Whether the present empirical tests can be correlated with any rational method of design ultimately developed, or whether one or more entirely new tests will be required, is for the future to answer. Be that as it may, the author believes that the time has come when serious consideration should be given to developing a rational method of design and to breaking away from our present dependence on empirical tests. As long as we maintain these empirical tests as our only basis for design, whenever a wheel loading or tire pressure changes materially, we are faced with another laborious cycle of laboratory testing and field correlation. In this respect, our present standard approach to bituminous pavement design is not far removed from the engineering technique of the ancients, who had to load the bridge they had just completed to failure, to determine what weight it could carry.

DEPARTMENT OF MATERIALS AND CONSTRUCTION

C. H. Scholer, Chairman

PLANT STABILITY TEST FOR HOT-MIX ASPHALTIC CONCRETE MIXTURES

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SYNOPSIS

A new method of testing for the control of asphaltic concrete mixtures at hot-mix plants is suggested. The unique feature of this test is the rapidity of its operation. Time from the molding of the specimen to the end of testing is about ten minutes.

A single mold has been developed for both molding and testing which eliminates the need for extruding the specimen. In addition, an armored thermometer is used to measure the temperature of a specimen before testing It is not necessary, therefore, to keep a specimen in a hot water bath or constant temperature oven for a certain period as required in ordinary stability tests.

These two developments give a rapid field stability test to help the plant inspector keep better control over the asphaltic concrete mixture at hot-mix plants.

Stability tests have long been employed as valuable aids in the design of asphaltic concrete mixtures By making such tests, it is possible to select better materials and to find the optimum combination of the selected materials, so that mixtures of high quality can be expected. Common stability tests for such a purpose are the Hubbard-Field, the Hveem, and the Marshall test.

Although the design of mixture is a necessary step for securing a quality asphaltic concrete pavement, control of the mixture at producing plants is no less important. At asphaltic concrete plants, it is hardly possible to keep everything exactly the same as has been assumed in the design. Whenever deviations from the design condition occur, it is possible that the quality of the mixture may be impaired even if such deviations are within specification limits. It is the duty of a plant inspector to check the quality of mixtures produced and, if necessary, make proper adjustments to the mix-formula.

In the prevailing practice for asphaltic concrete plant inspection, samples of the mixture are sent by the inspector to a nearby laboratory, where they are reheated, molded, and tested The inspector cannot get test results from the laboratory until one or more days afterward In case the mixture is found to be unsatisfactory by the laboratory stability test, it may be too late for adjustment because a

large quantity of mixture has already been produced and laid. Furthermore, any delayed adjustment based upon tests of the mixture of one day might be improper for the mixture of another day, since it is almost impossible to keep everything constant, especially at continuous plants. Therefore, there is an urgent need for a fairly accurate but very rapid stability test which can be conveniently performed right at the plant.

This paper is a progress report on a research project whose purpose is the development of apparatus and a technique for testing asphaltic concrete mixtures at a hot-mix plant with sufficient accuracy and speed to enable a plant inspector to supplement his judgment with factual data. A test is suggested (*1*)[1] which appears to have considerable merit for the above stated purpose. It will be called the plant stability test. This test is suggested primarily as a field control test and is not intended to supplant the presently used laboratory tests for the design of mixtures. It is recognized that a few of the currently used stability tests, such as the Marshall Test, are sometimes used for controlling mixtures at hot-mix plants However, the plant stability test is designed for more rapid operation and it requires less equipment. For the purpose of clarity, the test mold and the test specimen of plant stability test will be described separately.

