Strength-Consistency Indices For a Cohesive Soil

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Stress-strain response data from approximately 200 constant strain-rate, uniaxial, compression tests on a remolded, plastic clay are analyzed to determine an analytic form of stress-strain relation in terms of strength-consistency indices. These indices are the compressive strength and failure strain of the soil. Variables included in the study are stress, strain, compressive strength, failure strain, moisture content, material history and preparation procedure. The methods of preparation are compaction and extrusion and the various imposed histories include creep, vibration (repeated load applications), overconsolidation and desiccation. Illustrative examples from the literature include the effects of variable strain rate and confining stress and are presented to demonstrate the usefulness of the strength-consistency indices in control and testing of materials.

• A PROBLEM of considerable importance in control and testing of materials, as well as the practical aspects of many phases of highway construction, is that of estimating the response of a cohesive soil at a particular consistency or strength under a particular set of environmental circumstances from the response for the same set of circumstances but at a different moisture content or consistency of the soil. One approach to this problem is the use of strength-consistency indices based on the compressive strength and failure strain of the soil as determined by a constant rate of strain test. The potential usefulness of this approach is illustrated by the stress-strain response of a particular remolded plastic clay at various conditions of consistency and history.

The variables involved in this study are stress, strain, compressive strength, failure strain, moisture content, material history and method of preparation. Specimens were prepared by extrusion and compaction processes. Extruded specimens were subjected to a variety of histories, including creep, vibration (repeated load applications), overconsolidation and desiccation.

Each of the imposed histories attempts to reproduce actual field conditions encountered in dealing with such materials. For example, the specimens subjected to vibratory histories undergo a maximum of approximately 100,000 load applications prior to testing. Such a repeated load history is extremely important in rational highway pavement design. The creep histories may be related to a progressive-type failure phenomenon often associated with highway embankments. A desiccation history may be imposed in the field by alternate wet and dry periods or variations in the ground water table, both during construction and during performance. Overconsolidation history may be imposed on a soil by current causes, such as an embankment surcharge, existing structure, or desiccation, as well as by geologic causes, such as glaciers. The use of extrusion and compaction preparation processes allows for the comparison of results between different soil particle orientations as imposed by various field placement methods.

Paper sponsored by Committee on Stress Distribution in Earth Masses.

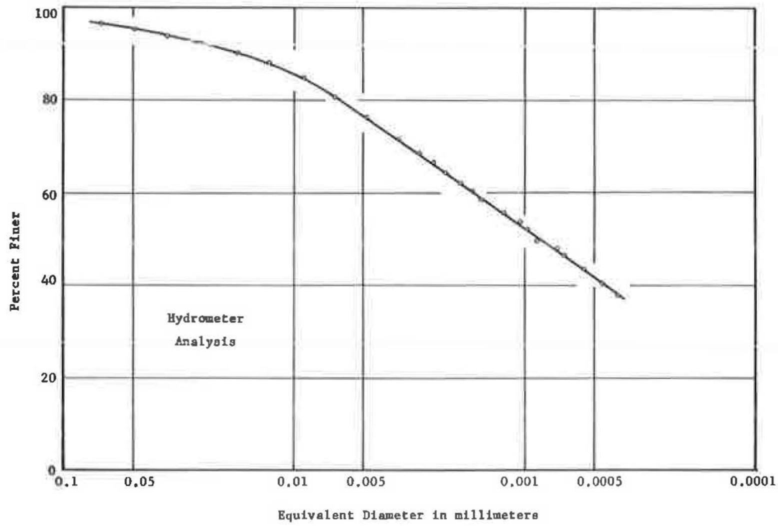

Figure 1. Grain size distribution.

Uniaxial compression tests were then conducted on all specimens and stress-strain response is expressed in analytic form as a function of the strength-consistency indices. These characteristic indices are given for various soil specimens at different moisture contents. Particular emphasis is directed to the significant difference in strength between compacted and extruded specimens, all other factors (density, moisture content, void ratio, etc.) being very nearly the same.

Following the development of the analytic form for stress-strain response, the usefulness of such indices in control and testing of materials is illustrated for some aspects of creep and vibratory loading phenomena and for triaxial and variable strain-rate test data obtained from the literature. Other test procedures for obtaining strength-consistency indices are discussed.

MATERIAL INVESTIGATED

The soil investigated is a remolded, plastic clay sold commercially under the name Jordan Buff by the United Clay Mines Corp., Trenton, N. J. Figure 1 shows the particle size distribution as determined by hydrometer analysis. The characteristics of the clay are: liquid limit, 46 percent; plastic limit, 30 percent; shrinkage limit, 20 percent; plasticity index, 16 percent; and specific gravity, 2.74.

EXPERIMENTAL PROCEDURE

Preparation of Specimens

The soil specimens were prepared from a dry, powdered form by mixing with a predetermined amount of distilled water. After the clay and water were satisfactorily blended, by hand and by mechanical mixer, specimens were formed by either compaction or extrusion.

In the compaction process, the clay-water mixture was subjected to standard Proctor compactive energy of 12,400 ft-lb per cu ft. After the required compaction test information (Fig. 2) was obtained from the mold, three cylindrical specimens 3.65 cm in diameter were cored from each mold by use of specially constructed sampling tubes. The specimens were then removed from the tubes and placed in miter boxes where they were trimmed with a wire saw to lengths of 8.20 cm (giving a length-diameter ratio of 2.25) and immediately tested.

In the extrusion process, the clay-water mixture was passed through a "Vac-Aire" sample extruder similar to that used by Schmertmann and Osterberg (1) and described

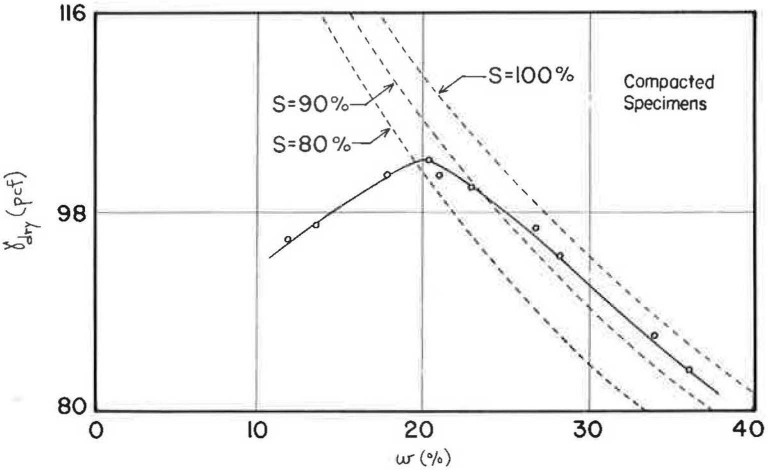

Figure 2. Dry density vs moisture content: compacted specimens.

