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16. ABSTRACT

The highway engineer confronted with the problem of designing or testing bituminous paving mixtures has access to a great variety of design methods and criteria. Many papers and learned discussions have been published and the engineer has a wide variety to choose from in selecting a method that best suits his fancy. In selecting a method, however, the engineer should ask himself the pertinent question: Do the results obtained by this method distinguish not only between a good pavement and an obviously unsatisfactory pavement, but also can the intermediate or so-called borderline cases, often involving local materials be identified. A borderline mixture can either be eliminated or one of several methods may be employed to improve its quality such as the addition of a filler, coarse rock or perhaps a more viscous type of bituminous binder. A design method which will enable you to select with a reasonable degree of confidence some nearby local deposit of suitable aggregate in preference to importing a costly material from some distant proven source would appear, from the economical standpoint to be the most satisfactory method.

Some of the more commonly known design methods in use include the:

Hubbard Field Method, Marshall Method, Bureau of Public Roads--- Unconfined, Compression Test, Asphalt Institute Method (Triaxial), Hveem Stabilometer Method and of course the all important method for proportioning the "Right" amount of asphalt by "Experience". True, experience is a wonderful teacher but any method to be successful has to be "Right" in practically all cases with all types of aggregates, whether it be the native soil, uncrushed gravel or crushed quarry rock. Also, the method has to be "Right" whether the bituminous binder consists of liquid asphalt, asphaltic emulsion or paving asphalt.

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STATE OF CALIFORNIA
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MATERIALS AND RESEARCH DEPARTMENT

CORRELATION BETWEEN PAVEMENT DESIGN AND PERFORMANCE

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February 18, 1954

CORRELATION BETWEEN PAVEMENT DESIGN AND PERFORMANCE

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CORRELATION BETWEEN PAVEMENT DESIGN AND PERFORMANCE

The highway engineer confronted with the problem of designing or testing bituminous paving mixtures has access to a great variety of design methods and criteria. Many papers and learned discussions have been published and the engineer has a wide variety to choose from in selecting a method that best suits his fancy. In selecting a method, however, the engineer should ask himself the pertinent question: Do the results obtained by this method distinguish not only between a good pavement and an obviously unsatisfactory pavement, but also can the intermediate or so-called borderline cases, often involving local materials be identified. A borderline mixture can either be eliminated or one of several methods may be employed to improve its quality such as the addition of a filler, coarse rock or perhaps a more viscous type of bituminous binder. A design method which will enable you to select with a reasonable degree of confidence some nearby local deposit of suitable aggregate in preference to importing a costly material from some distant proven source would appear, from the economical standpoint, to be the most satisfactory method.

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and of course the all important method for proportioning the "Right" amount of asphalt by "Experience". True, experience is a wonderful teacher but any method to be successful has to be "Right" in practically all cases with all types of aggregates, whether it be the native soil, uncrushed gravel or crushed quarry rock. Also, the method has to be "Right" whether the bituminous binder consists of liquid asphalt, asphaltic emulsion or paving asphalt. The type and intensity of traffic such as may be encountered on a local secondary road carrying a limited amount of truck traffic, or a road on our main highways subjected to heavy industrial traffic should also be given due recognition in any design method.

When confronted with the problem of correlation between design, or test results and actual performance of the pavement, a search of the literature does not present an overwhelming amount of correlation data nor convincing evidence in favor of some of the above mentioned methods. This point of view, of course, depends somewhat upon the evaluator, his experience and preferences for a certain test method.

All of the methods mentioned of course have some merit and undoubtedly show correlation in certain cases. However, upon closer examination of some of the design methods, it is evident that some methods can not be used indiscriminately but are applicable only under certain conditions with certain types of pavements or certain types or grades of bituminous binder.

Data on correlation between design and performance is somewhat difficult to obtain as a number of factors such as quality and thickness of base, subbase or basement soil, and also climatic conditions enter into the picture, therefore, any correlation data presented between pavement design and performance and particularly if there is more than one design method involved has, of course, to assume that the underlying foundation is of sufficient thickness and quality to carry the design loads.

As you undoubtedly know, we in the California Division of Highways have used the Hveem Stabilometer test method for over 20 years for the design and testing of bituminous pavements. As the Stabilometer primarily measures friction between the aggregate particles, the results obtained are not greatly influenced by ordinary temperature changes or by the viscosity of the bituminous binder.

I will not go into the description of all the various test methods but for a better understanding of the examples listed in this paper, I will just briefly summarize the various steps required in the design and testing of bituminous surfaces as employed by the California Division of Highways.

In designing bituminous mixes, the California method based on Stabilometer tests consists briefly of the following steps:

1. After grading analysis of the aggregates, the required amount of bituminous binder is determined by the Centrifuge Kerosene Equivalent test method. In the CKE method, after saturation with kerosene, we subject a portion of the aggregate passing the No.4 sieve, to a centrifugal force of 400 x Gravity for a period of two minutes. The coarse aggregate is soaked in lubricating oil SAE #10 and allowed to drain. From the amount of kerosene and oil retained by the sample by means of appropriate charts the optimum amount of asphalt is determined.

2. After mixing the asphalt with the aggregates and after proper curing, test specimens are formed by means of our kneading compactor and then tested in the Stabilometer. The Stabilometer value is obtained from the transmitted horizontal pressure of 400 psi vertical load and is expressed in a scale which ranges from 0 to 100. 0 represents a liquid which will transmit laterally the full amount of pressure applied and 100 represents a solid which will transmit no lateral pressure under

a given load. Stabilometer values of less than 35 indicate mixtures of doubtful value for heavy traffic unless offset by a high Cohesiometer value. Stabilometer values of less than 25 are generally unsatisfactory regardless of the Cohesiometer value.

3. After the Stabilometer test the same specimen is subjected to our Cohesiometer test. The Cohesiometer is an instrument designed to measure the cohesion or tensile strength of a compacted bituminous mix. The temperature of testing is generally 140°F. The Cohesiometer test consists essentially of clamping the compacted specimen rigidly between two sets of hinged plates so that it may be broken by cantilever loading. The load is applied at the end of the 30" lever arm. The Cohesiometer value is expressed in grams for a hypothetical specimen 1" in width and 3" high. Values under 50 indicate the mix is lacking in cohesion and may ravel or tear under traffic.

