THE EFFECT OF FINES (P-200) ON BITUMINOUS BASE MIXTURES

MICHIGAN DEPARTMENT OF STATE HIGHWAYS

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Research Project 70 TI-17
Research Report No. R-753R

Lansing, February 1971

INTRODUCTION

At the request of Paul J. Serafin (letter of August 19, 1970) the Research Laboratory conducted laboratory studies to determine effects of fines (P-200 material) on the stability of bituminous mixtures. A tentative procedure for the work was included with the request. Because of time limitations it was realized at the start that the project would be limited in scope and might require additional investigations to fully cover all of the problems involved.

In the production of bituminous bases, it is desirable to utilize the most economical aggregates available. In some areas this may result in values of P-200 material close to or even less than the 3 percent specification minimum. In such instances it is necessary to add fines in order to meet the minimum specification requirement. Mr. Serafin felt that it would be desirable to investigate the possibility of deleting the fines requirements from our specifications and suggested a laboratory study to determine the importance of fines with regard to stability; and also to find out if clay materials are detrimental to stability, particularly in the presence of water. In this study it was proposed that the Marshall method be used to measure the stability of bituminous mixtures prepared from a modified 23A aggregate, manufactured in the Laboratory, containing various amounts of fines and 4 percent asphalt cement. It was also proposed that the testing be duplicated on samples in which the P-200 material was a clay. The findings of the study would be used to prepare an updated Supplemental Specification for Bituminous Bases.

In this investigation the percentages of fines content in the test specimens were modifed from values proposed by Mr. Serafin (0, 1, 2, 5, 10, and 15) since it was thought that 1 percent increase in fines content would not show an appreciable difference in the Marshall stability values. Asphalt mixtures containing 0, 3, 6, 10, and 15 percent fines were used throughout the study.

Tests were also conducted on samples with the same fines content (3 percent) but using different types of fines. This was done in order to determine the effect of different kinds of P-200 material on the stability of the mix.

Triaxial tests were conducted on specimens containing different percentages of fines to determine the effect of the P-200 content on the ultimate strength of the mixture.

A series of compressive strength tests were conducted on water-submerged samples and air-cured samples to determine the effect of water on compacted bituminous mixtures. These tests were conducted on samples with clay fines and on samples with non-plastic fines in order to determine if clay fines have any harmful effects on the strength of the mixture.

TESTING PROGRAM

Material Tested and Sample Preparation

The basic aggregate used in this study was a 23A gravel from which the P-200 material was removed and added back in the required percentages (0, 3, 6, 10, and 15); tests indicated that these fines were non-plastic. Samples with different types of P-200 material were prepared using 3 percent fines in order to determine the relative effect of equal quantities of different types of P-200 on the stability of the mix. The P-200 materials used were: Ontonagon clay, fly ash, portland cement, and limestone dust. The asphalt cement used had a penetration of 120-150, and was added in a quantity of 4 percent by weight of the total mix.

The Marshall specimens were prepared according to ASTM D 1559-65, "Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus." Three samples were prepared with each of the selected percentages of fines, and three samples with 3 percent of each of the different types of fines. Additional samples with 3 percent Ontonagon clay were prepared to determine the effect of water on the mix. A day after a sample was compacted, the "Bulk Specific Gravity of Compacted Bituminous Mixture" (G_{mb}) was measured according to ASTM D 1188-68.

Specimens for compressive strength tests were prepared according to ASTM D 1074-60 "Compressive Strength of Bituminous Mixtures" and treated according to ASTM D 1074-54 "Effect of Water on Cohesion of Compacted Bituminous Mixtures." A total of eighteen samples were prepared; ten samples with non-plastic fines, and eight samples with plastic fines (Ontonagon Clay). Five of the samples with non-plastic fines and four of the samples with Ontonagon clay were submerged in water, while the remaining samples were maintained at test temperature in air. This was done according to the procedure of ASTM D 1074-54.