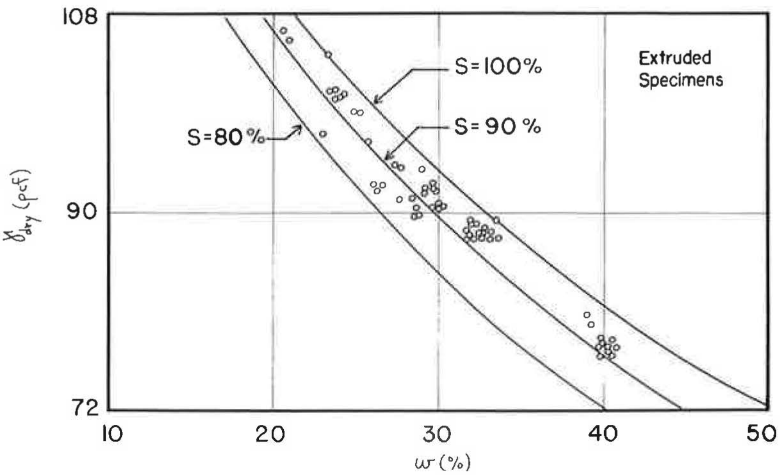

Figure 3. Dry density vs moisture content: extruded specimens.

in detail by Matlock, Fenske and Dawson (2). Depending on the moisture content at which it was mixed, the clay was passed through the extruder two or three times. It was found that the soil mixture decreased in moisture content about 0.5 to 1 percent with each extrusion because of the heat generated. During the last extrusion, as the clay passed through the 3.65-cm diameter die, it was cut into lengths greater than 8.20 cm. The resulting curve of dry density vs moisture content for the extruded specimens is shown in Figure 3. Some of these extruded specimens were placed in the miter box, trimmed with a wire saw to a length of 8.20 cm and immediately tested. However, most specimens were covered with five or six coats of a flexible wax and stored vertically in a single layer at approximately 100 percent RH.

The wax was composed of a mixture of paraffin and petrolatum (trade name, Standard Oil Co., Chicago, Ill.) and provided a protective coating that was not susceptible to large shrinkage upon cooling, not brittle, and could be peeled from the specimen with ease. By maintaining the wax at a temperature a few degrees above its melting point, the driving-off of the more volatile hydrocarbons was prevented. The loss of these hydrocarbons would tend to cause a more permeable and brittle coating upon cooling.

After the wax was removed, the extruded specimens were subjected to various histories to determine their effect on the stress-strain response characteristics. Such histories include overconsolidation, desiccation, creep and vibration. In addition, thixotropic effects were studied for more than a year.

The overconsolidation history was induced by placing a trimmed specimen (L, 8.20 cm; d, 3.65 cm) encased in filter paper in a standard triaxial compression cell and subjecting it to hydrostatic pressure for several days. Lateral confinement was obtained using glycerine as the chamber fluid within a lucite cell. Pressures obtained by applying air pressure to the chamber fluid were measured with a Bourdon pressure gage. All the specimens were free-draining and volume changes were measured by use of a pipette connected to the specimen through the base of the chamber. Axial deformations of the specimens were measured with an indicator dial having a sensitivity of 0.001 in. Overconsolidation pressures varied between 3 and 5 kg per sq cm and were applied for 3 to 7 days. After the consolidation pressure was removed, the specimens were permitted to rebound under conditions of free drainage before testing.

The desiccation history was obtained by removing the wax coating from the specimens and exposing them to a relatively uniform environmental atmosphere for prescribed periods of time. The specimens then were rewaxed and stored in a humid room for at least 10 days to provide reasonable time for a homogeneous redistribution of moisture. They were then stripped of their wax cover, placed in a miter box, trimmed and tested. The creep history was imposed on the trimmed specimens by subjecting them to a constant load in unconfined compression for approximately 20,000 min (2 wk). The loads were then removed and the specimens were allowed to rebound for approximately 10,000 min (1 wk). During this time a protective coating of two membranes with petrolatum on the outer membrane maintained the loss of moisture in the specimens at approximately 0.25 percent. After this history, the membrane coverings were removed and the specimens were tested.

The vibratory history was given to the trimmed specimens by subjecting them to a static stress of approximately 0.54 kg per sq cm and superimposing sinusoidally varying dynamic strain amplitudes of approximately 50,100 and 200 μ-in. per in. for time periods of 1, 4, 16 and 64 min. The frequency of oscillation was 25 cps. Under these conditions, failure would have occurred at approximately 400 μ-in. per in. The specimens exposed for 16 and 64 min were covered with a single uncoated membrane to reduce moisture losses. The vibratory apparatus used for this purpose has been described in detail by Kondner and Krizek (3). Following this history, the rubber membranes were removed and the specimens were immediately tested.

Thixotropic effects were investigated by testing extruded specimens at various intervals throughout a period of approximately 15 mo from the date of extrusion.

Description of Test

After the prescribed history was imposed on the specimens, they were subjected to a constant rate of axial strain test in unconfined compression to determine stress-strain response. These tests were conducted in a standard triaxial compression cell without lateral pressure with a custom-built gear-type testing machine where the rate of deformation was 0.122 cm per min. The use of the triaxial cell helped to reduce drying of the specimen during the test. The degree of deformation of the specimen was obtained by measuring the motion of the upper platen with an indicator dial, and the value of the compressive load was obtained from a proving ring placed in series with the test specimen.

Axial strain of the specimen was determined by dividing the measured deformation by the initial length. Axial stress was determined by dividing the measured compressive load by the corrected specimen area as computed by a uniform, constant-volume area correction. Initial measurements of the specimens were always those associated with the beginning of the unconfined compression test, not the beginning of the load history.

The compressive strength and strain at failure are used as convenient indices for specifying the strength and consistency characteristics of the various specimens. The compressive strength, q, is the maximum axial stress attained in an unconfined com-

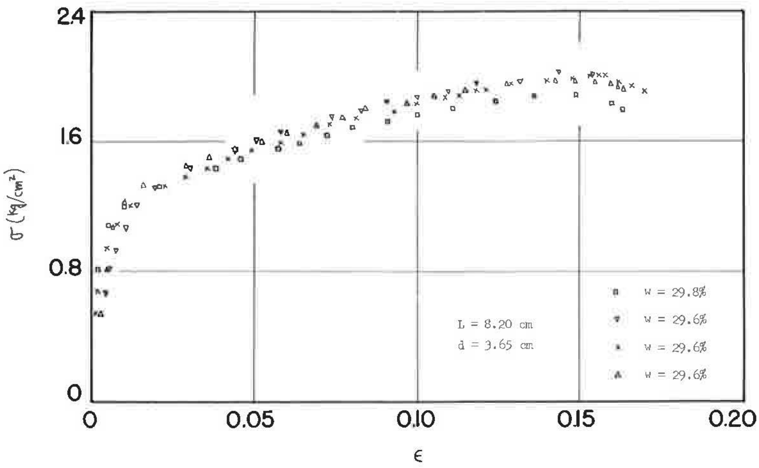

Figure 4. Typical stress-strain response for unconfined compression tests.

pression test or the maximum deviator stress attained in a triaxial test (each based on a constant-volume area correction). The strain at failure, ϵ_f, is the strain associated with the compressive strength on a stress-strain plot.