4. In order to determine the resistance to water action another specimen in subjected to a swell test. The test consists of compacting a specimen about 2" high in a 4" diameter mold and covering the surface with 500 cubic centimeters of water. At the end of a 24 hour period, the vertical increase in height is measured to the nearest .001". A swell of less than 0.030" generally indicates satisfactory material.

5. From a evaluation of the above test results a recommendation of design asphalt content is then made to our construction or maintenance forces.

A recent addition to our test procedure is the Sand Equivalent Test in which we determine volumetrically the amount of detrimental clay in the mixture. It was primarily designed as a rapid field test for base materials but will be incorporated into our new bituminous mixture specifications.

We come now to the all important end result of any design method, namely, how do the laboratory test results correlate with actual service behavior of the pavement under the traffic for which it was designed.

I will attempt with the following examples to present some factual correlation data between design method, test results and known pavement performance.

1. Yolo Job

During the summer of 1951, the California Division of Highways conducted an experiment on a section of a heavily travelled major highway leading into Sacramento. The section selected consisted of asphalt concrete pavement which had been in service for many years and though extremely hard and brittle had become rough and cracked. The experiment involved breaking up and pulverizing the old surface, then adding an asphalt softener (developed by the Shell Oil Co.) to rejuvenate the mix and relay it (The method has been called Reclaimix).

No Stabilometer tests were performed on the mixture which contained about 5 to 6% of asphalt prior to reworking, however, tests were made on the mixture after the addition of 1.3% of the softener and Stabilometer values obtained were in the neighborhood of 10 which indicated that the stability was totally inadequate to carry the heavy traffic loads as this section of highway would require a minimum of 35 Stabilometer value.

The contractor elected to lay out a short section of this unstable mixture just "to see what would happen". After one week end of traffic the result was complete failure from distortion and the mixture had to be bladed off the road.

Laboratory tests were then made by adding various percentages of screenings to the unstable mixture and it was found that by the addition of about 33% of our medium fine screenings (5/16 inch by No. 8) a stable mix showing Stabilometer values above 35 could be obtained. This indicated amount of screenings was then incorporated into the mix which was then relaid and compacted.

This experimental section has been under heavy traffic since 1951 with an average of about 20,000 vehicles per day, a large percent of which are trucks, and no sign of distortion, instability or ravelling has been evident.

Retained samples of the two mixtures, after adding the softener and also after the addition of the screenings, were later obtained by the University of California for a research project in which the following test methods were employed:

1. Specimen prepared by static load of 1500 psi. (double plunger) and tested in Stabilometer.

2. Specimen prepared by Marshall drop hammer and tested in Hveem Stabilometer.

3. Specimen prepared and tested by Marshall Method.

4. Specimen prepared and tested by Hveem Stabilometer method.

Table I is a summary of the results obtained by the University of California.[1]

TABLE I

SUMMARY OF TEST RESULTS ON
TWO REJUVENATED BITUMINOUS PAVING MIXTURES

Compaction Method	Test Method	Stability Values	
		Softener Only	Softener & Screenings
Static load; Double Plunger, 1500 psi	Stabilometer	21	28
	Cohesiometer	94	64
	Bulk Specific Gravity	2.40	2.38
Impact load; Marshall drop hammer, 100 blows 10 lbs. at 18 in.	Stabilometer	15	13
	Cohesiometer	95	30
	Bulk Specific Gravity	2.41	2.33
Impact load; Marshall drop hammer, 100 blows 10 lbs at 18 in.	Marshall Apparatus load (lbs)	333	280
	flow (1/32")	22.5	19.5
Kneading Compactor; 150 tamps at 500 psi	Stabilometer	9.6	38
	Cohesiometer	80	68
	Bulk Specific Gravity	2.45	2.40

A comparison of Hveem Stabilometer values indicates that of the three compaction methods tried only the kneading method definitely correlates with pavement performance, bringing out the fact that one mix is unstable and the other stable. Although the Stabilometer values for the double-plunger method reflect an increase, with the addition of screenings, this increase is a relatively moderate one; and, if the usual specification requirement of a Hveem Stabilometer value of 35% minimum is used as a criteria, both mixes remain in the doubtful range.

The purpose of using various compaction methods is simply to illustrate that the method of fabricating test specimens is a very important one and to emphasize that the kneading compaction is an integral part of the Hveem Stabilometer method.

A comparison of Cohesiometer values shows fairly good agreement. In most cases Cohesiometer values were of approximately the same order of magnitude and in all cases were lower for the more stable mix. This was to be expected because of the reduction in percent of asphalt due to the addition of new aggregate.

The Marshall test results indicate that the mix after the addition of screening is more unstable than before which is in direct contradiction to field performance record. It should be pointed out that the drop in Marshall test values parallels the drop in Cohesiometer test values of the above specimens which tends to confirm other evidence that the Marshall test is primarily a measure of cohesion.

While mixtures exhibiting little or no cohesion present no problem in testing by the Stabilometer method, they definitely do not lend themselves for testing in the Marshall apparatus.

2. Las Cruces Job

The second example deals with 3 samples submitted to our laboratory in 1951 from our Highway District V. The samples consisted of bituminous treated shoulder material with notations by the resident engineer that two samples were taken from areas exhibiting severe distortion under traffic and the third sample from a fair to good area showing no distress. The District requested that we recommend a correction treatment. From the Stabilometer results, extraction results and visual inspection it was obvious that an excess of asphalt plus moisture was the reason for the unstable or lubricated condition.

A number of test specimens were prepared in which various percentages of hydrated lime, screenings, and a sandy gravel were blended with the unstable mixture. Table II summarizes the test results. A review of these results would indicate that the addition of any one of the three materials would provide a suitable corrective measure. From a construction standpoint our laboratory work influenced the decision to select the sandy gravel as blending material on the grounds that it could be combined more readily with the overly rich mixture and could be more uniformly distributed in mixing operations than either of the other two blending materials.

The reason for adding the gravel to the apparently stable sample was that it is usually simpler and easier for the maintenance forces to treat an entire shoulder uniformly instead of skipping small isolated areas that appear to be in good condition.

