The Triaxial Institute and the Stabilometer

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● IT has long been recognized by those best informed on the behavior of granular materials when subjected to highway loadings that the underlying principles embodied in the triaxial test provides the most promising approach to the problem of properly and accurately evaluating the ability of both soils and asphaltic mixtures to sustain heavy vehicle loads in the design of highway pavements. Although several road building agencies were utilizing triaxial testing in one form or another, there did not exist in 1947 any group exclusively devoting its energies to a study of the triaxial test with a view toward implementing its application to a greater degree through programs of cooperative research, standardization and correlation with performance. Moreover, the triaxial test methods in use were so varied procedurally and dimensionally, with a corresponding disparity in nomenclature and units of measure, that it was indeed difficult to relate one to the other. Truly, a state of confusion existed then from which we have not as yet emerged.

ORGANIZATION OF THE TRIAXIAL INSTITUTE

In the belief that an attempt should be made to alleviate the situation, at least on a regional basis, a group of asphalt technologists on the Pacific Coast in 1947 proposed the formation of a West Coast group to be known under the somewhat ambitious title of "The Triaxial Institute" with its purpose expressed, briefly, as follows:

> "... to develop, standardize and promote the principles of triaxial testing".

The initial meeting of this group was held in Klamath Falls, Oregon, on May 5th and 6th, 1948, and the organization was formed with a charter membership representing State Highway Departments, Educational Institutions, and Asphalt Producers. It was subsequently made a project committee of subcommittee B-2 of ASTM Committee D-4. For detailed information surrounding the formation and early development of The Triaxial Institute, the reader is referred to another source (*5*).

During its brief existence the organization has been maintained on a rather informal and flexible basis with rules and regulations governing its operations improvised and adopted as the occasion demanded. However, at its sixth annual meeting held on February 10 and 11, 1953, a constitution was adopted which sets forth the objectives of The Triaxial Institute, more specifically, as follows:

> "... to study the strength properties of both soils and asphaltic mixtures, to investigate the application of the principles of triaxial testing thereto, and to develop and standardize related testing procedures".

It might also be noted here that the meetings of this organization are essentially discussion periods in which agenda are not tolerated and a surprising degree of unanimity generally prevails. There are no officers (other than a chairman, who functions primarily as a moderator at the meetings), no funds and no staff, with all members sharing in the activity on a more or less equal basis.

DEVELOPMENT OF A PROGRAM

Since the formation of the group in 1948, meetings have been held periodically at which numerous detailed discussions on various subjects related to triaxial testing have been held. From these meetings there have emerged a number of planned programs of testing and research which have, in turn, resulted in development of new ideas; new items of equipment, procedures and techniques; and a better understanding of the problems in evaluating the strength characteristics of granular masses.

For instance, it was clearly evident in discussions at the first meeting of the group that the immediate concern of the membership would be the preparation of laboratory test specimens which would be as representative as possible of the prototype in the field.

Fabricating or producing a so-called "realistic" remolded test specimen of a soil or an asphalt-aggregate mixture was known to involve such factors as mixing method, procedure and technique; curing or "conditioning" time and temperature; and type and amount of compaction. This matter alone presented a formidable obstacle to the work of the group as it was generally agreed that until the problem of forming representative laboratory test specimens was resolved, it would not be possible to proceed with any program in triaxial testing, or for that matter, on any type of test hoping to predict overall performance.

KNEADING COMPACTOR

Considerable time and effort was spent, therefore, on the development of a procedure for preparing test specimens employing a kneading-type compactor having certain basic operating features considered to be essential in producing the desired result. The State of California had developed a kneading compactor in 1937 and several members of the group had been using kneading-type compactors of various arrangement and detail of mechanical design. The first pilot model of the Triaxial Institute kneading compactor (Figure 1) was completed in the summer of 1950 at the University of Calfiornia (*2*). After an extensive program of testing to check the operational features of this mechanical compactor and of comparison with other compaction methods and field cores (*7*, *12*), drawings and specifications were prepared by the California Division of Highways incorporating some modifications and changes considered to be desirable. By the summer of 1952 over 30 such kneading compactors were in operation, with 16 in laboratories of member organizations equipped to carry out programs of testing and research. To date, at least 41 kneading compactors are known to be in operation throughout the United States with several in Canada and others in France, Union of South Africa, etc.

