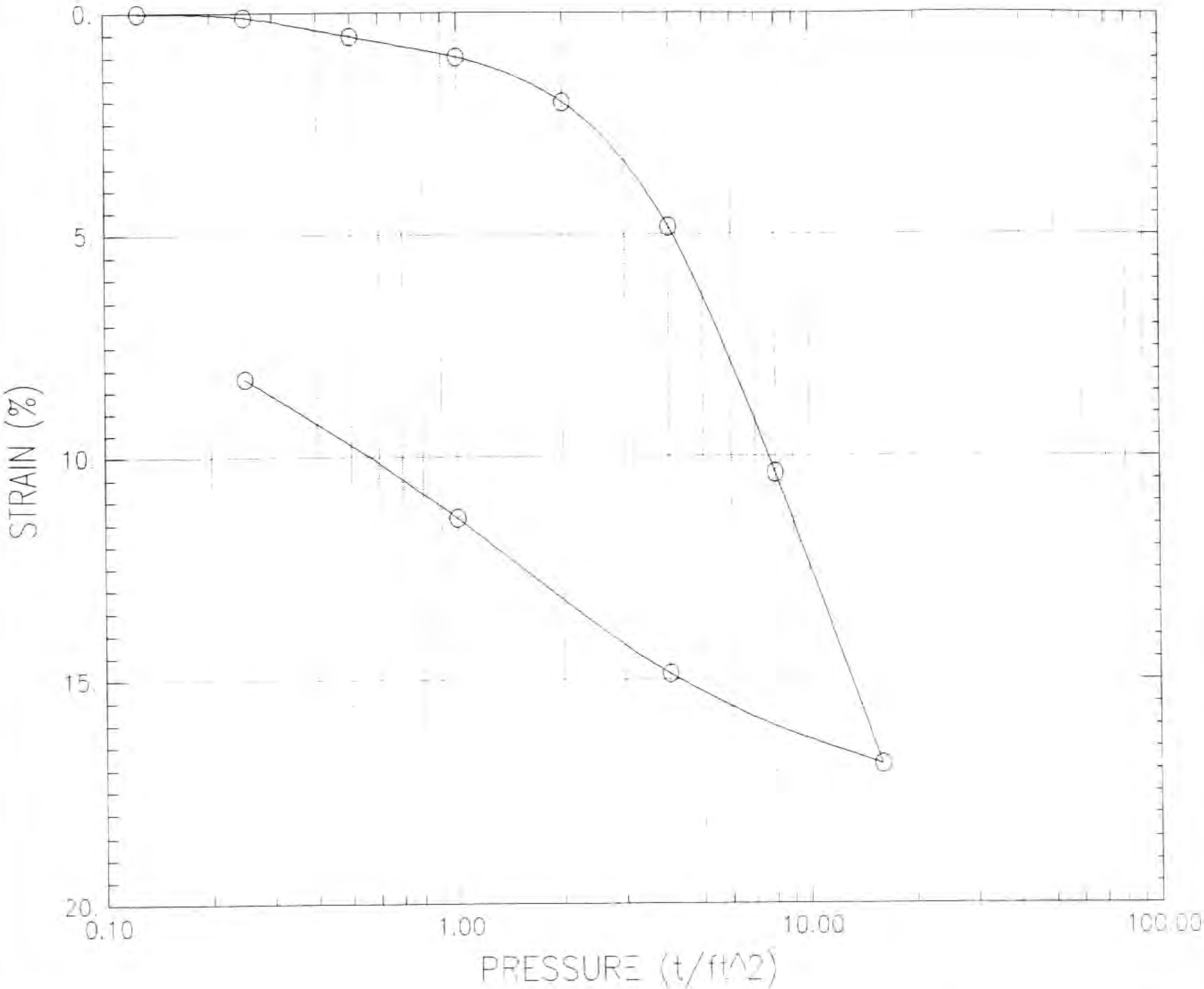


			BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)		WATER CONTENT (%)	45.418	32.650
PRECONSOL. PRESSURE (t/ft^2)		DRY DENSITY (lb/ft^3)	75.377	91.917
COMPRESSION INDEX		SATURATION (%)	100.738	108.180
TYPE SPECIMEN		VOID RATIO	1.195	0.800
DIA. (in) 1.970	HT. (in) 1.000	BACK PRESSURE (t/ft^2)		
CLASSIFICATION				
LL 0.0 PL 0.0	PI 0.0	PROJECT South Dakota Research		
GS 2.650	D_{10}	Data File: C1.ASC		
REMARKS		BORING NO.	SAMPLE NO. T1	
C1, Karol Warner, 24 hr increments		DEPTH	DATE 11/25/92	
		CONSOLIDATION TEST REPORT		

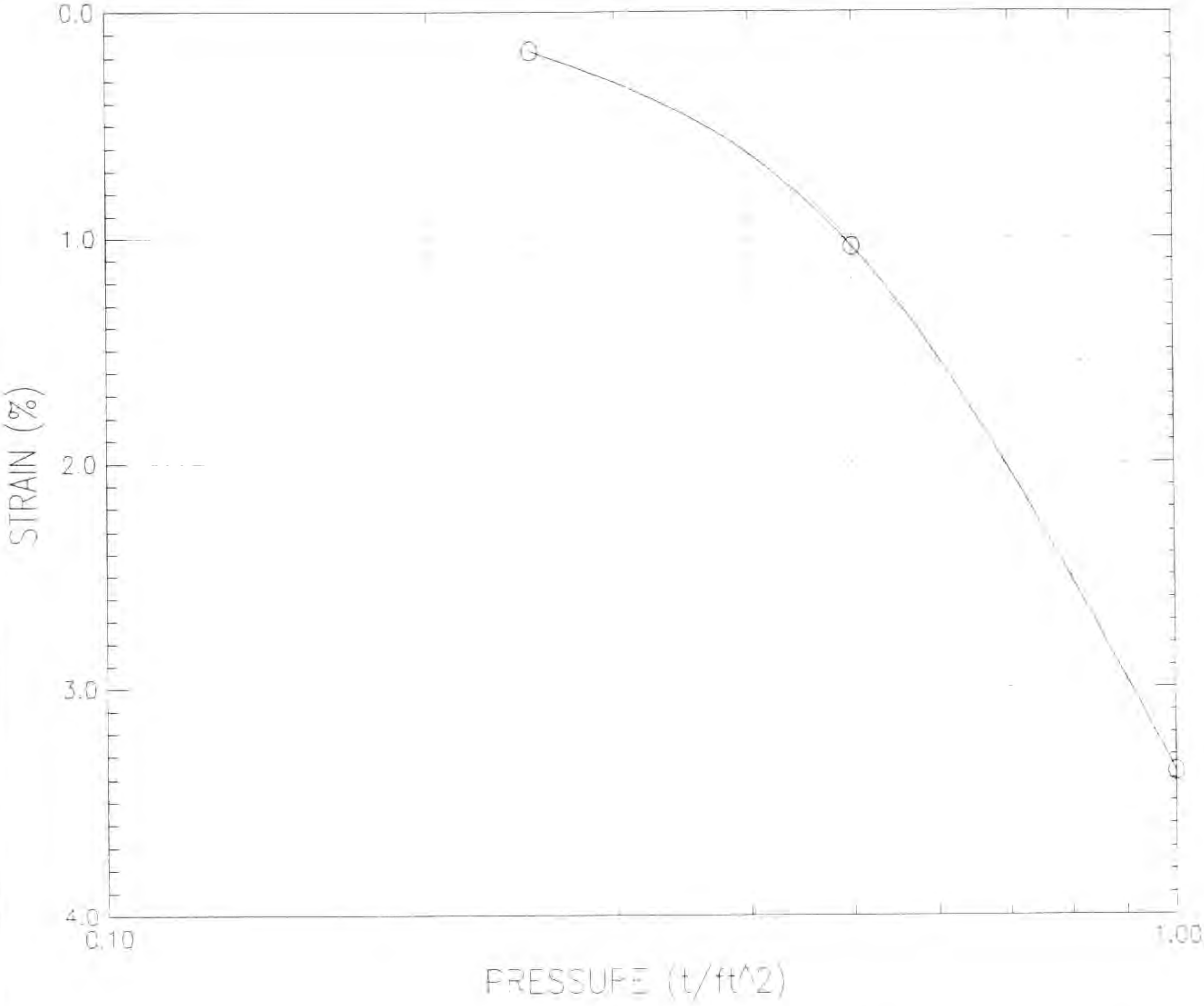


				BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)			WATER CONTENT (%)	41.886	31.770
PRECONSOL. PRESSURE (t/ft^2)			DRY DENSITY (lb/ft^3)	80.099	93.953
COMPRESSION INDEX			SATURATION (%)	100.749	105.612
TYPE SPECIMEN			VOID RATIO	1.143	0.827
DIA. (in) 2.500	HT. (in) 1.000		BACK PRESSURE (t/ft^2)		
CLASSIFICATION					
LL 0.0	PL 0.0	PI 0.0	PROJECT South Dakota Research		
GS 2.750	D_{10}		Data File: C2.ASC		
REMARKS			BORING NO.	SAMPLE NO. T1	
C2, LoadTrac, T100 + 1 hr increments			DEPTH	DATE 11/24/92	

CONSOLIDATION TEST REPORT



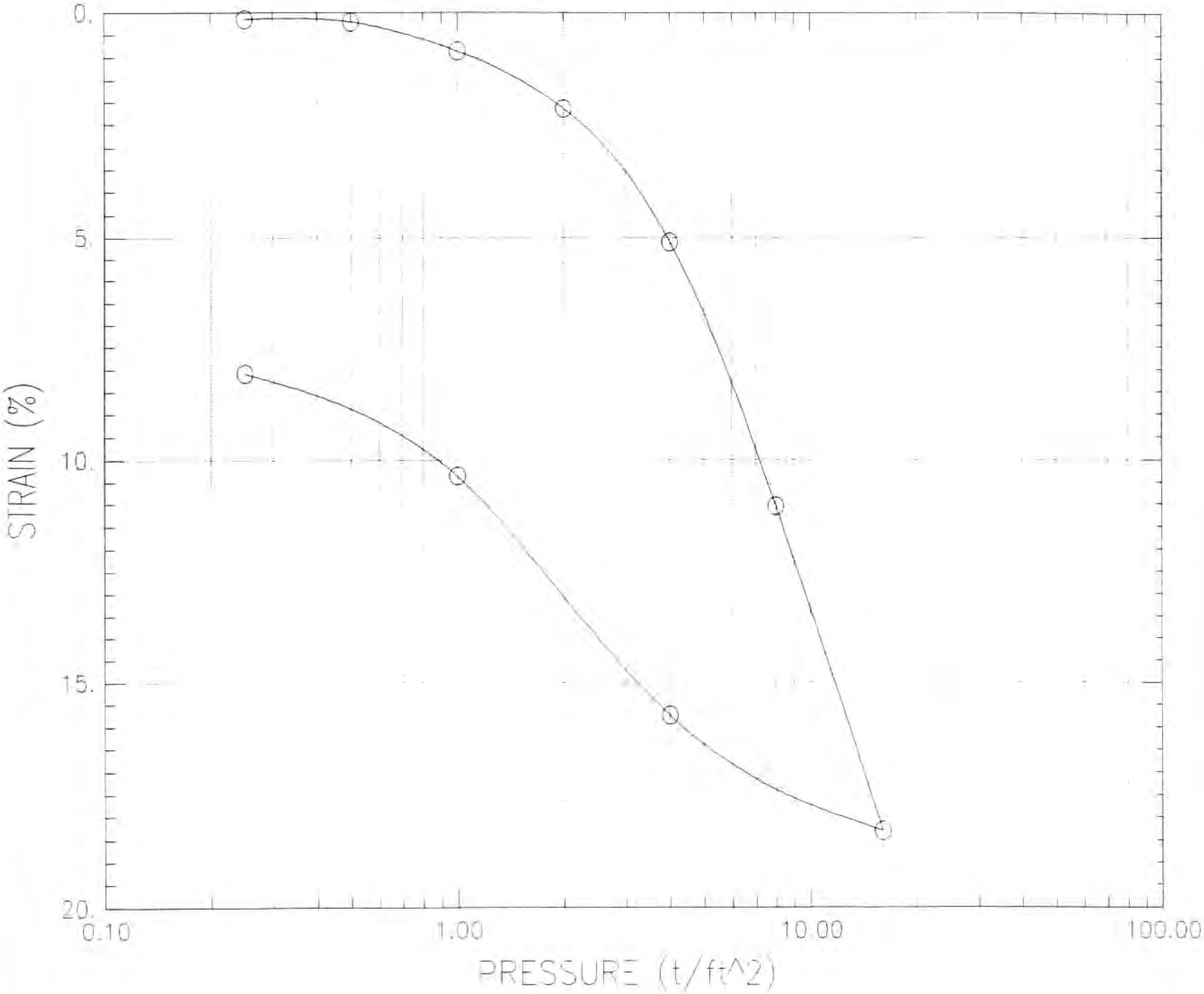
			BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)		WATER CONTENT (%)	44.169	39.895
PRECONSOL. PRESSURE (t/ft^2)		DRY DENSITY (lb/ft^3)	77.329	84.228
COMPRESSION INDEX		SATURATION (%)	99.554	105.667
TYPE SPECIMEN		VOID RATIO	1.220	1.038
DIA. (in) 2.500	HT (in) 1.000	BACK PRESSURE (t/ft^2)		
CLASSIFICATION				
LL 0.0	PL 0.0 PI 0.0	PROJECT South Dakota Research		
GS 2.750	D_{10}	Data File: C3.ASC		
REMARKS		BORING NO.	SAMPLE NO. T2	
C3, LoadTrac, 24 hr increments		DEPTH	DATE 11/29/92	
		CONSOLIDATION TEST REPORT		



			BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)		WATER CONTENT (%)	48.165	35.787
PRECONSOL. PRESSURE (t/ft^2)		DRY DENSITY (lb/ft^3)	74.216	76.802
COMPRESSION INDEX		SATURATION (%)	103.845	82.176
TYPE SPECIMEN		VOID RATIO	1.229	1.154
DIA. (in) 1.970	HT (in) 1.000	BACK PRESSURE (t/ft^2)		

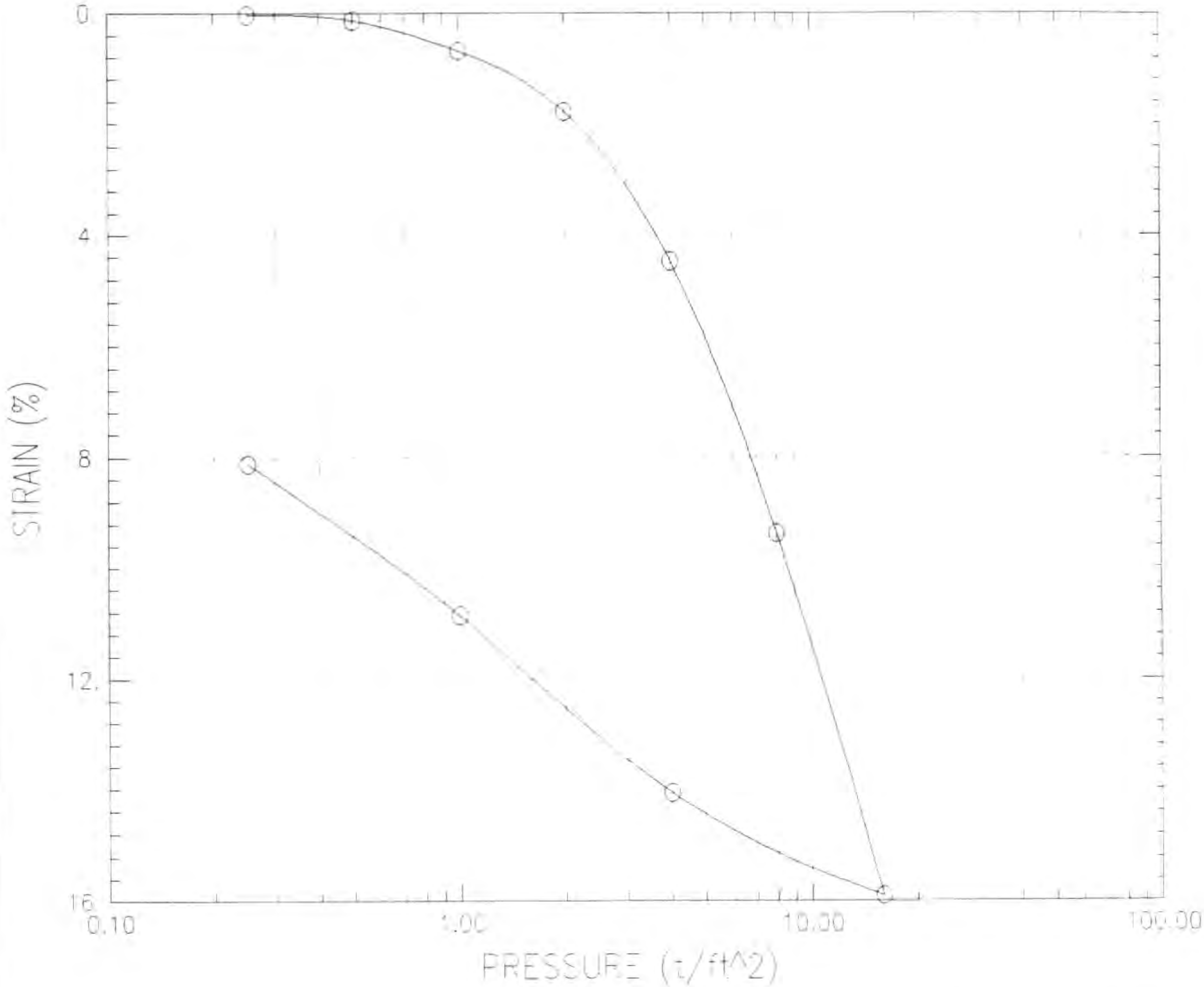
CLASSIFICATION			
LL 0.0	PL 0.0	PI 0.0	PROJECT South Dakota Research
GS 2.650	D_{10}		Data File: C4.ASC
REMARKS			BORING NO. / SAMPLE NO. T1
C4, Karol Warner, 24 hr increments			DEPTH / DATE 12/2/92

CONSOLIDATION TEST REPORT



			BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)		WATER CONTENT (%)	44.358	40.010
PRECONSOL. PRESSURE (t/ft^2)		DRY DENSITY (lb/ft^3)	77.887	84.735
COMPRESSION INDEX		SATURATION (%)	101.301	107.233
TYPE SPECIMEN		VOID RATIO	1.204	1.026
DIA. (in) 1.970	HT. (in) 1.000	BACK PRESSURE (t/ft^2)		
CLASSIFICATION				
LL 0.0 PL 0.0	PI 0.0	PROJECT South Dakota Research		
GS 2.750	D_{10}	Data File C5.ASC		
REMARKS		BORING NO.	SAMPLE NO. T2	
C5, Karol Warner, 24 hr increments		DEPTH	DATE	

CONSOLIDATION TEST REPORT

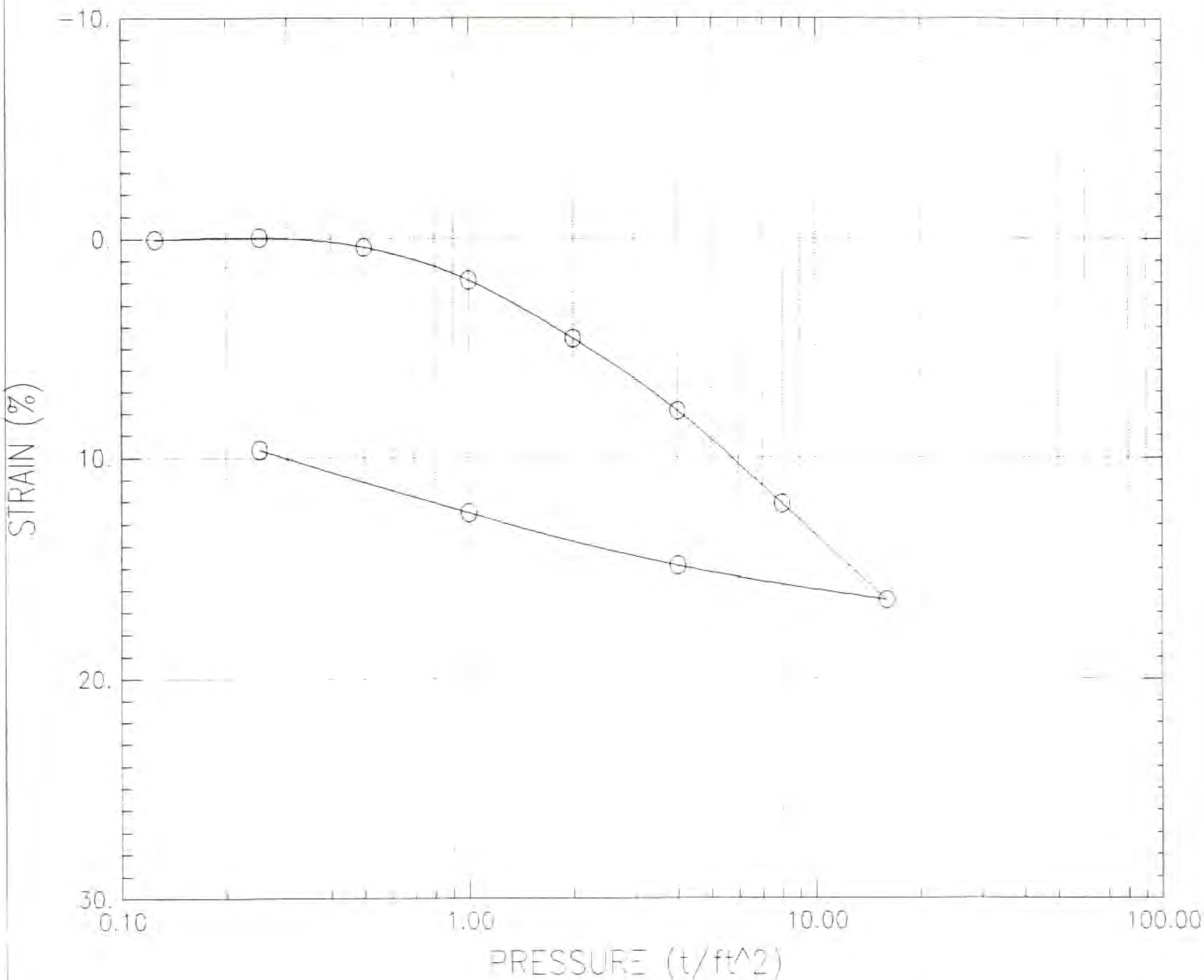


			BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)		WATER CONTENT (%)	35.581	32.484
PRECONSOL. PRESSURE (t/ft^2)		DRY DENSITY (lb/ft^3)	84.213	91.656
COMPRESSION INDEX		SATURATION (%)	94.224	102.322
TYPE SPECIMEN		VOID RATIO	1.036	0.873
DIA. (in) 2.500	HT (in) 1.000	BACK PRESSURE (t/ft^2)		