3. Buellton Job

The third example deals with four samples of bituminous mixtures which were submitted for tests with the request that the laboratory determine the cause for distortion and roughening of the pavement represented by samples C and D. Samples A and B were taken from stable sections showing no distortions. The samples are identified and test results are tabulated in Table III, Figure 1 shows a graph of the Stabilometer values obtained.

TABLE II
CORRECTIVE MEASURES USED ON
FAILED SECTIONS ON CONTRACT 1-5VC36, V-SB-2-E,D

Test No.	Corrective Treatment	% Bit.	% Moist.	% #4	% 200	Cohes. 140°F	Stabilometer Room Temp*	Stabilometer 140°F	Remarks
4729	None	7.7	1.5	71	8	150	1	5	Sample from unstable pavement
4729-A	3% Hydrated Lime					502		4	
4729-B	5% Hydrated Lime					506		34	
4729-C	40% Med. Fine Screenings					172		37	
4729-D	25% Sand and Gravel					274		41	
4729-E	35% Sand and Gravel					288		41	
4730	None	4.2	1.6	57	6	59	37	39	Sample from satisfactory area
4730-A	3% Hydrated Lime					227		44	
4730-B	30% Med. Fine Screenings					141		37	
4730-C	15% Sand and Gravel					65		30	
4730-D	25% Sand and Gravel					64		36	
4731	None	5.2	2.6	60	8	199	1	6	Sample from unstable pavement
4731-A	3% Hydrated Lime					383		18	
4731-B	5% Hydrated Lime					439		44	
4731-C	35% Med. Fine Screenings					147		30	
4731-D	20% Sand and Gravel					222		39	
4731-E	30% Sand and Gravel					134		35	

Note: Sand and Gravel is District Sample M-51 from John Gardner property that was used on this contract.
*Tested at room temperature with amount of moisture shown.

The specimens were tested in the laboratory with the moisture as received and the Stabilometer values are plotted against the total liquid content (asphalt plus water).[2]

The Cohesiometer values have also been superimposed indicating that Cohesiometer values or tensile strengths tend to increase with an increase in the liquid content, which is the typical trend in the majority of cases. Based on Stabilometer tests, specimens A and B would be considered to be satisfactory, however, it will be noted that the Stabilometer value falls very rapidly with a slight increase in asphalt or water content beyond the amount found in specimen B. Therefore, it has been considered good practice to specify a somewhat lower asphalt content in order to provide some latitude for variation during construction.

It must be emphasized that the four specimens tested are not of identical composition as they were taken from different points on the roadbed and as will be seen in Table III there is some increase in the percentage of fines which probably contributes to the low stabilometer value on specimen D.

It should also be noted that there is no difference in asphalt content between specimens C and D. The chief distinction is in the fact that specimen D contains about twice as much moisture as specimen C. Therefore, the total liquid content is higher.

The test results on the above samples were selected because the actual quality of the materials could be attested by known performance under traffic. The four samples also serve to illustrate the variations caused by differences in asphalt content and the similar influence of varying amounts of moisture.

TABLE III

TEST RESULTS ON SAMPLES OF BITUMINOUS PAVEMENT REPRESENTING BOTH STABLE AND UNSTABLE AREAS ON THE SAME PROJECT

Contract 5DXC1-P, V-SB-149-D

Test No.	Identification Letter used on Charts and in Discussion	Percentage Passing Number 200 Sieve	Percentage of Moisture in Mix	Percentage of Asphalt by Extraction	Total Liquid Content	Cohesio-meter Value at 140°F	Stabilo-meter Value*	Comments on Condition of Road
57649	A	10	1.0	4.3	5.3	74	45	Condition good. No sign of failure.
57652	B	9	1.1	5.1	6.2	135	40	Condition very good. Best looking mix to date.
57651	C	10	1.2	5.5	6.7	124	19	Condition poor. Bumps bladed off.
57650	D	15	2.7	5.5	8.2	129	6	Condition poor. Bumps bladed off.

*Stabilometer tests were made on the samples as received without drying.

4. District II

The next example I shall mention only briefly. In 1939, I was assigned the job of making a rather intensive investigation of certain roads in our Highway District II which is located in the northeast corner of California. Some 34 roads were investigated and about 110 samples of the surfacing material were obtained. Prior to sampling, the roads had been roughly classified by visual inspection into two groups namely, "Poor to Failing" and "Fair to Good". Space and time does not permit any presentation of detailed data but when summarizing the data we found that Stabilometer values ranging from about 17 to 27 were obtained for the poor to failing sections and from 28 to 45 for the fair to good sections.

5. Soledad-Gonzales Job

My last example deals with a rather comprehensive correlation study of various design methods which was conducted last year by Mr. Vallerga (then with the University of California) and myself. This study involves a bituminous pavement designed by the Stabilometer method and constructed in 1936 in our Highway District V.

For the purpose of this investigation five currently used design methods were used to provide a comparison of design asphalt content. Table IV lists the design methods used.

TABLE IV

SUMMARY OF DESIGN METHODS

Design Method	Method of Fabricating Test Specimens	Method of Testing for Stability
Hubbard-Field	Manual Tamping per standard procedure	Hubbard-Field Extrusion device
Corps of Engineers	Impact (100 blows; 10 lbs at 18")	Marshall Apparatus
Bureau of Public Roads	Double Plunger (3000 psi) static loading	Direct Compression (ASTM D1074-49T)
State of California	Kneading Compactor (150 tamps at 500 psi)	Hveem Stabilometer and Cohesiometer
Asphalt Institute	Kneading Compactor (250 tamps at 335 psi)	V. Smith Triaxial Cell

The material selected for this program of comparison was, essentially, a densely graded disintegrated granite combined with an ROMC-5 liquid grade asphalt. (Which is a blend of SC6 and kerosene). Selection of this material was predicated on the following:

1. A section of main highway in California had been constructed during the summer months of 1936 using this material as plant-mixed surfacing and as of 1953, after seventeen years of continuous service under main-line traffic, the pavement is still in excellent condition.

2. Original design recommendations with both plant and laboratory control data are a matter of record.

3. Locations of the original source of material were well established and were readily accessible.

4. The low viscosity characteristics of the ROMC-5 asphalt, even after extended curing, would tend to magnify differences between stability test methods.