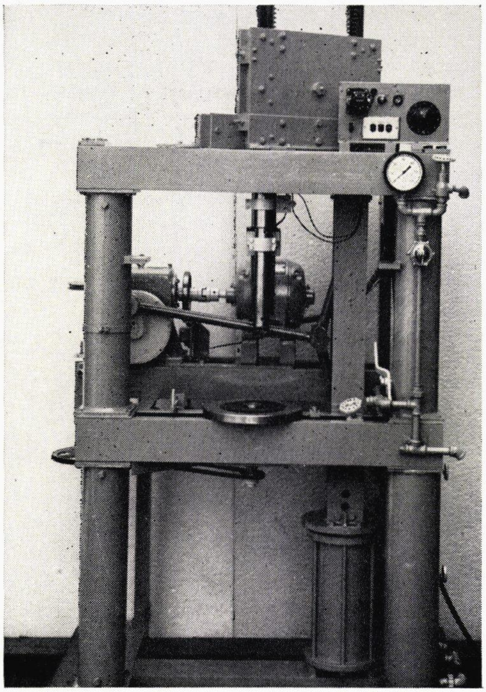

Figure 1. Triaxial Institute kneading compactor.

PROGRAM TO DATE

Procedure

During the last 7 years members of The Triaxial Institute have carried on programs of testing and research on both soils and asphaltic mixtures, primarily with reference to asphaltic paving mixtures, bases and subgrades. The initial emphasis has been placed on asphaltic mixtures because of their ready adaptability to a cooperative program of testing. Also, test specimens fabricated of this material can be of specified and uniform composition which is readily achieved. Moreover, these specimens are relatively easy to handle, and are less likely to change their properties significantly with time.

At present the work of The Triaxial Institute can be divided into two parts: (1) that which is accomplished through a planned cooperative program of research administered by The Triaxial Institute and (2) that which is carried on independently by various members of the group. Projects are underway in each type of activity and many papers have been prepared by members and presented through the medium of various technical organizations. The list of references at the end of this paper presents a list of papers known to have been published by members of the institute dealing with subject matter of direct interest to the membership.

Since the many and varied activities carried out under Item 2, above, are generally covered in the literature, no attempt will be made to review or analyze the work done. Instead, the following paragraphs will be devoted to a description of the cooperative test program under Item 1, above, with a presentation and discussion of some of the data obtained and observations made.

Cooperative Test Programs

Following the development and calibration of the essential features of an acceptable Kneading Compactor, there were two major cooperative test programs carried out by The Triaxial Institute: (1) A cooperative investigation of the various compaction and stability test methods in common use, with two aggregates of similar grading (but of different strength characteristics) combined with varying proportions of 85–100 penetration asphalt: (a) Watsonville granite (rough surfaced), high stability; and (b) Cache Creek gravel (smooth surfaced), borderline stability. (2) A cooperative investigation of the application of the Hveem Stabilometer test to soils, using three soils: a gravel, a fine-grained clayey soil and a fine-grained silty soil.

The first cooperative test program listed above involved a very elaborate exchange of specimens among the eight participating laboratories. Over 1,000 specimens were shuttled between laboratories and the volume of test data obtained can only be fully reported if and when a research report is issued by The Triaxial Institute. However, a portion of the data is presented here to indicate the nature of the results obtained.

Asphaltic Paving Mixtures

Figures 2 and 3 show the effects of various compaction methods on results obtained from from the Hveem Stabilometer.[1] From data such as these and field correlation studies carried out by member laboratories, it was concluded that of the methods used, kneading compaction alone duplicated reasonably well the compacting action of rollers and rubber-tired traffic. Some such correlation data have been published (*16*).

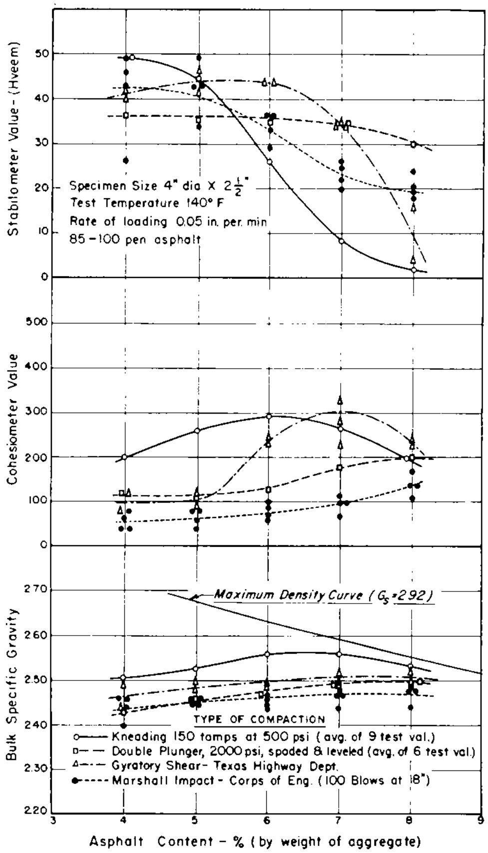

Figure 2. Comparison of compaction methods, Hveem stabilometer, Watsonville granite.