Duplicate triaxial samples were prepared with 4 percent asphalt cement and with 0, 6, and 15 percent non-plastic fines. The triaxial samples were 4 in. in diameter and 8 in. high. The mixture was prepared similar to that used for the Marshall specimens. Samples for the triaxial tests were compacted in 5 layers using 60 blows of a 10 lb hammer per layer.

Test Procedure

The Marshall stability test was conducted according to ASTM D 1559-65. In this procedure, all samples were heated to a temperature of 140 F in a water bath, except three of the six samples with clay as the P-200 material which were heated in an oven at 140 F (according to an alternate heating procedure in the ASTM D 1559-65). This was done to determine if the clay detrimentally effected the mixture when water was present. At the end of the Marshall tests, the "Maximum Specific Gravity of Mixture" (G_{mm}) was determined for every mixture sample, according to ASTM D 2041-69.

The specimens for the compressive strength test were treated according to the procedure of ASTM D 1075-54, then their compressive strength was measured according to ASTM D 1074-60.

The triaxial tests were conducted at room temperature with confining pressures of 5, 10, and 15 psi.

TEST RESULTS

Results of the Marshall stability tests, conducted on bituminous base mixtures to determine the effect of fines content on the stability of the mix, are listed in Table 1. This table also gives the bulk specific gravity of the compacted mixture (G_{mb}), voids filled with asphalt (percent), air voids (percent), and voids in mineral aggregate (VMA, percent). A plot of the fines content in percent of 23A aggregate versus the plastic flow, and versus the Marshall stability are shown in Figure 1.

TABLE 1
EFFECT OF P-200 ON STABILITY OF BITUMINOUS MIXTURES

P-200[1], percent	Sample	G_{mb}	G_{mm}	Volume, percent of total			VMA, percent	Stability, lb		Flow, $\frac{1}{100}$ in.
				Eff. AC	Agg.	Air voids		Meas.	Adjust.	
0	a	2.34						620	651	9.0
	b	2.34						540	551	7.0
	c	2.35						750	802	8.5
	Average	2.34	2.56	7.91	83.50	8.59	16.50		668	8
3	a	2.41						800	872	9.5
	b	2.37						798	803	7.5
	c	2.41						820	894	9.0
	Average	2.40	2.49	10.42	85.97	3.61	14.03		856	9
6	a	2.40						960	1075	11.0
	b	2.41						1270	1397	9.0
	c	2.42						1140	1277	10.5
	Average	2.41	2.48	10.85	86.33	2.82	13.67		1250	10
10	a	2.45						1200	1344	9.5
	b	2.42						1060	1155	10.0
	c	2.41						1110	1254	7.5
	Average	2.43	2.55	11.92	83.37	4.71	16.63		1251	9
15	a	2.44						980	1068	9.5
	b	2.41						930	995	12.0
	c	2.42						1140	1243	11.0
	Average	2.42	2.49	11.46	85.73	2.81	14.27		1102	11

[1] Non-plastic

Summary of the Marshall stability tests, conducted on bituminous base mixtures to determine the effect of the type of fines on the stability of the mix, are listed in Table 2. All tests reported in Table 2 were conducted on samples containing 3 percent fines (P-200).

The compressive strength tests were conducted on bituminous base mixtures to investigate the effect of water on the strength of the mixture

