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16. ABSTRACT

Before discussing the use of the Stabilometer as applied to the design of flexible road surfaces in California, it might be appropriate to give an outline of the steps which led to the development and use of the instrument.

The type of flexible pavement which is probably of greatest interest to the Westerner is the well-known oil mix, using a dense-graded aggregates with either slow curing or medium curing liquid asphalt as a binder. The first oil mix surface on a state highway in California was constructed in 1926, and the process appeared so promising that additional mileage increased rapidly. By 1929 there were at least a dozen sections scattered throughout the state which had been surfaced by either plant or road mix methods using the equivalent of an SC-2 road oil.

By the beginning of 1929, however, it was becoming evident that the oil mix process was not a sure fire success in all cases. Several sections had given considerable trouble, and one or two were definitely failures. As often happens, the so-called oil mix process was developed through necessity to meet the very
serious problem of constructing a suitable road surface through an arid country where the older methods were virtually impossible due to lack of water. It was early made evident that proper proportions of oil and aggregate were essential, and many supposedly significant signs such as color of the mixture, tendency to crawl, and so on, were used as guides by the engineer.

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USE OF STABILOMETER DATA IN THE DESIGN OF FLEXIBLE ROAD SURFACES

By

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Before discussing the use of the Stabilometer as applied to the design of flexible road surfaces in California, it might be appropriate to give an outline of the steps which led to the development and use of the instrument.

The type of flexible pavement which is probably of greatest interest to the Westerner is the well-known oil mix, using a dense-graded aggregate with either slow curing or medium curing liquid asphalt as a binder. The first oil mix surface on a state highway in California was constructed in 1926, and the process appeared so promising that additional mileage increased rapidly. By 1929 there were at least a dozen sections scattered throughout the state which had been surfaced by either plant or road mix methods using the equivalent of an SC-2 road oil.

By the beginning of 1929, however, it was becoming evident that the oil mix process was not a sure fire success in all cases. Several sections had given considerable trouble, and one or two were definitely failures. As often happens, the so-called oil mix process was

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developed through necessity to meet the very serious problem of constructing a suitable road surface through an arid country where the older methods were virtually impossible due to lack of water. It was early made evident that proper proportions of oil and aggregate were essential, and many supposedly significant signs such as color of the mixture, tendency to crawl, and so on, were used as guides by the engineer.

Generally speaking, the design of the mixture was largely up to the man on the job, and much of the work done by such rule-of-thumb methods has never been bettered. However, regardless of how skilled and infallible an individual may become as a result of long experience, it is usually impossible for him to pass on his experience to another, and thus construction work becomes an art rather than a science, and as such it is difficult to profit by mistakes and to make consistent progress. It might also be pointed out that most people prefer to remember their successes rather than their failures, and most of us who pride ourselves on our ability to judge good concrete or good bituminous mixtures by visual inspection have conveniently forgotten the cases where it did not work out so well.

While the early history of oil mix development included many successes, it soon became evident that the quality of the work depended on several factors which were not at all understood. The same engineers working under the same specifications produced both good and bad results without the cause being apparent; it therefore appeared necessary to study the work already done and determine in the Laboratory, if possible, just what factors were important, and how they could best be controlled.

Studies along these lines made both in the Laboratory and in the field have brought to light a great deal of evidence, and modern specifications now include a number of requirements as a result of these investigations. Some of the factors now identified which were hardly thought of in 1927 include: tests for the rejection of definitely hydrophilic aggregates; limitation on the moisture content; grading specifications for the mineral aggregate; and minimum values for the stability of the mixture. In addition, a number of formulas or methods have been proposed for estimating in advance the amount of asphaltic binder required. Tests for preferential wetting have been fully described elsewhere, and are not pertinent to this discussion. A consideration of stability measurement, however, does encroach upon and involve most of the other considerations. Therefore, it is necessary to enumerate some of the properties which a bituminous pavement should have.

Anyone discussing the design of bituminous pavements apparently must do so from either the practical viewpoint or from theoretical considerations. Occasional disparaging remarks have indicated a definite lack of enthusiasm for either theorists or experts, and one hastens to disclaim being either. Apparently the practical man must actually enjoy seeing a beautiful theory destroyed by an ugly fact.