CLASSIFICATION		
LL 0.0	PL 0.0	PI 0.0

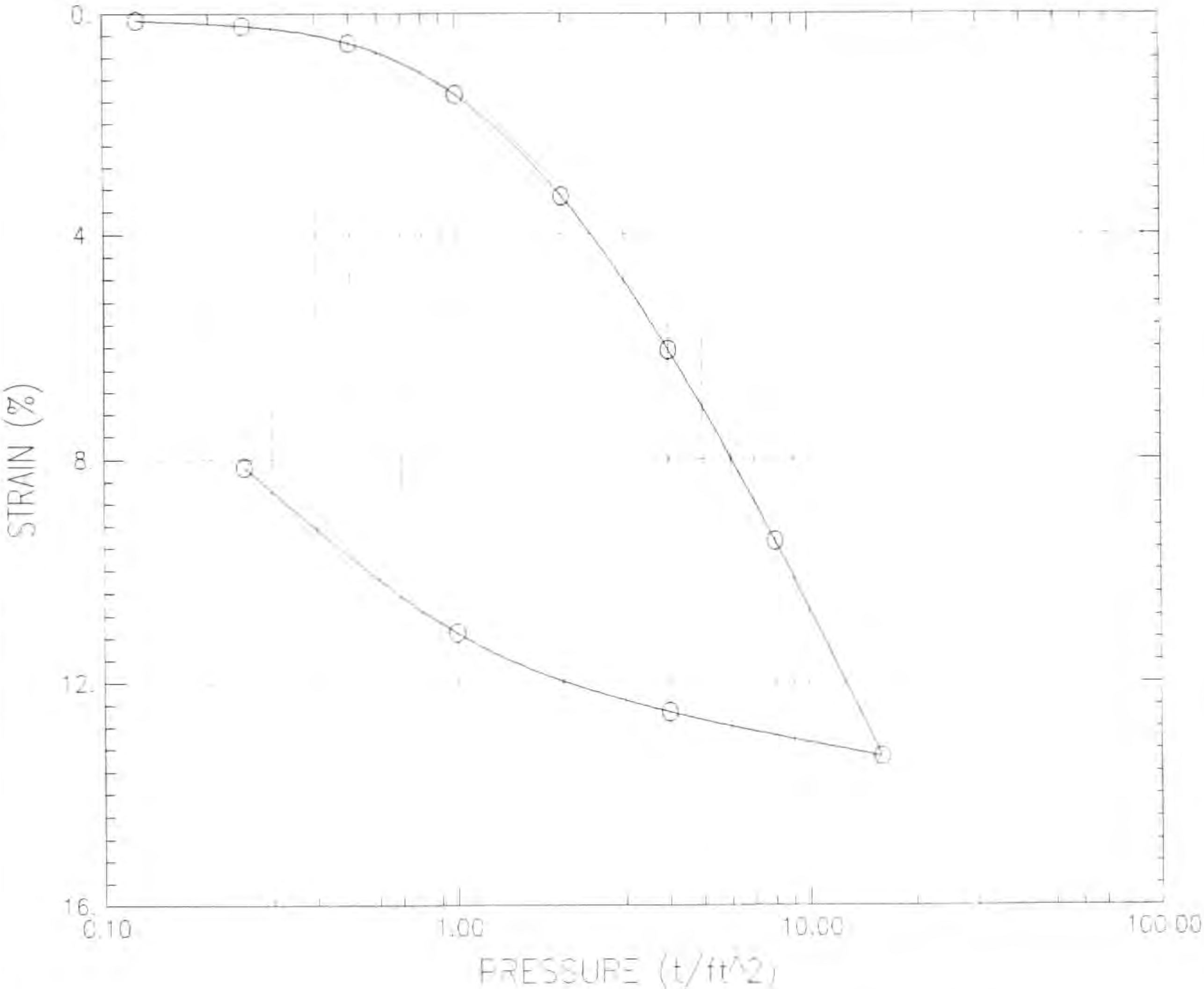
GS 2.750	D_{10}	Data File: C6.ASC
		PROJECT South Dakota Research
REMARKS	BORING NO.	SAMPLE NO. T2
C6, LoadTrac, T100 + 1 hr increments	DEPTH	DATE 12/24/92

CONSOLIDATION TEST REPORT

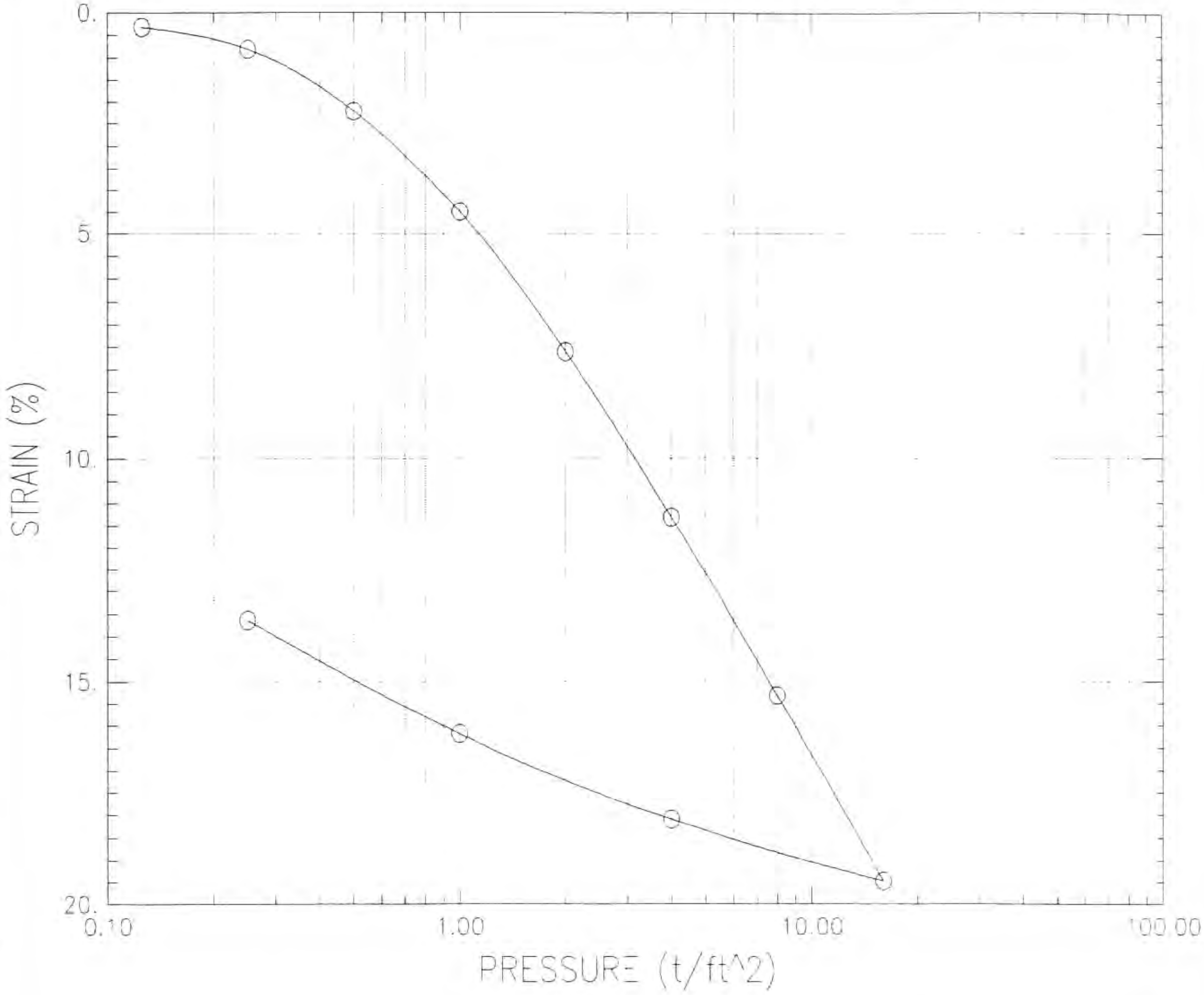


				BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)			WATER CONTENT (%)	31.434	28.071
PRECONSOL. PRESSURE (t/ft^2)			DRY DENSITY (lb/ft^3)	89.764	99.356
COMPRESSION INDEX			SATURATION (%)	93.694	104.605
TYPE SPECIMEN			VOID RATIO	0.932	0.745
DIA. (in) 2.500	HT (in) 1.000		BACK PRESSURE (t/ft^2)		
CLASSIFICATION LoadTrac, 24 hr increments					
LL 0.0	PL 0.0	PI 0.0	PROJECT South Dakota		
GS 2.778	D_{10}		Data File: NC-1.ASC		
REMARKS			BORING NO.	SAMPLE NO. #3	
NC-1, LoadTrac, 24 hr increments			DEPTH	DATE 4/1/93	

CONSOLIDATION TEST REPORT

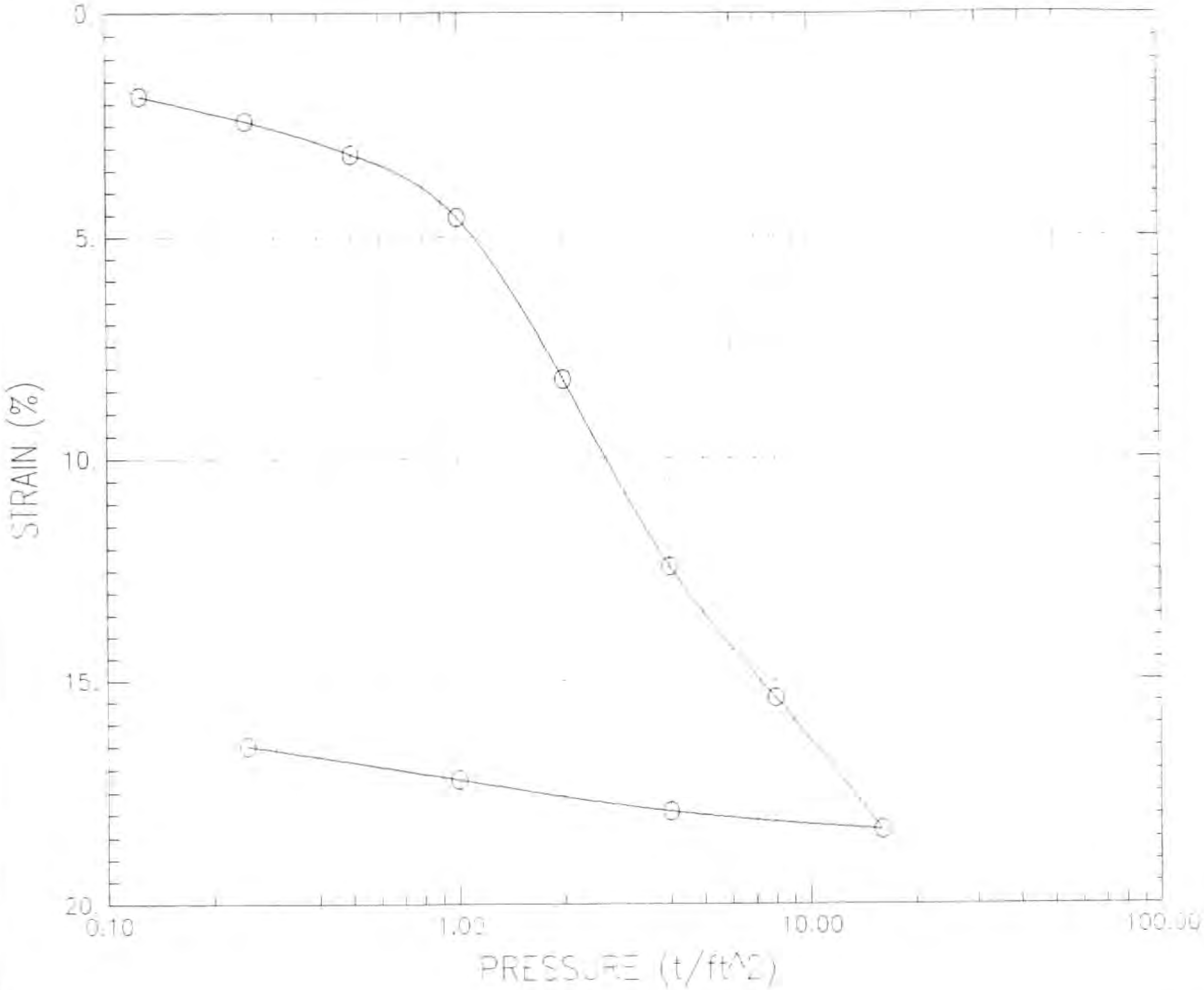


			BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)		WATER CONTENT (%)	26.943	23.863
PRECONSOL. PRESSURE (t/ft^2)		DRY DENSITY (lb/ft^3)	95.727	104.207
COMPRESSION INDEX		SATURATION (%)	95.204	103.780
TYPE SPECIMEN		VOID RATIO	0.767	0.623
DIA. (in) 2.500	HT. (in) 1.000	BACK PRESSURE (t/ft^2)		
CLASSIFICATION T100 + 2 hr				
LL 0.0 PL 0.0 PI 0.0		PROJECT South Dakota		
GS 2.709	D_{10}	Data File NC-2.ASC		
REMARKS		BORING NO.	SAMPLE NO. #3	
NC-2, LoadTrac, T100 + 2 hr increments		DEPTH	DATE 4/12/92	
		CONSOLIDATION TEST REPORT		

