Mixed-In-Place Stabilization Of Highway Base Aggregates And Pulverized Bituminous Surfacing Using Asphalt Stabilizers

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Final Report

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MIXED-IN-PLACE STABILIZATION OF HIGHWAY BASE AGGREGATES AND PULVERIZED BITUMINOUS SURFACING USING ASPHALT STABILIZERS

Final Report

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Testing and Research Division
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INTRODUCTION

In February 1972 the Research Laboratory initiated this research study for the purpose of developing specifications for mixed-in-place bituminous stabilization of base course aggregates. Application of the mixed-in-place method by the Department in 1970 pointed to the need for further research to develop quantitative guidelines and specifications for future construction (1). A preliminary phase of the research, completed in 1974, consisted of laboratory experiments to measure strength parameters of a limited number of material combinations (2). The final phase of the study, which is the subject of this report, consisted of both laboratory and field testing of stabilized materials used in recent construction projects.

These projects provided an opportunity to follow-up the research results with actual application experience and information. Research Laboratory engineers and technicians cooperated with Construction engineers and inspectors by providing data concerning bituminous application rates and stability values, along with corresponding design density and moisture values. The purpose of this report is to summarize the information obtained from these projects and thus provide a basis for the design and construction of future jobs.

Project Description

Six projects involved reconstruction of shoulders along Interstate freeways while two consisted of roadbed reconstruction of a state trunkline highway and ramps. The eight projects, described in Table 1, involved the pulverization of existing bituminous surfacing then blending it with existing base aggregate to a depth of 5 in. The blended mixture was then stabilized with the addition of the asphalt material, aerated to proper moisture content, shaped, compacted, and subsequently paved with a bituminous wearing surface. The old bituminous surfaces on the shoulder projects were less than 2 in. thick; the M 49 surfacing ranged in thickness from 2 in. to more than 6 in. over extensive areas.

TESTING PROGRAM

The testing program consisted of a series of tests on the materials prior to construction, followed where possible by tests on the stabilized mixtures in their as-constructed state. Preconstruction testing involved laboratory tests for stability, strength, and density at various levels of asphalt and moisture content to determine mix proportions. The as-constructed testing consisted of measuring the in-place density, obtaining asphalt and moisture contents, and forming test specimens of the freshly

TABLE 1
MIXED-IN-PLACE STABILIZATION PROJECTS

Project No.	Control Section	Job No.	Route	Construction (stabilizer)	Location
1	70063	06780A 06781A	I 96	Shoulder (emulsion)	West County line to east County line of Ottawa County. 1974 construction 18.8 miles.
2	09034	01464A, etc.	I 75	Shoulder (emulsion)	Saginaw County, I 675 northerly to M 13 connector. 1974 construction, 8.5 miles.
3	38102	06777A, etc.	I 94	Shoulder (emulsion)	Jackson County, from 1,100 ft west to M 99 to 225 ft west of Michigan Ave. 1974-1975 construction, 4.77 miles.
4	30012	05924A	M 49	Roadway (emulsion)	Hillsdale County, US 12 northerly to Hening Rd. 1974 construction.
5	82022	01871A	I 94	Shoulder (emulsion)	Wayne County, Shook Rd easterly to US 24 interchange. 1975 construction, 7.42 miles.
6	76023 25042	04293A 04294A	I 69	Shoulder (asphalt cement, cutback)	Shiawassee County, 2,400 ft southwest of Morrice Rd to Miller Rd interchange. 1975 construction, 24.5 miles.
7	38101 38103	08076A 01476A 08074A	I 94	Shoulder (asphalt cement, cutback)	Jackson and Washtenaw Counties, Michigan Ave easterly to Liberty Rd. 1975-1976 construction, 28.9 miles.
8	03112	09320A	US 131	Roadway (asphalt cement)	Ramps at US 131-142nd Ave interchange.

mixed material on the job site. Laboratory tests for strength and stability were then made on these specimens. All strength and stability tests were performed in the laboratory at room temperatures which ranged from 72 to 78 F.

Preconstruction Testing

Samples of existing surfacing and base materials were obtained from as many of the job sites as possible, several months in advance of construction. The bituminous surfacing was pulverized and mixed with the base aggregate in proportion to their respective thicknesses on the job. Marshall test specimens were then prepared and tested at room temperature with various percentages of liquid asphalt to determine amounts required in the field. These tests were also performed at different levels of moisture content to simulate possible field conditions. Associated measurements of density and extracted asphalt content were also made. Figure 1 shows the stability, flow, and density values obtained at the various levels of added liquid asphalt for Projects 1 through 4.

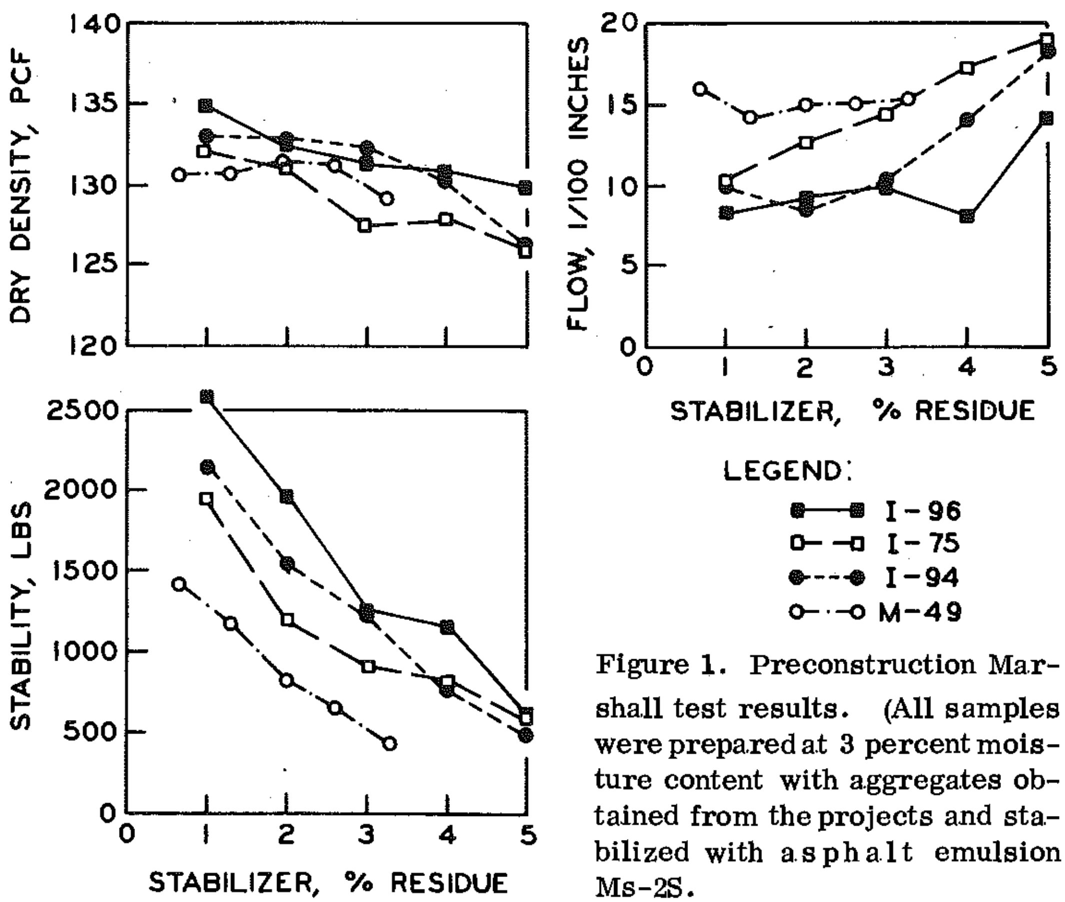


Figure 1. Preconstruction Marshall test results. (All samples were prepared at 3 percent moisture content with aggregates obtained from the projects and stabilized with asphalt emulsion Ms-2S.

Preconstruction testing was also conducted for Project 5, I 94 in Wayne County. It was anticipated that MC-800 would be used and that moisture contents greater than 3 percent would be encountered during construction operations. Laboratory procedures included a measure of the effects of various moisture contents on mixes containing specified amounts of the liquid asphalt. Samples of aggregate and pulverized bituminous surfacing were first mixed with several proportions of MC-800 at 3 percent moisture content as is shown in Figure 2. Three percent moisture was used in this test series based on previous tests involving MS-2s emulsion described elsewhere in this report in connection with the 1974 construction projects.

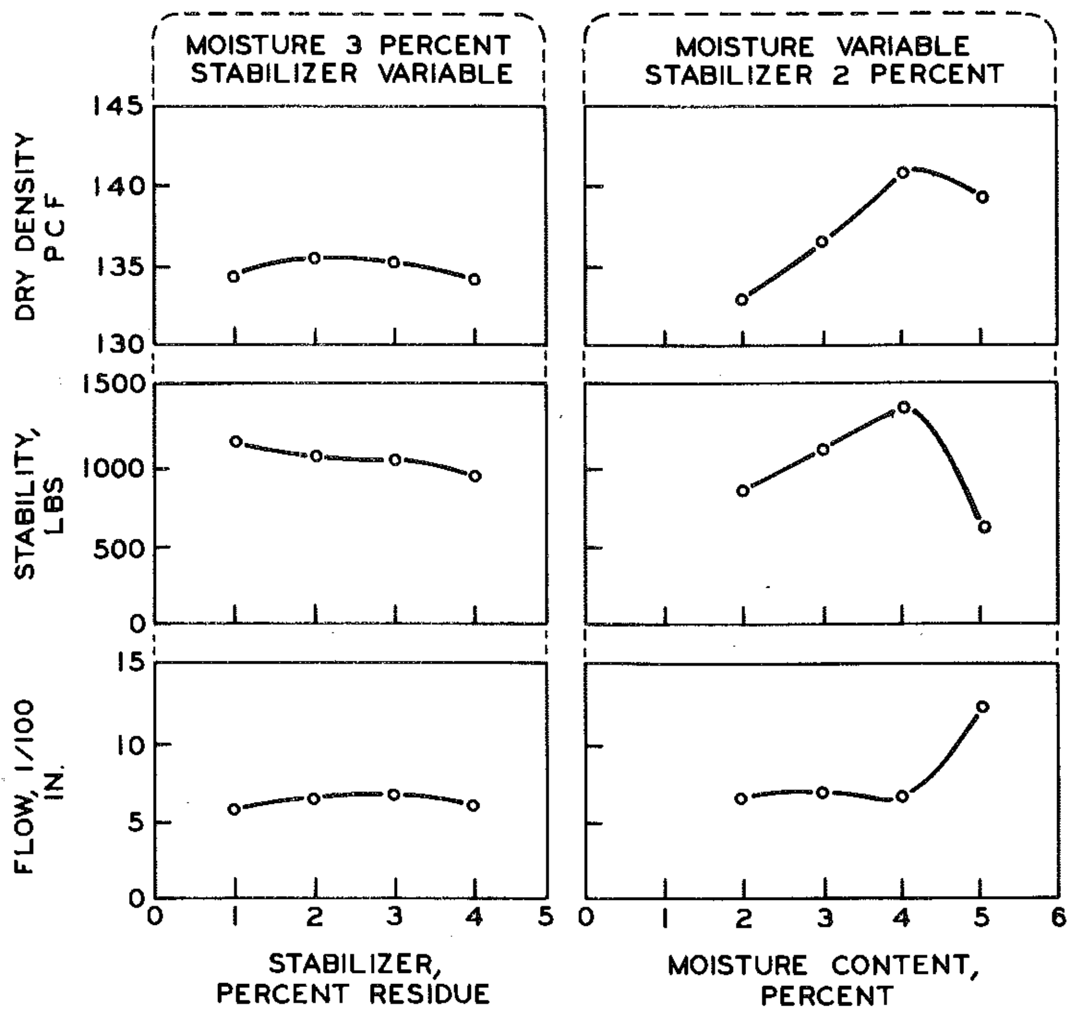


Figure 2. Preconstruction Marshall test results (aggregate material sampled from I 94 and stabilized with MC-800).

Possible effects of different field moisture levels, at the time of mixing, were next measured. For this, a set of samples was prepared by adding 2 percent asphalt residue (in the form of MC-800) with aggregate material prepared at several levels of moisture content. Marshall stability, flow, and density values were significantly influenced by moisture content, also shown in Figure 2.

During the preconstruction testing just described it became apparent that several additional factors might influence stabilization results and should, therefore, be studied. These factors included the differing proportions of aged bituminous surfacing to be pulverized and blended into the mixture and the influence of curing time between stabilization and paving. Durability of the stabilized mixtures is also an important factor and was included in the evaluation at this time. Because the projects constructed during 1974 permitted the use of either MS-2s emulsion or MC-800 cutback at the contractors option, both asphalts were compared with respect to the above factors. One project (M 49) involved large amounts of old bituminous paving so that a measure of possible rejuvenation through action of the kerosene solvent in MC-800 seemed desirable.