5. Field specimens were readily obtainable by field coring operations.

The asphaltic pavement constructed of the material used in this study is located in California Highway District V in Monterey County between the towns of Soledad and Gonzales and is part of the existing coast highway, U. S. 101. The project covers a distance of about 8 miles and was constructed in 1936. It consisted partially of blanketing an old, badly cracked concrete pavement with 2-1/2 inches of plant-mixed surfacing and constructing an entirely new roadway on certain line and grade changes. In the latter case, crusher-run base was imported and covered with 2-1/2 inches of the same plant-mixed surfacing.

Traffic in 1935 totaled about 4,000 cars per day, of which approximately 20 percent were trucks. Present day traffic has increased in both numbers and in weight of axle loads. The 1951 report of average daily traffic by the California Division of Highways shows an increase to approximately 7,000 vehicles per day, of which about 17 percent were trucks.

The asphaltic paving mixture was manufactured by plant mixing a blend of approximately 60 percent by weight of fine disintegrated granite with 40 percent by weight of coarse crushed granite rock and adding between 4.2 to 4.4 percent ROMC-5 liquid grade asphalt by weight of dry aggregate. The fine material was obtained from a local borrow pit and the crushed granite imported from a nearby commercial source. In Table V are contained the gradings of the combined aggregates at various stages of the operation together with the grading selected for use in the test program of this investigation.

TABLE V

SUMMARY OF AGGREGATE GRADINGS

Sieve No.[a]	Specifications (1935 Standards)	Preliminary Design (1936)	Control,[b] After Extraction (1936)	Experimental (1952)
1"	100	100	100	100
3/4"		88	91	90
1/2"		70	-	77
3	52-66	65	63	66
10	36-48	45	47	47
20		31	-	32
30		26	-	26
40	20-30	23	25	22
80		18	18	15
200	6-11	10	8	9
270(Wash)		8	-	8

a. Sieves are those used during construction in 1936.
b. Average of eleven control samples tested during construction.

The bituminous binder used during construction in 1936 was a liquid asphalt ROMC-5. Current specifications no longer include this type of asphalt and, therefore, a special blend of SC-6 (approximately 350 penetration) and 10% kerosene was prepared for the experimental series of tests. Test results on this special blend were almost identical to those recorded for the material used in 1936.

Prior to construction, in 1936, a preliminary mix design was made by the Materials Laboratory of the California Division of Highways on samples of the aggregate and asphalt. Normal test procedures involved the testing of laboratory specimens in the Hveem Stabilometer to evaluate stability and to establish the asphalt content. Table VI indicates the tests that were performed and the essential test results. From an analysis of the data by the California procedure, the design asphalt content appeared to be about 4.4 percent. It was therefore, recommended on the preliminary report that the asphalt content should be between 4.4 to 4.7 percent by weight of dry aggregate. For this range of asphalt content Stabilometer values exceed the minimum of 35 required for asphaltic pavements subjected to main-line traffic in California.

TABLE VI

PRELIMINARY DESIGN DATA FOR PLANT-MIXED SURFACING
(Test No. 9864, August 13, 1936)

<table>
<tr><th colspan="2">Grading Analysis as Used</th><th colspan="4" rowspan="3">Note: Grading represents blend of
37% crushed granite (1" x #3)
55% disintegrated granite (Passing #3)
8% disintegrated granite (Passing #40)

Surface Area - 45 sq. ft. per lb.</th></tr>
<tr><th>Sieve Number</th><th>% Passing by Weight</th></tr>
<tr><td>1"
3
10
40
200</td><td>100
65
45
23
10</td></tr>
<tr><td colspan="2">Asphalt Content - % Wt. agg.</td><td>3.0</td><td>4.4</td><td>4.7</td><td>5.0</td></tr>
<tr><td colspan="2">Stabilometer Values</td><td>37</td><td>38</td><td>39</td><td>34</td></tr>
<tr><td colspan="2">Bulk Specific Gravity</td><td>2.35</td><td>2.37</td><td>2.38</td><td>2.38</td></tr>
<tr><td colspan="2">Swell Test, inches</td><td></td><td>.002</td><td></td><td></td></tr>
<tr><td colspan="2">Permeability, ml. per 24 hrs.</td><td></td><td>50</td><td></td><td></td></tr>
</table>

During construction field control samples were taken periodically and checked for compliance with specifications. In general, the samples showed high Stabilometer values and satisfactory resistance to water action as measured by the Swell test.

With the above backlog of data and evidence that the pavement had given excellent service, a program of testing was initiated to obtain data on which comparisons between the five design methods could be made. Sufficient quantities of materials were obtained from the original sources to supply the needs of a testing program which included the molding of at least two specimens at five different asphalt contents for testing by each of the five methods given in Table IV

In addition to the above laboratory program a number of field cores were taken from the existing highway constructed in 1936. These cores were cut with diamond bits 4 inches and 5 inches in diameter. The cores were subjected to stability tests, bulk specific gravity determinations and other tests, depending on the suitability of the cores for such purposes.

Identical procedures were followed in the preparation of the asphaltic mixtures for the various test specimens. Blending, proportioning, mixing and curing were carefully controlled. The mixing temperature was maintained between 200 - 230°F and after proper curing at 140°F all specimens were molded at a temperature between 200 - 230°F in accordance with the standard procedure for each test method.

Figures 2, 3 and 4 illustrate graphically the results obtained by some of the design methods and Table VII lists the design asphalt content based on criteria generally employed with the particular method. The table lists the design asphalt content for all 5 methods whereas only 3 typical methods are graphically illustrated. For a more detailed discussion of this investigation, reference should be made to the original paper which was presented at the annual meeting of the A.S.T.M. in July, 1953.[3]

TABLE VII

COMPARISON OF ASPHALT CONTENT ACCORDING TO DESIGN METHOD

Design Method	Asphalt Content % Recommended for Design
Hubbard-Field	over 7.0
Corps of Engineers (Marshall Test)	about 6.3
Bureau of Public Roads	about 6.0
State of California	about 5.0
Asphalt Institute	about 6.0

The data from the Hubbard-Field test (Fig. 2) rates this mix very poorly in terms of stability, the densities are rather low and assuming that the mix would not be rejected for low stability the asphalt content would be in excess of 7%.