An interesting chart illustrating the field correlation of the Triaxial Institute kneading compactor and also the effects of prolonged compaction on both density and stability is given in Figure 4. The reader should note that 150 repetitions of a tamping pressure of 500 psi. in the kneading compactor is considered to reproduce a field density equivalent to that of a pavement rolled and subjected to approximately one year of average "main-line traffic".

The effects of various compaction methods are also illustrated for the Asphalt Institute (Smith) Triaxial Cell[2] in Figures 5 and 6. The similarity between the response of the Triaxial Cell and that of the Stabilometer to the various compaction methods is quite

[1] *Laboratory Manual of California Standard Test Procedures*, Materials and Research Department, California Division of Highways, Sacramento, California, November 10, 1954.

[2] "Manual on Hot-Mix Asphaltic Concrete Paving" *Construction Specification A-2-b*, The Asphalt Institute, pp. 73–86.

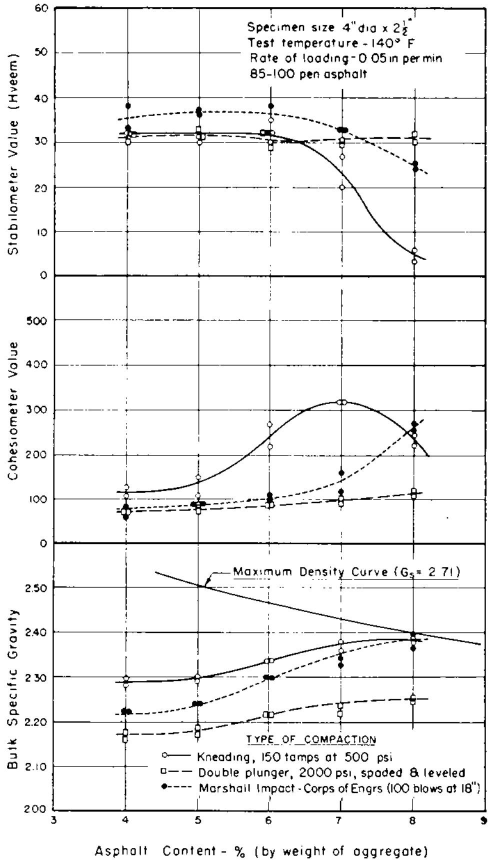

Figure 3. Comparison of compaction methods, Hveem stabilometer, Cache Creek gravel

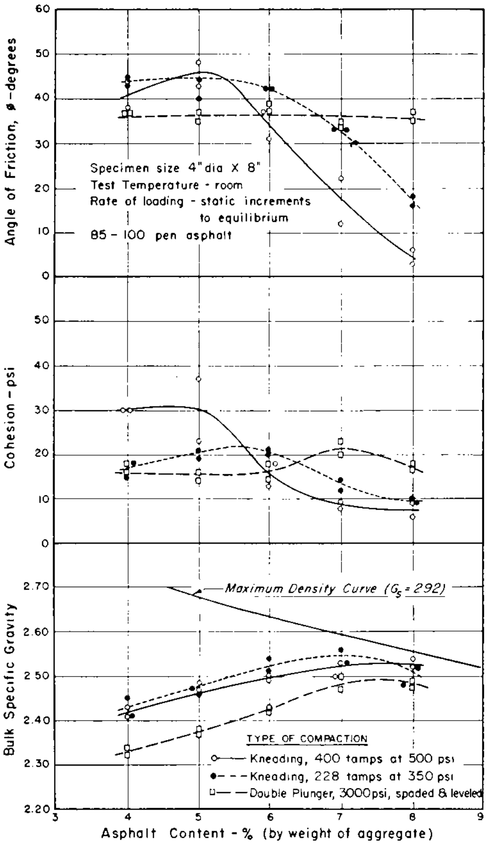

Figure 5. Comparison of compaction methods, Smith triaxial test, Watsonville granite.

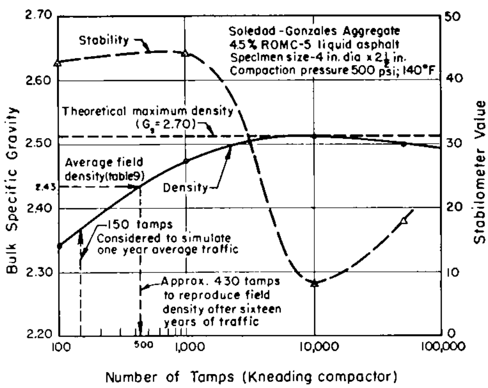

Figure 4. Effect of prolonged kneading compaction on density and stability.

evident for both aggregate materials. Since both the above stability testing devices operate on the same "closed-system" triaxial principle (i.e., while vertical loads are applied, lateral confining pressures are allowed to develop), it is not surprising that this would be the case.