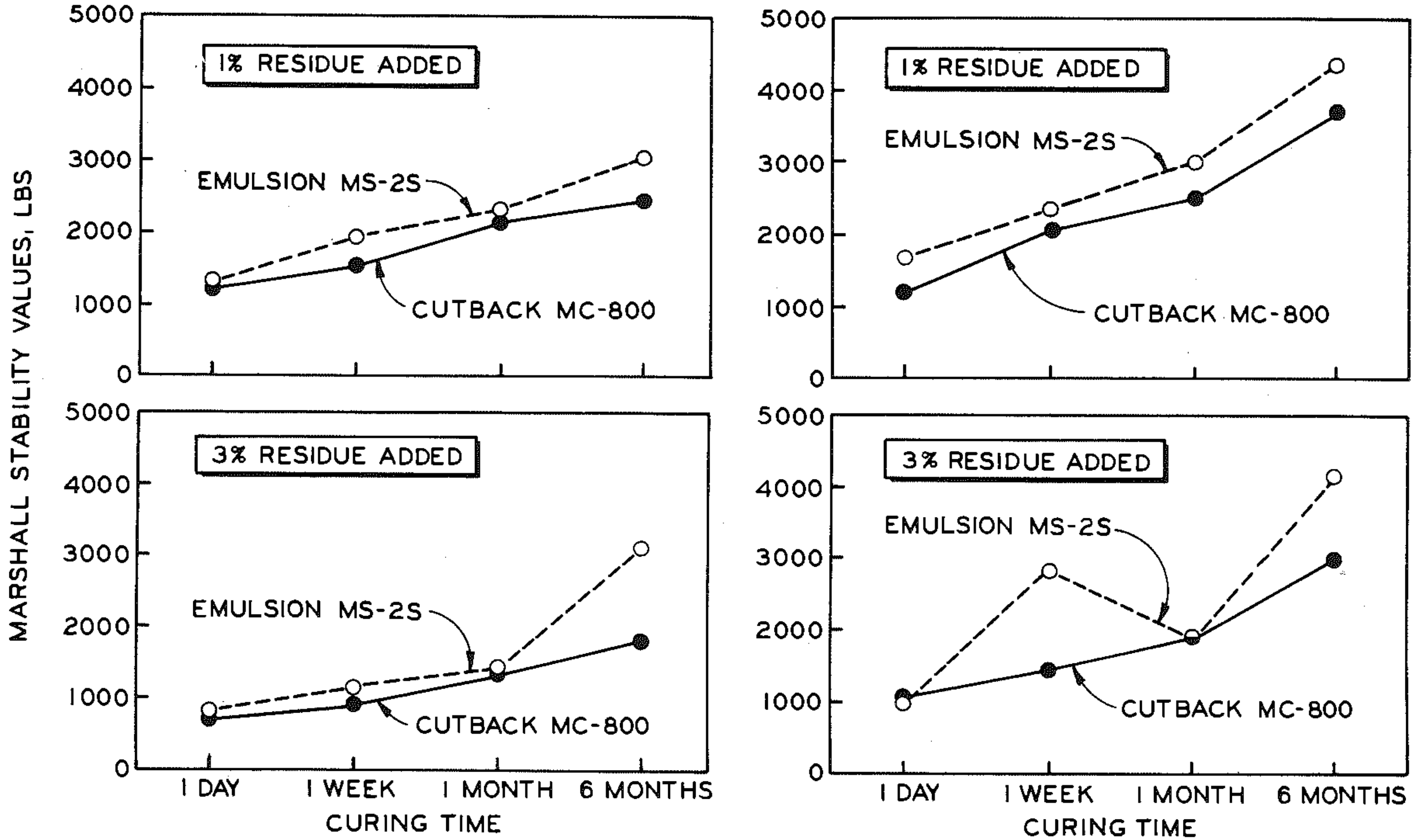
Cutback Versus Emulsion

This study was conducted to compare an MS-2s emulsion with an MC-800 cutback as stabilizers of mixtures containing pulverized bituminous surfacing materials. The study, furthermore, was designed to make this comparison with different amounts of both stabilizing agent and pulverized bituminous material. The effect of curing time was also included because it was felt that the kerosene solvent in the cutback would react with the aged pulverized asphalt whereas emulsions, which contain water, would probably not flux the existing asphalt. Marshall tests for stability were performed on mixtures prepared from roadway samples involving the following variables:

Asphalt Type:	MC-800 cutback, MS-2s emulsion
Amount of Asphalt Added:	1 percent, 3 percent
Aggregate to Pulverized Surfacing Ratio:	1:1, 3:1
Curing Times:	1 day, 1 week, 1 month, 6 months

Three specimens were formed for each of the combinations and were tested after specified curing time intervals.

Results of these tests are presented in Figure 3 and seem to indicate:



Ratio of base aggregate to pulverized surfacing = 1 : 1

Ratio of base aggregate to pulverized surfacing = 3 : 1

Figure 3. Comparison of cutback and emulsion for stabilizing base aggregates blended with pulverized bituminous surfacing (M 49).

1) greater stability on the average for mixtures containing MS-2s emulsion as compared with MC-800 cutback,

2) greater stability with mixtures containing the lesser portion of pulverized bituminous surfacing,

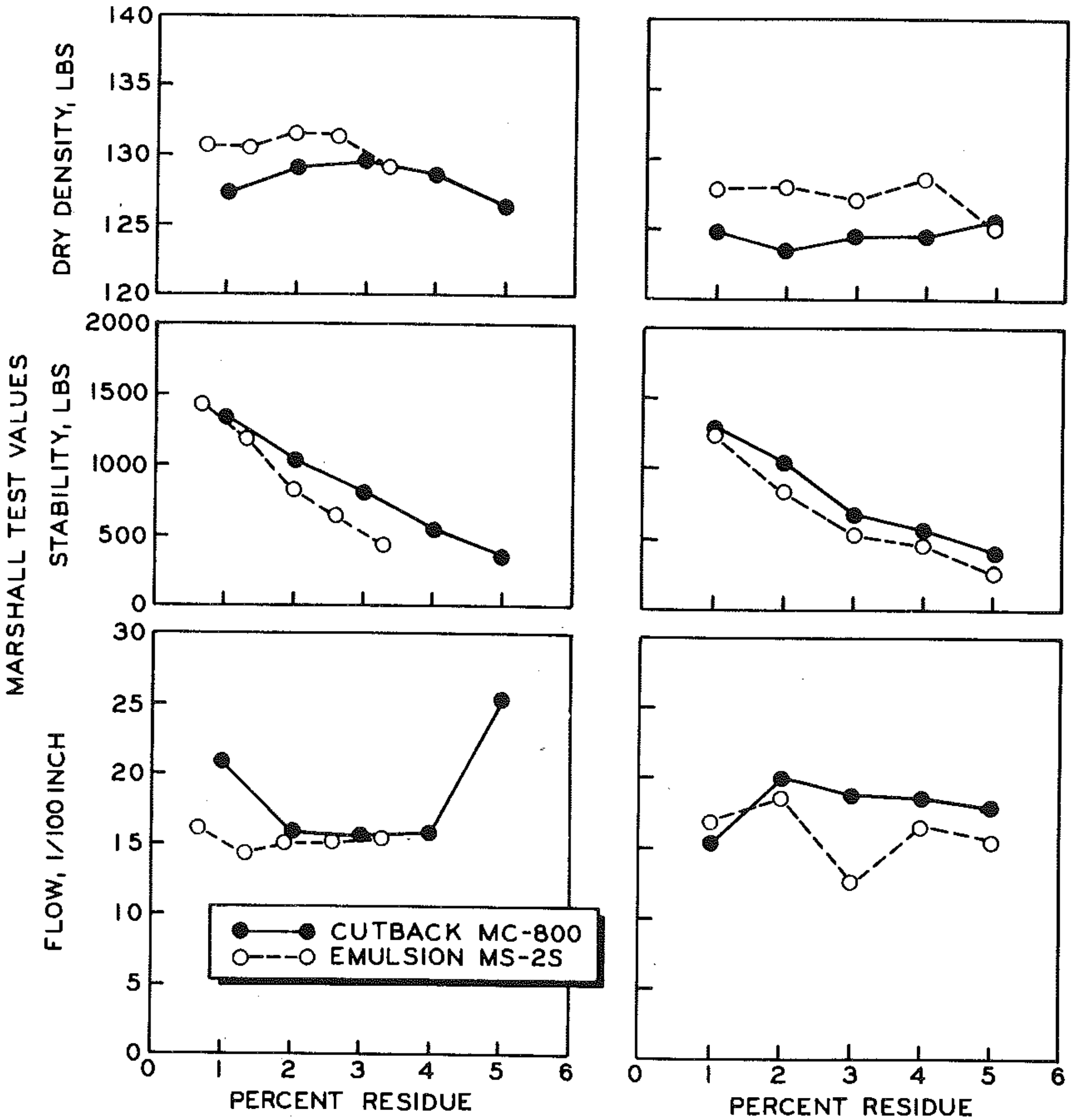
3) mixtures containing the 1 percent added asphalt were more stable than those mixtures containing 3 percent added asphalt, and

4) the average rate of increase in stability was essentially the same for all of the mixtures tested.

In a second series of tests a cutback (MC-800) and an emulsion (MS-2s) were again used to stabilize pulverized surfacing and base material from M 49. Marshall test results in Figure 4 show the MC-800 to be somewhat more stable than the emulsion at equal amounts of stabilizer as did a similar comparison using 22A aggregate (without pulverized surfacing), also shown in Figure 4. Durability of mixtures stabilized with the two liquid asphalts was also measured in this comparison by soaking samples in water prior to testing. Two levels of stabilizer residue were used with samples cured in three ways; one day air cure; 14 days air cure; and seven days air cure followed by seven days immersion in a water bath at room temperatures. Results presented in Figure 5 show no advantage of either asphaltic material at the 2 percent residue level; however, the MC-800 mixture at 4 percent residue was more stable than the emulsion mixture. Both mixtures were less stable at the 4 percent level than at the 2 percent level. The most significant result of this comparison is the overall loss of stability of both mixtures after immersion; the resultant stability is about the same for both asphalt mixtures regardless of stabilizer content.

This comparison between the two liquid asphalts should not be strictly interpreted because no attempt was made to exactly match residue characteristics. The asphalts used were obtained from supply tanks and were intended to comply with ranges set forth in Departmental specifications.

The lack of consistency in these comparisons (Figs. 3 through 5) may be due to the variable nature of the liquid asphalts. For example, emulsions sampled from 13 tanker trucks on one project ranged in penetration (of recovered residue) from 182 to 439 as compared to the 150 to 300 specification range. Furthermore, the average penetration of the 13 samples was 311 and there were seven of the 13 which were above the upper specification limit of 300. The influence of penetration on mixture stability can be seen in Figure 6, where two different MS-2s emulsions were used with the same base aggregates. Both emulsions met Department specifications



Base material blended with pulverized bituminous surfacing (M 49).

Base material, 22A.

Figure 4. Comparison of cutback and emulsion asphalt for stabilizing base materials at 3 percent moisture content.

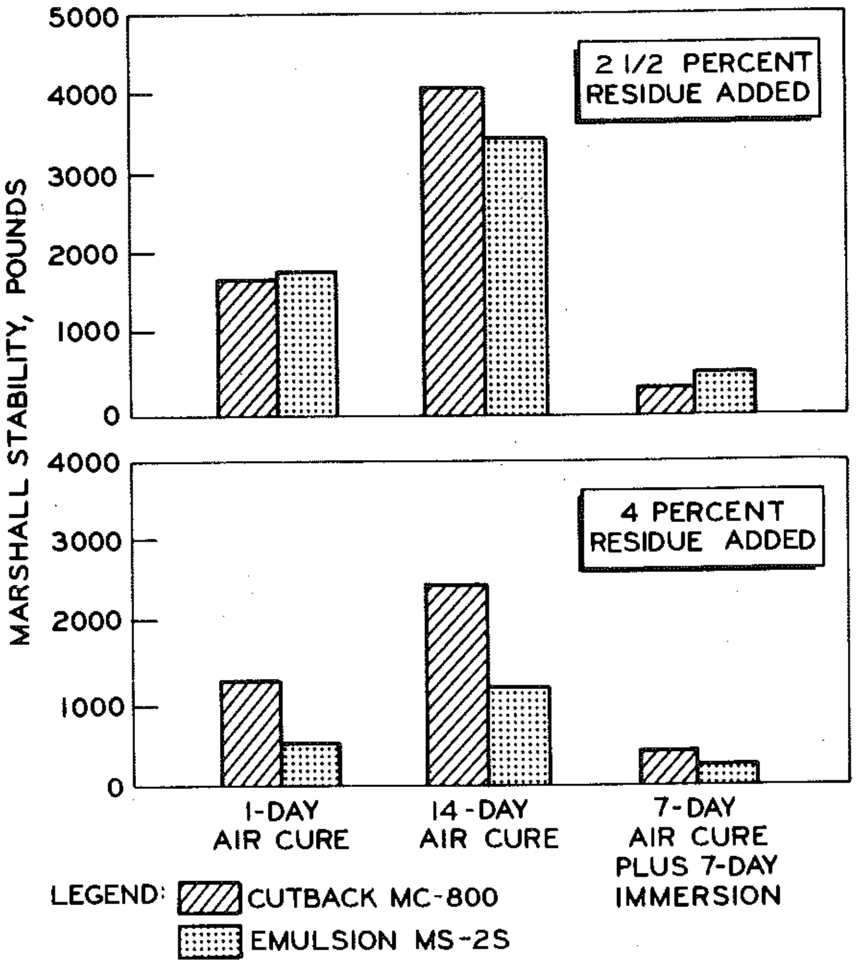


Figure 5. Influence of curing and immersion on cutback and emulsion treated 23A aggregate at 3 percent moisture content.

for MS-2s, one for road mix and the other for plant mix, with the lower penetration material yielding a more stable mix as might be expected.