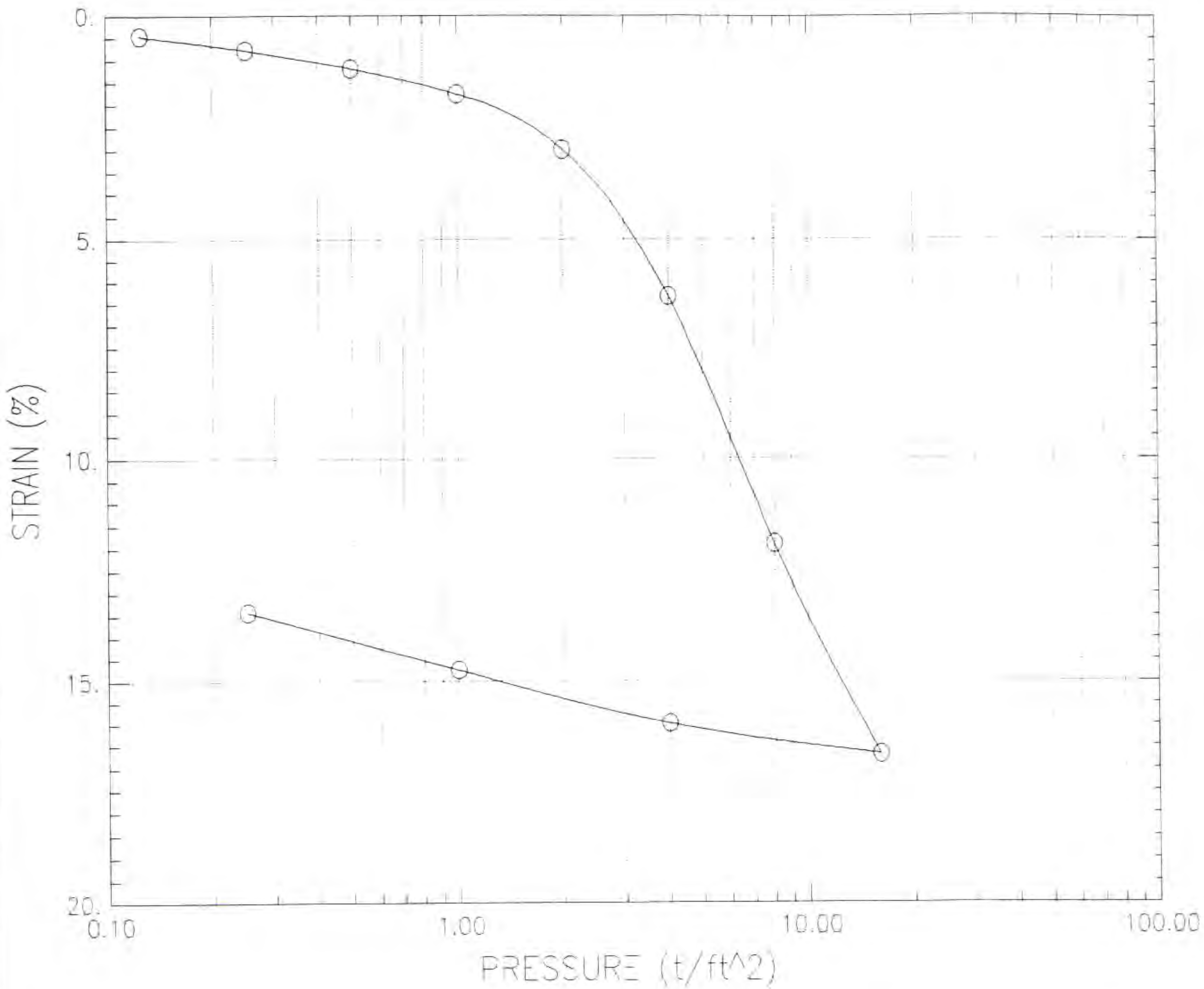


				BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)			WATER CONTENT (%)	31.381	25.456
PRECONSOL. PRESSURE (t/ft^2)			DRY DENSITY (lb/ft^3)	87.490	101.300
COMPRESSION INDEX			SATURATION (%)	93.187	106.296
TYPE SPECIMEN			VOID RATIO	0.894	0.636
DIA. (in) 2.500	HT. (in) 1.000		BACK PRESSURE (t/ft^2)		
CLASSIFICATION LoadTrac, T100 + 4 hr increments					
LL 0.0	PL 0.0	PI 0.0	PROJECT South Dakota		
GS 2.654	D_{10}		Data File: NC-3.ASC		
REMARKS			BORING NO.	SAMPLE NO. #3	
NC-3, LoadTrac, T100 + 4 hr increments			DEPTH	DATE 4/16/93	

CONSOLIDATION TEST REPORT



				BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)			WATER CONTENT (%)	33.573	22.546
PRECONSOL. PRESSURE (t/ft^2)			DRY DENSITY (lb/ft^3)	88.820	106.335
COMPRESSION INDEX			SATURATION (%)	100.975	104.033
TYPE SPECIMEN			VOID RATIO	0.898	0.585
DIA. (in) 2.500	HT. (in) 1.000		BACK PRESSURE (t/ft^2)		
CLASSIFICATION LoadTrac, T100 + 2 hr increments					
LL 0.0	PL 0.0	PI 0.0	PROJECT		
GS 2.700	D_{10}		Data File: NC-4.ASC		
REMARKS			BORING NO. 25122.2	SAMPLE NO. T-2	
NC-4, LoadTrac, T100 + 2 hr increments			DEPTH 22-24 ft	DATE 5/2/93	
			CONSOLIDATION TEST REPORT		

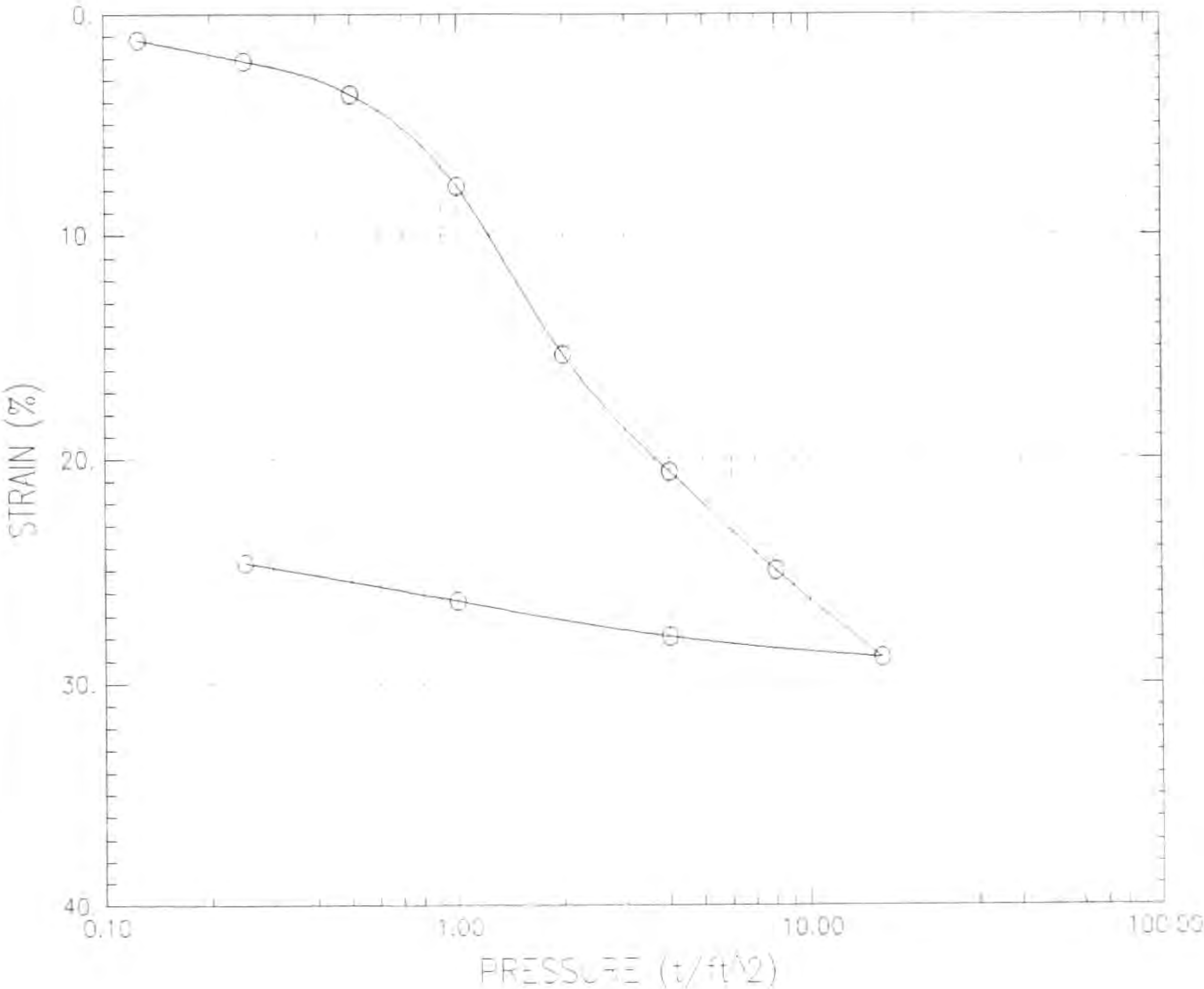


			BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)		WATER CONTENT (%)	34.463	26.854
PRECONSOL. PRESSURE (t/ft^2)		DRY DENSITY (lb/ft^3)	87.517	101.078
COMPRESSION INDEX		SATURATION (%)	100.488	108.611
TYPE SPECIMEN		VOID RATIO	0.926	0.668
DIA. (in) 2.500	HT. (in) 1.000	BACK PRESSURE (t/ft^2)		