However, in the more commonly encountered "open-system" principle of triaxial testing as embodied in the Bureau of Public Roads triaxial equipment[3], the results presented in Figures 7 and 8 would indicated that the effect of compaction method is not a critical matter. The significance of this piece of evidence has not as yet been fully explored by the membership, although it has been the topic of some discussion. It is evident, however, that this open-system test would give little difference in rating or "stability"

[3] "An Improved Triaxial Compression Cell for Testing Bituminous Paving Mixtures", C. A. Carpenter, J. F. Goode and R. A. Peck, *Public Roads*, Vol. 26, No. 9, August 1951, pp. 173–179.

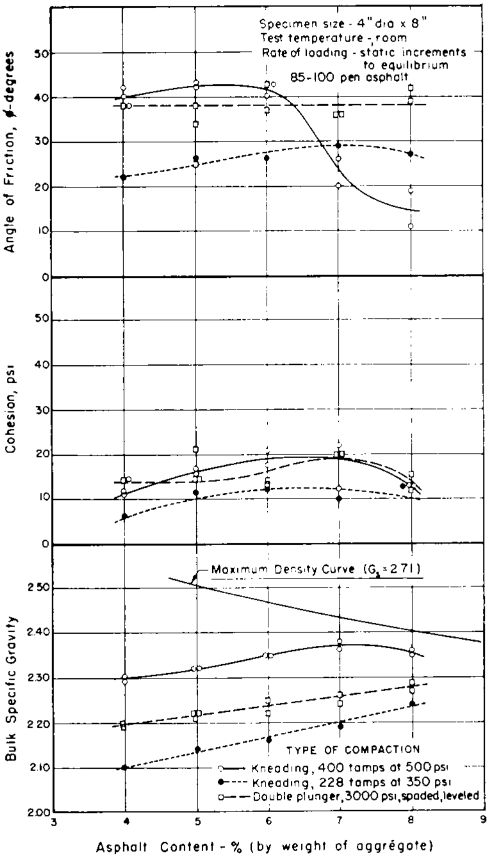

Figure 6. Comparison of compaction methods, Smith triaxial test, Cache Creek gravel.

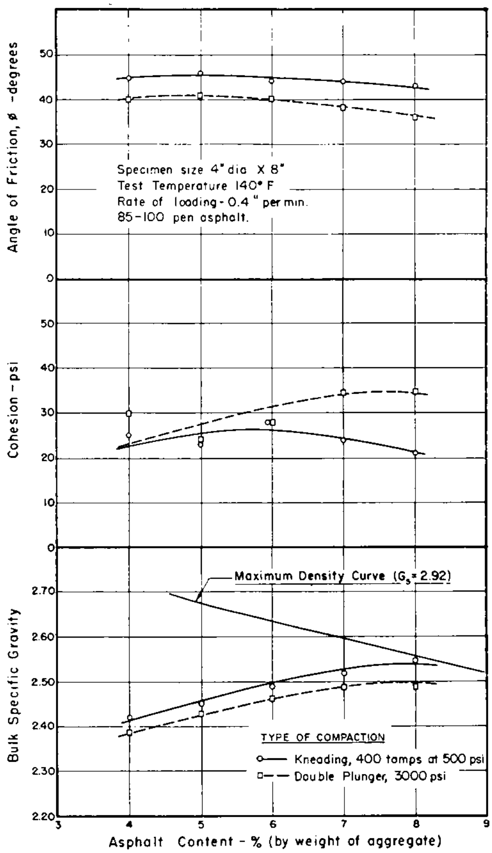

Figure 7. Comparison of compaction methods, BPR triaxial test, Watsonville granite.

for an asphalt mix ranging from 4 to 8 percent of asphalt.

Figures 9 and 10 are presented to illustrate the variations between various types of kneading compactors, and the need for establishing certain limitations on the following variables, for any given specimen size: (1) size and shape of tamper foot; (2) degree of rotation of mold per tamp; (3) Rate of tamping; (4) Number of tamps per specimen; and (5) Characteristic shape of time-pressure curve (with allowable tolerances) to control rate of load application, "dwell" period and rate of load release. Initial recommendations regarding the above listed items are in the literature. Additional work is still being done, however, to evaluate these variables, particularly with respect to Item 5, above.