Laboratory Comparison with Asphalt Cements

In the previous section a laboratory comparison was made between two types of liquid asphalt, an emulsion and a cutback. Subsequent sections of this report describe the use of both liquid asphalts and asphalt cements as stabilizers for reconstruction of shoulder base. It is the purpose of this section to present the results of a laboratory study comparing the three types of asphalts (emulsion, cutbacks, and asphalt cements) under equivalent and controlled laboratory conditions. The asphalts involved in these

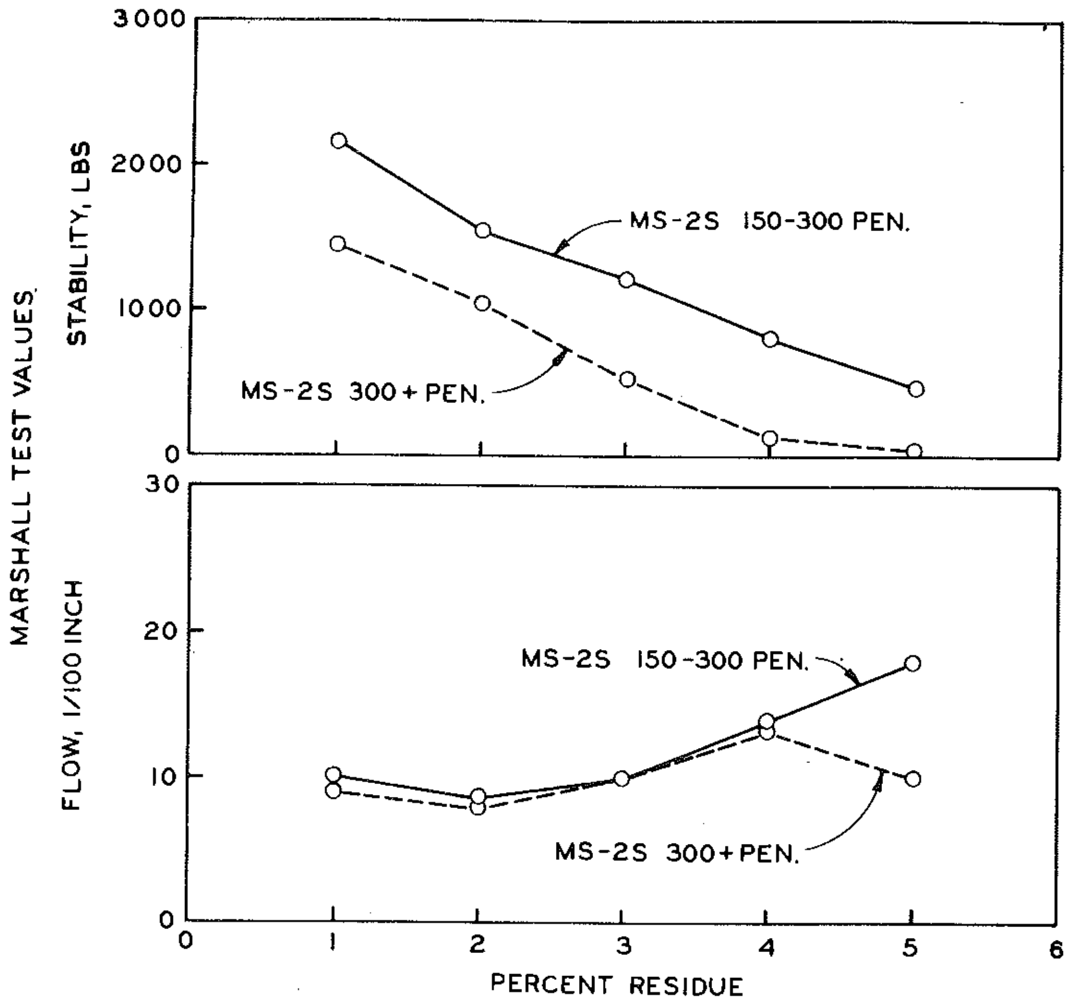


Figure 6. Comparison of two asphalt emulsions of different penetration ranges when used to stabilize shoulder and base aggregates.

comparisons have all been used in shoulder stabilization projects by the Department. These evaluations were conducted to make direct comparisons between the different asphalts and to determine which is more suitable for mixed-in-place stabilization purposes. An initial phase of this comparison involved the use of four different asphalts for stabilizing a 22A aggregate (MS-2s emulsion, MC-800 cutback, 120/150 penetration asphalt cement, and a 200/250 penetration asphalt cement). Results of this comparison show the mixtures containing asphalt cements to be significantly more stable than those established with liquid asphalts throughout the range of residue contents used for stabilization (Fig. 7).

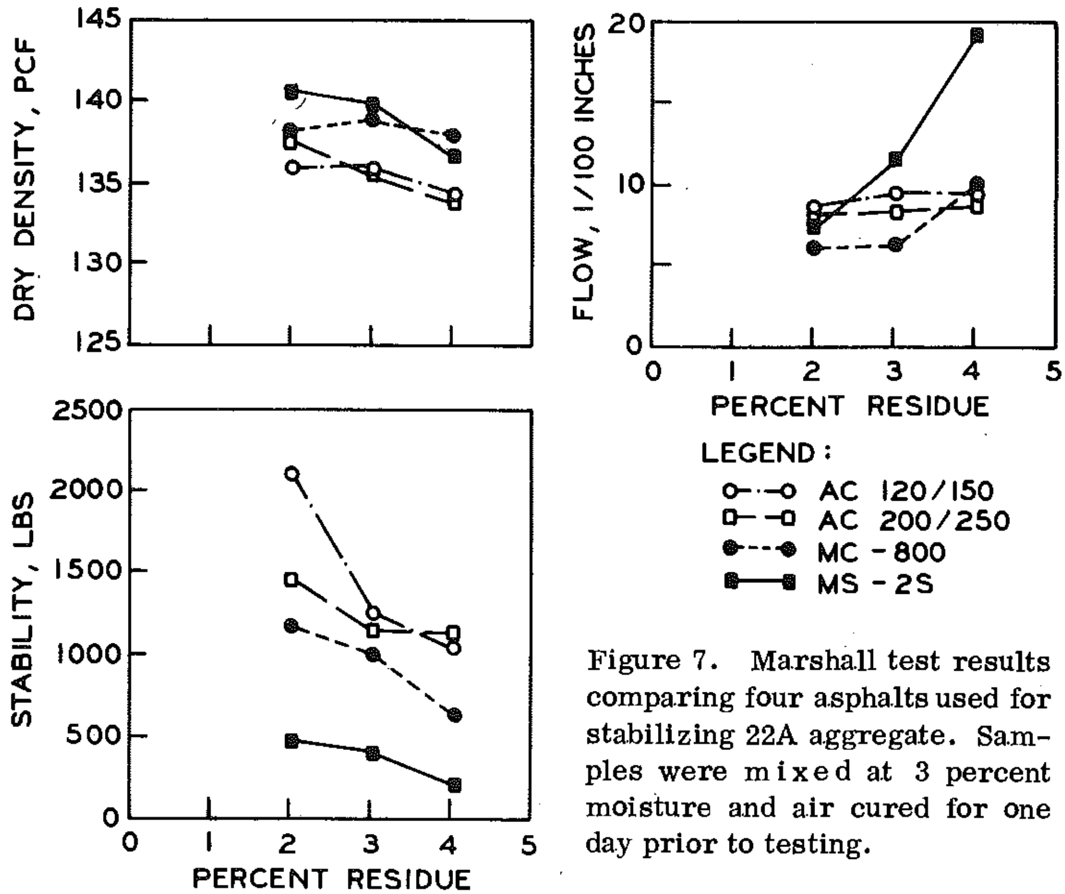


Figure 7. Marshall test results comparing four asphalts used for stabilizing 22A aggregate. Samples were mixed at 3 percent moisture and air cured for one day prior to testing.

Many Michigan rehabilitation projects are expected to involve mixtures containing pulverized bituminous surfacing. For this reason a second series of tests was conducted to compare the different asphalt types. It was thought that the aged asphalt residue in the pulverized material might react differently with each type of asphalt being added. Kerosene, for example, in a cutback was expected to provide initial softening action followed by increased stability with time. Hot asphalt cement, on the other hand, might tend to plasticize the mixture slightly for a short time after mixing followed by only a slight gain in strength with curing. Emulsions with no solvent and lower delivery temperature were expected to have almost no effect on the aged residue so that the rate of stability increase would be a function of the curing of the residue added in emulsion form.

In this experiment, the three asphalt types were compared when used as stabilizers with aggregates containing large portions of aged asphaltic material. The aggregate consisted of equal portions of pulverized bituminous surfacing and shoulder aggregate both sampled from I 75 near Indian

River as part of another study involving recycling of materials (3). Marshall stability tests were performed to evaluate the asphalts under soaked and unsoaked conditions at selected residue contents and curing time. Freeze-thaw durability tests were also conducted on the various mixtures. Finally, moisture-density relationships were determined for mixtures prepared at asphalt contents typical of those used for mixed-in-place stabilization.

Evaluation of durability was based on the Marshall stability test to compare strengths of soaked and unsoaked samples after one day, one week, and one month curing times. The samples contained 2, 3, and 4 percent residue added as the stabilizer. Marshall stability and flow results are presented in Figures 8 and 9, respectively, and show that all mixtures increased in stability during curing while flow values remained essentially unchanged. The effect of soaking the samples for 24 hours prior to testing caused a substantial loss in stability for all asphalts until sufficient curing had been obtained. As indicated in Figure 8, adequate curing requires at least one week for all the stabilized mixtures.

Freeze-thaw durability of the various mixtures was compared by Marshall specimens after three 24-hour freeze-thaw cycles. In this comparison two sets of samples were prepared and cured under equivalent conditions for one month. One set of samples, designated as immersed, was tested immediately after soaking for 24 hours while the other set of samples, designated durability, was subjected to the freeze-thaw cycling after soaking. Results of these tests, shown in Figure 10, indicated no significant effects of freeze-thaw exposure on any of the asphalts. Again, in this study the asphalt cement produced greater stability than either of the liquid asphalts.

DENSITY AND COMPACTION CONSIDERATIONS

Throughout this study tests were performed to provide information concerning density requirements for the bituminous stabilized mixtures. Laboratory tests were conducted to show the effects of several variables, including asphalt type and content, moisture content, and compaction effort on stability and aggregate (dry) density. Field density tests were performed during construction operations and the results summarized for comparison with laboratory density values.

Effects of Asphalt Type and Content on Density

Samples of aggregate and pulverized surfacing were obtained from several of the projects scheduled for reconstruction. These materials were

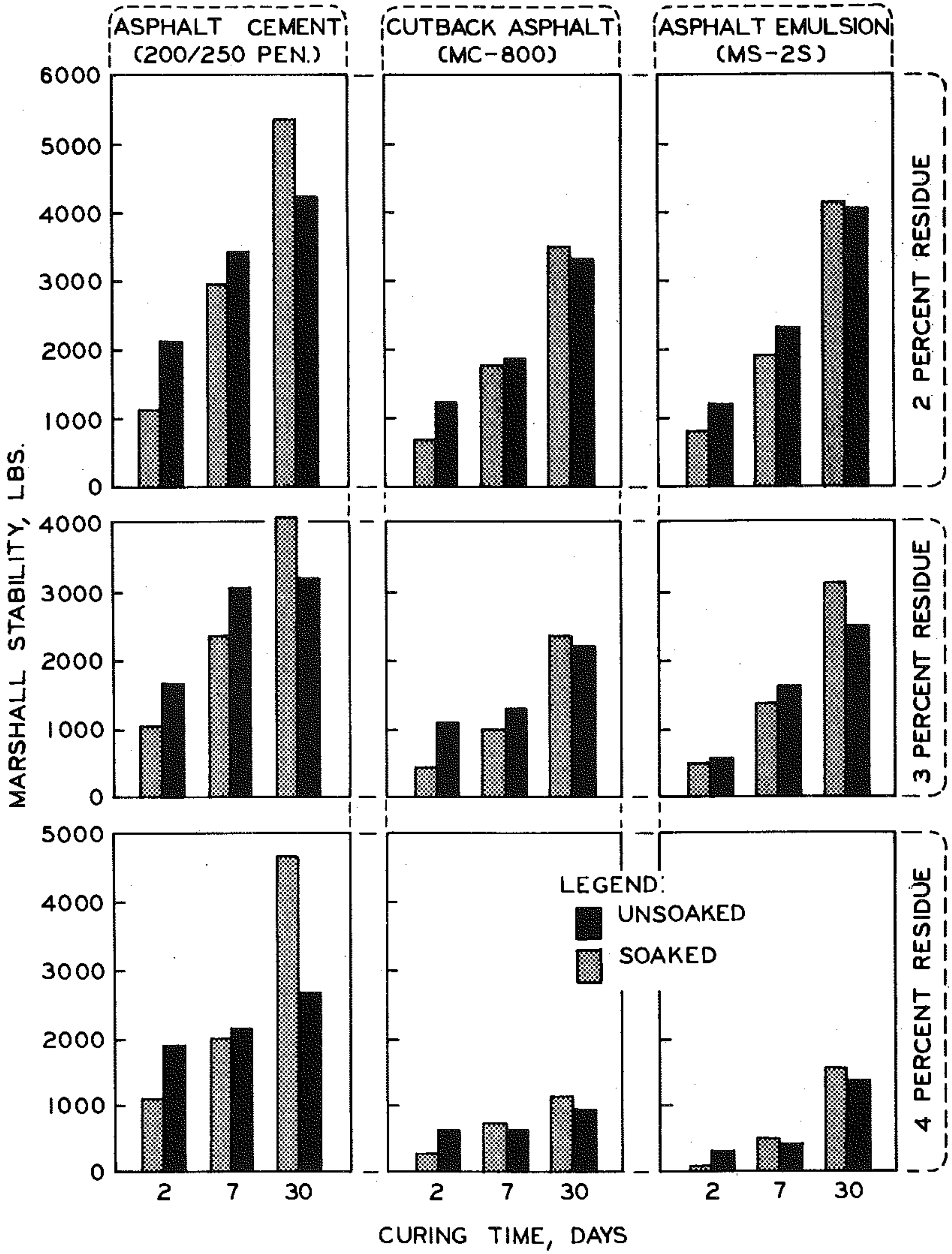


Figure 8. Relationship of stability and curing time for soaked and unsoaked samples.