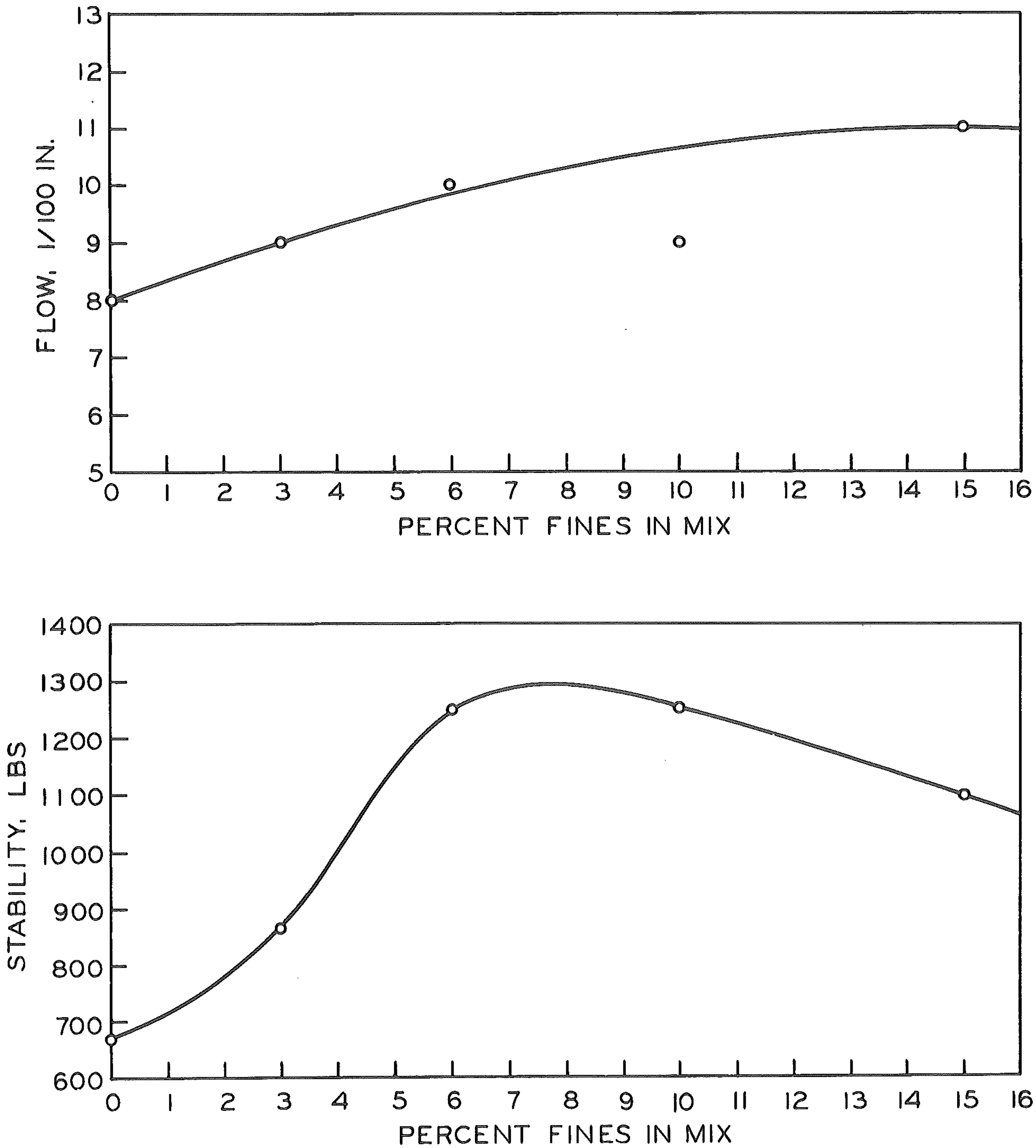


Figure 1. Fines content versus plastic flow (upper) and Marshall stability (lower) of bituminous base mixtures.