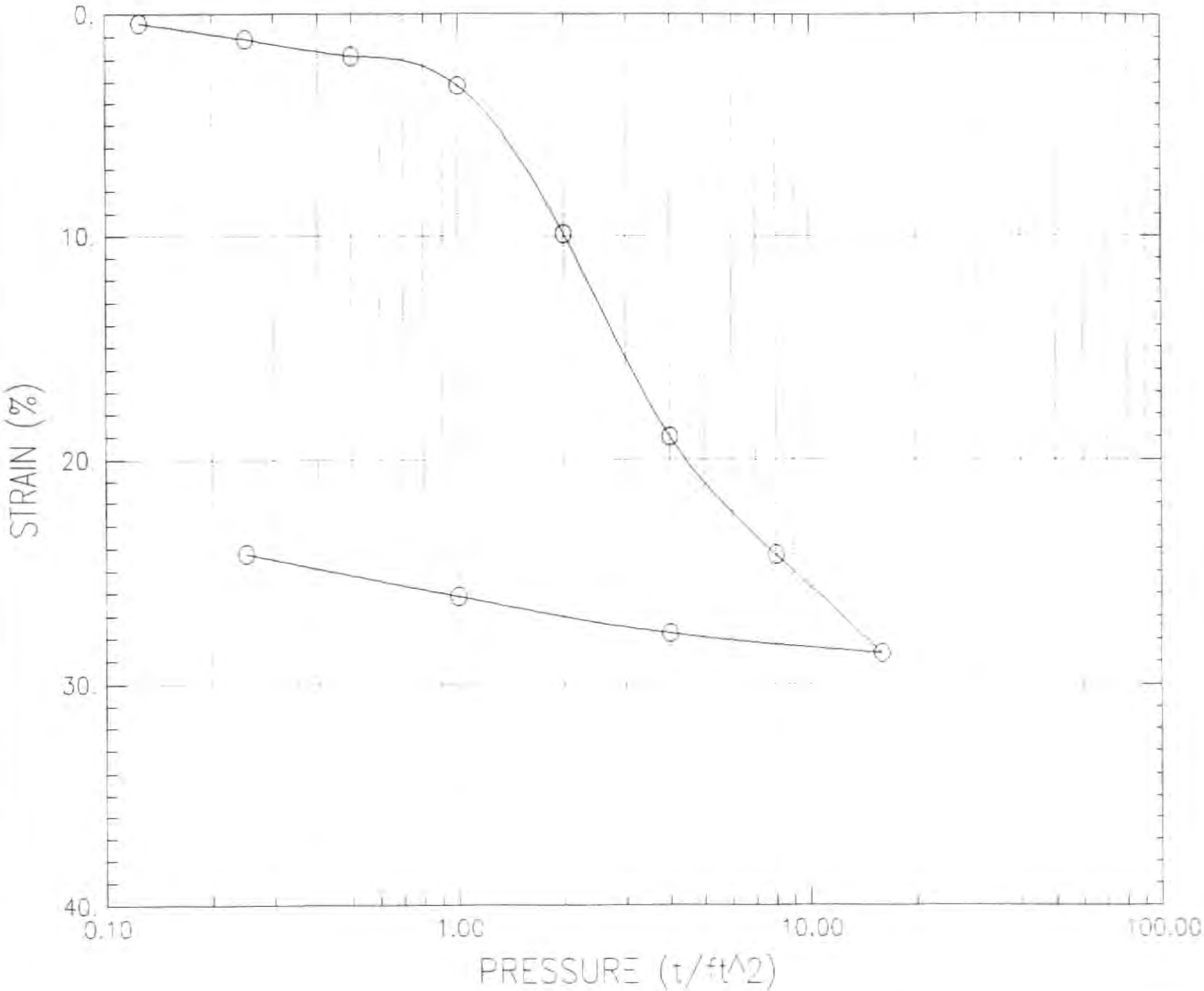
CLASSIFICATION LoadTrac, T100 + 2 hr increments		
LL 0.0	PL 0.0	PI 0.0
GS 2.700	D_{10}	
REMARKS		
NC-5, LoadTrac, T100 + 2 hr increments		

PROJECT Maine clay	
Data File: NC-5.ASC	
BORING NO.	SAMPLE NO. T-1
DEPTH 11-13 ft	DATE 5/4/93

CONSOLIDATION TEST REPORT

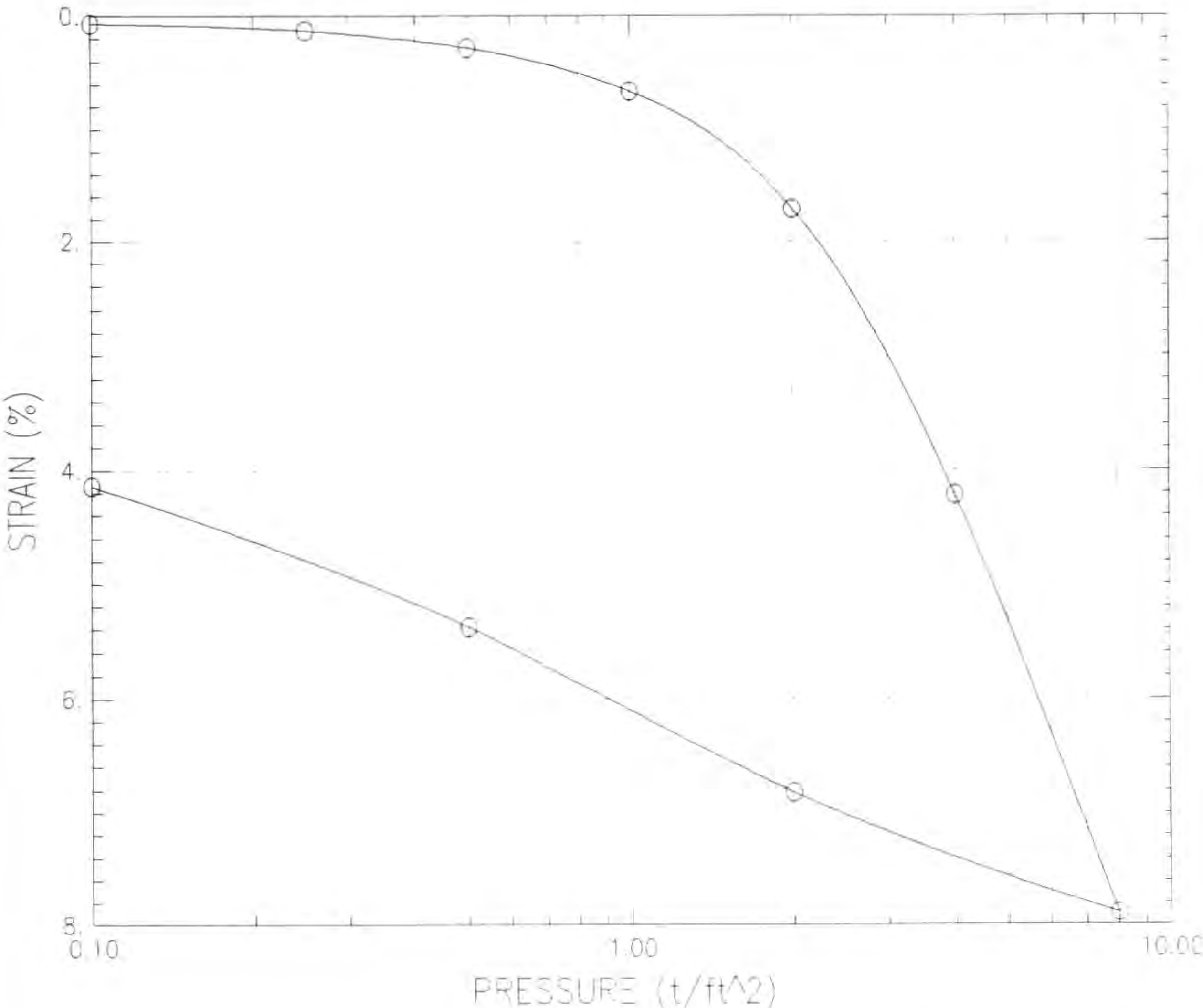


			BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)		WATER CONTENT (%)	50.734	30.874
PRECONSOL. PRESSURE (t/ft^2)		DRY DENSITY (lb/ft^3)	72.174	95.786
COMPRESSION INDEX		SATURATION (%)	102.578	109.725
TYPE SPECIMEN		VOID RATIO	1.335	0.760
DIA. (in) 2.500	HT (in) 1.000	BACK PRESSURE (t/ft^2)		
CLASSIFICATION LoadTrac, 24 hr increments				
LL 0.0 / PL 0.0 / PI 0.0		PROJECT SD		
GS 2.700	D_{10}	Data File NC-6.ASC		
REMARKS		BORING NO. 25122.2	SAMPLE NO. T-2	
NC-6, LoadTrac, 24 hr increments		DEPTH 22-24 ft	DATE 5/10/93	
		CONSOLIDATION TEST REPORT		



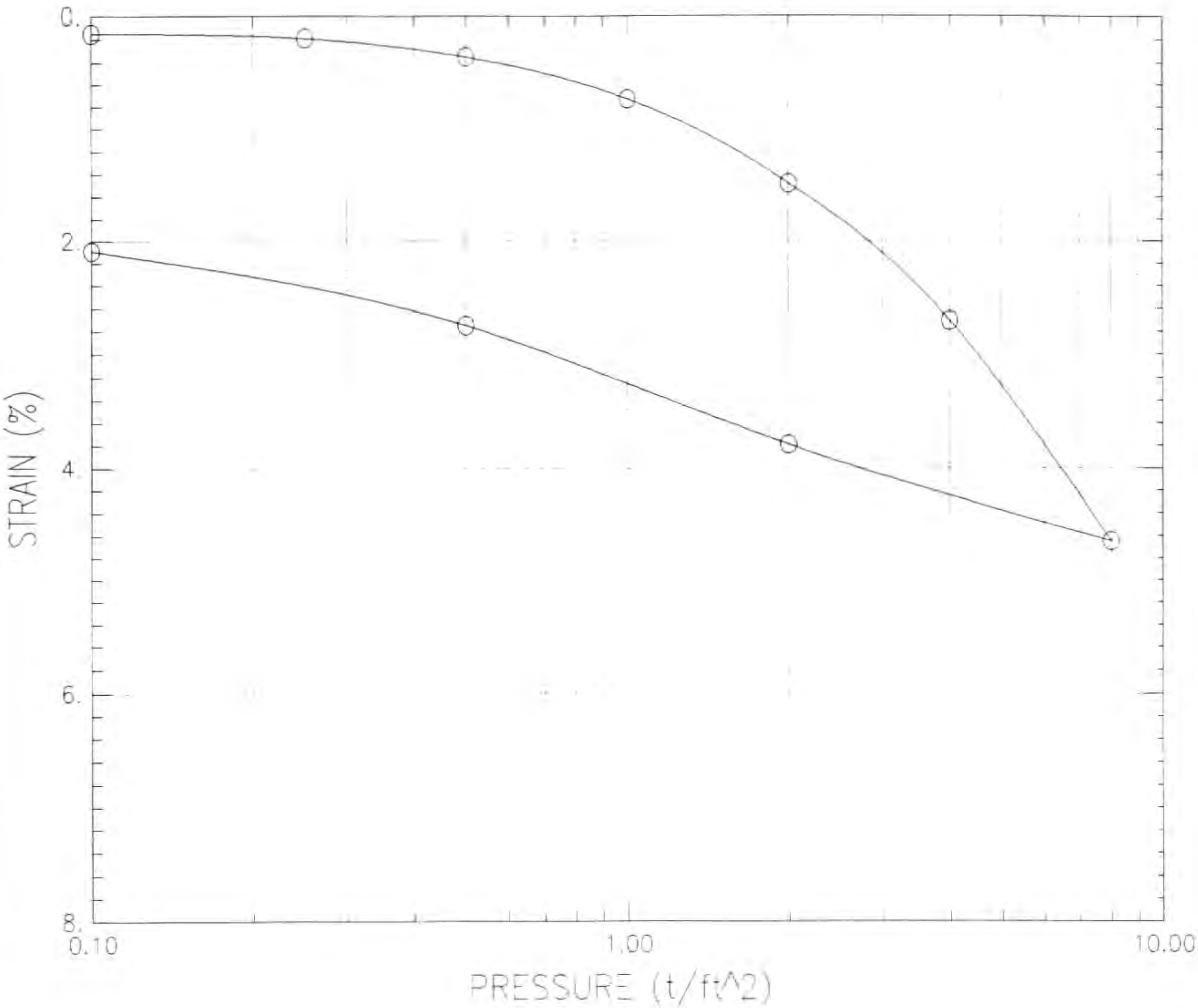
			BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)		WATER CONTENT (%)	50.636	30.996
PRECONSOL. PRESSURE (t/ft^2)		DRY DENSITY (lb/ft^3)	71.680	94.603
COMPRESSION INDEX		SATURATION (%)	101.160	107.058
TYPE SPECIMEN		VOID RATIO	1.351	0.782
DIA. (in) 2.500	HT. (in) 1.000	BACK PRESSURE (t/ft^2)		
CLASSIFICATION LoadTrac, T100 + 2 hr increments				
LL 0.0 PL 0.0	PI 0.0	PROJECT		
GS 2.700	D_{10}	Data File: NC-7.ASC		
REMARKS		BORING NO. 25122.2	SAMPLE NO. T-2	
NC-7, LoadTrac, T100 + 2 hr increments		DEPTH 22-24 ft	DATE 5/20/93	