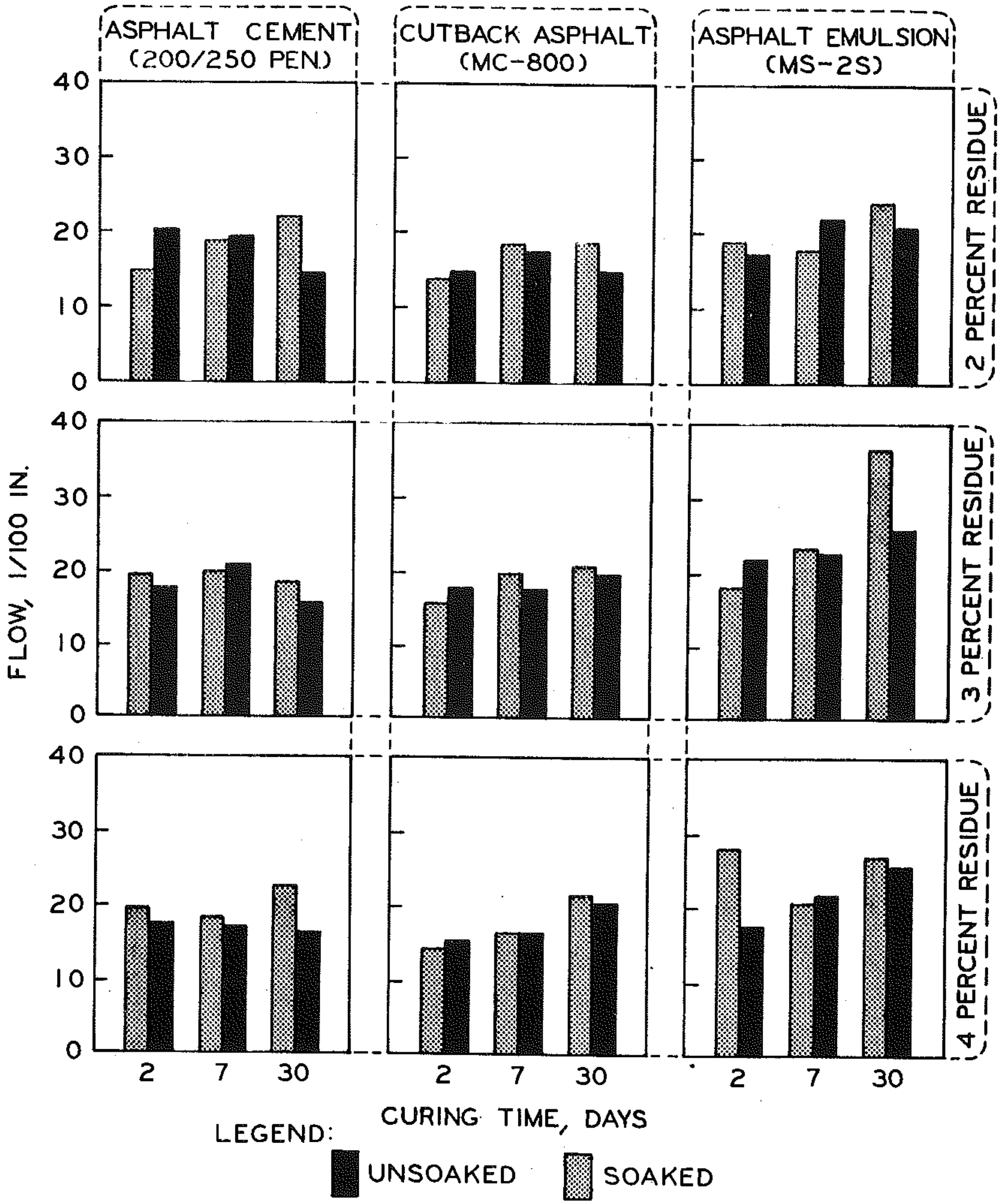


Figure 9. Relationship of Marshall flow and curing time for soaked and unsoaked samples.

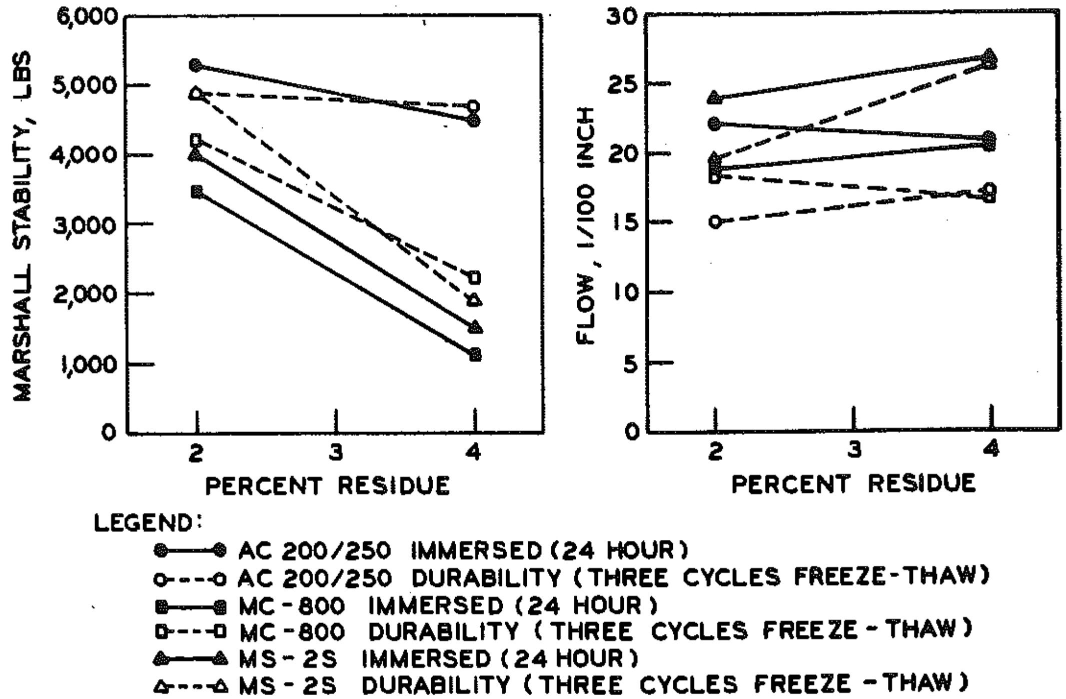


Figure 10. Freeze-thaw durability of three asphalts used for stabilizing recycled bituminous surfacing mixed with aggregate from I 75.

blended with 3 percent moisture and mixed with various amounts of an asphalt emulsion (MS-2s) and a cutback asphalt (MC-800). Marshall test specimens were then formed, using 50 blows-per-face compactive effort, and the dry density determined. The influence of the amount of asphalt on density is negligible as shown in Figure 11.

In an additional test series the comparison was expanded to include two asphalt cements of 120/150 and 200/250 penetration grades. The aggregate used in this series was a 22A with no bituminous surfacing included. Again a 3 percent moisture content was used as a value typical of that encountered during construction. Results of these tests, Figure 12, again show little effect due to changes in asphalt content; 4 lb/cu ft difference was the maximum observed; for 200/250 penetration grade asphalt cement. The effect of different asphalt types, however, is significant with asphalt cement mixture lower in density by approximately 6 lb/cu ft as compared with the liquid asphalt mixtures. Density values of asphalt cement mixtures are also slightly more affected by asphalt content than are the mixtures made with the liquid asphalt.

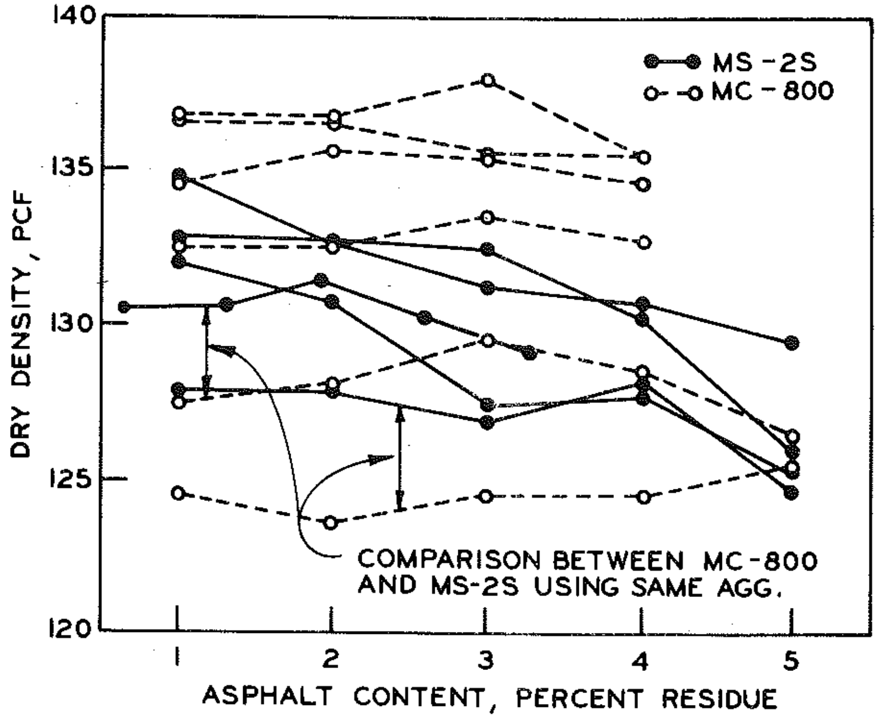


Figure 11. Effect of asphalt content on density of stabilized mixtures sampled from shoulder construction projects.

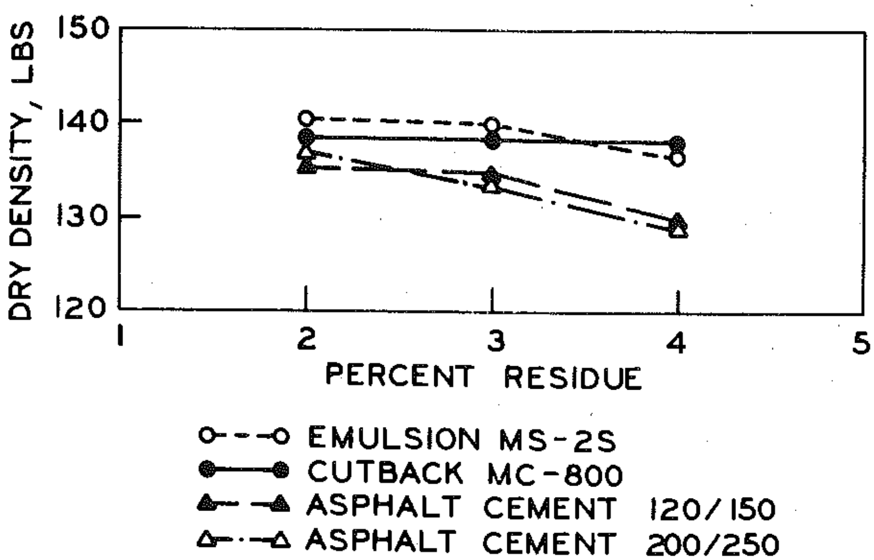


Figure 12. Comparison of densities obtained with different asphalt types used for stabilizing 22A aggregate at 3 percent moisture content.

Moisture-Density Relationship of Stabilized Mixtures

Even though the influence of asphalt content was found to be minor, especially for liquid asphalts, it was thought that field moisture content might influence the level of dry density obtainable. As described in a previous section of this report, samples of pulverized shoulder material from I 94 in Wayne County were mixed with 2 percent cutback asphalt (MC-800) and prepared for stability testing by the Marshall method, 50 blows-per-face on the specimen. Test specimens were formed at moisture contents ranging from 2 to 5 percent with density results shown in the upper portion of Figure 2. A range in density of 8 lb/cu ft was obtained which corresponds to 5.7 percent of the 141.0 lb/cu ft maximum obtained; such a difference could be of importance in field compaction and inspection testing.

Because this one test series indicated significant influence of moisture content, additional tests were made involving four different asphalts blended with material sampled from I 75 in Cheboygan County (3). This material, containing pulverized bituminous surfacing, was mixed with 2 percent (residue) asphaltic stabilizers then compacted at various moisture contents by the AASHTO T-180 soil compaction method. Moisture-density relationship curves for each of the mixtures, are the result of repeating the test procedure three times for each mixture. A completed moisture density curve involving one sample per moisture value was determined for each mixture. The procedure was then repeated for a total of three replications. Individual test points and an average curve for each mixture are presented in Figure 13. These curves show that moisture content can influence density values by as much as 7 lb/cu ft, within moisture content ranges which might normally be encountered in the field. To illustrate the results which might be obtained when individual curves are determined, as in the field, the test series conducted with AC 120/150 mixtures is shown in Figure 14. In this figure each curve is one replication as previously described.