Figure 9 is of particular interest in this respect because the five kneading compactors are somewhat different in design features, loading rates, pressures, etc. It is evident, however, that in spite of these differences all the curves are of similar shape, being typical of curves obtained with specimens prepared by kneading action when tested in the Stabilometer. In Figure 10 all three compactors were identical in design features and used the same compacting procedure. The good reproducibility of results among the three laboratories where different operators and items of equipment were used to prepare, compact and test the specimens, is clearly evident from these data.

On the basis of its research work on the two aggregates used in this cooperative test series, together with results of additional unilateral activities on at least three additional aggregates

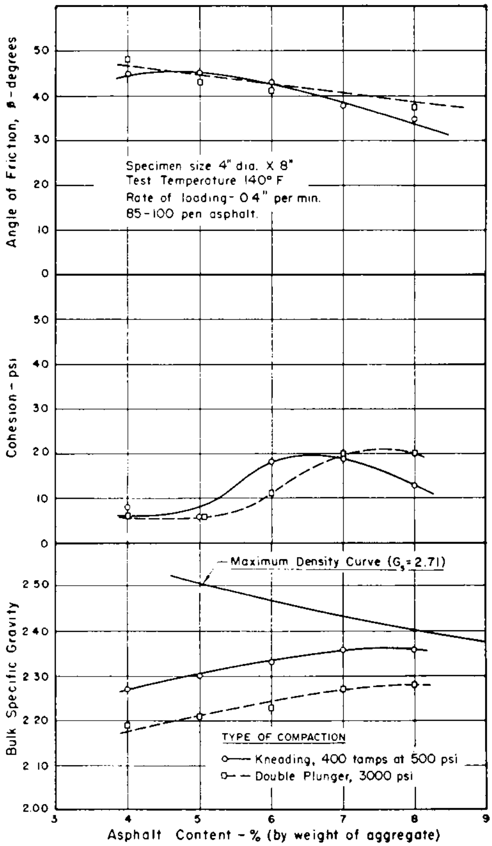

Figure 8. Comparison of compaction methods, BPR triaxial test, Cache Creek gravel.

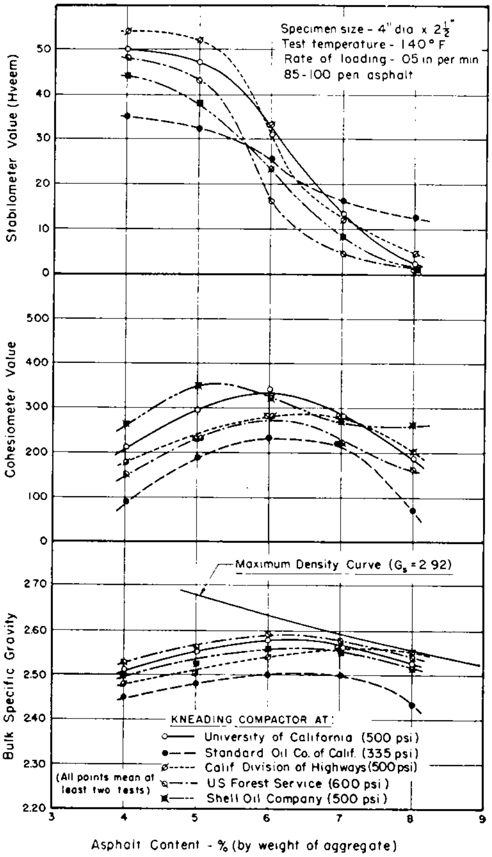

Figure 9. Comparison of kneading compactors, Hveem stabilometer, Watsonville granite.

by members of the group, plus the backlog of field experience accumulated with this device by the California Division of Highways and the Washington Department of Highways, The Triaxial Institute went on record at its 1953 annual meeting as endorsing and recommending the use of the Hveem Stabilometer for evaluating the strength characteristics of asphaltic paving mixtures, provided that test specimens are prepared by an approved kneading-type compaction.

Base and Subgrade Materials

In the interest of expediting the work of The Triaxial Institute in soils as related to pavement bases and subgrades, it was decided at the 1953 annual meeting to investigate the reproducibility of the Hveem Stabilometer on three widely different soils: a gravel, a fine-grained clayey material, and a fine-grained silty material, all to be representative of materials normally encountered in field operations on the Pacific Coast. At the same time it was also decided to have each cooperating laboratory run a complete pavement thickness design on all three soils based on the California Division of Highways procedure employing the Hveem Stabilometer and Swell Pressure device, which is described in the literature (*1*). Summaries of the results obtained are given in Tables 1, 2 and 3 for each soil tested. These Tables are based on data supplied by each cooperating laboratory and Figure 11 is included to illustrate the result of plotting all data submitted on one chart and drawing a single curve to fit. In Figure 11 the plotted data are for the Washington fine-grained clayey soil only. Figure 12 illustrates