EXPERIMENTAL RESULTS

General Stress-Strain Response

For any test program to possess a high degree of reliability, it is necessary to be able to duplicate any given test within a reasonable amount of experimental error. To illustrate that this requirement has been satisfied in this test program, the results of four virtually identical tests on four different specimens are shown in Figure 4 in the form of axial stress vs axial strain. Most other tests throughout the program were conducted two or three times to insure duplicability under other conditions.

To investigate the effect of moisture content on the stress-strain response, unconfined compression test data on five different specimens at five different moisture contents (21.0, 25.2, 29.6, 32.9 and 40.4 percent) are shown in Figure 5. As may be anticipated, moisture content plays a significant role in the constitutive response. If the same data are plotted in the form of the ratio of stress to unconfined compressive strength (stress-strength parameter) vs the ratio of strain to strain at failure (strain-failure parameter) (Fig. 6), all five curves of Figure 5 seem to describe one curve in Figure 6. The apparent absence of any phenomenological order would suggest that unconfined compression data presented in this form may be considered explicitly independent of moisture content within the range considered. Of course, the effect of moisture content is implicit in the unconfined compressive strength and failure strain of a soil. Moisture content is not the only variable whose influence is implicitly expressed in the consistency indices q and ϵ_f.

If the data of Figure 6 are replotted in the form of the reciprocal of the secant modulus vs the strain-failure parameter (Fig. 7), the response can be approximated by a straight line whose equation is

$$\frac{\epsilon\, q}{\epsilon_f\, \sigma} = a + b\frac{\epsilon}{\epsilon_f} \qquad (1)$$

Eq. 1 can be rearranged into the equation of a two-constant hyperbola, as follows:

$$\frac{\sigma}{q} = \frac{\dfrac{\epsilon}{\epsilon_f}}{a + b\dfrac{\epsilon}{\epsilon_f}} \qquad (2)$$

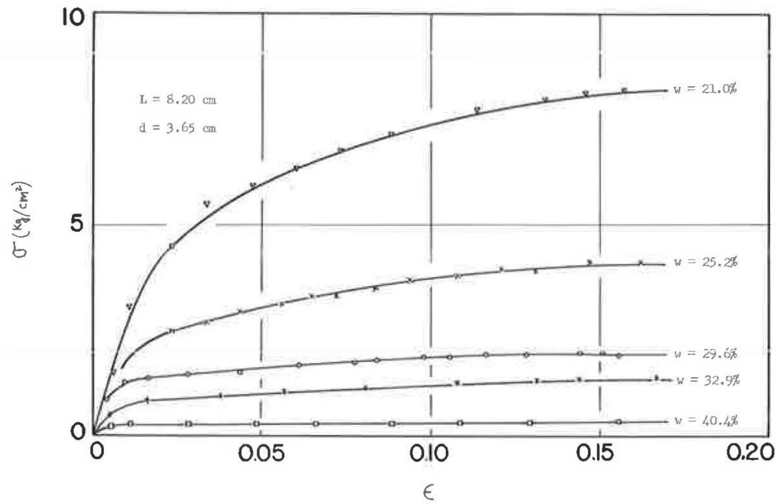

Figure 5. Stress vs strain: different moisture content.

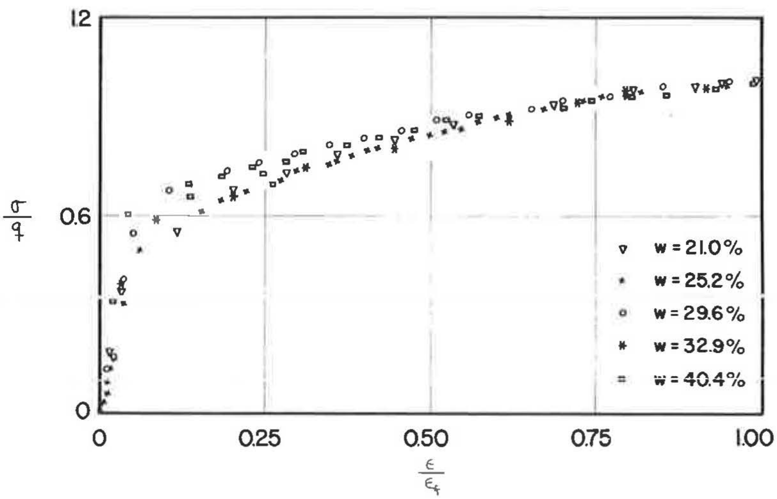

Figure 6. Stress-strength parameter vs strain-failure parameter: different moisture content.

in which 1/a represents the initial slope of the stress-strength parameter vs strain-failure parameter curve and 1/b represents the theoretical ultimate value of the stress-strength parameter as the strain-failure parameter increases to infinity. The actual ultimate value of the stress-strength parameter is, of course, unity. In the region of large strains, the curve is very flat and actual failure conditions are somewhat subjective. The usefulness and application of such a hyperbolic formulation have been shown by Kondner and Krizek (4) and Kondner (5, 6).

Types of Failure

The predominant type of failure encountered was along a plane inclined approximately 45° to the axis of the specimen. Many of the specimens exhibited base failures; that is, the failure plane intersected the base of the specimen. For the specimens with high

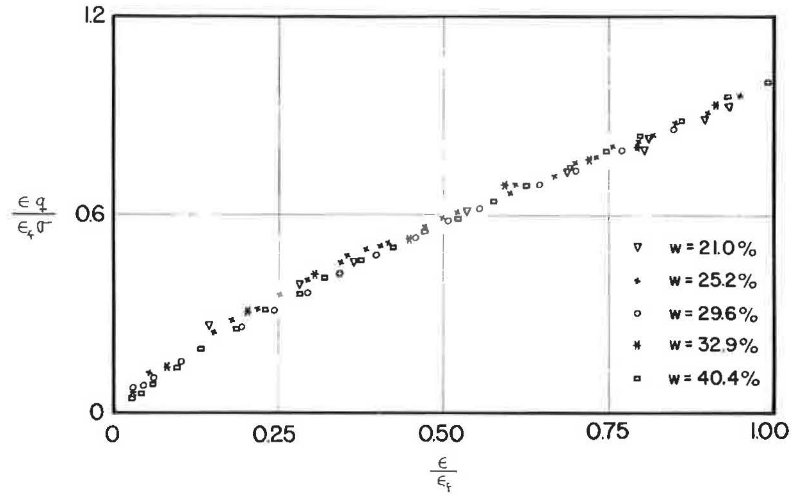

Figure 7. Transformed hyperbolic stress-strain response: different moisture content.

moisture contents (in the neighborhood of 40 percent), many failures were of a "bulging" nature, in which the specimen gradually increases in diameter as it shortens in length, even at very high values of axial strain.