TEST MOLD

Since the primary requirement of a field test is rapidity of operation and simplicity of equipment, it is difficult to adopt any analytic test for this purpose Therefore, the suggested test must be empirical in nature. Nevertheless, in the design of the test mold, efforts have been made to simulate as much as possible the loading condition to which a pavement is subjected. Considering a block of bituminous pavement under a wheel load, it is obvious that this block will receive vertical compression from the wheel and a corresponding reaction from the base. These two vertical forces are simulated in the compression test developed by Vokac (*2*). Besides these, there are certain side pressures exerted by adjoining masses of the pavement. In order to simulate more closely the pressure situation which exists in a pavement under a load, it is desirable to provide for similar side pressures in a stability test. However, the distribution of such side pressures follows no definite pattern When the wheel is accelerating or decelerating, the distribution of the side pressures will be influenced accordingly. A common practice is to assume uniform distribution of side pressure as has been done in the triaxial and Hveem Stabilometer test. Both of these tests are valuable for design or research work, but it seems impracticable to apply them directly or in modified form as a control test at asphaltic concrete plants. In order to meet the requirements of a field

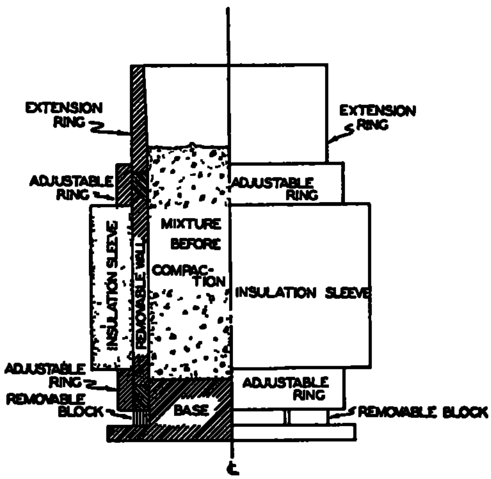

Figure 1. Assembly of Apparatus for Molding

test, and more nearly conform to the facts relative to the existence of both vertical and side pressures in a pavement, a type of semi-confined compression has been chosen as the basis for the plant stability test. In other words, certain side pressure is furnished in addition to the uniform vertical pressure. Since the plant stability test is empirical in nature, the merit of such arrangement has to be verified by laboratory experiments and practical application.

Based upon the foregoing consideration, a test mold was designed which has several unique features (See Figs. 1, 2 and 3). One of these is its versatility. It can be used for both molding and testing. In ordinary stability tests for hot mixtures, the specimen is prepared in a mold. After molding, the assembly has to be cooled in water for a few

[1] Italicized figures in parentheses refer to the list of references at the end of the paper.

minutes and then the specimen is extruded from the mold. By using a single mold for both molding and testing, no cooling of the assembly or extrusion of specimen is necessary. Therefore, this particular type of mold helps to reduce the time required for the test.

Specimens for the plant stability test have been 4-in. in diameter and 4-in. high. The height-diameter ratio of the specimen is always a subject of great controversy. In the Hveem Stabilometer test, a ratio of about 0 6 is

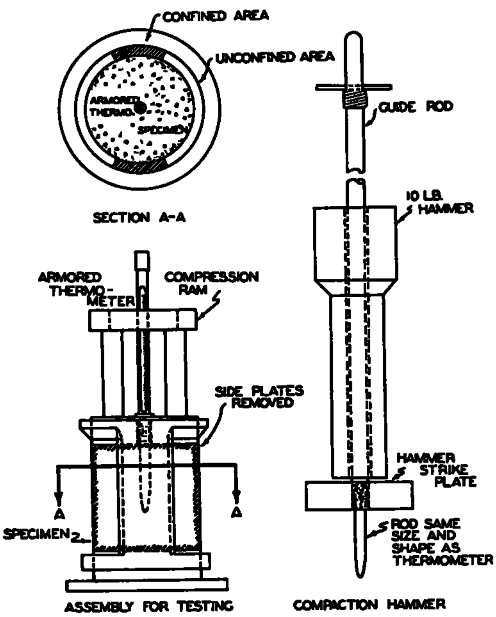

Figure 2. Test Apparatus and Compaction Hammer—Plant Stability Test

used Vokac (*2*) made a series of experiments and suggested a maximum value for D/H of 1.33, which is the same as specifying a minimum value of 0.75 for H/D On the other hand, Pfeiffer (*3*) and Nijboer (*4*) criticized all tests using specimens with low height-diameter ratio. They pointed out that, in tests of such specimens, a disturbing effect would be caused by the friction between the steel bearing plate and the ends of the test specimen. Their suggestion is to use the ratio 2 as a minimum.