While most engineers connected with construction regard themselves as eminently practical, and profess to prefer facts to theory, a careful study of the record will demonstrate that many unsound beliefs persist in spite of contradictory evidence.

For example, it has been often stated and widely believed that maximum density is essential for a good pavement mixture, whether hydraulic or asphaltic concrete. It can be shown that many of the most satisfactory mixtures have considerably less than maximum density.

Mathematical formulas based on theory have been put forth to calculate the thickness of pavement necessary to carry traffic over a given subgrade. One such formula indicated that it would require from 18 to 20 inches of bituminous pavement to reduce the subgrade pressure to an amount equal to that under a 7-inch concrete slab. Regardless of formulas, many thousands of cars are being carried by less than 3 inches of bituminous surfacing over such subgrades.

Another belief held by many engineers, which is, however, not a theory sponsored by many asphalt technologists, is that hard asphalt is necessary to secure stability in bituminous mixtures. This notion persists even in the face of successful behavior of oil mix roads. One could enumerate many such inconsistencies between theoretical considerations and actual facts.

When the study of oil roads was first undertaken in California to find out why certain sections had rutted and grooved under traffic and why others had raveled and disintegrated from abrasive action, and why still others become soft and muddy in wet weather, various sections were analyzed to find out what common factors were present in the good sections and also which conditions were common to the failed areas.

One of the easiest, hence the first item compared, was the grading of the aggregate. It did not take long to find out that almost every conceivable combination of particle sizes had been used to produce a successful road in some section or other, and that the aggregate in the failed sections apparently covered about the same range of variation, so far as sieve analysis was concerned. It was impossible to believe that some particular grading of aggregate was either responsible for failures or essential to success. The maintenance and construction engineers had ruined some very good theories about the importance of grading.

Another concept that was once universally accepted, and which appeared as a matter of course in virtually all specifications, was the stipulation that the aggregate must be hard, sound, and durable, and free from flat or elongated particles. When sections of both good and bad pavements were studied, the only trend that came to light seemed to show that a greater percentage of unstable sections contained very hard stone, and that taking everything into consideration, the roads built with soft aggregate were most stable.

Therefore, if stability could be achieved regardless of density, gradation, hardness of the aggregate, or grade of asphaltic binder, and if instability was most frequently encountered with hard, smooth aggregates and an excess of oil or water, then it was a simple deduction to conclude that high frictional resistance between the particles of aggregate is one of the essentials for good stability.

Unstable pavements have a tendency to flow in the direction of traffic as evidenced by the displacement of traffic lines, etc; therefore displacement is due to the weight of the vehicle, which tends to push the surface downward, and assuming that the subgrade is firm enough to carry the loads, rutting or grooving of the surface itself can only occur as a result of lateral displacement of the mixture beneath the wheel.

In order to prove that rough stone particles would have less tendency to move than smooth polished gravel, a simple device was built in the form of a split steel cylinder which could be filled with loose sand or gravel, and the aggregate submitted to load. The split cylinder would expand according to the tendency of the aggregate to be squeezed out under pressure, and a few tests demonstrated that there is a wide variation in the tendency of various dry aggregates to move under load. As the same type of movement occurs in an unstable pavement, the next step was to find out whether this tendency persisted when the aggregate was mixed with bituminous material and compressed to pavement density.

A more suitable apparatus was constructed and tests on typical paving mixtures demonstrated that there is considerable variation depending on the type of aggregate, and an even greater variation depending on the quantity of asphalt used. As the over-rich mixtures are usually unstable in practice, and the same over-rich types indicated low stability when tested, it appeared that the test method was a step in the right direction.

After some preliminary study of oil mix types, a specimen of asphaltic concrete was tested at a temperature of 140° F. and we were astonished to find that at that temperature it had as much tendency to displace under load as did some of the oil mix samples. This tendency was verified by further experiments, and at first it seemed so much at variance with what is often called "common sense" that the validity of the test was seriously questioned. There is no doubt, however, that a compressed mixture of asphaltic concrete or sheet asphalt does have hardness characteristics which are not found in the average oil mixture, and in order to measure these differences, a test for cohesion or tensile strength was developed.