TABLE 2
EFFECT OF THE TYPE OF P-200 ON STABILITY OF BITUMINOUS MIXTURE

P-200[1]	Sample	G_{mb}	G_{mm}	Volume, percent of total			VMA, percent	Stability, lb		Flow, $\frac{1}{100}$ in.
				Eff. AC	Agg.	Air voids		Meas.	Adjust.	
Non-plastic soil	a	2.41						800	872	9.5
	b	2.37						798	803	7.5
	c	2.41						820	894	9.0
	Average	2.40	2.49	10.42	85.97	3.61	14.03		856	9
Ontonagon clay	a	2.42						1820	2038	11.0
	b	2.43						1430	1630	10.0
	c	2.42						1240	1389	10.5
	Average	2.42	2.49	10.50	86.69	2.81	13.31		1686	11
Ontonagon clay (oven cured)	d	2.42						1700	1938	9.0
	e	2.41						1640	1837	9.0
	f	2.43						1540	1725	8.0
	Average	2.42	2.49	10.50	86.69	2.81	13.31		1833	9
Fly ash	a	2.35						960	1046	5.0
	b	2.37						670	730	7.0
	c	2.39						720	720	7.0
	Average	2.37	2.49	10.28	84.90	4.82	15.10		832	6
Portland cement	a	2.39						1090	1188	8.0
	b	2.38						1040	1134	8.0
	c	2.37						1300	1417	7.0
	Average	2.38	2.55	8.39	84.94	6.67	15.06		1246	8
Limestone dust	a	2.36						820	894	11.5
	b	2.38						1290	1406	7.0
	c	2.37						820	894	11.5
	Average	2.37	2.48	10.66	84.90	4.44	15.10		1065	10

[1] 3 percent aggregate

and to determine if the clay fines have a harmful effect on the mixture, especially in the presence of water. A summary of the results of these tests are listed in Table 3. A typical stress-strain curve of a compressive strength test is shown in Figure 2.

Results of triaxial tests, conducted on compacted bituminous base mixture samples with 0, 6, and 15 percent fines in the aggregate, are shown in Figures 3, 4, and 5. These figures show the p-q[1] diagram and the Mohr-Coulomb envelope for each set of tests. Summary of the strength parameters determined by the triaxial tests are listed in Table 4.

[1] $p = \frac{\sigma_1 + \sigma_3}{2}$, $q = \frac{\sigma_1 - \sigma_3}{2}$

TABLE 3
COMPRESSIVE STRENGTH OF BITUMINOUS MIXTURES

Sample Description	Sample No.	Density, PCF	Compressive Strength, psi	Average Compressive Strength, psi
23A modified -200 mtl., Pontiac silt 4% asphalt Air cured	2	144.63	220.5	220.3
	4	143.95	179.1	
	13	145.63	214.9	
	14	144.96	242.8	
	16	144.63	244.3	
23A modified -200 mtl., Pontiac silt 4% asphalt Water submerged	1	143.63	238.8	236.4
	3	143.95	226.1	
	5	144.96	227.7	
	6	145.63	209.4	
	15	144.96	280.2	
23A modified -200 mtl., Ontonagon clay 4% asphalt Air cured	8	146.10	277.1	277.5
	10	147.45	248.4	
	12	145.42	244.4	
	17	146.44	340.1	
23A modified -200 mtl., Ontonagon clay 4% asphalt Water submerged	7	145.76	259.6	280.1
	9	146.77	272.3	
	11	145.76	254.0	
	18	146.44	334.4	