Constitutive Response

Extruded Specimens.—

Extrusion History Alone.—Approximately 60 tests were performed on specimens subjected solely to the extrusion preparation process. Because of the high pressures encountered in this process, some preconsolidation stress may also exist in the specimens. If present, such stresses are probably of relatively consistent magnitude in all specimens at a particular moisture content, and their effects are considered insofar as they contribute to the over-all strength characteristics of the soil. These extruded specimens were tested at various intervals from immediately to 15 mo after extrusion. Curing of specimens for extended periods of time allows migration of water to insure a uniform distribution of moisture content throughout the specimen. Also, effects due to thixotropy have ample time to develop. A constant-strain-rate unconfined compression test was conducted on each specimen and representative data for moisture contents from approximately 21.0 to 41.2 percent are plotted in transformed hyperbolic form in Figure 8. All data seem to describe a single straight line and effects in the normalized stress-strain response due to migration of water or thixotropy are either very small or of the same order as experimental error.

Overconsolidation History.—Ten extruded specimens with high moisture contents (approximately 40 percent) were subjected to overconsolidation stresses up to 5 kg per sq cm for periods up to 7 days. During this time, measurements were obtained and void ratio, moisture content and degree of saturation were calculated. The specimens were tested immediately in unconfined compression and normalized stress-strain results are shown in Figure 9. The loci of all points tend to trace out a single curve. At the time of the unconfined test, the specimens ranged in moisture content from approximately 33.4 to 38.0 percent.

Desiccation History.—Approximately 30 extruded specimens were desiccated for periods up to 25 hr. Initial moisture contents before desiccation were approximately 40 and 32 percent, whereas final moisture contents after desiccation ranged down to 8.4 percent. The rate of desiccation was found to be approximately 1 percent change in moisture content per 100 min. After a curing period of at least 10 days to allow for a homogeneous redistribution of moisture content, specimens were tested in unconfined compression. Normalized constitutive response data are shown in Figure 10.

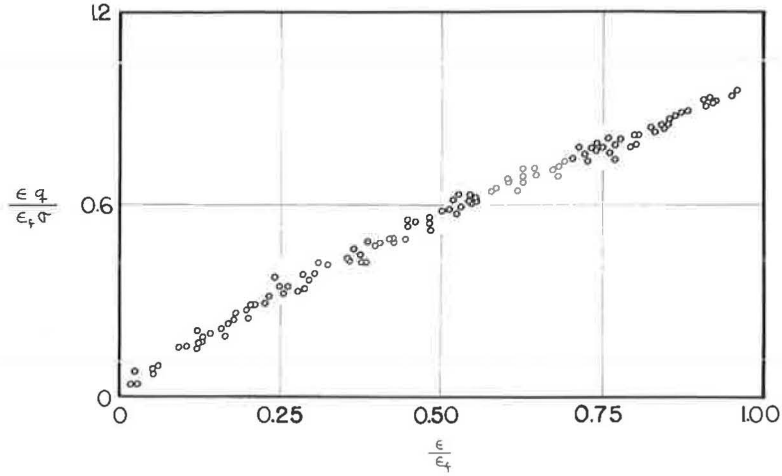

Figure 8. Transformed hyperbolic stress-strain response: extrusion history alone.

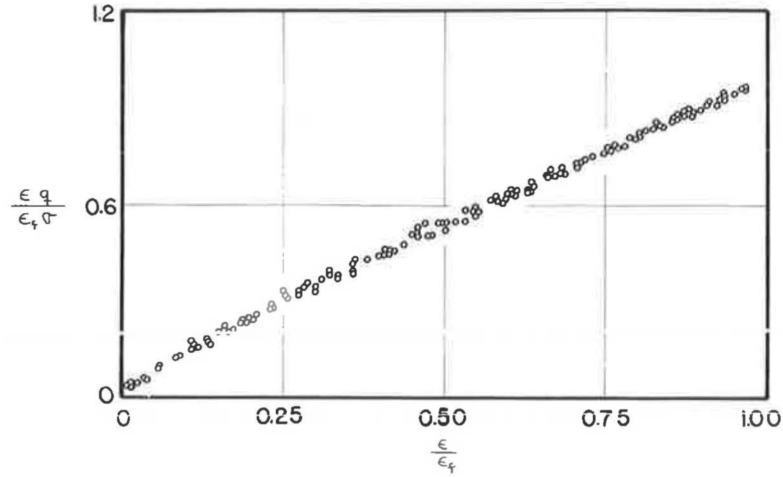

Figure 9. Transformed hyperbolic stress-strain response: overconsolidation history.

Vibratory History.—Fifteen extruded specimens with moisture contents from approximately 26.1 to 32.7 percent were subjected to vibratory histories in which a prescribed cycle of deformation was applied approximately 1,500 to 96,000 times. The strain amplitudes correspond to stress amplitudes of approximately 20 to 60 percent of the stress value required to cause failure under the given test conditions. The specimens then were tested in unconfined compression and normalized stress-strain results are shown in Figure 11.

Creep History.—Thirty-five extruded specimens with moisture contents varying from 23.2 to 40.6 percent were subjected for 2 wk to applied constant loads up to approximately 75 percent of the compressive strength of the soil; then the load was removed and each specimen was rebounded for 1 wk. Following this, uniaxial compression tests were conducted on the specimens and normalized data in transformed hyperbolic form are shown in Figure 12.

Compacted Specimens.—Approximately 40 compacted specimens (using the standard Proctor energy) of the same geometrical configuration as the extruded ones were tested

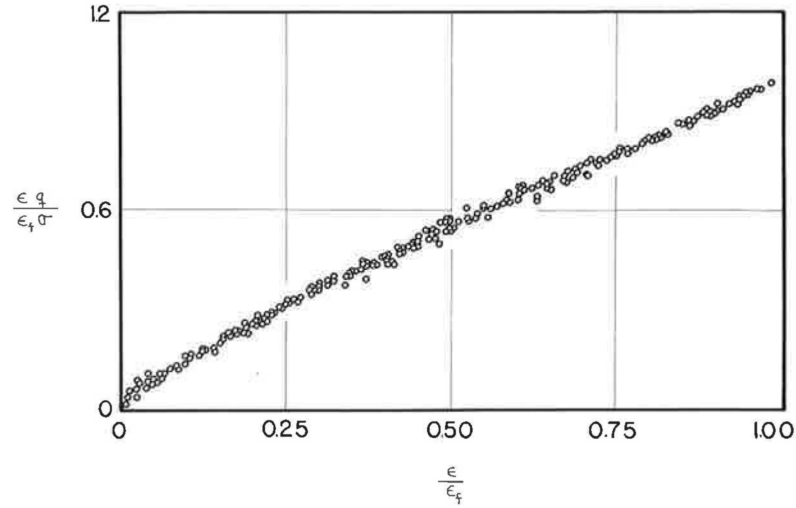

Figure 10. Transformed hyperbolic stress-strain response: desiccation history.