Taking all the available evidence from both field and laboratory studies, it may be concluded that the ability of a pavement to remain smooth and to resist the destructive effects of traffic is dependent on four properties. These four properties are virtually independent variables, and the various combinations of the four elements are responsible for variations in the quality of the pavement. These properties are:

First, internal friction, or more accurately, sliding resistance between the particles of mineral aggregate.

Second, a property which may be various described as cohesion, tensile strength, or more precisely in the case of bituminous pavements, as liquid friction, which varies according to the amount and character of the bituminous binder present, and is affected by the density of the mix, the amount and type of filler, and varies with the temperature.

Third is the inertia, which depends on the mass of the pavement.

Fourth, the angle of shear, which produces a variable effect when the ratio of depth to the diameter of the loaded area is less than one.

These factors respond differently to the area of the applied load and to the speed or duration of contact; for example, when a heavily loaded vehicle with large tires moves very slowly over a bituminous pavement, the resistance to deformation depends almost entirely on the internal friction, only slightly on the cohesion, and while the effect will vary definitely depending on the thickness of the surfacing layer, results will be only slightly modified due to inertia of the mass. On the other hand, when a loaded vehicle travels at a high speed, the distorting effect will also be resisted by the internal friction, but in this case the cohesion between the particles and the inertia of the mass are increasingly important in resisting deformation.

It appears, however, that the chief value of slab inertia is to reduce the stress on the subgrade which would otherwise result from rapidly moving loads. Nevertheless, for all types of traffic and for service over a long period of time, the actual stability value of the pavement will depend on the friction and cohesion, and as stated above, the friction is the only property which operates equally to resist both slow moving and rapid moving loads. This value is little affected by time, speed of travel, or temperature.

Experimental data indicates that Stabilometer results depend almost entirely on internal friction of the mass, and are influenced to only a slight degree by the so-called cohesion, or the viscous resistance of the pavement. The oil mix type of surface, using a low percentage of slow curing road oil, must depend for stability almost entirely on friction between the particles, as the cohesion is usually very low. In this case, Stabilometer values represent almost the entire stability value of the mixture. At the other extreme, however, is the sheet asphalt type using a relatively large amount of hard paving asphalt, in which the cohesion or viscosity furnished by the asphalt is an important factor. For such materials, Stabilometer values may represent only a part of the true stability of the pavement, and for accurate measurement, the cohesion value must also be included.

Stabilometer tests are used primarily to determine the maximum amount of asphaltic binder which can be introduced in a given aggregate without developing instability. In view of the fact that richer mixtures have longer life, and resistance to water action and ability to withstand cracking and raveling are improved by additional asphalt, design is based on the principle that the richer mixtures are preferred. The only limiting factor is danger of instability, and this point is determined by Stabilometer measurements. As Stabilometer results show in practically all cases that when enough asphalt is added the resistance to deformation is reduced, it is merely a question of finding out by trial how much asphalt can be added without over-lubricating the mass. Many details of operation have been worked out to expedite this procedure and give accurate results. In order to reduce the number of trial mixes, the proper amount of asphalt can be closely estimated in advance by means of surface area analysis of the particular aggregate, grading tolerances can be fixed to provide the necessary degree of workability, permeability, and surface texture, and the Stabilometer then used to determine how much asphalt can be added with safety. With these stipulations, it is possible to utilize a wide range of aggregates with practically any gradation desirable, so far as stability alone is concerned. There is no evidence that the grading of the aggregate has any direct or predictable effect on stability.