Design Density Comparison

Laboratory measurement of mixture stability involved samples prepared by the Marshall method whereas compaction testing in the field involves maximum density values determined by a procedure such as the AASHTO T-180 method. The relationship between these two methods was measured in two laboratory test series. The first series compared density values obtained by preparing specimens identical in size and shape using both T-180 compactive effort and compactive effort equivalent to 50 blow-per-face Marshall compactive effort on identical materials. Two aggregates, 22A and a Granular Material Class I, were combined with several percentages of an MC-800 cutback and an MS-2s emulsion to provide some

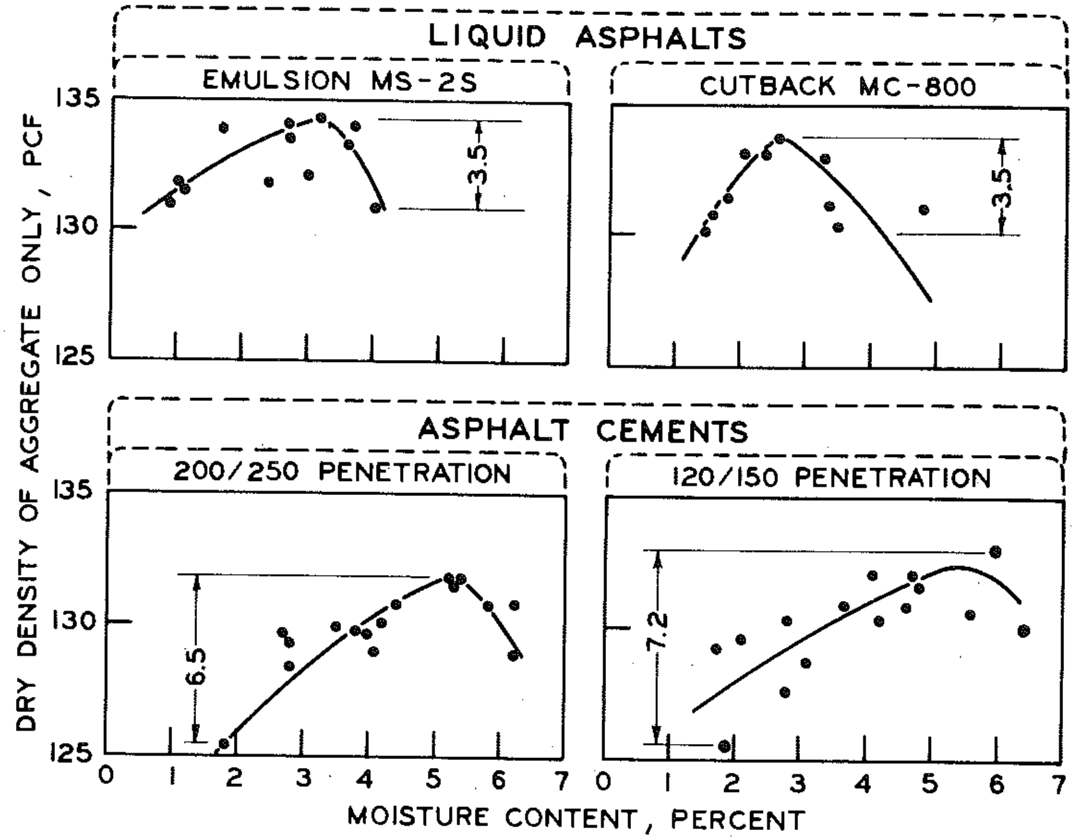


Figure 13. Moisture-density relationships for stabilized base aggregates blended with pulverized bituminous surfacing.

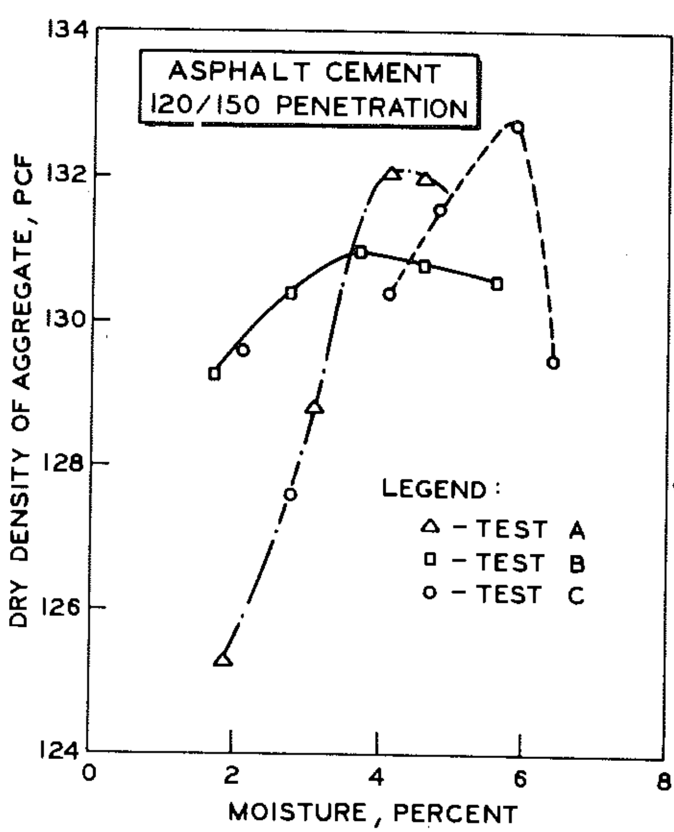


Figure 14. Variation of individual moisture-density curves for stabilized base aggregates blended with pulverized bituminous surfacing.

reasonable range in mixtures. Results of this comparison in Figure 15 show the Marshall compactive effort to yield slightly higher densities than the T-180 method for each aggregate and each asphalt and at all asphalt contents.

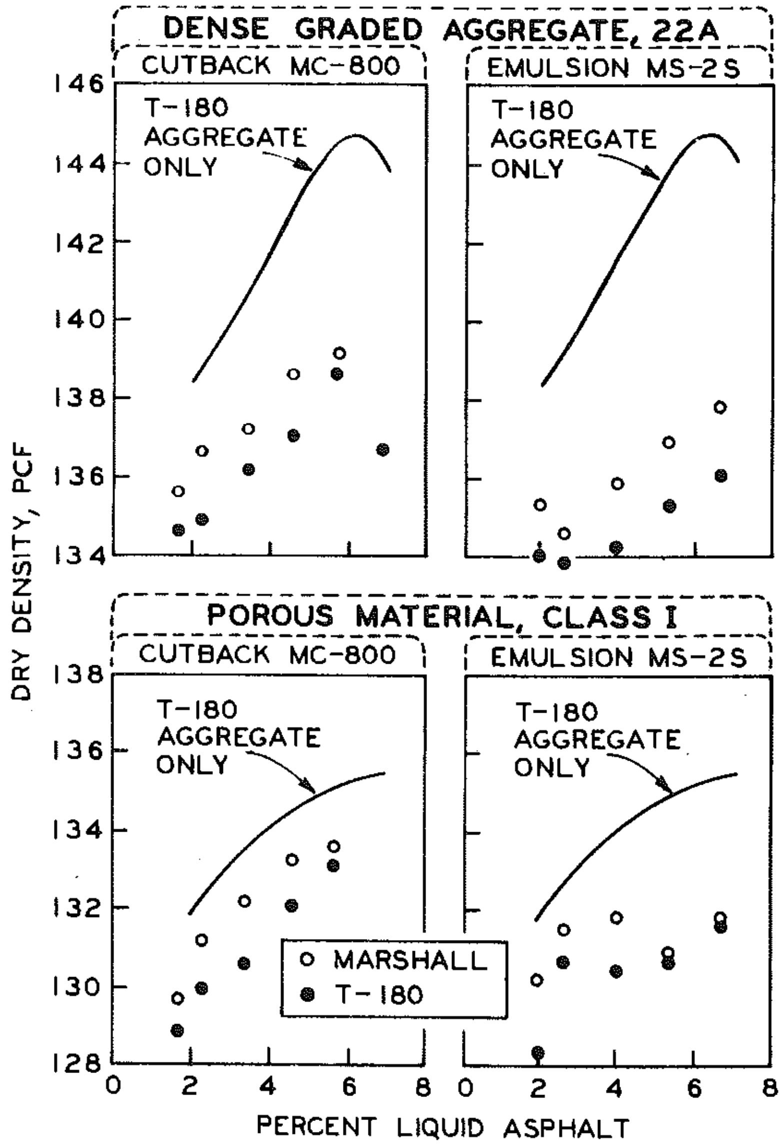


Figure 15. Comparison of Marshall method and AASHTO T-180 compactive efforts in determining maximum unit weights for various stabilized mixtures.

In this first test comparison the samples were formed with T-180 molds and hammers with Marshall compactive effort achieved by adjusting the total blows delivered to the sample. In the second comparison, Marshall specimens 4 in. in diameter by 2-1/2 in. high were prepared using an automatic Marshall compactor to deliver the 50 blows-per-face compactive effort. These samples were prepared by incorporating 3 percent moisture and 2 percent residue of the asphalt types used in comparing T-180 compaction characteristics as described in the previous section (Fig. 13). Results of this test series show that the Marshall method of compaction produces greater densities than the standard T-180 effort (Fig. 16). It should be recalled at this point that Marshall procedures were modified throughout this research project by compacting and testing at ambient temperatures rather than at 140 F.

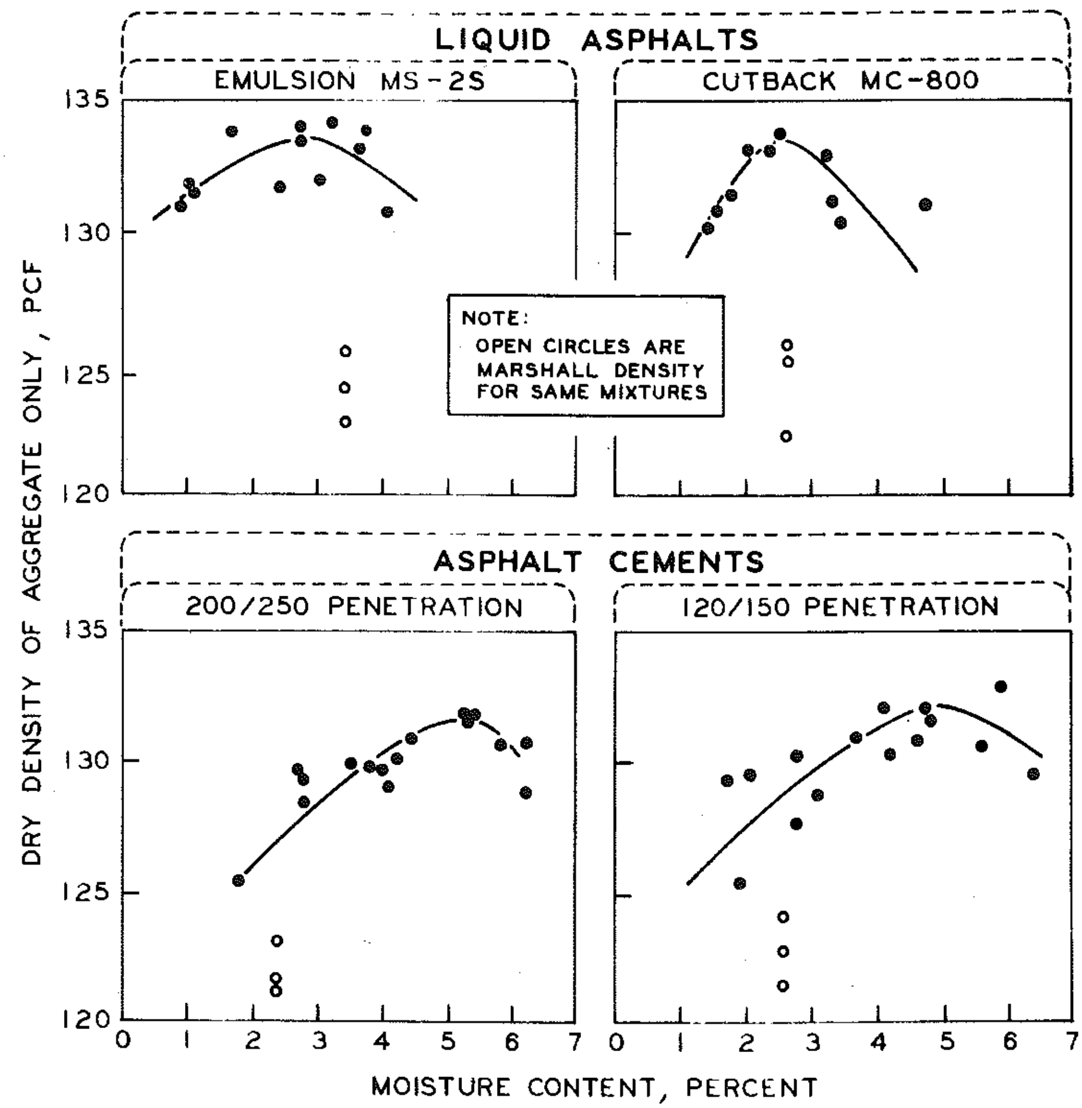


Figure 16. T-180 moisture-density relationships for stabilized base aggregates blended with pulverized bituminous surfacing.

In the first comparison, Marshall compactive effort was achieved with a T-180 rammer by adjusting the blow count to provide energy to the specimens in terms of lb-ft/cu ft of specimen material (Fig. 15). No adjustment was made for the fact that the Marshall tamping foot is 3-7/8 in. in diameter as compared to the 2-in. diameter of the T-180 rammer. This may account for the apparent contradiction of the two comparisons shown in Figures 15 and 16.

Field and Laboratory Density Comparisons

Adequate compaction is an important factor in the construction of stabilized bases. Table 2 presents density values obtained in the laboratory as well as values measured on the job. Laboratory density values, column one, were determined prior to construction and were picked from the curves of Figure 1 at a typical asphalt content of 3 percent. In-place densities and job-mix laboratory values of columns two and three, respectively, are those shown later in Table 3.