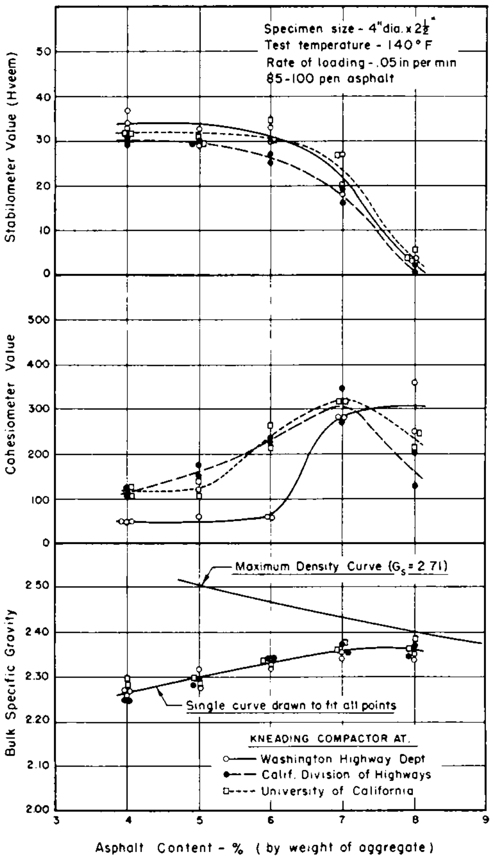

Figure 10. Comparison of kneading compactors, Hveem stabilometer, Cache Creek gravel.

graphically the results of the thickness design values obtained by each cooperating laboratory, and the degree of reproducibility obtained for each type of soil.

From Tables 1, 2 and 3 it is apparent that the degree of reproducibility in R values by both exudation and expansion pressures is fairly good while the reproducibility of pavement thicknesses as illustrated by Figure 11 is very good, considering the fact that some of the operators had had limited experience with the California method of pavement thickness design.

On the basis of its cooperative work with the three typical base and subgrade soils, and taking cognizance of the experience with the California method accumulated by the California Division of Highways and the Washington Department of Highways, The Triaxial Institute went on record at its 1954 annual meeting as endorsing and recommending the use of the California method of pavement design which employs the Hveem Stabilometer to evaluate the strength characteristics of soils, provided that an approved kneading-type compaction is used to prepare laboratory test specimens.

Although certain conclusions and recommendations have been reached by The Triaxial Institute to date regarding various meth-

TABLE 1
SUMMARY OF STABILOMETER TEST RESULTS AND INDICATED THICKNESS OF COVER
Washington Gravel Soil

Testing Agency	R-Value by Exudation Pressure	R-Value by Expansion Pressure	R-Value at Equilibrium	Indicated Thickness of Cover
California Division of Highways	76	—	76	3.7
Oregon Department of Highways	72	—	72	4.75
Washington Department of Highways	77	—	77	3.5
U. S. Forest Service	—	—	—	—
Standard Oil Company of California	81	—	81	2.5
Shell Oil Company	71	81	71	5.0
University of California	74	90	74	4.0
Average	75.2	85.5	75.2	3.9
Standard Deviations	±3.6	±6.4	±3.7	±0.9

TABLE 2
SUMMARY OF STABILOMETER TEST RESULTS AND INDICATED THICKNESS OF COVER
Washington Fine-Grained Clayey Soil

Testing Agency	R-Value by Exudation Pressure	R-Value by Expansion Pressure	R-Value at Equilibrium	Indicated Thickness of Cover
California Division of Highways	53	22	22	18.0
Oregon Department of Highways	47	32	32	15.5
Washington Department of Highways	23	23	23	18.0
U. S. Forest Service	45	27.8	27.8	16.4
American Bitumuls & Asphalt Co.	46	33	33	15.5
Shell Oil Company	39	28	28	16.4
University of California	40	26	26	17
Average	41.9	27.4	27.4	16.7
Standard Deviation	±9.5	±4.2	±4.2	±1.4

TABLE 3
SUMMARY OF STABILOMETER TEST RESULTS AND INDICATED THICKNESS OF COVER
Oregon Fine-Grained Silty Soil

Testing Agency	R-Value by Exudation Pressure	R-Value by Expansion Pressure	R-Value at Equilibrium	Indicated Thickness of Cover
California Division of Highways	77	81	77	3.5
Oregon Department of Highways	74	74	74	4.5
Washington Department of Highways	75	75	75	4.2
U. S. Forest Service	78.2	78.2	78.2	3.0
American Bitumuls & Asphalt Co.	77	77	77	3.5
Shell Oil Company	74	75	74	4.2
University of California	80	77.5	77.5	3.3
Average	76.5	76.7	76.6	3.7
Standard Deviation	±2.3	±2.4	±2.6	±0.6