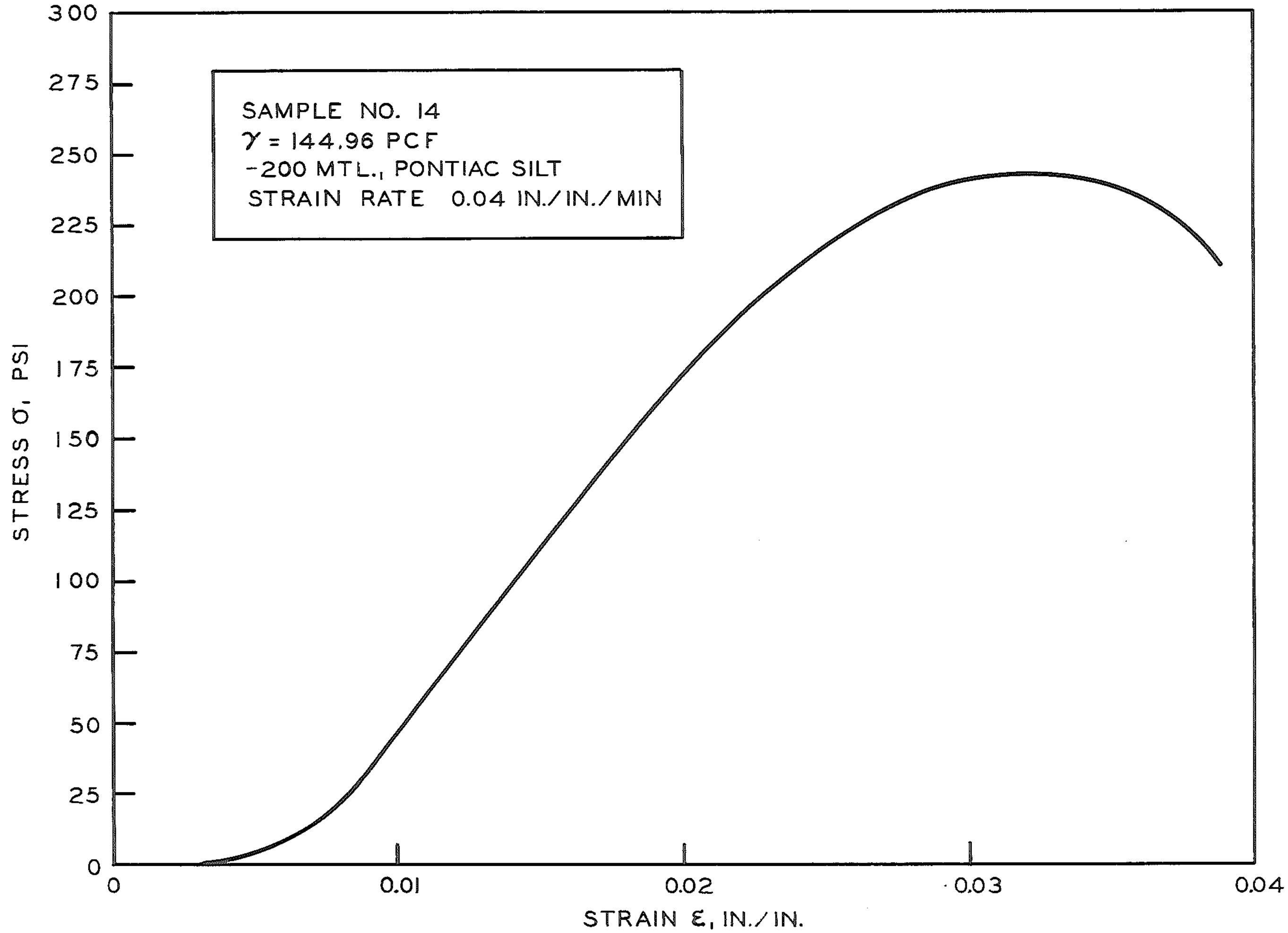


Figure 2. Stress strain curve of a typical compressive strength test.