TABLE 2
FIELD AND LABORATORY
DENSITY COMPARISONS

Project No.	Laboratory Density, dry [1]	In-Place Density, dry [2]	Job-Mixed Laboratory Density dry [3]
2	127.4	128.6	130.5
4	134.8	125.4	131.1
6	128.1	132.5	131.3

[1] Marshall density at 50 blows-per-face with 3 percent residue added.

[2] In-place nuclear density.

[3] Marshall density at 50 blows-per-face at field moisture content.

In-place values were measured by nuclear gages at the time of construction. Samples of the stabilized material were then taken to the laboratory and compacted to the in-place densities of column three, Table 2, into specimens for laboratory testing of strength and stability.

Density values presented in this section provide only a casual comparison due to the small number of tests involved. Furthermore, differences

TABLE 3
TEST RESULTS OBTAINED FROM THE SEVEN PROJECTS DURING CONSTRUCTION

Project No.	Dry Density, pcf	Moisture Content, percent	Asphalt Content, percent residue	Laboratory Test Value					
				Marshall			Triaxial		
				Stability, lb	Flow, 1/100-in.	Dry Density	C, psi	ø deg	E*, psi
1	121.3	4.50	2.19	2,069	7.94	130.8	6.53	41.6	16,600
2	128.6	3.21	3.00	1,423	9.75	130.5	5.83	34.1	15,000
3	132.5	2.80	3.56						
4	125.4	3.46	3.45	2,111	12.24	131.1	7.00	45.9	18,300
5									
6	132.5	3.11	4.46	1,288	10.50	131.3	5.00	40.0	12,600
7		2.90	2.50						

in moisture contents, amount of mixing and aeration, as well as degree of pulverization can strongly influence such a comparison. Project 4, M 49, involved pulverization of old bituminous as much as 6 in. in thickness; samples of this material were readily pulverized in the laboratory to less than 1-1/2 in. whereas this could not be completely achieved on the job. It should be stated that compaction was tested on all projects even though density values are shown for only three; earlier projects involved control strip procedures with nuclear count rates other than density values used as the measure of compaction. In-place density values could be obtained for only those locations where complete density-moisture tests were performed.

Effects of Delayed Compaction

On one of the shoulder reconstruction projects, Project 3, the asphalt emulsion was added to the aggregate two weeks prior to final compaction in some areas. Frequent rains and high humidity interfered with drying and attempts to compact the mixture at near-saturation moisture content resulted in an unstable rubbery condition; extensive mechanical aeration was required before adequate stability could be achieved.

To measure possible effects of the delay and extra mixing, samples were obtained from the shoulders which had been mixed with emulsion but were not immediately compacted; periods of time ranging from 3 to 16 days elapsed after mixing. The samples were compacted in the laboratory, cured 24 hours, and tested for Marshall stability. Results of the study show that mixed material laying uncompacted on the shoulder for only three days achieved 1,150-lb stability as compared to the 600-lb stability of materials mixed but uncompacted for the greater lengths of time (Fig. 17). The purpose of these tests was to show the effect of excessive manipulation and delayed compaction; the differences in stabilities for the several time intervals shown could also be due to the variability of the physical properties of the emulsion used as mentioned in the previous section. Because of emulsion variability, it became necessary to sample each tanker load as it was delivered to the project and tested for conformance with Department specifications.

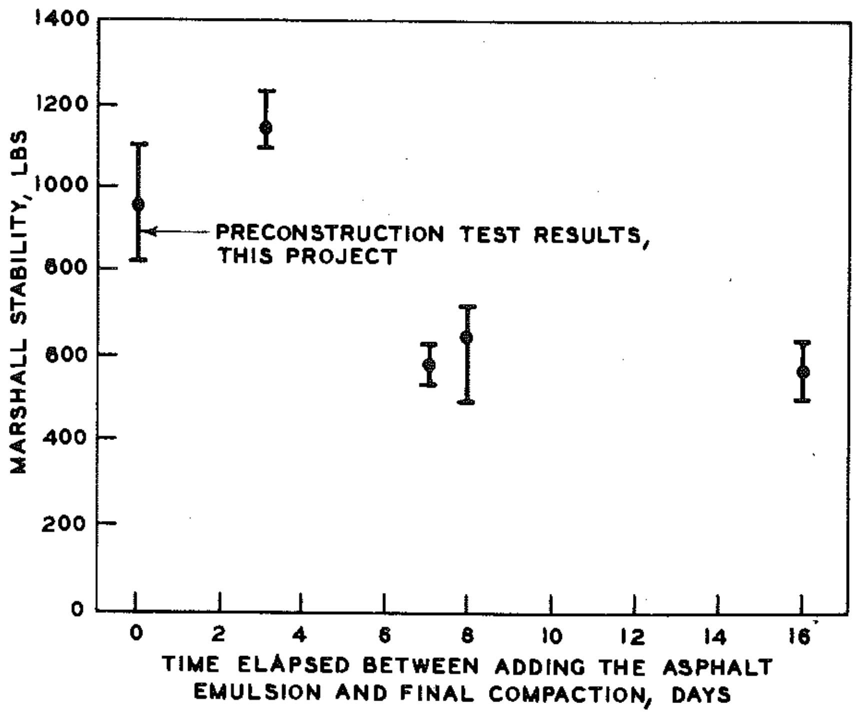


Figure 17. Effect of remixing and delayed compaction on stability.

CONSTRUCTION

Eight rehabilitation projects were included as part of this research study as listed in Table 1. Projects 1 through 5 were constructed during 1974 and 1975 and involved MS-2s emulsion as the stabilizer. Projects 6 through 8, 1975 and 1976 construction, were stabilized with penetration grade asphalts (asphalt cements). A small portion of Project 6, approximately 3,000 ft, was stabilized with an MC-800 cutback so that information concerning the three asphalt types could be obtained.

The mixed-in-place stabilization method used on these projects involved certain basic steps with modifications to suit the types of asphalt stabilizer, the nature of the material to be stabilized, and the type of construction, i.e., shoulder or full roadbed rehabilitation. In general, the stabilization process consists of the following steps:

1) Scarify and pulverize the existing surfacing
2) Precondition the aggregate by manipulation in order to dry and mix with pulverized bituminous surfacing material
3) Add bituminous stabilizer and mix to achieve uniform distribution
4) Aerate by further mixing to reduce moisture or volatile content
5) Compact and shape to grade and slope
6) Cure
7) Surface

Existing bituminous surfaces 2 in. or more in thickness are generally plant mix paving courses and will require pulverization with a hammermill or other equipment specifically designed for crushing (Fig. 18). Seal coats generally can be crushed sufficiently with the same single-axle mixers used

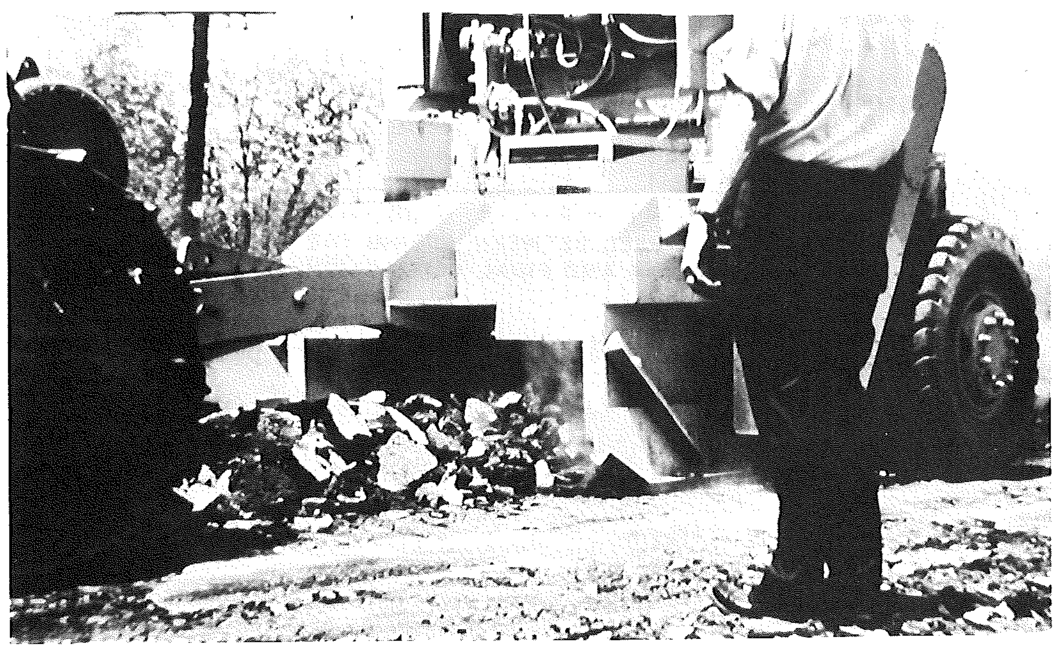


Figure 18. Traveling hammermill used to pulverize old bituminous surfacing.

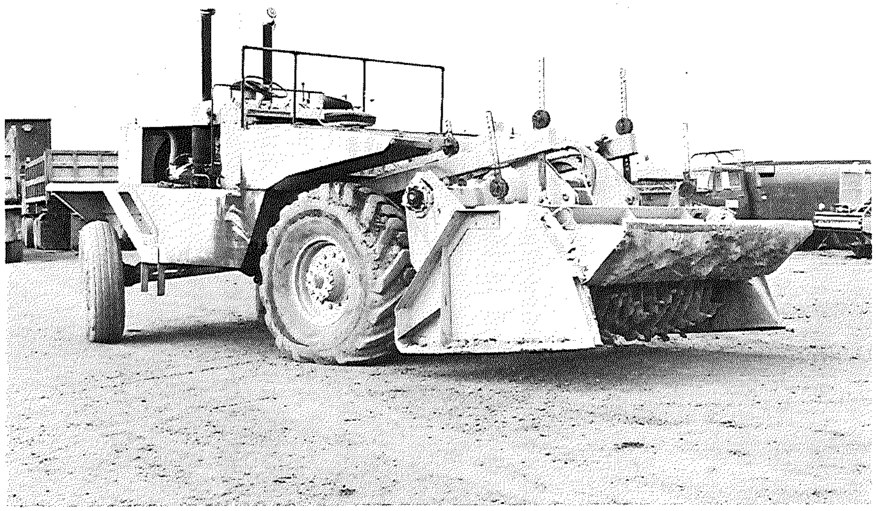
for blending and aeration, provided they are equipped with appropriate chopping teeth (Fig. 19). The resultant mixture of existing surfacing (pulverized) and base aggregate should be aerated and dried to contain less than 3 percent moisture before the asphalt stabilizer is added.

Asphalt cements, when used as the stabilizer, are blended with the conditioned aggregate through a single pass mixer with the stabilized mixture immediately shaped and compacted (Fig. 20). A small single-axle mixer may be needed directly behind the larger mixer to achieve uniform asphalt distribution. The asphalt cement is added at temperatures normally recommended for 120/150 penetration grade in accordance with Standard Specifications. Liquid asphalts, emulsions, and cutbacks require, in addition to the previous steps, manipulation of the stabilized mixture prior to compaction to dry out the water and solvent used to liquify them. After compaction a curing period is usually recommended especially when emulsions are used. This curing period involves further loss of solvents and emulsifiers accompanied by time-dependent hardening of the asphalt residue.

Reconstruction of shoulders adjacent to concrete pavement requires the existing shoulder to be trenched along the slab edge to assure treatment of all material. Mixing operations are confined to the shoulder width, usually 9 or 10 ft. Guardrails or other structures may restrict operating area and not allow passage of the larger multi-axle single pass mixers. The compacted mixtures must be graded to such elevation as to allow for application of the surfacing course which should be flush with the pavement surface. This shaping must be done within a day or so after compaction while the material can be easily cut.

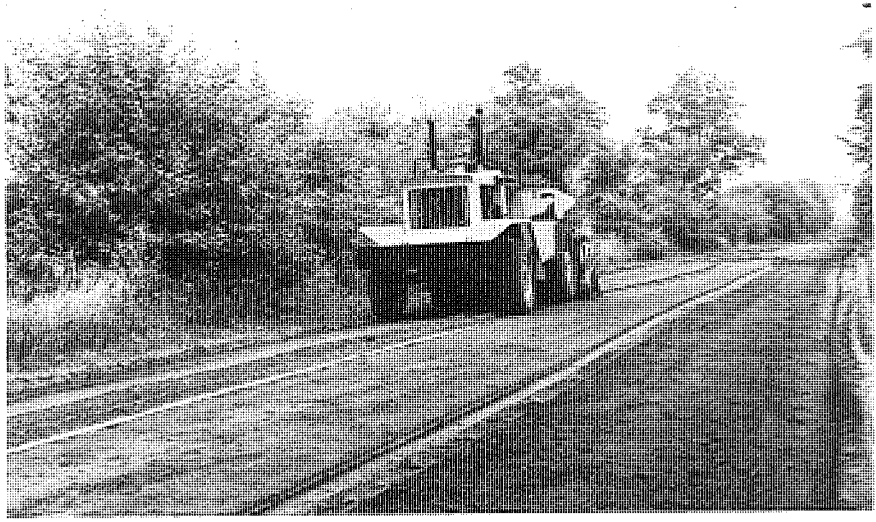
Stabilization with Emulsion

Five of the projects described in this report were stabilized with emulsified asphalts. Construction procedures outlined in the previous section were followed, with the aeration and drying phases requiring considerable emphasis. Difficulties were encountered in achieving stability on three of these projects because of excess moisture in the stabilized mixture. Even though the material could be compacted to acceptable density values, construction traffic and paving equipment would rut and shove the base in large areas. Sampling in these areas revealed large amounts of moisture. Such areas, when detected in advance of paving, were aerated further and then recompacted. Tests show that remixing, after initial compaction, causes a significant reduction in strength (Fig. 17). Several areas were replaced with conventional hot-mix material at the time of paving to avoid further construction delay.