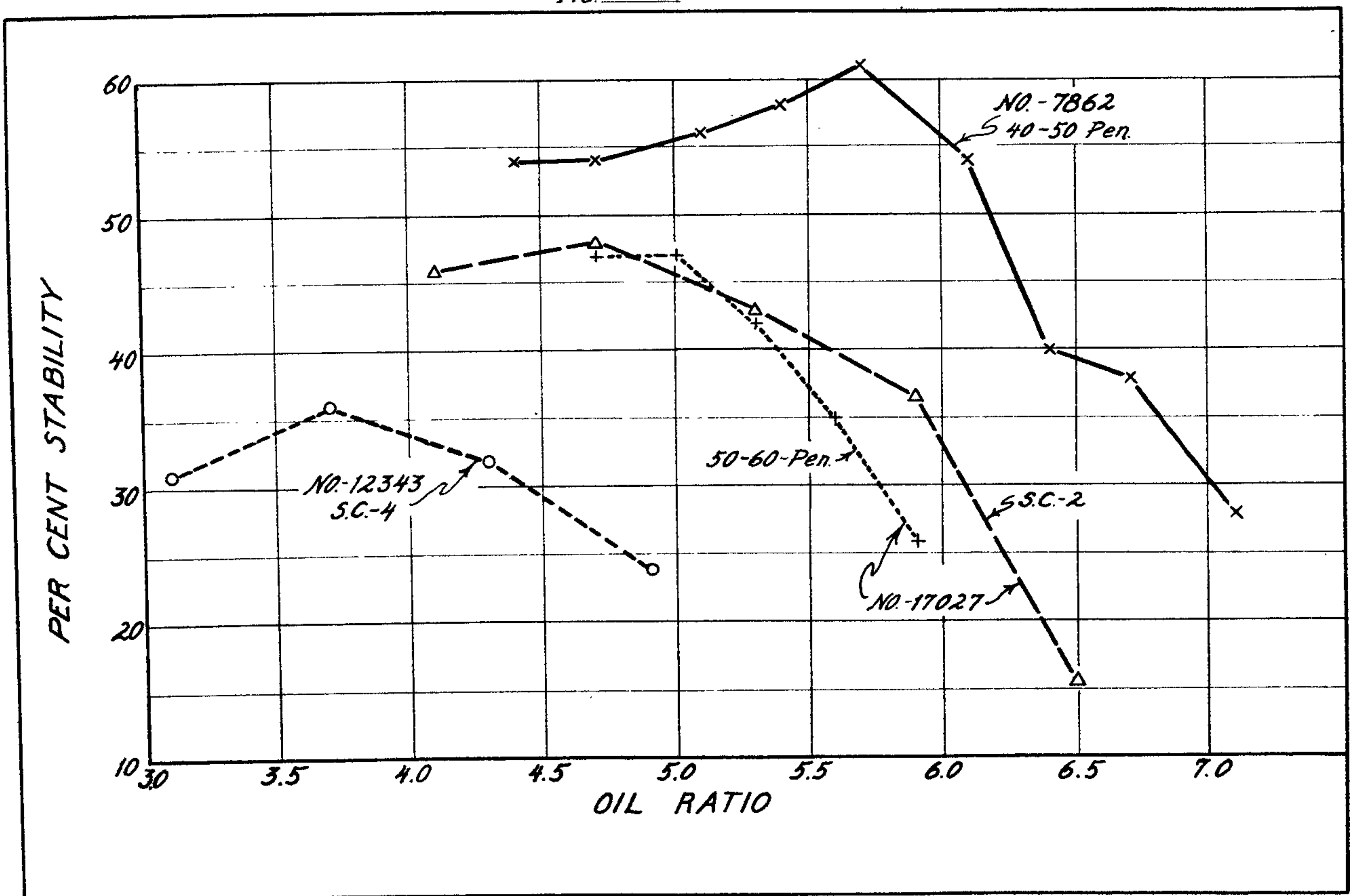
Stability of the oil mix type appears to depend almost entirely on the resistance between the particle surfaces; angularity seems to be of little importance. It is a matter of sandpaper texture or a glassy texture, and the amount of lubricant present (oil-water-clay).

No attempt has been made to report Stabilometer results in terms of fundamental concepts. Tests on mixtures were compared with actual performance, and from accumulated experience stability values were established in a scale which ranged from 0 to 100. 0 represents a fluid mixture which will transmit laterally the full amount of any pressure applied. At the other end of the scale, 100% represents a hypothetical solid which will transmit no lateral pressure under a given load.