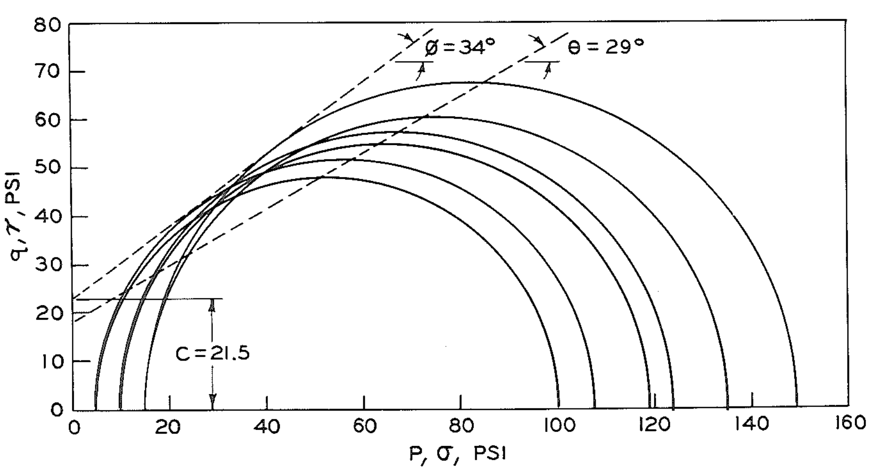
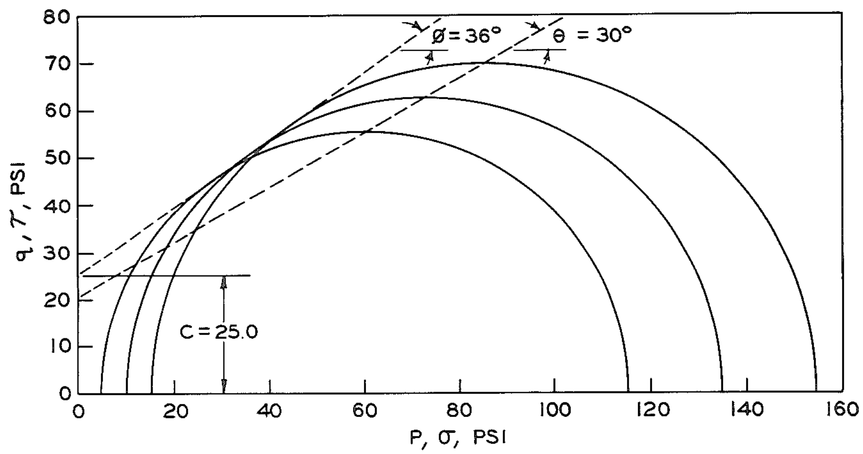


Figure 3. p-q diagram and Mohr-Coulomb envelope of triaxial tests conducted on bituminous base mixtures with no fines.

Figure 4. p-q diagram and Mohr-Coulomb envelope of triaxial tests conducted on bituminous base mixtures with 6 percent fines.



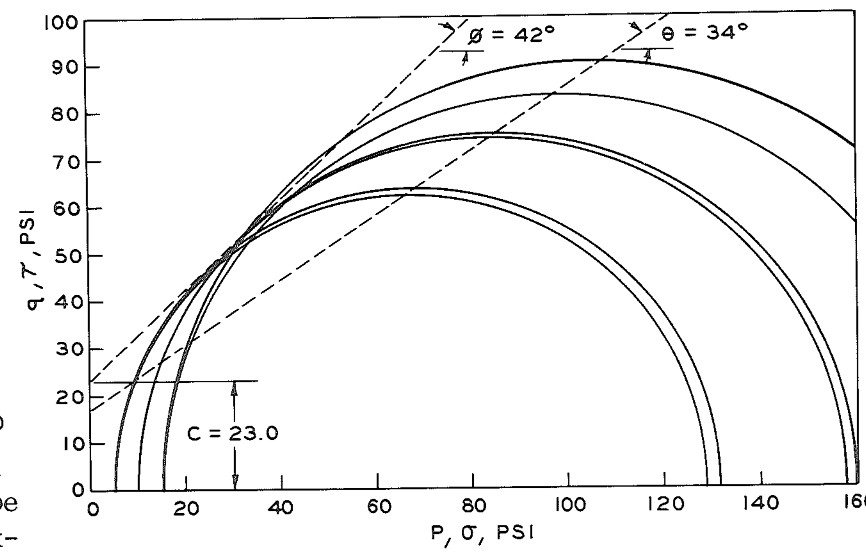


Figure 5. p-q diagram and Mohr-Coulomb envelope of triaxial tests conducted on bituminous base mixtures with 15 percent fines.