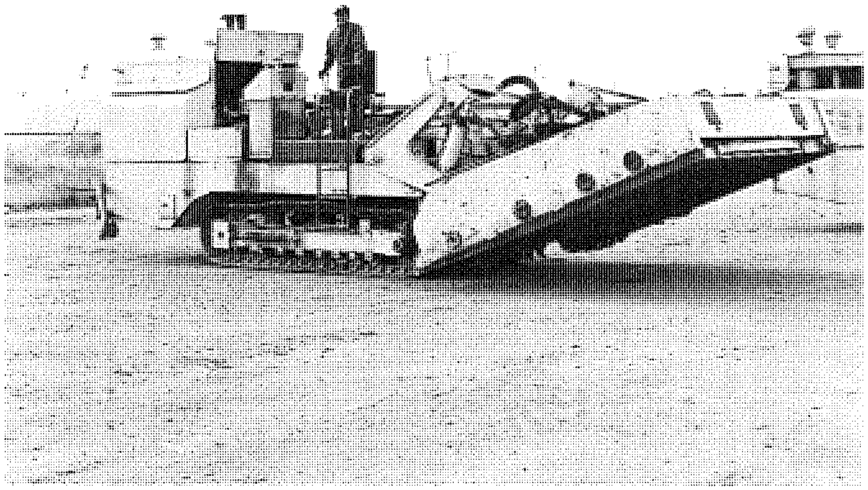
Multipass mixer-stabilizer with mixing chamber raised for travel.

Multipass stabilizer blending asphalt with shoulder base aggregate along an interstate freeway.

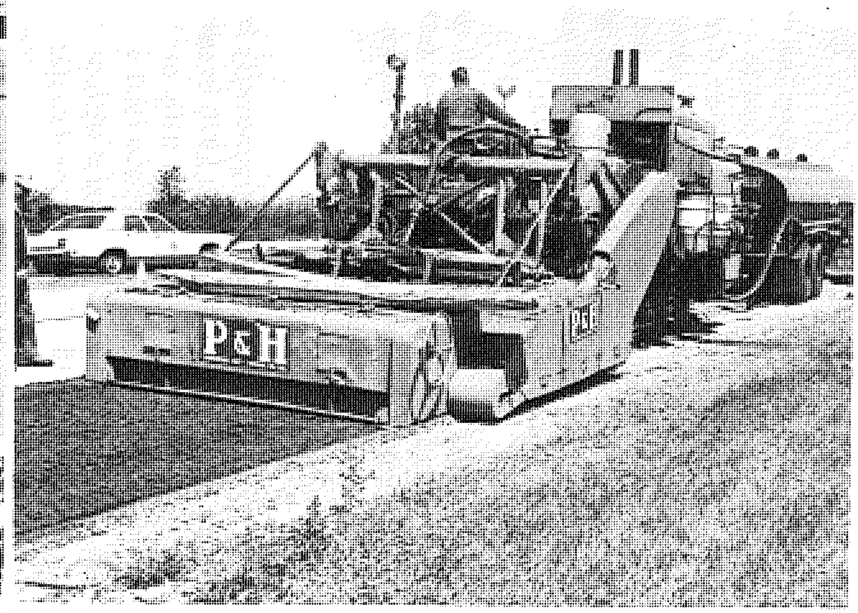


Multipass stabilizer mixing and aerating aggregate-asphalt base course mixture on a rural highway.

Figure 19. Multipass, single axle mixer-stabilizer.



Single-pass stabilizer with four axle mixing chamber raised for travel.



Single-pass stabilizer forming a stabilized shoulder base along an interstate freeway.

Single-pass stabilizer as used to form an asphalt stabilized base course on a rural highway.

Figure 20. Single-pass multiaxle stabilizer.

The moisture problem occurred on these projects because the existing surface was scarified and pulverized several days, and on one job several weeks, in advance of stabilization operations. Rainy weather during the interim saturated the material and the emulsion stabilizer was added while the material contained excessive moisture. During stabilization and initial attempts to compact the material on this job, moisture contents were as much as 10 percent. After proper aeration, adequate stability was achieved at moisture contents of about 3.5 percent, Project 4, Table 3.

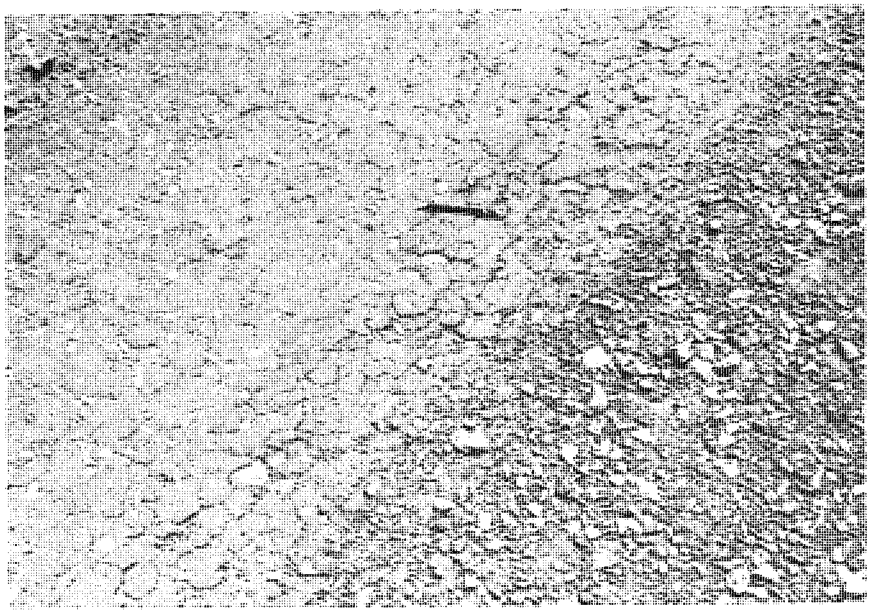
Figure 21 shows typical cracking of an emulsion base which is unstable due to excess moisture within the mixture; progressive stages of failure of a surface placed over an unstable base such as this are also shown.

In-Place Stabilization with Asphalt Cements

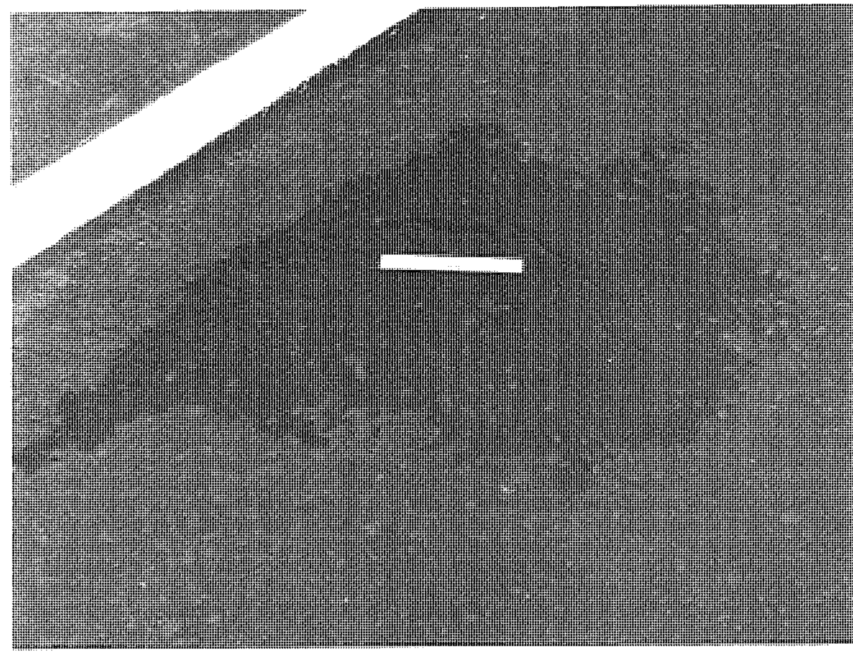
In the past, in-place or road-mix stabilization has generally involved liquid asphalt, either cutbacks or emulsions. During the 1975 construction season 24.5 miles of freeway shoulders were stabilized with asphalt cements (Project 6, Table 1). Both AC 120/150 and AC 200/250 were used on the project which also included two short sections mixed with an MC-800 cutback to provide a comparison with liquid asphalts. Construction operations were nearly the same as with liquid asphalts previously listed with two important exceptions. First, the asphalt cement was added and mixed in one step with a single-pass mixer followed immediately by compaction and final shaping. Step 4 of the previous procedure was not necessary and would be detrimental to the mixture since the asphalt cement hardens on cooling to provide stability. Curing, Step 6, is thus omitted and paving can take place as soon as the compacted shoulder is finished to proper grade and shape. In using asphalt cements the aggregate must be dry (3 percent moisture or less) prior to blending with asphalt. As with liquid asphalt, no more of the old surface should be scarified and exposed to the weather than can be stabilized in a day. With compaction and paving operations following close behind mixing, only relatively short stretches are exposed to wet weather conditions while being mixed. A second project involving asphalt cement was started in 1975 and is listed as Project 7 in this report in order to complete the list of stabilization projects for future reference.

As-Constructed Test Results

During construction, in-place density and moisture content measurements were made at selected locations. Samples of the mixture obtained from these locations were then prepared for laboratory strength and stability tests at the in-place state of moisture and density. The test specimens were prepared immediately upon sampling from the roadway in order



Compacted emulsion stabilized base containing excess moisture. Crack pattern indicates unstable condition due to moisture.



Early stage of failure of surface course placed over an unstable base such as the one above.

Complete failure of pavement surface placed over emulsion base containing excess moisture.

Figure 21. Effects of excess moisture.

to duplicate the as-constructed state of moisture content and mixture workability. Duplication of density values was achieved by varying compactive effort applied during molding.

As-constructed test values are presented in Table 3 for all projects where such tests were made. In addition to Marshall stability and flow, triaxial strength parameters along with in-place density and moisture contents and asphalt percentages are also presented.

In-Place Strength Comparisons

The previously described laboratory comparisons provided for control of all variables and permitted evaluation of the several asphalt types on an equal basis: aggregates, mixing methods, and curing were the same for each asphalt. In addition to such comparisons, it was also desireable to measure relative strength as actually constructed in order to reflect normal variations in materials and on-the-job operations. For this purpose a hydraulically operated penetration device was assembled as shown as a sketch in Figure 22.

In-place penetration tests were performed on the recycled stabilized base of shoulder reconstruction projects stabilized with an emulsion, a cutback, and asphalt cements. On each project three tests were conducted at each of five locations. Locations were selected to provide a measure of material and construction variation along the length of roadway; the three tests made at each location averaged localized effects such as stones under the point of the penetration device and lateral variation in mixing.

Each test consisted of a series of preselected loads applied to the point along with a measurement of the corresponding penetration. Stronger material resulted in lower penetration values under a given load than weaker materials. Results of these comparisons show that the material stabilized with asphalt cement is stronger than mixtures made with either of the two liquid asphalts (Fig. 23).

CONCLUSIONS

1) On the basis of strength and stability tests performed in this study, shoulder and base course reconstruction using mixed-in-place stabilization can best be accomplished with asphalt cements rather than the liquid asphalts.

2) Base aggregates containing significant portions (to nearly 100 percent) of pulverized bituminous surfacing can be stabilized with asphalt cements using mixed-in-place methods.

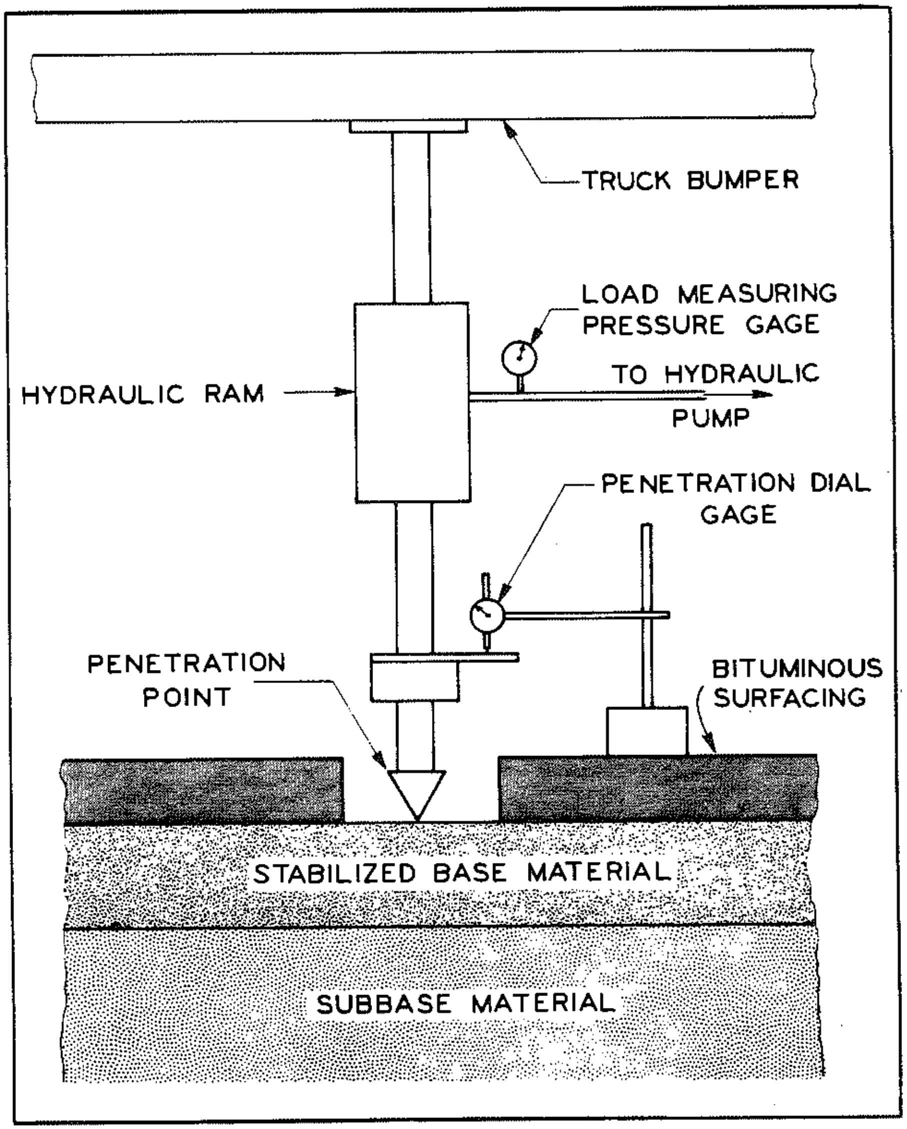


Figure 22. Penetration test equipment for measuring in-place strength of stabilized base material.