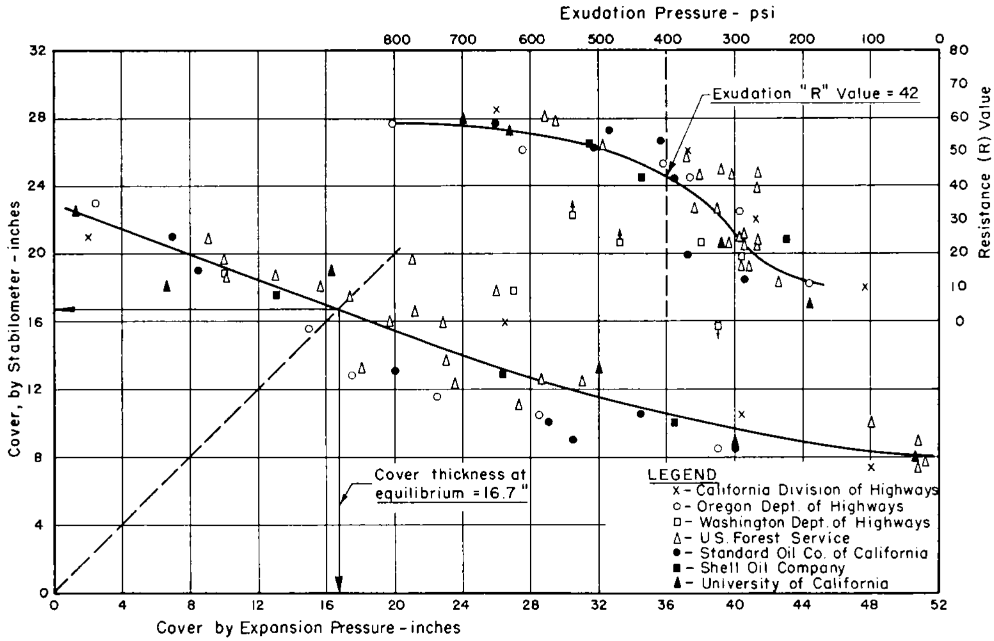

Figure 11. Cooperative test results, Washington fine-grained clayey soil.

ods of preparing, compacting and testing both asphaltic paving mixtures and base and subgrade soils, it should be recognized by the reader that such decisions have been based on information, data and experience records currently available to the group and does not preclude the possibility of The Triaxial Institute changing or even reversing its position should additional data or evidence require such an adjustment. The following paragraphs amplify the preceding statement and should make clear to the reader that The Triaxial Institute as a group is determined to maintain an open mind with respect to the entire subject of triaxial testing and its related fields.

PLANS FOR THE FUTURE

Outline of Program

In discussions of the future program of The Triaxial Institute, including its scope of activities, an outline of the functions and future operations of the group has been prepared and agreed upon, as follows: (1) to develop and recommend test procedures of a triaxial type for routine use by operating agencies for evaluating the strength properties of both soils and asphaltic paving mixtures; (2) to obtain a continuous correlation between test data and road performance; (3) to sponsor and conduct investigations to establish a sound theoretical background for the understanding and explanation of all data and facts; and (4) to