In Fig. 3 the Marshall test results would be taken to indicate that with a maximum stability of only 700 lbs. this material would be considered of questionable quality.

Fig. 4 presents the results obtained in the California method which show that Stabilometer values are adequate up to 5% of asphalt content. It also clearly indicates that kneading compaction is more effective in obtaining high densities more in line with densities produced by traffic action than the other two methods illustrated.

Results somewhat similar to Fig. 2 and 3 were obtained for the Bureau of Public Roads and Asphalt Institute methods.

Data obtained on field cores reveal several significant points. Field densities from this pavement under traffic for 17 years are invariably higher than densities on freshly compacted laboratory mixes. The operation of our kneading compactor is adjusted to simulate about one year's traffic on the average road. The average density of the field cores obtained was 2.43. Therefore, the lower densities and resulting larger volume of air voids obtained in the Hubbard-Field and Marshall Test permit a much higher asphalt content. It is evident, however, from the densities obtained in our kneading compaction and the actual field core densities that ultimately any mixture with an asphalt content much above 5% would become unstable. Calculations indicate that by our kneading compaction a 5% asphalt content would permit about 5.5% voids and a 6% asphalt content about 2.5% air voids in the freshly compacted mixture. It seems to be a generally accepted practice that any stable mixture should show not less than about 4% air voids.

The plant-mixed surfacing has been in continuous service for 17 years on a main highway in California and although, subjected to heavy traffic this pavement has performed excellently with a normal amount of maintenance and is still in good condition.

An asphalt content of between 4.2 and 4.7% was actually used in construction and there is no evidence to indicate that any more (or less) asphalt should have been used, at least not more than 5% by weight of the dry aggregates. Therefore, any design method that indicates an asphalt content in excess of 5% for this particular aggregate is certainly not in line with the performance on the road.

Summarization of all the data in this investigation seems to indicate that some of the most commonly used design methods would recommend the use of too much asphalt for the type and grading of aggregate and grade of asphalt that was used in this investigation.

Summary and Recommendations

I have listed five examples demonstrating the reliability of the Stabilometer method for the design or testing of bituminous pavements and its correlation with actual pavement performance. A comparison with the Stabilometer method and other currently employed design methods is also presented.

From the data shown and also from the actual pavement performance stated, the conclusion seems inescapable that most currently used design methods have a tendency to recommend the use of too much asphalt, at least when compared to the conditions and standards as set up by the California Division of Highways.

While the procedures and experiences described are those in use in a State Highway Department, it is recognized that cities and counties construct each year many miles of fine streets and roads.

It is my understanding that a large portion of the audience consists of representatives from counties and cities and therefore, I shall address my closing remarks especially to this group.

It is realized of course, that quite often counties and cities are not equipped to do any testing or very much in the way of preliminary design work. The selection of the correct or "right" bitumen content and gradation of the aggregates are often left to the selection of some experienced individual and surprisingly enough, satisfactory results are obtained in the majority of cases. However, on the other hand, with one or two jobs "going sour", the cost of correction would pay for a considerable amount of testing equipment.

I should like to emphasize that I do not know of any short-cuts or simple or easy way of designing a bituminous pavement at least not when you are confronted with a variety of aggregates such as we have in California which may vary from the native disintegrated granite all passing the #4 sieve up to the best quality quarry rock or it may vary from smooth nonabsorptive beach gravels requiring about 3.5% of asphalt to very absorptive volcanic cinders requiring as much as 15% of asphalt. I fully realize that in most cases it is not economically feasible to install elaborate equipment such as a University or State Highway Department might afford but if your geographical area is narrowed down and if materials of known performance are available the design method may be somewhat simplified or modified, therefore, with this view in mind, I should like to recommend a few pieces of equipment which I consider essential for any agency involved in the design or construction of bituminous pavements.

1. A set of sieves 1-1/2" to #200
2. Centrifuge Kerosene Equivalent Apparatus
3. A good balance
4. A Sand Equivalent apparatus for preventing inclusion of undesirable amounts of clay in your mixes and particularly in your bases.

The above four pieces of equipment can be purchased for less than $500.00 and the benefits derived through proper use of this equipment should be many fold.

As an additional piece of apparatus I would also recommend a reliable bitumen extractor for the purpose of providing a positive check on the bitumen content and grading composition of the mixture being placed.

This paper is entitled "Correlation Between Pavement Design and Performance". If you have not already adopted a design method it might be well to choose one best suited to your needs or adopt some policy whereby you can have at least your major surfacing jobs designed on some scientific basis. Use the method and try it out regardless of how limited the amount of testing equipment available to you. After your roads have had sufficient service, analyze their behavior and draw your own conclusions as to the merits of your design method and its performance record.