Further study of this detail of the test specimen is underway, but for the present, the value unity is tentatively adopted for this ratio. When field application is considered, the difficulty in molding might be the practical limitation for increasing the height of specimen.

During testing, vertical load in the direction of the cylindrical axis of the specimen is applied. The compressive strength of the specimen is defined as its stability It is considered that stability is a good indication of the quality of mixture. Attempts are being made to include deformation characteristics of the specimen under compression By examining the stability and deformation of a specimen, one should be able to predict the service behavior of the corresponding mixture. In this paper, discussion will be limited to stability only.

A very important requirement for a stability test is high sensitivity to all factors affecting the quality of mixture. Sensitivity

Figure 3. Disassembled Test Mold

of a test depends upon various factors such as the test mold, the method for preparing the specimen, the testing speed, etc. Among these factors, it appears that the test mold is the most essential one. In investigating the sensitivity of the mold, other factors have to be held constant Since the plant stability tests is somewhat similar to the unconfined compression test used by the Bureau of Public Roads (*5*), it was decided to use the same method in regard to preparation of specimen and speed of testing as has been used in the unconfined compression test. The complete series of sensitivity tests has not been completed and no definite comparison can be made between the suggested test mold and other testing devices used in stability tests. However, preliminary tests have been performed and there is enough background to believe that the test mold can reflect all variations with respect to type and grading of aggregate and filler, type and percentage of asphalt, density of mixture, etc.

In order to compare the suggested mold

with other testing devices, one set of test results is shown in Figure 4. Asphalt cement of 70–85 penetration was used as binder and ¾-in. crushed stone as coarse aggregate. The size of specimen was 4-in. by 4-in. for both unconfined compression and plant stability tests, 6-in. in diameter and about 2-in. high for the Hubbard-Field test (*6*), and 4-in. in diameter and 2.5-in. high for the Hveem Stabilometer test (*7*, *8*) All specimens were prepared by applying a static load of 3000 psi maintained for 3 min. The speed of testing complied with that specified for the various tests. An automatically controlled water bath was used to regulate the temperature of the specimens at 140 deg. F before testing. Stability values are the average of the test results for three specimens

It is seen from Figure 4 that an optimum stability is indicated in all curves except that for Hveem Stabilometer test This is one of the characteristics of the Hveem test (*7*). Since specimens of the same size were used for both the unconfined compression and the plant stability test, it is interesting to compare their results The stability curve for the plant stability test magnifies the general character of the unconfined compression test. When field application is concerned, this magnification is advantageous. Since portable testing machines are far less sensitive than laboratory stationary machines, magnified stability readings tend to give a clearer indication of the quality of mixture.