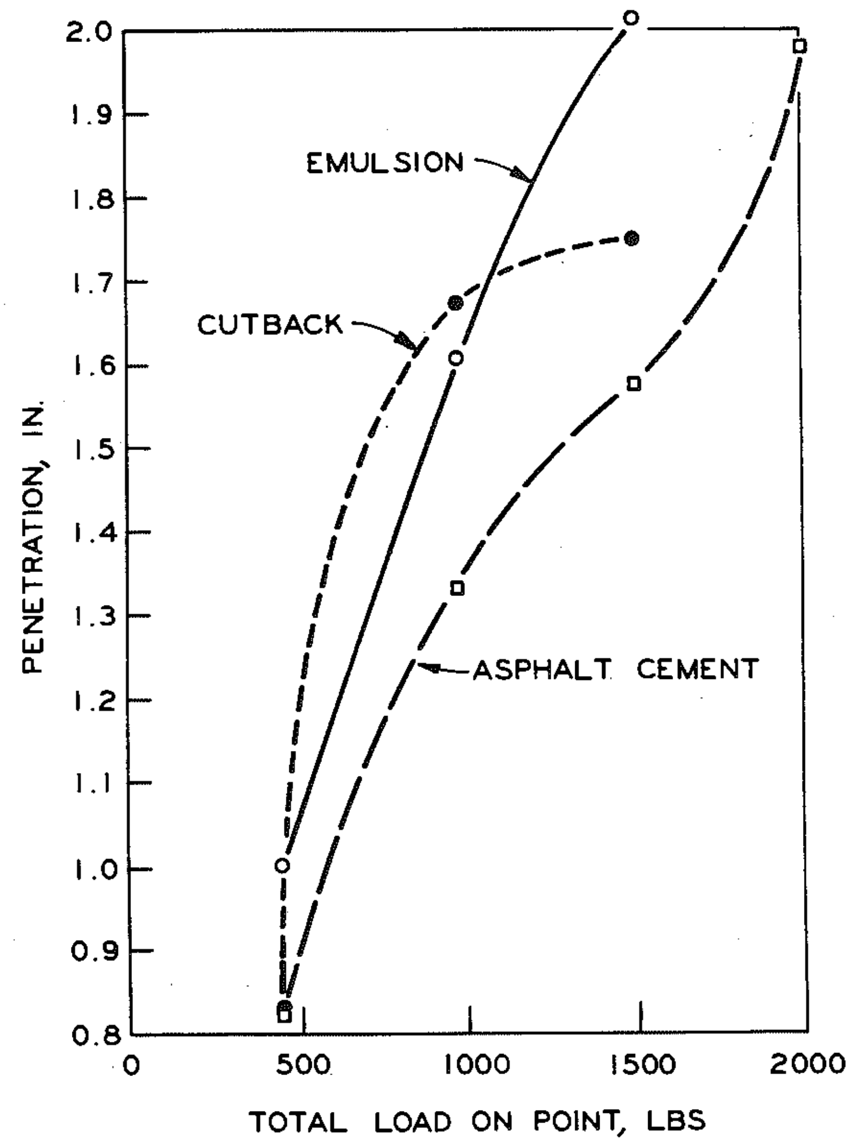


Figure 23. In-place comparison of asphalt types for mixed-in-place stabilization (lower penetration value indicates greater stability for any given lead).

3) The aggregate material to be stabilized should be adequately dried (3 percent moisture or less) prior to adding the asphalt, and the stabilized mixture must also be sufficiently dry (3 percent or less) when compacted in order to achieve a stable base for surfacing.

4) Problems with excess moisture and resultant unstable areas often developed in the bases stabilized with emulsions. Re-aeration and drying of these areas was required before paving could proceed.

RECOMMENDATIONS

1) Recycling of shoulder and roadway bases by mixed-in-place stabilization should be adopted as a regular procedure and used whenever justified by the need to conserve aggregate and provide a durable base.

2) Asphalt cements of the 120/150 or 200/250 penetration grades are to be preferred over emulsions for aggregate stabilization in situations where high moisture content of the aggregate might be a problem.

3) Recommended specifications for the use of mixed-in-place stabilization in Departmental projects are included as an Appendix to this report.

4) A field inspection test for stability should be developed. Presently the best method is to test roll the base, prior to paving, and observe for excessive deformation or cracking of the base.

5) Emulsions appear to be more susceptible to variations in local materials and construction conditions than are other methods of asphalt stabilization. Further research is suggested to obtain more information concerning the reaction of different types of emulsions with Michigan aggregates.

REFERENCES

1. Copple, F., and Chritz, A. P., "Performance Evaluation of Mixed-In-Place Bituminous Stabilized Shoulder Gravel," Michigan Department of State Highways and Transportation, Research Report No. R-792, 1971.

2. DeFoe, J. H., "In-Place Stabilization of Soil-Aggregate Mixtures with Bituminous Materials," Michigan Department of State Highways and Transportation, Research Report No. R-923, 1974.

3. Experimental Work Plan No. 41, "I 75, Cheboygan County Recycling of Asphalt Pavement," Research Project 75 D-30, May 1975.

4. Standard Specifications for Highway Construction, Michigan Department of State Highways and Transportation, July 1976.

APPENDIX

RECOMMENDED SPECIFICATIONS

The specifications recommended here are the result of experience gained during the course of this study involving three asphaltic stabilizers and incorporate provisions for pulverizing significant thicknesses (two or more inches) of existing bituminous surfacing.

RECOMMENDED SPECIFICATIONS FOR BITUMINOUS AGGREGATE BASE COURSE STABILIZED IN PLACE

Description

This work shall consist of scarifying, pulverizing, crushing, adding new material as required, and shaping to the plan grade for stabilizing with bituminous material, and shaping, rolling, and compacting the stabilizer aggregate to the proper elevation and slope.

Materials

The bituminous materials shall meet the requirements specified in MDSHT Standard Specifications (4) as follows:

Bituminous Materials

MC-800, Asphalt Cement Penetration Grade 120/150, 200/250 and Emulsion MS-2s

The bituminous material shall be applied at the rate as determined by the Engineer so that the residual bitumen added will be between 2 and 5 percent by weight of the bituminous mixture. Residual bitumen content shall be computed based on the residue of the bituminous material being applied.

When additional aggregate is required, it shall be 20A or 22A aggregate (4).

When the bituminous material to be used is not specified on the plans or in the proposal, the Contractor shall select one of the bituminous materials specified above.

EQUIPMENT REQUIREMENTS

Rollers

Rollers shall meet the requirements as specified under Rollers, (4.12.03-f) Standard Specifications (4), except that combination pneumatic-steel wheel and vibratory rollers will be permitted.

Crushing Equipment

When the use of crushing equipment is specified in the proposal, the equipment shall be an approved rotary reduction machine having positive depth control adjustments in increments of 1/2 in. and capable of reducing material which is at least 6 in. in thickness. The machine shall be of a type designed by the manufacturer specifically for reduction in size of pavement material, in place, and be capable of reducing the pavement material to the specified size. The cutting drums shall be enclosed and shall have a sprinkling system around the reduction chamber for pollution control. The rate of forward speed must be positively controlled in order to ensure consistent size of reduced material. The machine must be equipped with an accurate tachometer mounted in full view of the operator. The crushing equipment shall meet the approval of the Engineer.

Mixers

Mixers shall be self-propelled and a combination scarifier, pulverizer, mixer, and liquid distributor. Unless otherwise specified, a minimum of two mixers will be required. The mixing rotor or rotors shall have a positive depth control to ensure a uniform depth of mixing. The spray bar for distribution of the liquid shall operate in such a manner that all asphalt will be uniformly applied through the mixer at the time of mixing. The equipment for distributing the bituminous material shall be adjustable and shall measure accurately the amounts of bituminous material being applied. The bitumen pump shall be a positive displacement type pump. It shall be equipped in such a manner as to make it possible to check accurately the rate of application of the bitumen at any time. The mixer shall meet the approval of the Engineer. If asphalt cement is used, one mixer shall be a self-propelled single pass stabilizer, combining a cutting rotor, a blending rotor, and at least one mixing rotor in the mixing chamber.

CONSTRUCTION METHODS

Scarifying and Pulverizing

The material shall be scarified and pulverized to a maximum size of 2 in. and to the depth specified on the plans or in the proposal, by one or more passes. The maximum length or width of roadbed to be scarified and pulverized at any one time shall be as directed by the Engineer.

Grading

Excess material not incorporated into the work will become the property of the Contractor and shall be disposed of as specified under Disposing of Surplus and Unsuitable Material, (2.08.07) Standard Specifications (4).

Additional aggregate shall be placed as necessary to attain the plan cross section.

After the material has been balanced, it shall be thoroughly mixed. In guardrail areas, on ramps, and in bridge areas, the material to be mixed may be bladed into a windrow to provide working room for the mixer.

The grade shall be shaped to a uniform crown and grade.

Mixing with Bituminous Material

The bituminous material shall be added only to that material which can be completely mixed, aerated, dried, and compacted in one day. The bituminous material shall be added through the mixer, at the rate and temperature directed by the Engineer. The aggregate-bituminous mixture shall then be bladed into a windrow and mixed with the mixer, the operation proceeding from one side of the work area to the other (approximately four to eight windrow-mix coverages) until the mixture presents a uniform composition, free from fat spots and excess moisture, except that windrowing will not be required where asphalt cement is used, or for shoulder stabilization.

Aeration

Aeration of the mixture shall continue until the mixture is dried to the moisture content approved by the Engineer, within the range of 2 to 5 percent, based on dry weight.

Shaping, Rolling, and Compacting

Mixing, shaping, and compacting shall be done while the bituminous material is in a workable state. The mixed material shall be so shaped that, when compacted, it shall be in reasonably close conformity with the lines, grades, and cross-sections shown on the plans or established by the Engineer. Initial rolling may be done with a pneumatic-tired roller or rollers. The aggregate-bituminous mixture shall be compacted to not less than 98 percent of the unit weight obtained by the AASHTO T-180 test method. Such test shall be made on the aggregate-bituminous mixture at the field moisture content existing during the compacting operation. Required density shall be maintained until the material has been surfaced.

Curing

The base may be opened to traffic for a period of time as approved by the Engineer prior to placing of the surface.

Stability

The stabilized base shall be firm and stable under traffic loadings. The base shall be capable of carrying construction equipment during all phases of construction and paving of the wearing surface without excessive deformation or cracking of either the base or the applied paving. The Engineer may require test rolling prior to paving. Any imperfections shall be repaired as directed by the Engineer at contract unit price for base course stabilized in place.

Weather Limitations

Bituminous material shall not be applied to the grade or to the aggregate when rain is threatening or when the air temperature is lower than 55 F.

The stabilization work shall be performed in the Lower Peninsula during the period June 1 to September 15, and in the Upper Peninsula during the period June 15 to September 1, unless otherwise authorized by the Engineer.

MEASUREMENT AND PAYMENT

Method of Measurement

Bituminous Base Stabilization, to the depth specified, will be measured in square yards.

Bituminous base stabilizer required for stabilization will be measured by volume in gallons of residual bitumen at a temperature of 60 F in accordance with the methods specified under Measurement of Quantities, MDSHT Standard Specifications (4).

When additional aggregate is required, the additional aggregate will be measured by weight in tons or in cubic yards, loose measure, as Aggregate - Base Stabilizing. The pay weight for aggregate used in road mix will be based on the scale weight of the material, provided the moisture content, determined at the time of weighing, does not exceed 6 percent. If the material contains more than 6 percent moisture, the excess weight of water over 6 percent will be deducted from the scale weight. No correction or additions will be made to the scale weight if the aggregate contains less than 6 percent moisture. The determination of moisture content and pay weights will be as specified under Measurement of Quantities, MDSHT Standard Specifications (4).

Basis of Payment

The completed work as measured for BITUMINOUS AGGREGATE BASE COURSE STABILIZED IN PLACE will be paid for at the contract unit prices for the following contract items (pay items).

Pay Item	Pay Unit
Bituminous Base Stabilization	Square Yard
Bituminous Material -- Base Stabilizing	Gallon
Aggregate -- Base Stabilizing	Ton
Aggregate -- Base Stabilizing (LM)	Cubic Yard