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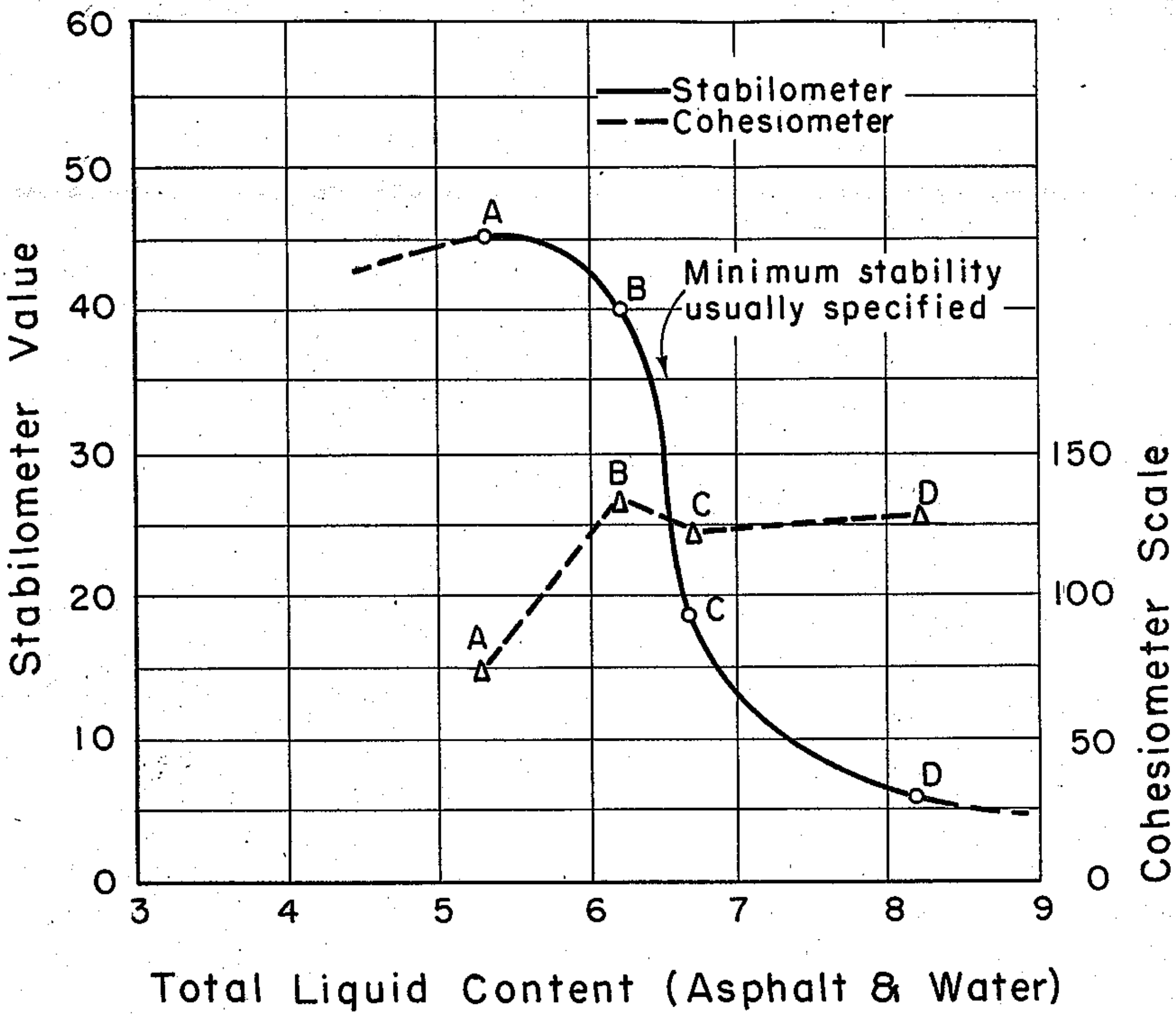


Stabilometer
Cohesiometer
Minimum stability usually specified
Stabilometer Value
Cohesiometer Scale
Total Liquid Content (Asphalt & Water)
60
50
40
30
20
10
0
150
100
50
0
3
4
5
6
7
8
9
A
B
C
D

Fig. I

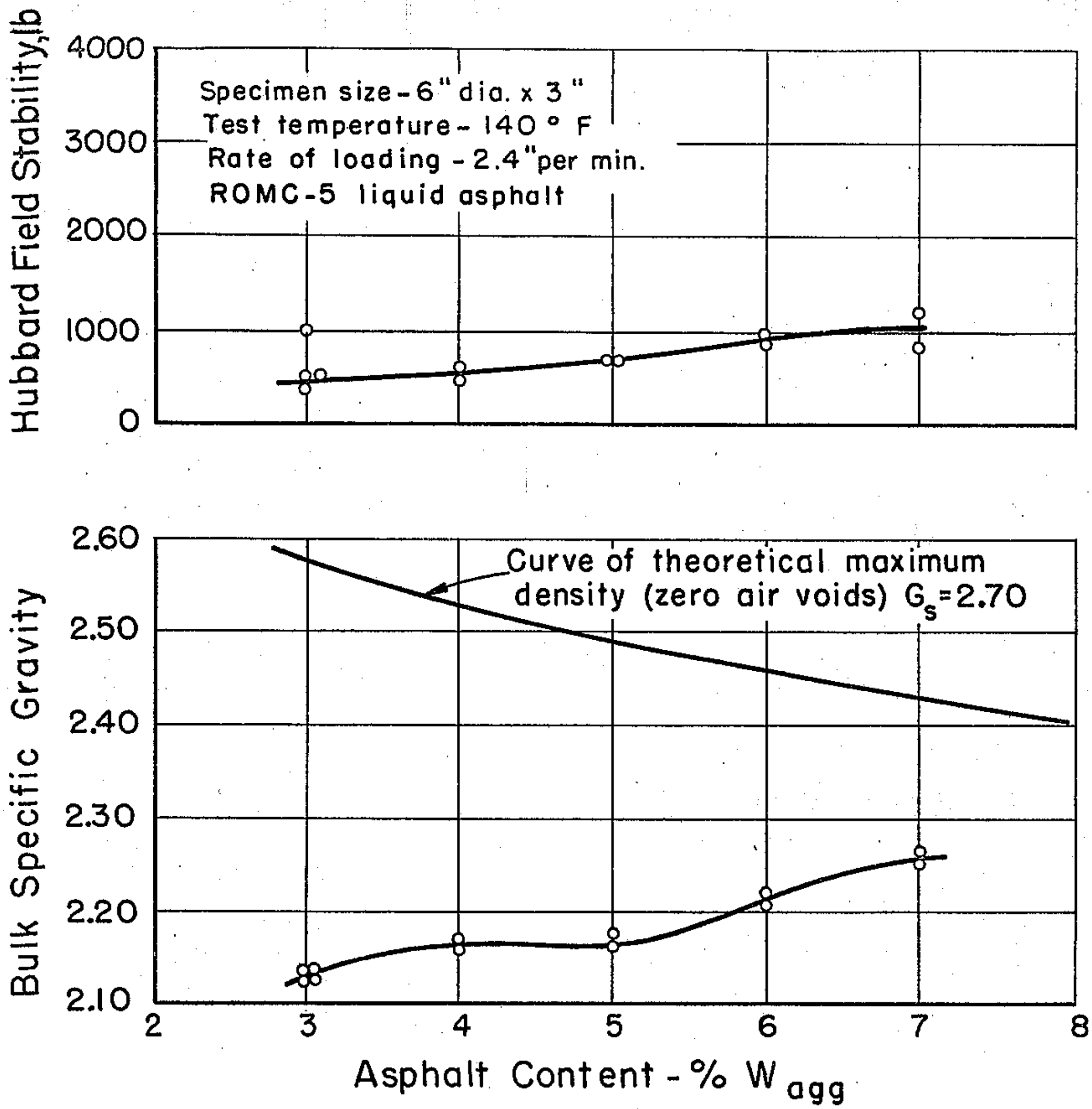


Fig. 2 Hubbard-Field Test Results, Soledad-Gonzales Agg.