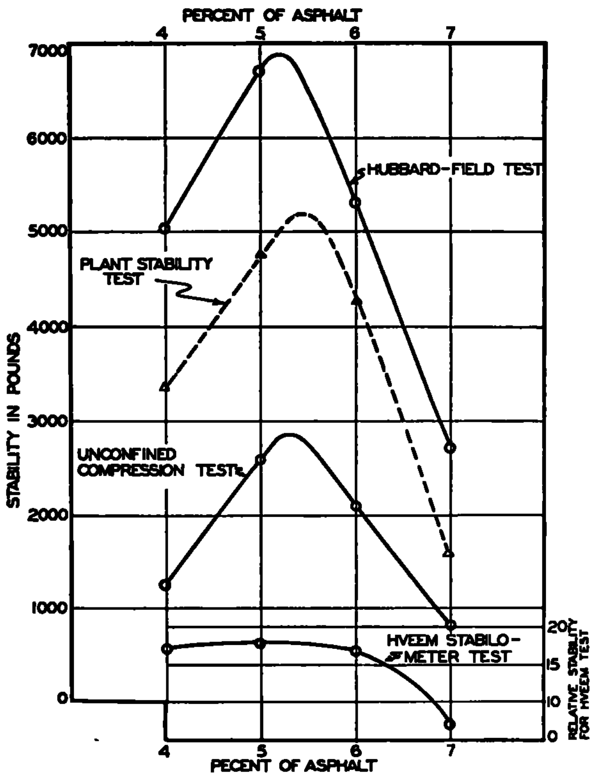

Figure 4. Typical Stability Curves for Various Tests

TEST SPECIMEN

Another unique feature of the plant stability test is the technique for molding the specimen and the method of measuring its temperature at the time of testing Although further studies are underway, the following practices relative to the mold temperature, compactive effort, density of the specimen and temperature control at the time of testing are tentatively recommended.

With respect to the temperature of the mold, there is no universal agreement as to

the optimum relationship between this temperature and that of the mixture. The purpose of using a hot mold (same temperature as the mixture) is to avoid sudden chilling of the mixture as it comes into contact with the mold. Usually, specimens prepared with a hot mold will have a smoother surface. However, the formation of the smooth surface may be the result of segregation in the mixture. In other words, there may be a concentration of asphalt mortar and free asphalt close to the mold, and consequently a deficiency of mortar and asphalt in the nearby inside region of specimen. The effect of this segregation may be very small. Nevertheless it can be considered as an advantage for using a cold mold (at room temperature). In that case, asphalt mortar and free asphalt will not be concentrated at the portion close to the mold Under the consideration of simplicity and shorter testing time, it is recommended that the mold be at room temperature for the plant stability test.

Almost every stability test has its own method for compacting the specimen. The general principle in preparing a specimen is to simulate the actual compaction of a bituminous pavement. Since the orientation of the particles is an important element related to efficiency of compaction, density alone does not tell the whole story For example: two specimens prepared by different types of compaction might have equal densities, but their resistance to deformation might not be the same. The general belief is that specimens prepared by static load alone cannot represent the condition in a bituminous pavement, although compaction by this means is still widely used in the preparation of specimens. This is because of its relative simplicity and the elimination of the personal equation which is often involved in other methods of compaction.

In choosing the type of compactive effort for the plant stability test, consideration was given to two factors, namely; simulation of pavement condition, and simplicity in operation. It is tentatively specified that 50 blows with a 10-lb. hammer be applied by dropping it from a height of 18-in. followed by 1000 psi. static load maintained for 1 min The rate of hammer dropping is approximately once per second In several correlative experiments, it was found that specimens prepared by this compactive effort had a density a little higher than that of an asphaltic concrete pavement made of the same mixture right after compaction. Since the traffic will, to a certain extent, increase the density of the newly constructed asphaltic concrete mat, specimens of higher density are considered desirable. On the other hand, more investigations regarding the uniformity of density of specimen and more correlative studies will be made in order to assure a proper compactive effort for the preparation of specimen.

Specific gravity of the specimen is usually determined by a water displacement method. For the plant stability test, this method cannot be applied, because the specimen is not extruded from the mold after molding. As the height of specimen can be measured and the cross sectional area is constant, it is simple to compute the density from its weight and volume. When other factors are held constant, the density of a specimen is a good indication of the quality of mixture. Therefore, it is advisable to have this additional information.

In order to insure uniformity of test conditions, measurement of temperature at the time of testing is a very important step in developing the plant stability test. Operation of this test would be as slow as of others if the use of constant temperature oven or water bath is not eliminated The solution is to use an armored thermometer inserted in the center of the specimen to give a definite indication of the temperature of the compacted mixture at the time of testing. This thermometer method cannot be reliable unless the temperature difference between the center and outside portion of the specimen follows a definite pattern.