CONSOLIDATION TEST REPORT



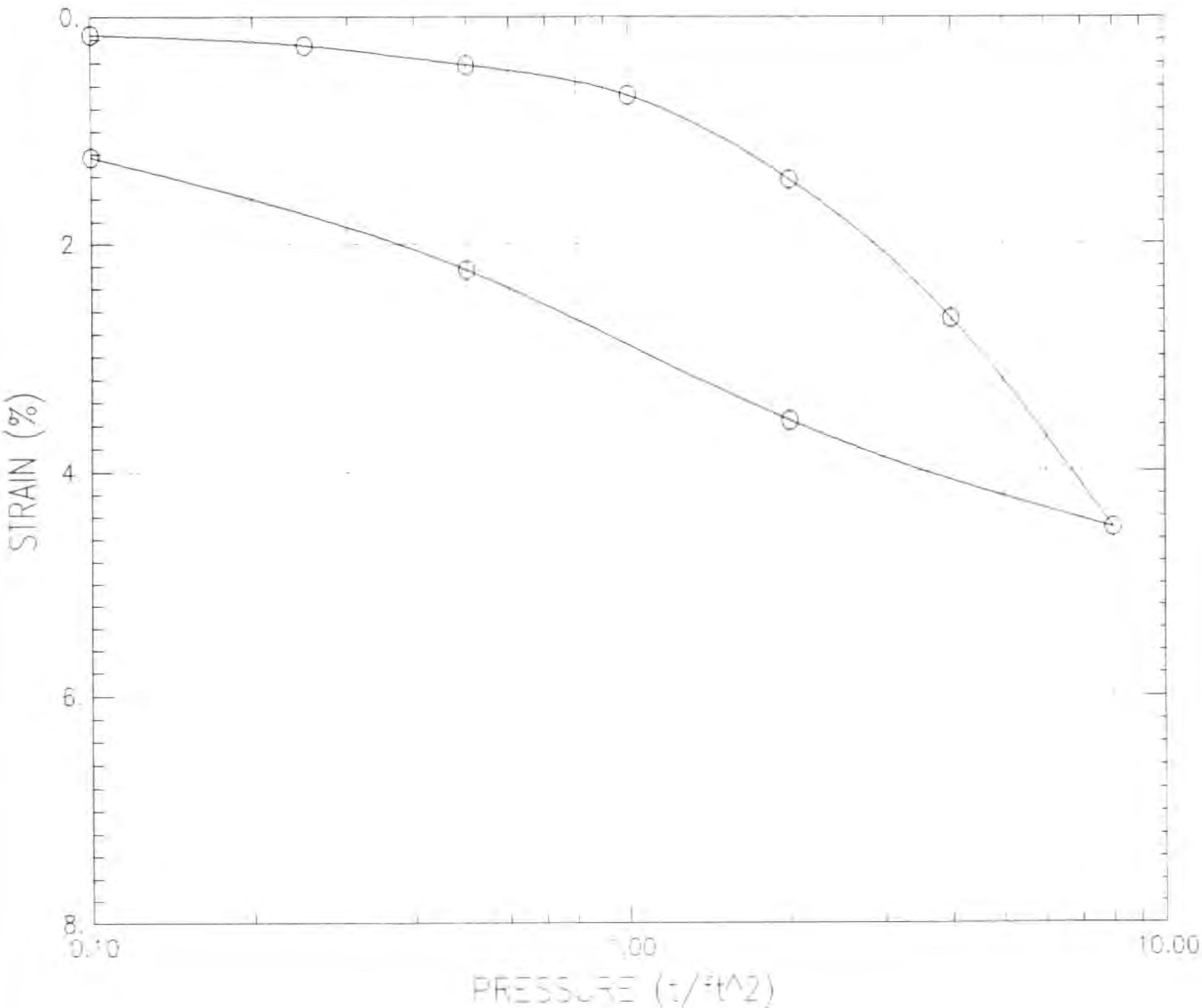
			BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)		WATER CONTENT (%)	27.949	28.657
PRECONSOL. PRESSURE (t/ft^2)		DRY DENSITY (lb/ft^3)	89.795	93.673
COMPRESSION INDEX		SATURATION (%)	86.033	96.790
TYPE SPECIMEN		VOID RATIO	0.877	0.799
DIA. (in) 2.500	HT (in) 1.000	BACK PRESSURE (t/ft^2)		
CLASSIFICATION LoadTrac, T100 + 6 hr increments				
LL 0.0 PL 0.0	PI 0.0	PROJECT SDDOT		
GS 2.700	D_{10}	Data File: M1-1.DAT		
REMARKS		BORING NO. AA	SAMPLE NO. ---	
M1-1, LoadTrac, T100 + 6 hr increments		DEPTH ---	DATE ---	

CONSOLIDATION TEST REPORT

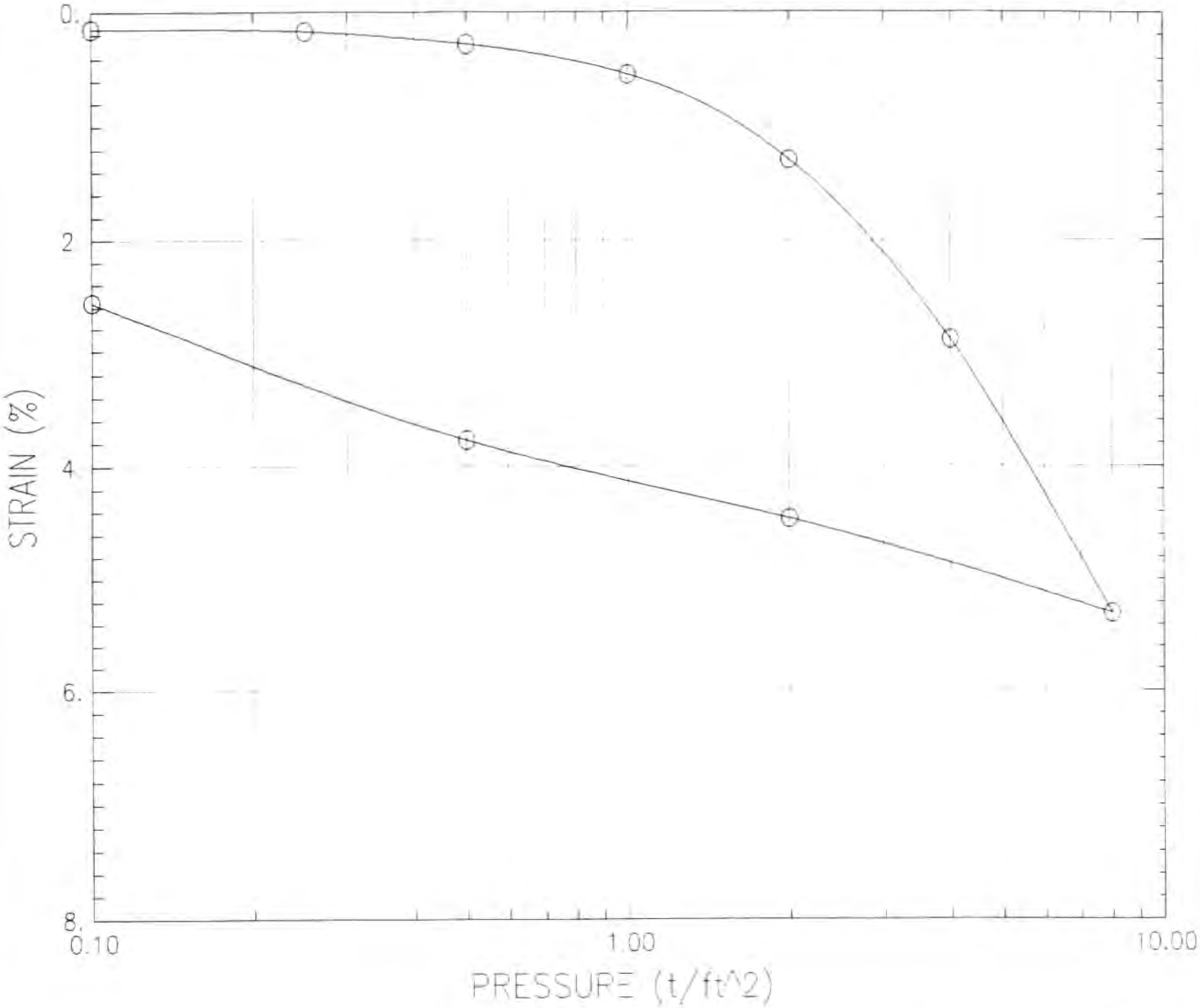


			BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)		WATER CONTENT (%)	23.013	23.974
PRECONSOL. PRESSURE (t/ft^2)		DRY DENSITY (lb/ft^3)	98.615	100.720
COMPRESSION INDEX		SATURATION (%)	87.611	96.107
TYPE SPECIMEN		VOID RATIO	0.709	0.674
DIA. (in) 2.500	HT. (in) 1.000	BACK PRESSURE (t/ft^2)		
CLASSIFICATION LoadTrac, T100 + 6 hr increments				
LL 0.0	PL 0.0 PI 0.0	PROJECT SDDOT		
GS 2.700	D_{10}	Data File: M1-2.DAT		
REMARKS		BORING NO. AA	SAMPLE NO. ---	
M1-2, LoadTrac, T100 + 6 hr increments		DEPTH ---	DATE ---	