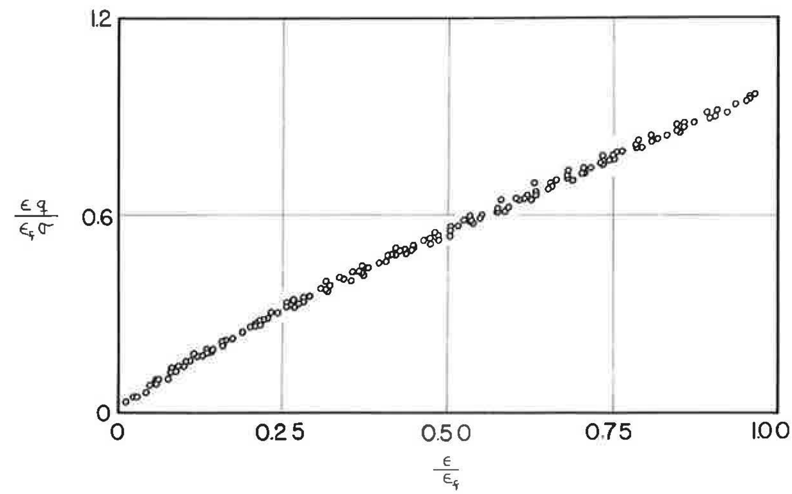

Figure 11. Transformed hyperbolic stress-strain response: vibratory history.

in unconfined compression immediately after they were cored from the mold. Moisture contents ranged from approximately 21.1 to 36.6 percent and normalized stress-strain response for these specimens is shown in Figure 13. Once again it can be seen that the data seem to trace out a straight line (except for the region of small strain); however, the line so described has a different slope and intercept from the corresponding plots for extruded specimens.

Analytic Representation

An examination of the constitutive response for all extruded specimens including any imposed history (Figs. 8-12) indicates that it can be represented within a reasonable amount of experimental error by a single equation of the form of Eq. 2. For this case, the coefficients a and b become 0.08 and 0.92, respectively. Thus, the analytic ex-

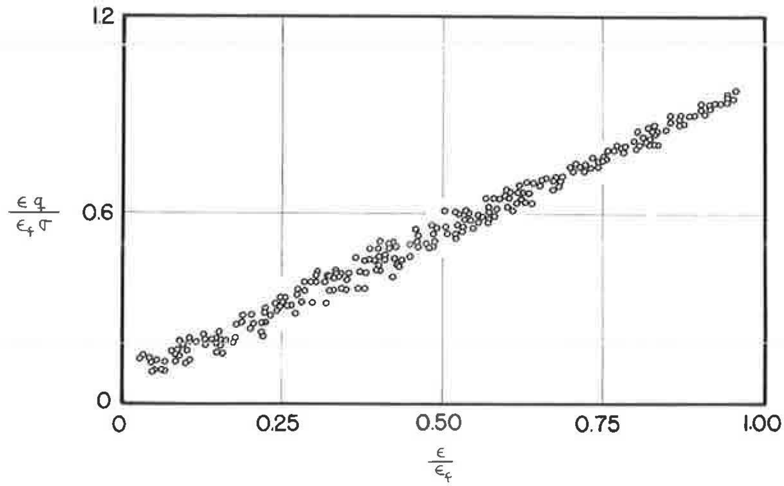

Figure 12. Transformed hyperbolic stress-strain response: creep history.

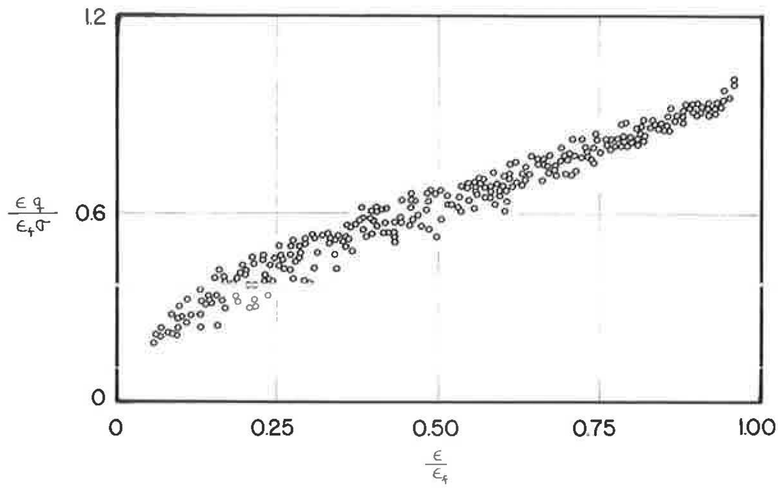

Figure 13. Transformed hyperbolic stress-strain response: compacted specimens.

pression for the extruded specimens can be written

$$\frac{\sigma}{q} = \frac{\frac{\epsilon}{\epsilon_f}}{0.08 + 0.92\,\frac{\epsilon}{\epsilon_f}} \tag{3}$$

For the compacted specimens (Fig. 13), the coefficients a and b may be approximated by 0.24 and 0.74, respectively. Hence, the representative analytic equation becomes

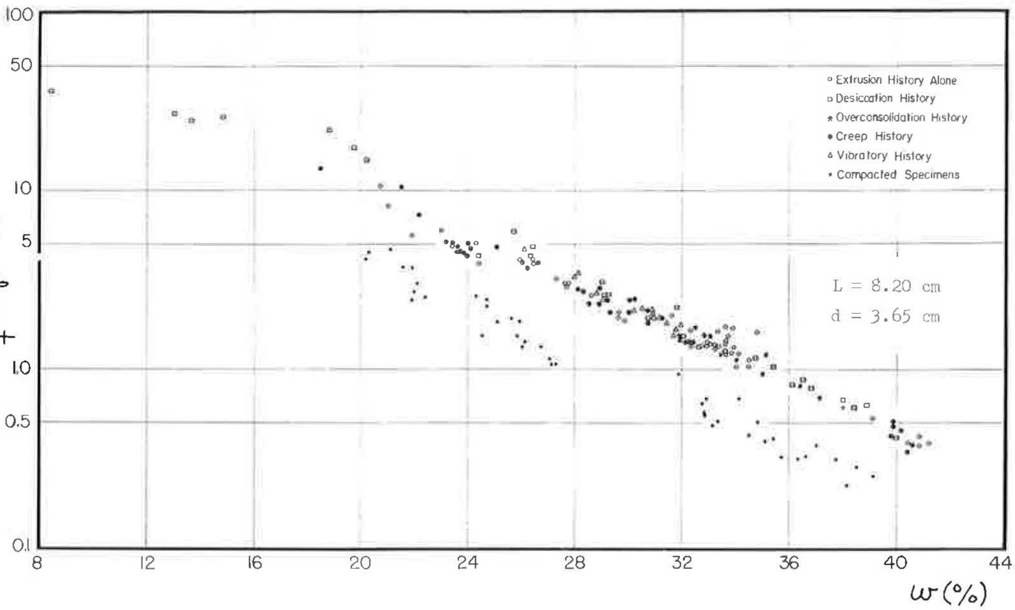

Figure 14. Unconfined compressive strength vs moisture content.

$$\frac{\sigma}{q} = \frac{\frac{\epsilon}{\epsilon_f}}{0.24 + 0.74 \frac{\epsilon}{\epsilon_f}} \tag{4}$$

Both methods of specimen preparation, extrusion and compaction, yield a similar qualitative analytic form, but the different preparation processes do result in different quantitative values for the respective coefficients. Because all data assume a relatively simple analytic representation in terms of the consistency parameters, q and ϵ_f, the stress-strain response of a specimen can be determined if the history and consistency relationships are known.