When a hot mixture is placed in a cool mold, the temperature of the mixture will gradually drop. In this case, the flow of heat is at an unsteady rate Primary factors affecting such heat flow can be listed as follows:

(1) Thermal character (specific heat and thermal conductivity) of the mixture and the mold
(2) Temperature of the mixture and the mold
(3) Time of flow
(4) Dimensions of the specimen and the mold
(5) Condition of the surrounding air such as temperature and wind velocity.

It is obvious that the thermal character of the mold and the dimensional factors are

always constant. In order to minimize the influence due to air temperature and wind velocity, a 1-in. insulating sleeve is used to cover the mold (Figs. 1 and 5). The temperature of the mixture just before molding can be specified. On the other hand, it is sufficient to specify that the mold must be at room temperature, because effects due to variation in room temperature have been found to be negligible. In short, among all the factors influencing the flow of heat, there are two variables only, the thermal character of the mixture and the time of flow. Since we are interested chiefly in the temperature of the outside portion of the specimen corresponding to a definite temperature at the center, no particular attention has to be paid to the time of flow.

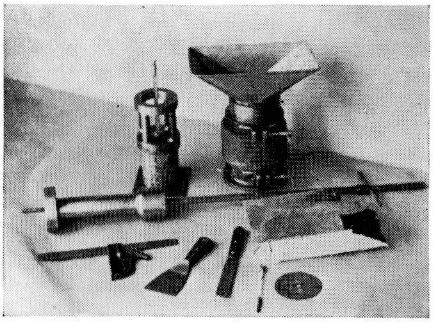

Figure 5. Arrangement of Apparatus Before Molding

Experiments were performed with various mixtures in order to measure the temperature difference between the center and outside portions of the specimen. Temperature was measured by thermo-couples inserted in the specimen before compaction. It was found that the temperature difference between the center and outside portion of a specimen followed a definite pattern. The effect due to variation in the quality of mixture as it may occur at a mixing plant is negligible. Therefore, it is considered that this thermometer method gives a sufficient measure of temperature for a field stability test.

Arrangements for inserting the armored thermometer are shown in Figures 2 and 6. A rod, 2.5 in. long, is attached to the bottom of the hammer strike plate in order to reserve a hole for the armored thermometer which is connected with the compression ram. This rod has exactly the same shape as that of the lower section of the armored thermometer. Temperature for testing is 160 deg. F. as indicated by the inserted thermometer. This temperature was selected because tests using thermometer controlled specimens at this temperature gave approximately the same stability value as that found in tests using specimens heated to 140 deg. F. in a water bath.

By using the thermometer method as described above, it is possible to run a test (from time of molding to the end of testing) within 10 min. One point to be considered in such a rapid test is the setting of hot asphalt cement contained in the mixture. It is necessary to investigate whether the time interval between molding and testing of the specimen will have any effect on the stability and flow characteristics. Since, for cold mixtures, this time interval will certainly cause an appreciable difference, a definite curing period is always allowed for the specimen before testing. However, in the case of hot mixtures, effects due to the curing of the specimen are usually negligible. While more experiments are being made to check the validity of the suggested method of testing, reports from other investigators can be quoted on this point. After making a series of tests with hot asphaltic concrete mixtures, the U. S. Waterways Experiment Station (*9*) arrived at the following conclusion:

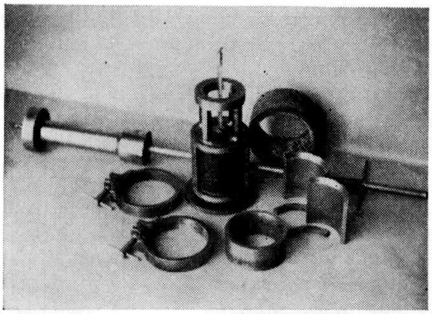

Figure 6. Specimen Ready for Testing

It was found that the stability and flow of specimens were not affected by the curing period. Specimens which were tested with no curing period showed stability and flow equal to those which had been cured for a period of 24 hours.