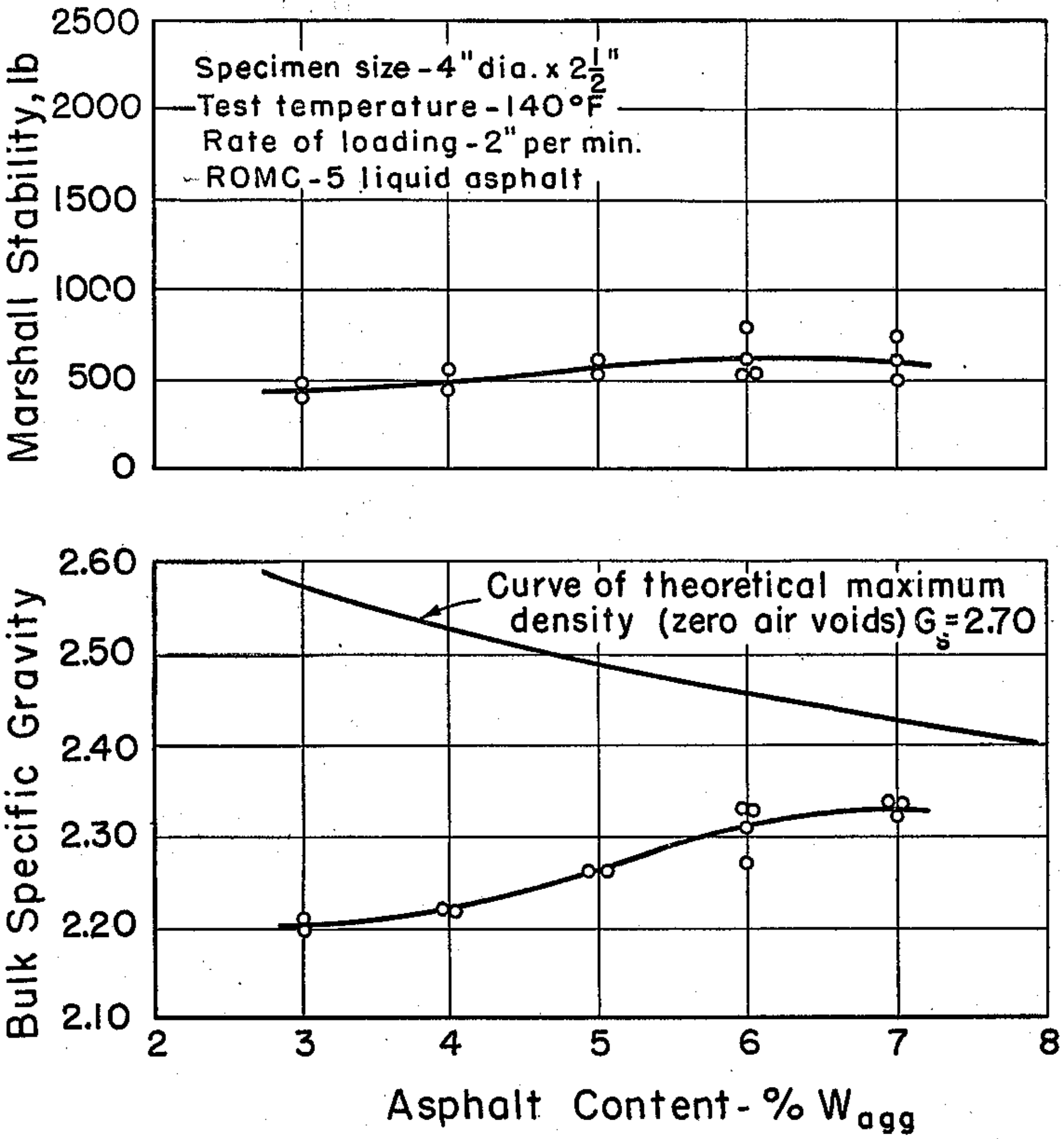
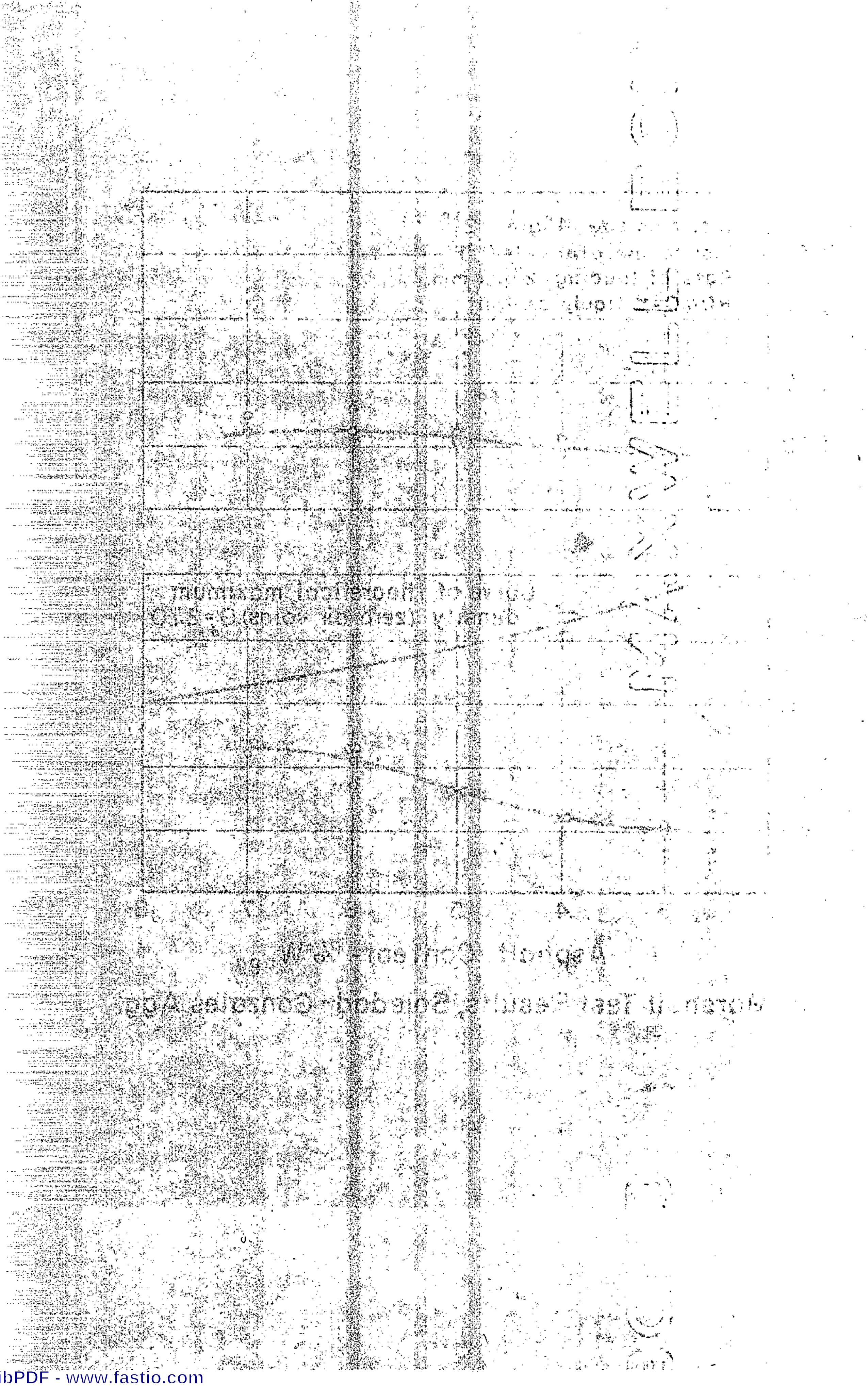