Consistency Relationships

The consistency indices employed are the compressive strength of the soil and the associated strain at failure. Because the current test program utilizes only the constant-strain-rate unconfined compression test, compressive strength is determined by the maximum axial stress (based on a constant-volume area correction) applied to the specimen. It must be emphasized that the strength so obtained is not an absolute measurement of the true strength of the soil but is only, in itself, an index thereof. Nonhomogeneous strain distributions throughout the specimen (especially as failure becomes incipient) necessarily cast doubt on any exact strength value obtained by use of the simplified constant-volume area correction, and the selection of a soil compressive strength becomes somewhat subjective. With this caution in mind, compressive strengths were obtained from more than 200 tests on specimens with moisture contents from approximately 8.4 to 41.2 percent (Fig. 14). Aside from the close correlation of all extruded specimens, regardless of subsequent history, the most striking point of Figure 14 is the reduction in the strengths of the compacted specimens to approximately one-half those of the extruded ones. For example, an extruded specimen with a moisture content of 22.2 percent and a void ratio of 0.650 had a strength of 7.69 kg per sq

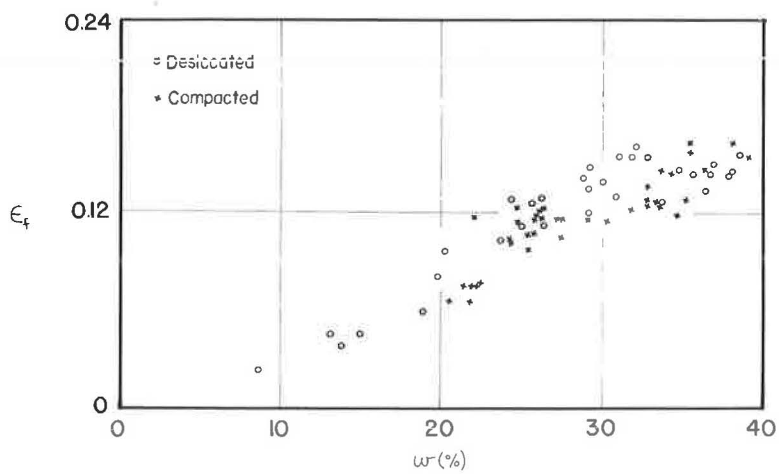

Figure 15. Strain at failure vs moisture content: compacted and desiccated specimens.

cm, whereas a compacted specimen with a moisture content of 22.4 percent and a void ratio of 0.651 had a strength of only 3.02 kg per sq cm. Such radical variations may be due to soil structure and/or the development of pore pressures during compaction and testing. The extrusion process imparts a spiral orientation to a specimen, whereas the compaction process probably results in a more random structure. Possibly overconsolidation stresses have been applied in varying degrees by both processes.

The strain at failure associated with the compressive strength is a more subjective parameter than the compressive strength itself. Its determination becomes extremely difficult because of the flat nature of the stress-strain curve in the region of failure. For this reason, one logical approach is to select such a value by statistical methods. However, in this experimental program the strain at failure is taken to be that strain existing in the specimen (based on the initial length) when the maximum deviator stress is attained. For a small portion of the tests (about 10 percent) in which the stress-strain curve in the failure region is extremely flat, appropriate failure strains consistent with the trend of the majority were determined from that region of the stress-strain curve beyond the point where the stress was 95 percent of its ultimate value. Such failure-strain values are shown in Figure 15 for the compacted and desiccated specimens in which the moisture content range is sufficiently large to indicate a trend. For the vibrated, overconsolidated and extruded specimens in which no trend could be established with moisture content, results are shown in bar graph form in Figure 16. For specimens with creep histories, the failure strain as obtained from a conventional unconfined compression test is a function of the creep strain imposed. Creep strain, in turn, is a function of the applied static load, time, and moisture content. Although failure strain as obtained from an unconfined test was quite variable, ranging from approximately 2 to 18 percent, for these creep history specimens, failure (that is, the point of maximum deviator stress) occurred at a relatively constant value, 16 ± 4 percent, of total strain as obtained from the sum of previously imposed creep strain and uniaxial compression strain from the unconfined test. Such a result is consistent with a maximum strain type of failure theory; however, any definite conclusion regarding this point is purely speculative and certainly premature at this time.

ILLUSTRATIVE EXAMPLES

Strain Rate Effects

To demonstrate a more general application of the preceding technique, data reported by Osterberg and Perloff (7) for variable strain rate tests on an oxidized and weathered glacial till have been analyzed. A typical set of tests corresponds to a moisture content of

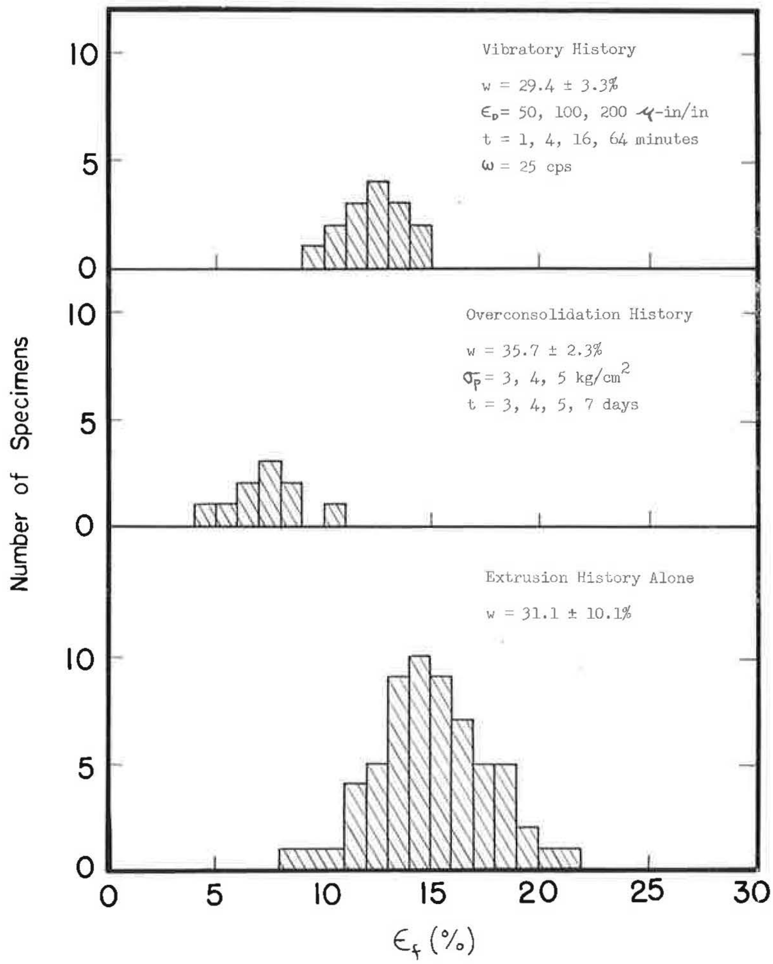

Figure 16. Bar graph representation of strain at failure: vibrated, overconsolidated and extruded specimens.