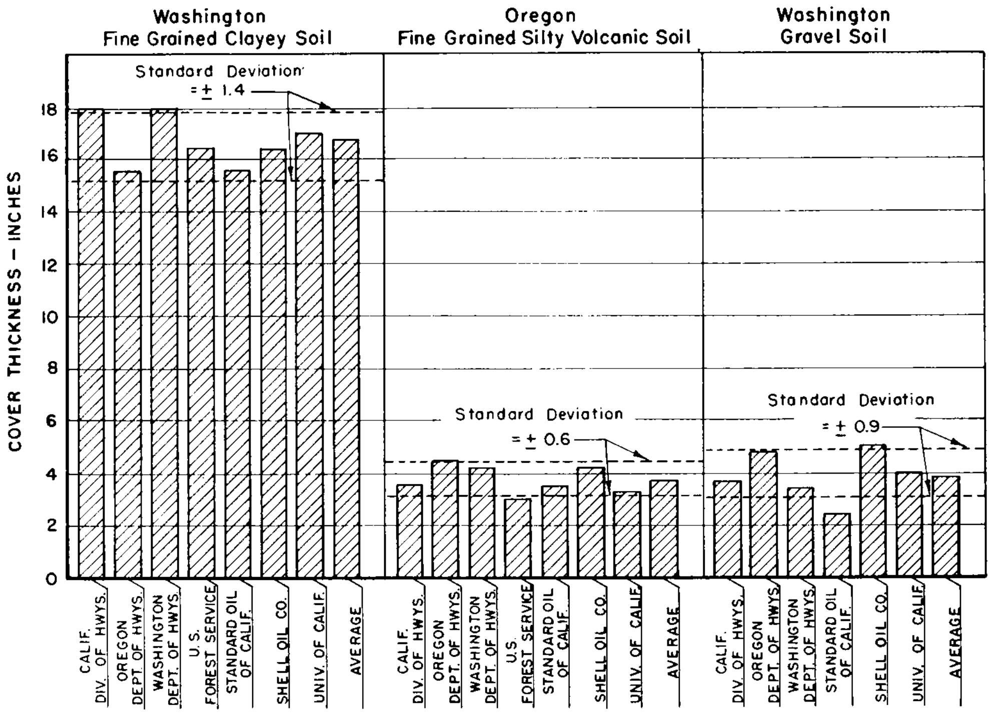

Figure 12. Summary of cover thickness as determined by cooperating laboratories.

search for the most practical and economical device capable of obtaining comparable results.

Implementation

In order to implement the above program, it was further agreed that the procedure should be, as follows: (1) scrutinize all available triaxial test data and supplement with additional cooperative test data, if necessary; (2) on the basis of above data accept, modifiy or develop better triaxial test methods and procedures and publish results; and (3) go on record as approving or recommending a test method or procedure.

Other Related Activities

The work of The Triaxial Institute has just begun as there are a number of subjects closely related to triaxial testing which are in need of study and investigation. Whether these are undertaken by the membership individually or as a group is not important, as long as the opportunity for free exchange of ideas and data prevails. For example, some topics which have recently been discussed at meetings of The Triaxial Institute and which are receiving considerable attention in several member laboratories include: (1) strength characteristics of soils under repeated loading; (2) deflection and fatigue studies of pavements; (3) effects of particle size, shape and surface texture on the strength of granular masses; and (4) the swelling mechanism of soils.

SUMMARY

Organized in 1947 to investigate the strength properties of both soils and asphaltic mixtures and to investigate the application of principles of triaxial testing to these materials as they are used in highway construction, The Triaxial Institute has made some progress which is reported in this paper. At meetings held periodically, many detailed discussions have been held from which have emerged planned programs of cooperative research which have, in turn, resulted in new ideas; new equipment, procedures and techniques; and a better understanding of the problems in evaluating the strength characteristics of granular masses.

Confronted first with the problem of specimen preparation, The Triaxial Institute developed and calibrated a mechanical kneading compactor, sometimes referred to as the Triaxial Institute Kneading Compactor, which has been described in some detail in the literature. Since the development of the kneading compactor, the emphasis of The Triaxial Institute has been toward the evaluation of existing test methods as to their reproducibility and reliability in evaluating the ability of soils and bituminous mixtures to sustain highway loadings. On the basis of an extensive program of cooperative research on asphaltic mixtures together with additional unilateral activity on the part of member organizations, a great deal of data has been accumulated which gives a good indication of the relationships existing among the various test methods. As a result of this work on asphaltic mixtures, it was concluded by The Triaxial Institute that the Hveem Stabilometer is the best existing triaxial-type test method which evaluates most nearly the strength properties of granular materials and is sufficiently practical and reproducible to allow its use in routine laboratory operations.

Following the cooperative work in asphaltic mixtures, it was decided to check the reproducibility of the Hveem Stabilometer in evaluating the strength of base and subgrade soils. A cooperative test series was initiated with three distinctive types of soil, generally encountered in the West: a gravel, a clayey soil and a silty soil. The results of the Stabilometer tests on the three soils were used together with expansion pressure measurements to determine the pavement thickness requirements over each soil for saturated conditions, using the California method. A summary of the data obtained with the Stabilometer on these three soils is included in this paper as well as the resulting pavement thicknesses. On the basis of the above work in soils, The Triaxial Institute has also gone on record as endorsing and recommending the California method of pavement design employing the Hveem Stabilometer.

An outline of the future program of The Triaxial Institute together with plans for its implementation is also included in this paper.

ACKNOWLEDGEMENT

The task of preparing this progress report of The Triaxial Institute befell the writer due to his tenure as Chairman for calendar years 1953 and 1954. However, full credit for any of the accomplishments of this group naturally belongs to the members, both individually and collectively, who have given and continue to give unselfishly of their time and talents. Furthermore, the writer considers his close association with the members of this group a very gratifying experience and a distinct personal pleasure and wishes to express his sincere appreciation for all the assistance and cooperation so freely and thoughtfully given.

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