TEST EQUIPMENT

Apparatus used for the Plant Stability test is as follows:

- Portable testing machine
- Complete set of test molds
- Compression ram with thermometer
- Compaction hammer and accessories
- Insulated weighing pan and thermometer
- Funnel
- Spatula
- Trowel
- Ruler (or dial with stand) for measuring the height of specimen

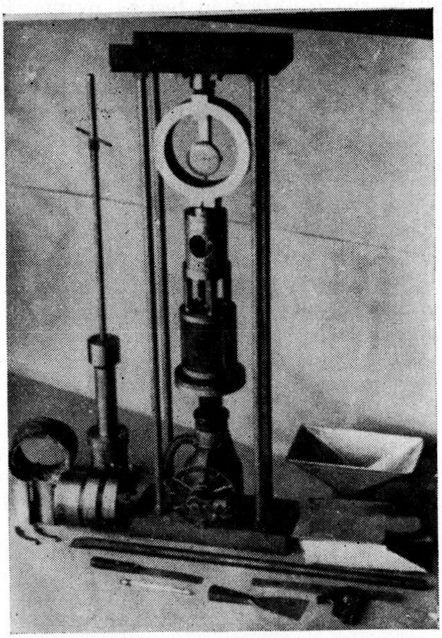

Figure 7. Complete Equipment for Plant Stability Test

- Balance sensitive to grams
- Two pails, one for sampling, the other filled with water

All of these items, except the balance and pails, are shown in Figure 7. Most of the items were built for the first trial in verifying whether the suggested testing device can be conveniently applied at hot-mix asphaltic concrete plants. If the test is applied for routine plant control, certain improvements can be made. For example, the journal jack used in the portable testing machine should be replaced by a gear box in order to make a more compact machine and to obtain better control of the speed of testing. It is planned to construct an improved set of equipment after further investigations of the test are completed. The test mold and accessories now in use will be described to present a more definite idea of the operation of the plant stability test.

All parts of the mold are shown in Figures 1, 2, 5 and 6. Before molding, the extension ring and two removable walls are attached to the mold by two 1-in. wide adjustable steel rings. Between these rings, an insulation sleeve is used to cover the entire mold. There are two curved blocks which can be placed directly under the wall of the mold. They must be removed after the specimen has received 10 blows from the hammer so that a double-plunger action will exist during further compaction. The extension ring, insulation sleeve, adjustable rings, and removable walls will be detached from the mold before testing.

TEST PROCEDURE

It is advisable to furnish two sets of molds at the plant laboratory. When one set is still warm after testing, the other set can be used. This does not mean that the plant stability test has to be performed continuously. Conditions at the plant will determine how often the test should be made. If the materials and plant operation are under normal condition, once every two hours is believed to be sufficient. On the other hand, continuous testing is desirable right after the change in mix-formula.

Before molding, a proper quantity of the sample mixture should be weighed out in the insulated weighing pan. The weight of mixture required to prepare a specimen can be estimated from results of previous tests. Usually it is approximately 1850 g. The pan should be covered with a thick cardboard and a thermometer inserted through a hole in the board into the center of the mixture. As the temperature of output at hot-mix plants is usually between 280 F. and 300 F., the temperature of the mixture in the pan after weighing will not be much higher than 260 F. When the temperature indicated by the thermometer drops to 260 F., the molding operation should be started.

The mixture in the mold receives 50 blows from a 10-lb. hammer dropping from a height

of 18-in. Then the compression ram together with an armored thermometer is placed over the specimen (the thermometer being inserted in the hole at the center of specimen) and a static pressure of 1000 psi. is applied for one minute. The combined height of specimen, compression ram, and base plate is measured to 0.01-in. When the temperature of the specimen as indicated by the inserted thermometer drops to 170 F., all attachments on the mold are removed and the specimen is ready for testing. The compressive load is applied when the thermometer reading drops to 160 F., speed of testing being 0.2 in. per minute. The maximum reading on the proving ring is recorded and its equivalent load in pounds is termed the stability of the mixture. Time from the beginning of molding to this stage is usually ten minutes.