Specimens are not tested to failure, but are subjected to a load of 400 pounds per square inch, which was arbitrarily selected to represent the combined effect of traffic due to load and impact, and the lateral pressure transmitted by the specimen under the applied load of 400 pounds per square inch is used to determine the relative stability in the above scale.

Stability values greater than 35% are considered satisfactory, for virtually all types of traffic. However, when the asphaltic binder is hard enough to supply substantial cohesion values, Stabilometer requirements may be decreased, in recognition of the value of high cohesion. This means that an oil mix type of surface will usually give trouble if the stability falls below 30%. However, asphaltic concrete mixtures with 25% stability or lower will probably be equally satisfactory in service. Further modifications of these values may come with wider experience.

FIG. ____



NO.-7862
40-50 Pen.
50-60-Pen.
S.C.-2
NO.-17027
NO.-12343
S.C.-4
PER CENT STABILITY
60
50
40
30
20
10
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
OIL RATIO

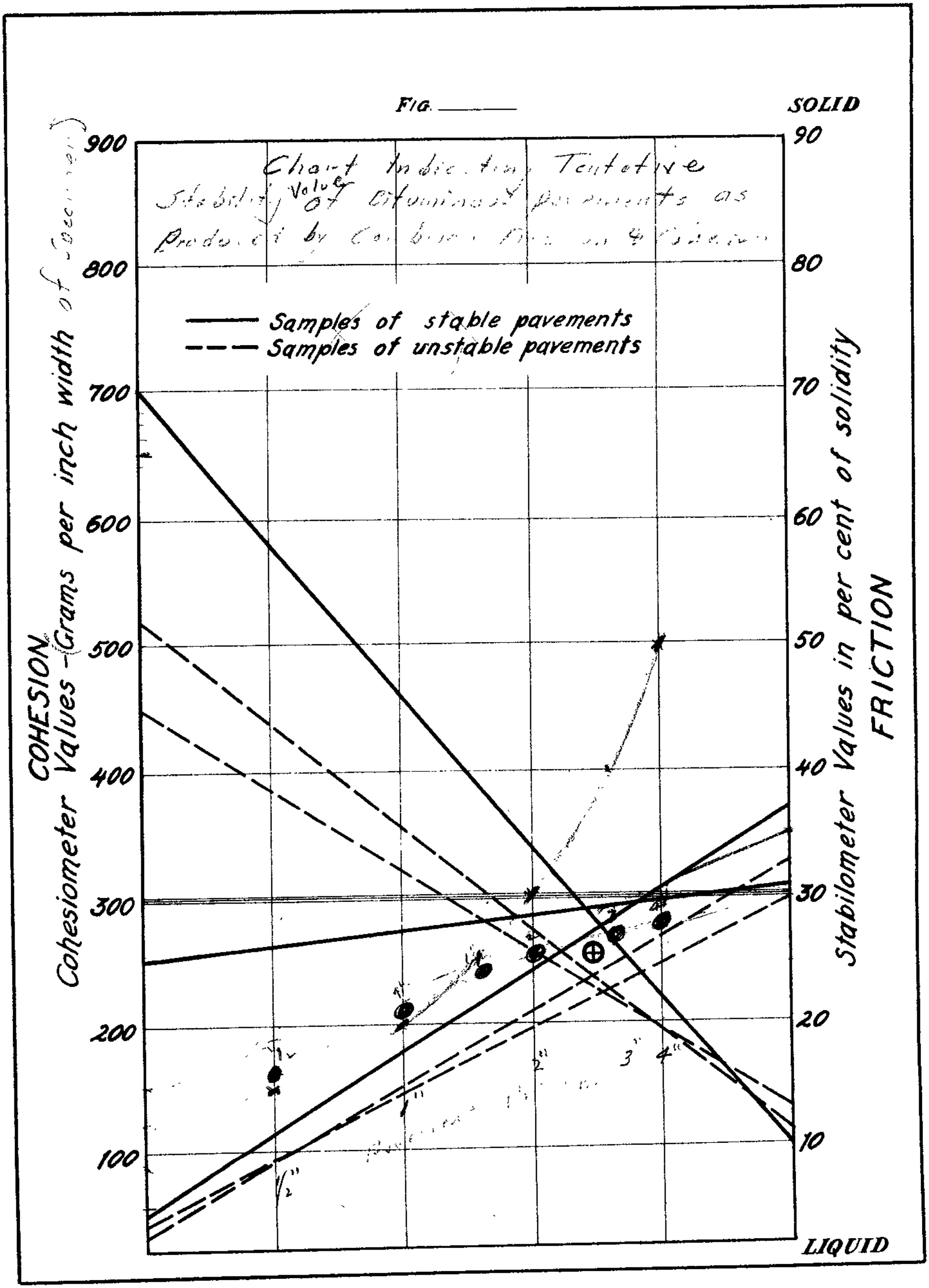
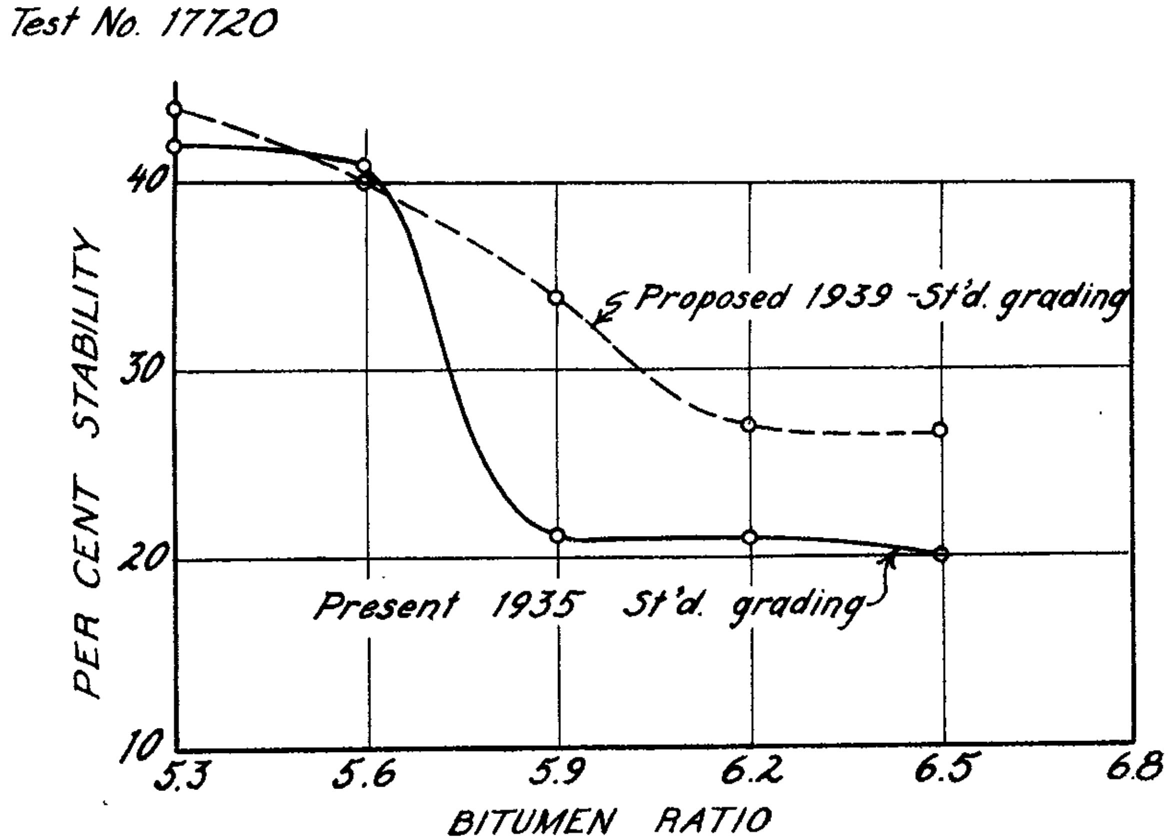
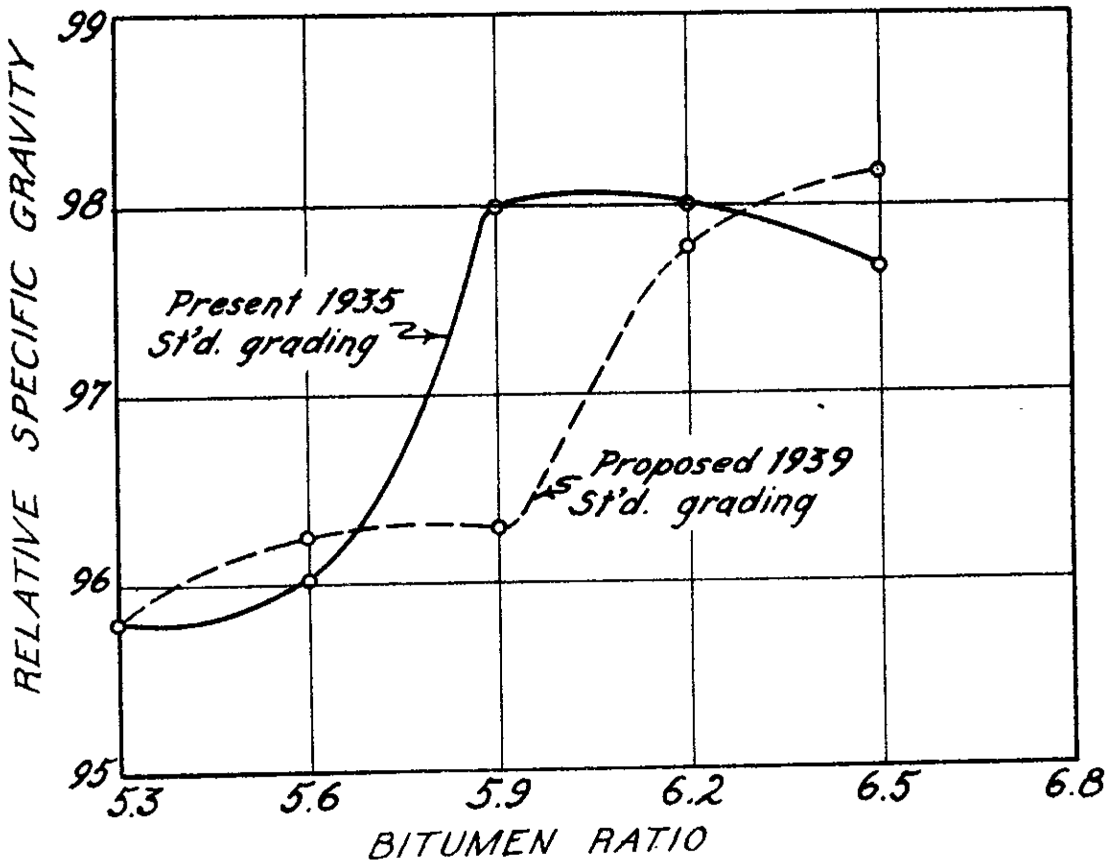

SOLID
Chart Indicating Tentative
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
Samples of stable pavements
Samples of unstable pavements
COHESION
Cohesiometer Values - Grams per inch width
FRICTION
Stabilometer Values in per cent of solidity
1"
2"
3"
4"
LIQUID

FIG. ______

FIG. ______



Test No. 17720
PER CENT STABILITY
40
30
20
10
Proposed 1939 - St'd. grading
Present 1935 St'd. grading
5.3
5.6
5.9
6.2
6.5
6.8
BITUMEN RATIO



RELATIVE SPECIFIC GRAVITY
99
98
97
96
95
Present 1935 St'd. grading
Proposed 1939 St'd. grading
5.3
5.6
5.9
6.2
6.5
6.8
BITUMEN RATIO

Fig.______

SIEVE SCALE GRAPH

SHOWING THE RELATION BETWEEN SIEVES AND SCREENS USED BY THE CALIFORNIA DIVISION OF HIGHWAYS AND THE U.S. STANDARD SIEVE SERIES