CONSOLIDATION TEST REPORT



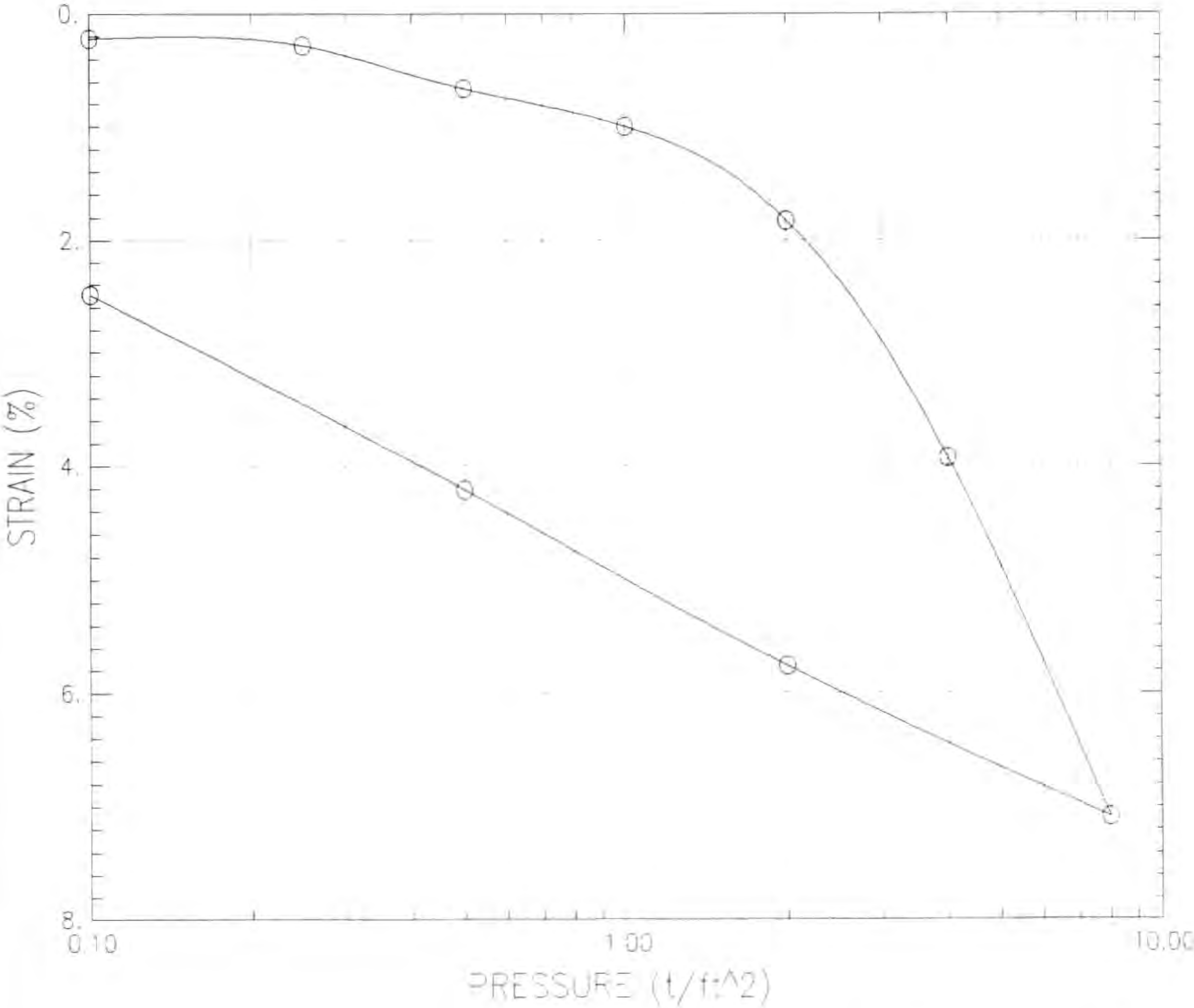
					BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)				WATER CONTENT (%)	23.676	25.004
PRECONSOL. PRESSURE (t/ft^2)				DRY DENSITY (lb/ft^3)	99.348	100.585
COMPRESSION INDEX				SATURATION (%)	91.765	99.905
TYPE SPECIMEN				VOID RATIO	0.697	0.676
DIA. (in) 2.500		HT. (in) 1.000		BACK PRESSURE (t/ft^2)		
CLASSIFICATION LoadTrac, T100 + 12 hr increments						
LL 0.0	PL 0.0		PI 0.0	PROJECT SDDOT		
GS 2.700		D_{10}		Data File: M1-3.DAT		
REMARKS				BORING NO. AA		SAMPLE NO. ---
M1-3, LoadTrac, T100 + 12 hr increments				DEPTH ---		DATE ---
				CONSOLIDATION TEST REPORT		



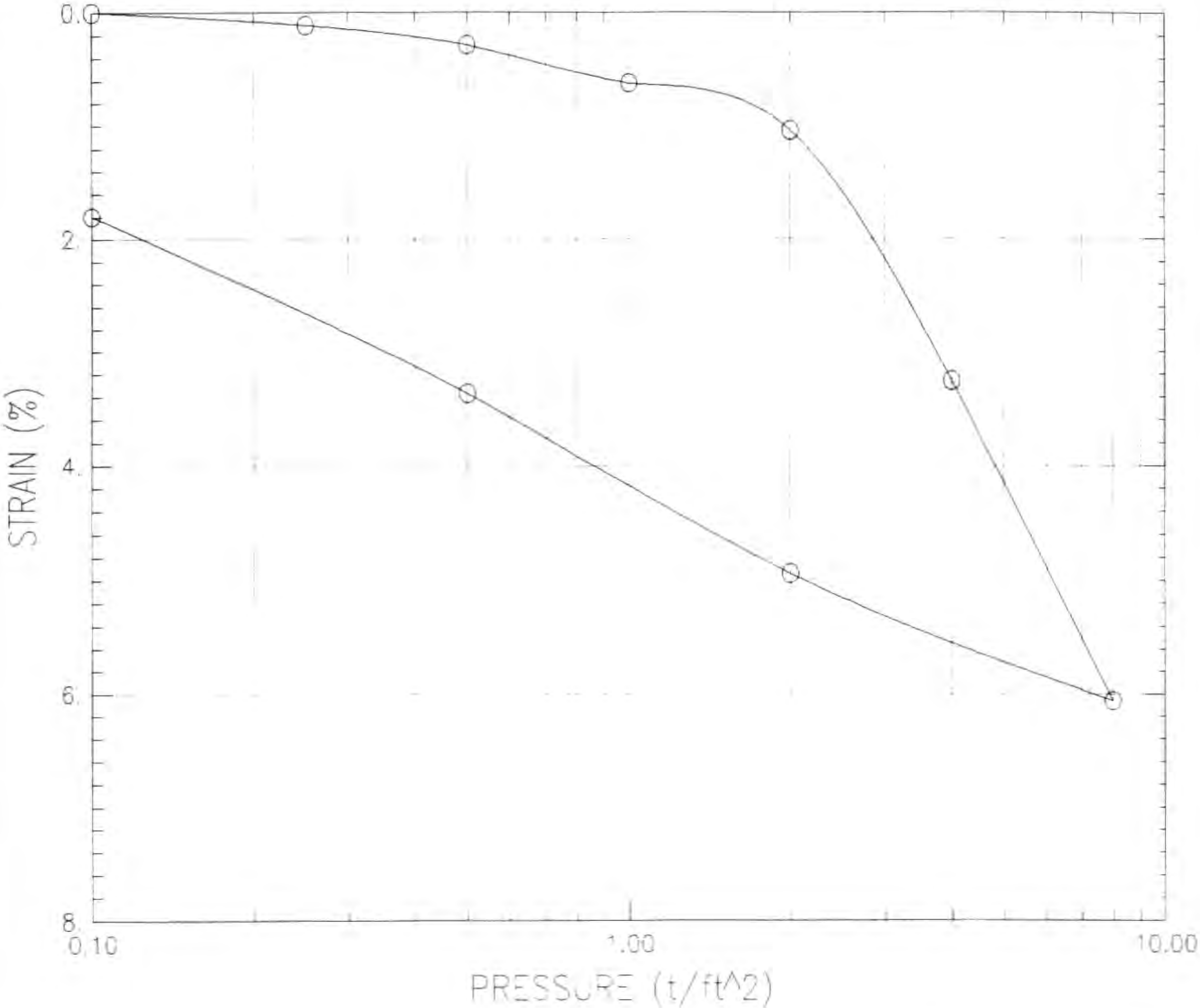
				BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)			WATER CONTENT (%)	18.895	19.704
PRECONSOL. PRESSURE (t/ft^2)			DRY DENSITY (lb/ft^3)	101.659	104.330
COMPRESSION INDEX			SATURATION (%)	77.525	86.420
TYPE SPECIMEN			VOID RATIO	0.658	0.616
DIA. (in) 2.500	HT. (in) 1.000		BACK PRESSURE (t/ft^2)		

CLASSIFICATION LoadTrac, T100 + 1 hr increments			
LL 0.0	PL 0.0	PI 0.0	PROJECT SDDOT
GS 2.700	D_{10}		Data File: M1-4.DAT
REMARKS		BORING NO. AA	SAMPLE NO ---
M1-4, LoadTrac, T100 + 1 hr increments		DEPTH ---	DATE ---

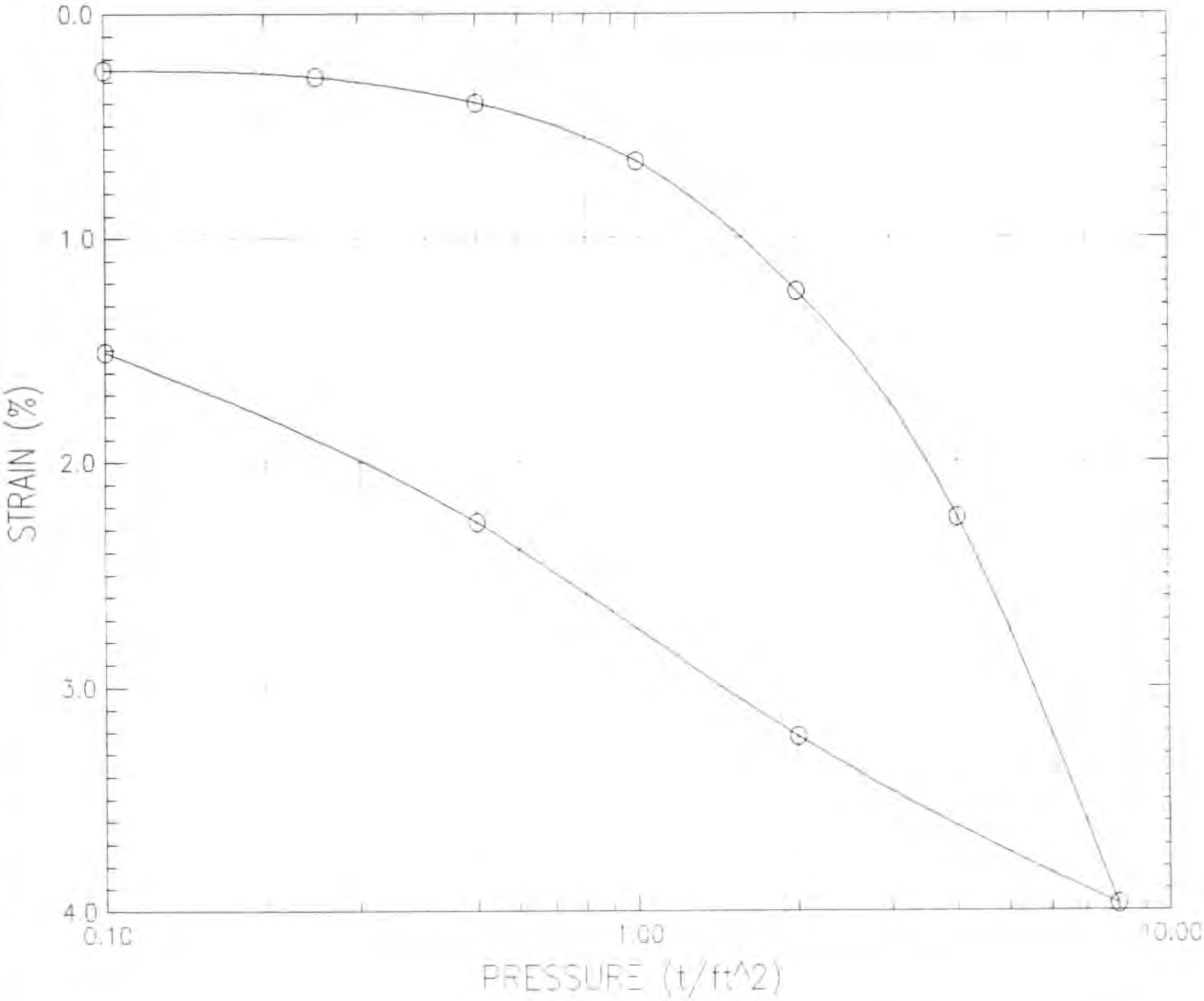
CONSOLIDATION TEST REPORT



						BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)					WATER CONTENT (%)	26.365	27.942
PRECONSOL. PRESSURE (t/ft^2)					DRY DENSITY (lb/ft^3)	93.148	96.346
COMPRESSION INDEX					SATURATION (%)	87.931	100.662
TYPE SPECIMEN					VOID RATIO	0.810	0.749
DIA. (in) 2.500		HT. (in) 0.750			BACK PRESSURE (t/ft^2)		
CLASSIFICATION Karol Warner cell, 24 hr increments							
LL 0.0	PL 0.0		PI 0.0		PROJECT SDDOT		
GS 2.700		D_{10}			Data File: M1-6.DAT		
REMARKS					BORING NO. AA		SAMPLE NO. ---
M1-6, Karol Warner, 24 hr increments					DEPTH ---		DATE ---
					CONSOLIDATION TEST REPORT		