23.1 ± 0.2 percent and seven different strain rates varying between 5.37×10^{-5} and 1.79×10^{-2} in. per in. per min. Stress-strain data obtained from the reported curves have been recomputed in terms of the stress-strength and strain-failure parameters, and results are shown in transformed hyperbolic form in Figure 17. The data may be approximated by an analytic expression of the form given by Eq. 2. These consistency indices are plotted as a function of strain rate in Figure 18. Hence, strain rate effects on constitutive response are included in the consistency indices, q and ϵ_f.

Triaxial Test Data

Data from approximately 35 triaxial compression tests on the embankment material of the Hybla Valley test track near Alexandria, Va., have been made available through the courtesy of E. S. Barber. A detailed description of this cooperative study conducted by the U. S. Bureau of Public Roads, the Asphalt Institute and the Highway Research Board may be found in a report by Benkelman and Williams (8). The triaxial tests were conducted with a lateral confining pressure of 1 kip per sq ft, moisture contents ranged from approximately 20 to 32 percent, and wet densities varied from approximately 118 to 128 pcf. Stress-strain response is normalized in terms of the maximum deviator

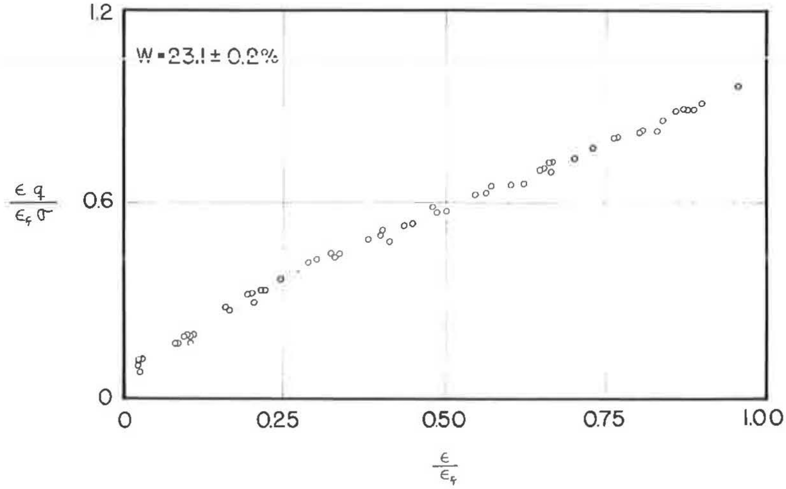

Figure 17. Transformed hyperbolic stress-strain response: different strain rate.

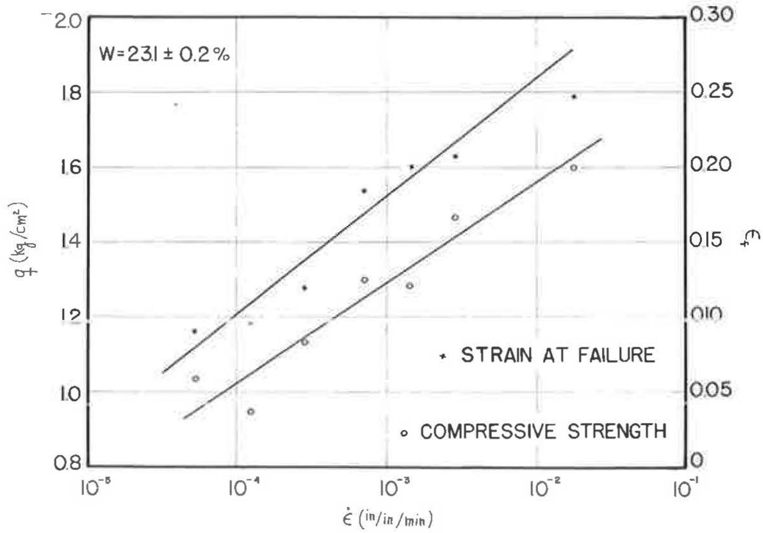

Figure 18. Unconfined compressive strength and strain at failure vs strain rate.

stress and failure strain and the results are shown in transformed hyperbolic form in Figure 19. For these tests, a form of Eq. 2, in which σ is replaced by $(\sigma_1 - \sigma_3)$, again provides a reasonable approximation for constitutive behavior. Compressive strength (maximum deviator stress) and strain at failure varied from approximately 2.9 to 6.7 kips per sq ft and 0.05 to 0.18 in. per in., respectively.

Vibratory Response

An extensive series of vibratory tests on Jordan Buff clay has been reported by Kondner, Krizek and Haas (9). Variations in moisture content have been handled by expressing dynamic stress-strain response in terms of a dynamic stress-strength parameter vs dynamic strain. The unconfined compressive strength was employed as the consistency index, and it apparently accounted for moisture content variations by

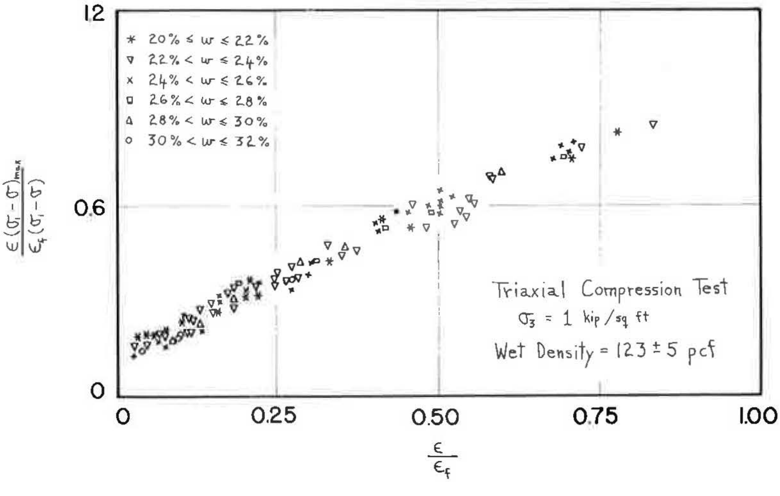

Figure 19. Transformed hyperbolic stress-strain response: triaxial test data.