After testing, the specimen together with the mold is weighed to the nearest gram and the density of mixture is computed. Since the temperature of the specimen is still high at this time, there is no difficulty in removing the specimen from the mold

SUMMARY

The plant stability test is designed exclusively for the control of asphaltic concrete mixtures at hot-mix plants. Although investigations of various aspects of the test are still going on, there is enough background to believe that this test can help the inspector to get more effective plant control. Regarding the application of the plant stability test, it is necessary to discuss two points, the criterion for control and the reproducibility of results.

Criterion for the control of asphaltic concrete mixtures can be specified in two ways. First, the required stability may be stated as a certain percentage of the stability for the designed mixture. For example, one may specify that when the actual stability value is below 90 percent of the designed value, a proper adjustment for the mix-formula has to be made Stability for the designed mixture can be found by making the test with a laboratory prepared mixture. Another way to establish the criterion is to specify a certain range for the stability value. This range has to be found from a great number of correlative experiments in order to compare the stability value of various mixtures with the service behavior of the corresponding pavement. Such extensive correlations may take years of time before final conclusions can be stated One possible short cut is to correlate the plant stability test with other stability tests so that the criteria for other tests can be converted Since different tests have different sensitivity to elements contributing to stability of mixture, such correlation between tests may be very difficult.

Asphaltic concrete mixtures are heterogeneous in character and, consequently testing results cannot be as uniform as those for homogeneous mixtures The larger the size of aggregate contained in the mixture, the greater will be the variation in testing results. For the suggested test, it was found that results were reproducible for mixtures using 1-in or smaller aggregates. For mixtures using larger aggregates, a mold of larger size will probably meet the requirement related to reproducibility of results.

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DISCUSSION

W. H Campen, *Omaha Testing Laboratories*—The authors have devised a semi-unconfined compression test for evaluating stability in bituminous mixtures The method is rapid, and for that reason is particularly suitable for plant control work.

Without detracting from the accomplishments of the authors, it should be pointed out that determination of stability in itself does not indicate the factors responsible for its magnitude. These factors include the quality of the aggregate, the gradation of the mixtures, and the asphaltic content, as well as the density. Since the stability of mixtures is governed by known factors, it appears simpler to control the factors themselves to insure the desired stability. As a matter of fact, in actual practice the mixture is designed for desired stability in the laboratory, and during plant operations the inspector sees to it that the desired mixture is produced. Occasional stability tests are also made in the laboratory to check the plant control.

AN APPROACH TO MEASURING THE QUALITY OF ASPHALTIC PRODUCTS

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SYNOPSIS

The need for a test or system of tests to measure the quality of asphaltic products is neither recent or new The renewed search for such a test or tests was undertaken in Kansas because of an unmistakable observation that many asphaltic products since approximately 1940 were generally of poorer quality than those produced prior to that time As a result of these conditions it was decided in 1947 to start a project which would bring to light some of the existing characteristics of asphalts used on the State system. It is believed that these findings might provide a method by which future asphalt production can be controlled to give consistently good quality materials.

This series of studies is being conducted in two phases, the first deals with the recovery and analysis of asphalts which have been in service for several years, the second phase examines the current asphalt production before and after it has been subjected to accelerated weathering tests.

There is no attempt here to draw conclusions nor to set up values of these tests, but we believe the data being obtained will make it possible to develop more satisfactory control tests for future asphalt production

The search for a test or system of tests devised to measure the quality of asphaltic products has been under way for at least 30 years and perhaps much longer. Most of the work has not yet produced adequate yardsticks of quality. Some tests have been successful in differentiating certain properties, or at least certain manufacturing processes of asphaltic properties, for example, the Oliensis Spot Test Many of these tests have proved extremely useful and some of them quite satisfactory. No one, nor any group of tests, seemingly, has been capable of consistently controlling production of good asphaltic products insofar as the engineers of Kansas have observed. In fact, it seems that there can be an unnecessarily wide range of quality of asphaltic products furnished within current specifications.

Kansas has no bone to pick with any refiner