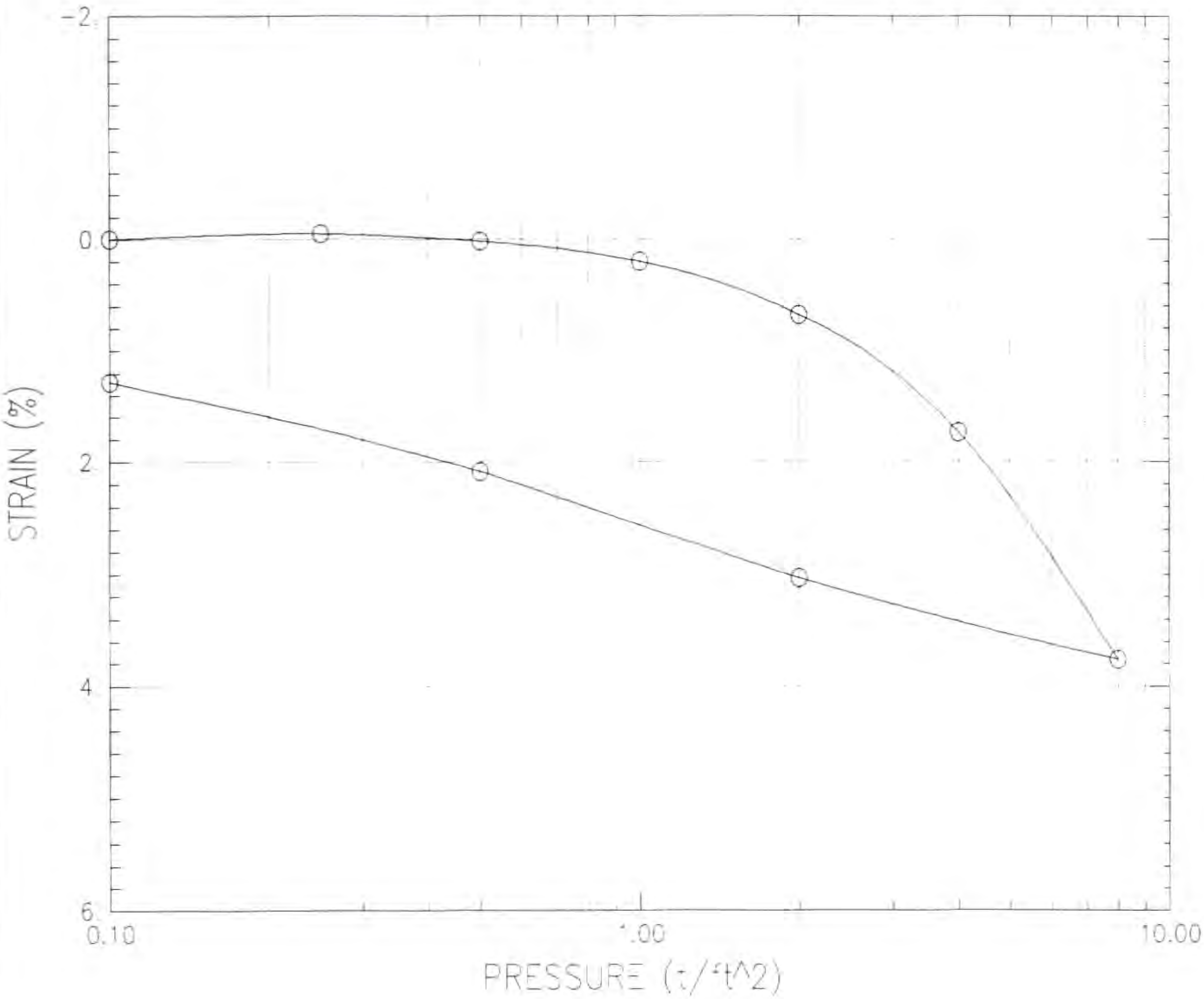


			BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)		WATER CONTENT (%)	24.158	25.958
PRECONSOL. PRESSURE (t/ft^2)		DRY DENSITY (lb/ft^3)	95.385	97.134
COMPRESSION INDEX		SATURATION (%)	85.029	95.318
TYPE SPECIMEN		VOID RATIO	0.767	0.735
DIA. (in) 4.285	HT. (in) 1.000	BACK PRESSURE (t/ft^2)		
CLASSIFICATION Karol Warner cell, 24 hr increments				
LL 0.0 PL 0.0 PI 0.0		PROJECT SDDOT		
GS 2.700	D_{10}	Data File: M1-7.DAT		
REMARKS		BORING NO. AA	SAMPLE NO. ---	
M1-7, Karol Warner, 24 hr increments		DEPTH ---	DATE ---	
		CONSOLIDATION TEST REPORT		



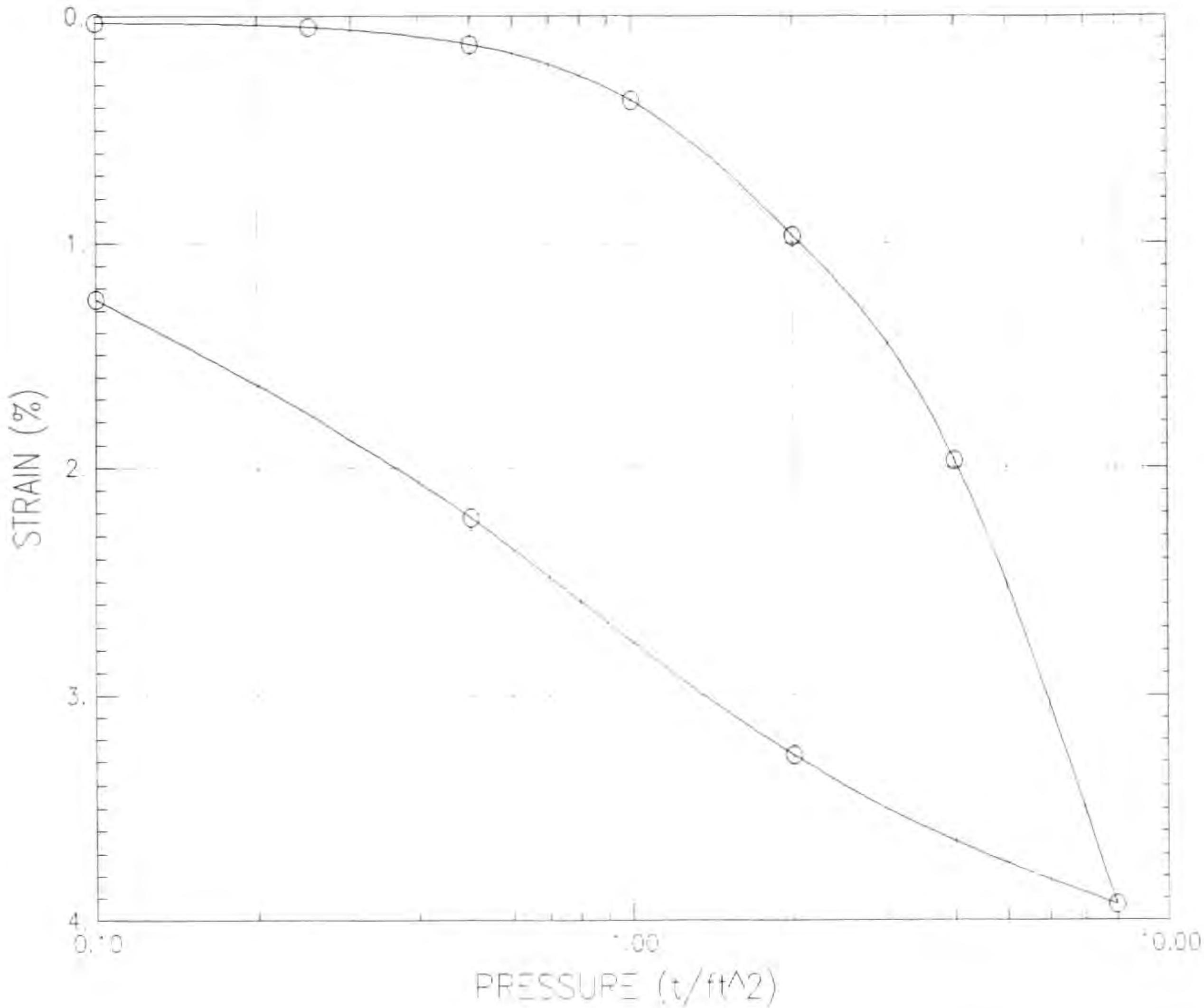
				BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)			WATER CONTENT (%)	19.226	20.540
PRECONSOL. PRESSURE (t/ft^2)			DRY DENSITY (lb/ft^3)	106.291	107.921
COMPRESSION INDEX			SATURATION (%)	88.615	98.708
TYPE SPECIMEN			VOID RATIO	0.586	0.562
DIA. (in) 2.500	HT. (in) 1.000		BACK PRESSURE (t/ft^2)		
CLASSIFICATION LoadTrac, T100+ 1 hr increments					
LL 0.0	PL 0.0	PI 0.0	PROJECT SDDOT		
GS 2.700	D_{10}		Data File: M2-1.DAT		
REMARKS			BORING NO. BB	SAMPLE NO. ---	
M2-1, LoadTrac, T100 + 1 hr increments			DEPTH ---	DATE ---	

CONSOLIDATION TEST REPORT



			BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)		WATER CONTENT (%)	19.093	20.661
PRECONSOL. PRESSURE (t/ft^2)		DRY DENSITY (lb/ft^3)	106.866	108.252
COMPRESSION INDEX		SATURATION (%)	89.302	100.141
TYPE SPECIMEN		VOID RATIO	0.577	0.557
DIA. (in) 2.500	HT. (in) 1.000	BACK PRESSURE (t/ft^2)		
CLASSIFICATION LoadTrac, T100+ 6 hr increments				
LL 0.0 / PL 0.0	PI 0.0	PROJECT SDDOT		
GS 2.700	D_{10}	Data File: M2-2.DAT		
REMARKS		BORING NO. BB	SAMPLE NO. ---	
M2-2, LoadTrac, T100 + 6 hr increments		DEPTH ---	DATE ---	

CONSOLIDATION TEST REPORT



			BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE (t/ft^2)		WATER CONTENT (%)	19.494	20.779
PRECONSOL. PRESSURE (t/ft^2)		DRY DENSITY (lb/ft^3)	106.923	108.277
COMPRESSION INDEX		SATURATION (%)	91.311	100.774
TYPE SPECIMEN		VOID RATIO	0.576	0.557
DIA. (in) 2.500	HT. (in) 1.000	BACK PRESSURE (t/ft^2)		
CLASSIFICATION LoadTrac, 24 hr increments				
LL 0.0 PL 0.0 PI 0.0		PROJECT SDDOT		
GS 2.700	D_{10}	Data File M2-3.DAT		
REMARKS		BORING NO. BB	SAMPLE NO. ---	
M2-3, LoadTrac, 24 hr increments		DEPTH ---	DATE ---	

CONSOLIDATION TEST REPORT