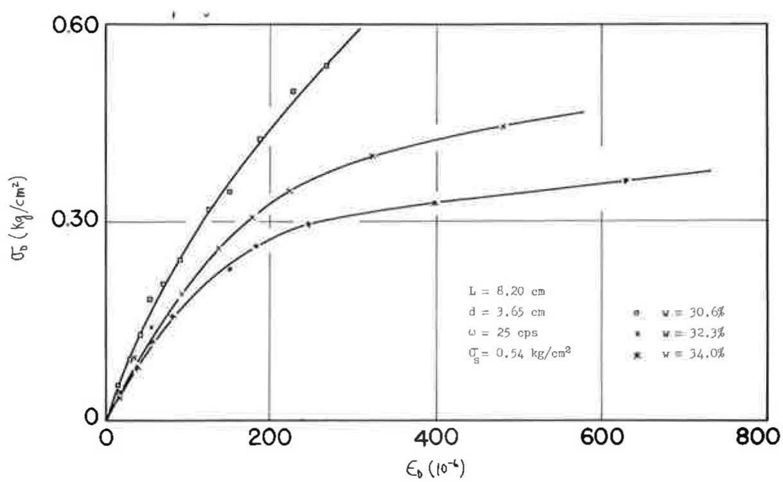

Figure 20. Dynamic stress amplitude vs dynamic strain amplitude: different moisture content.

transforming such vibratory data into a single curve within reasonable limits of experimental error. The usefulness of the dynamic stress-strength parameter may be seen by observing that the dynamic stress-strain data (Fig. 20) are significantly affected by a variation in moisture content within the range 30.6 to 34.0 percent, whereas the same data in terms of the dynamic stress-strength parameter (Fig. 21) seem to center around a single curve. Because most specimens actually failed in the vibratory test, compressive strengths were obtained from the moisture content of the specimen and Figure 14. Additional tests indicate that such a stress-strength technique based on the consistency index is applicable up to moisture contents of approximately 41 percent.

Creep Response

The consistency index, q, is very useful in facilitating a more unified presentation of experimental creep data. For example, 35 specimens with moisture contents between 23.2 and 40.6 percent, examined from the viewpoint of unconfined compression

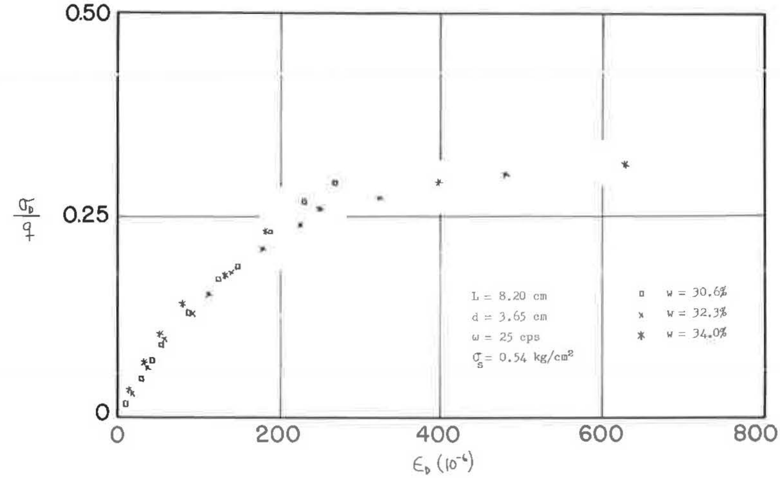

Figure 21. Dynamic stress-strength parameter vs dynamic strain amplitude: different moisture content.

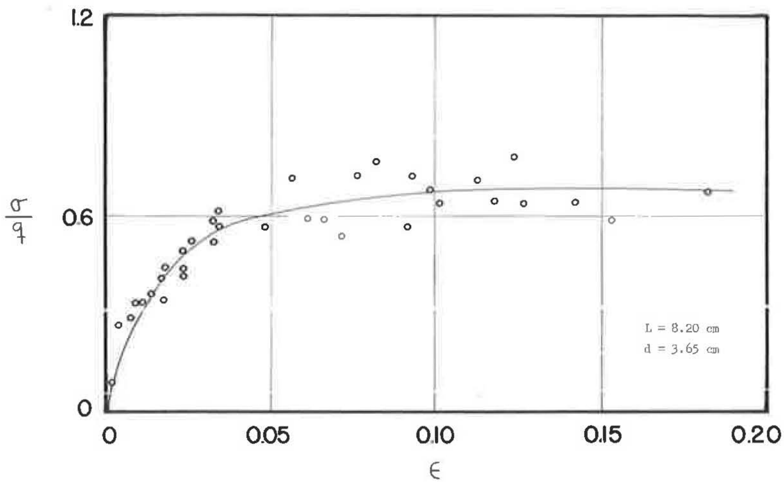

Figure 22. Stress-strength parameter vs strain: creep response.

stress-strain response on a material with creep history, were also analyzed for creep stress-strain response.

Figure 22 shows a typical example of such creep response associated with a particular time (10,000 min). The stress is taken as the applied load divided by the cross-sectional area (based on a constant-volume area correction) and the creep strain is the deformation divided by the initial length of the specimen. The compressive strength is determined by an unconfined compression test conducted on the specimen following the creep test. The tendency of all data points in Figure 22 to form the locus of a single curve over the large moisture content range indicates the usefulness of such a stress-strength parameter, based on the consistency index, q.

Field Determination of Consistency Indices

Since the preceding presentation centers strongly on the role of the consistency indices, q and ϵ_f, in facilitating a unified presentation of stress-strain response in control and testing of materials, the study assumes added significance in light of the possibility of determining these indices by relatively simple field tests. Examples of such tests are penetrometer, plate bearing, cone bearing, and CBR. It is important to note that all influencing variables, such as moisture content, density, void ratio, strain rate, and saturation, are taken to be implicit in the consistency indices of the material.

SUMMARY

The investigation reported in this paper has demonstrated the usefulness of the compressive strength, q, and failure strain, ϵ_f, as consistency indices in developing an analytic expression for the stress-strain response of a remolded, plastic clay at various moisture contents under various loading histories. The compressive strength and failure strain are obtained from uniaxial constant-strain-rate tests. The effects of soil structure, moisture content, density, void ratio, and saturation are taken to be implicit in these consistency indices.

Extrusion and compaction techniques were used for sample preparation, and specimens were subjected to various histories including creep, vibration (repeated load applications), overconsolidation, and desiccation. Consistency relationships are given for the various cases. The consistency indices were affected very little by the imposed history, but the preparation process had a strong influence on the compressive strength of the soil. Extruded specimens had compressive strengths on the order of twice that of compacted ones, all other variables, such as moisture content, void ratio, density, and saturation, being nearly the same. Preparation processes also affected the empirical constants in the analytic stress-strain relations.

Data from the literature indicate that the effects of strain rate and lateral confining pressure (triaxial test) may also be included in the consistency indices, and stress-strain response may be expressed by a similar analytic equation in each case. The consistency index, q, is utilized to form a stress-strength parameter shown to be helpful in unifying experimental response from vibratory and creep testing methods.

The potential for employing relatively simple existing field test techniques, such as penetrometer, plate bearing, cone bearing, and CBR, to determine the soil consistency indices gives added significance to the usefulness of this concept in control and testing of soil materials.

ACKNOWLEDGMENTS

The authors are indebted to Messrs. Ho, Zelasko, Haas, Hasan, Yamamoto, Cheng, Mahoney and Schwartz for their help in conducting various phases of the experimental program analyzed in this paper.

Grateful appreciation is extended the Northwestern University Computing Center for the extensive aid provided in regard to the multitude of routine calculations.

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