Fig. 3 Marshall Test Results, Soledad - Gonzales Agg.



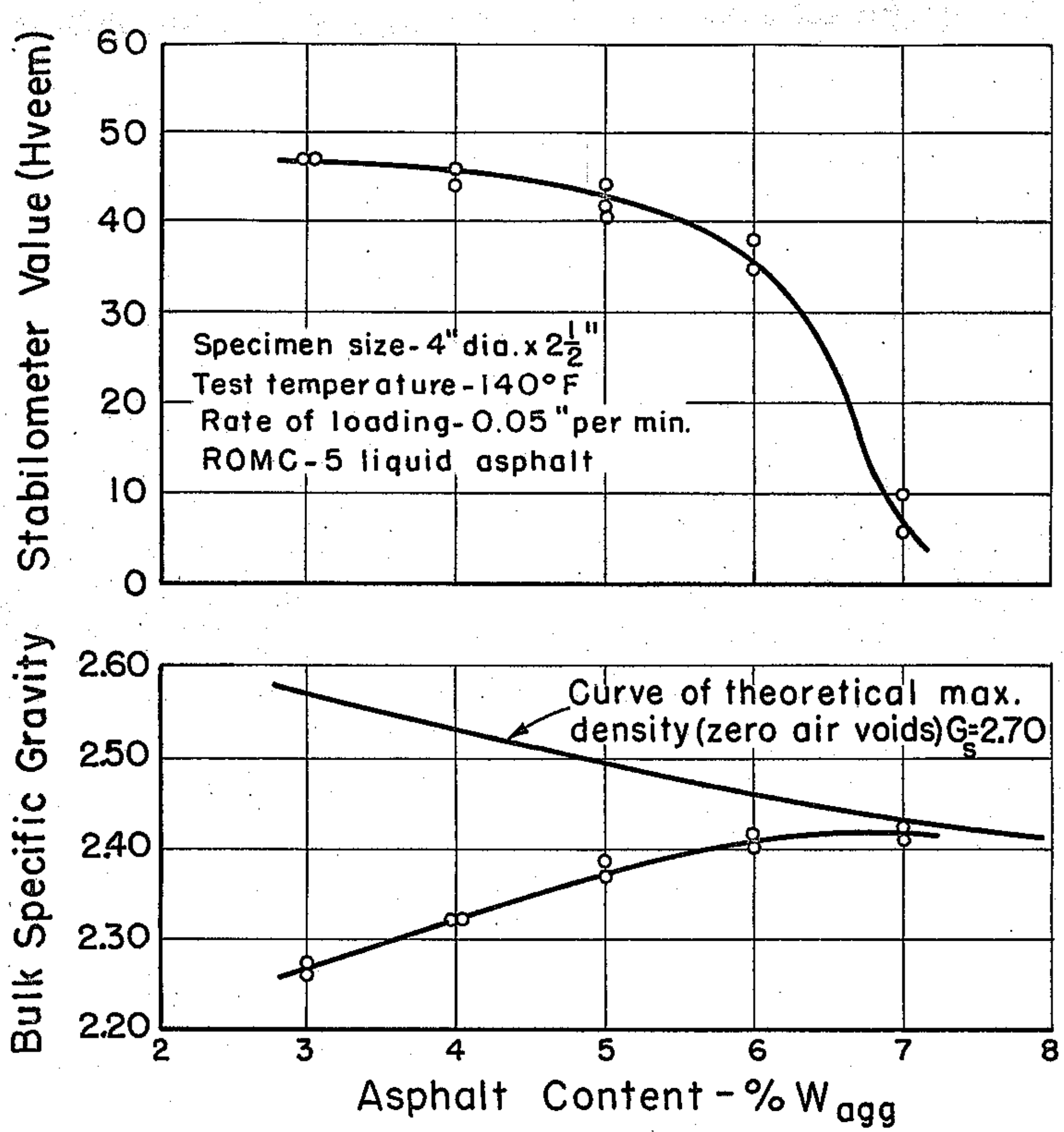


Fig. 4 Stabilometer & Cohesiometer Test Results, Soledad - Gonzales Agg.