TABLE 4

STRENGTH PARAMETERS OF BITUMINOUS MIXTURES

P-200, percent	C, psi	ø, deg.
0	21.5	34
6	25.0	36
15	23.0	42

DISCUSSION

Considering the results (Table 1) of the Marshall tests conducted on samples containing the same type of aggregate mixed at the same asphalt content, but with different percentages of P-200 material, it is apparent that fines contribute considerably to the stability of the bituminous mixture. Specimens with no fines exhibited lowest Marshall stability values. The stability increased with the increase in fines up to a maximum value, then the stability decreased. In this series of testing, the optimum fines content was approximately 8 percent (Fig. 1). Another trend indicated by these test results is that plastic flow increases with increase in fines content (Fig. 1).

Triaxial test results support the preceeding observations. Specimens with no fines exhibited lowest values of strength parameters and failed at lower strain level, while specimens with 6 percent fines exhibited highest values of cohesion.

Test results on bituminous mixtures containing the same percentage of fines but different type of P-200 material showed a wide range of stabilities affirming the fact that stability of bituminous mixtures is dependent on the type of P-200 material contained in the aggregate. Specimens containing Ontonagon clay exhibited highest values of stability among the samples tested, followed by those containing portland cement. Samples with fly ash exhibited a stability value similar to those containing non-plastic fines, but the plastic flow for fly ash samples was the lowest for all samples tested. Plastic flow of the specimens with non-plastic fines, Ontonagon clay, portland cement, and limestone dust were approximately equal.

There was a difference between the Marshall stability of samples containing Ontonagon clay when immersed in a water bath and when heated in an oven. This difference is not necessarily due to the presence of water since all clay particles in the mix were coated with asphalt cement. A possible reason for this difference is that the temperature control in the oven is not precise, making it difficult to maintain a constant temperature of 140 F for two hours (ASTM D 1559-65). Specimens tested at temperatures lower than 140 F would be expected to exhibit a higher stability and lower plastic flow.

The compressive strength tests indicate that the bituminous mixtures with clay fines exhibit higher strength than bituminous mixtures with non-plastic fines, which confirms the results of the Marshall stability tests. The results of the compressive strength tests does not show any significant difference between the strength of submerged and air-cured samples for both mixtures with clay fines and mixtures with non-plastic fines. The results in Table 3 indicate the submerged specimens (with clay fines or non-plastic fines) exhibited a slightly higher strength than air-cured specimens. This insignificant difference could be caused by the lack of precise temperature control, since it is easier to maintain a uniform temperature in a water bath than in an air bath. The difference in temperature of all tested compressive strength samples did not exceed 2 F (within the requirement of ASTM D 1075-54). From the results of the Marshall stability tests and the compressive strength test, it could be concluded that the clay fines in the bituminous mixture do not seem to induce a harmful effect on the mixture, even in the presence of water.

The findings of this investigation are not conclusive since only a limited number of tests were conducted. Important facts which should not be overlooked are that only one type of aggregate was used and all test specimens were mixed at the same asphalt content (4 percent), while the percentages of fines were changed. Change in fines content also changes the grain size distribution of the aggregate and eventually the optimum asphalt content required for the mix. To determine the effect of fines on the stability of the mixture, the optimum asphalt content should be determined for the aggregate at different percentages of fines and the specimens prepared accordingly. This was not done due to the short time assigned for the study.

The trends observed in this study concerning the stability of bituminous mixtures containing modified 23A aggregate might not be the same for mixtures containing other types of aggregate, especially at different asphalt contents. Therefore, a great degree of caution should be exercised in any attempt to generalize the findings of this study when applied to other types of bituminous base mixtures. This preliminary study indicates that the stability of a bituminous base mixture is dependent on the type and content of fines in the aggregate. The findings definitely warrant further study before attempting any changes in the specification of bituminous mix aggregates.

CONCLUSIONS

1. The P-200 material contributes significantly to the stability of bituminous base mixtures and control of the quantity should not be deleted from the specifications.

2. The stability of the bituminous base mixture is dependent on both the amount and type of fines present in the aggregate.

3. This study indicates that clay fines have no harmful effect on strength of bituminous mixtures.

4. It is feasible to establish an optimum fines content for bituminous mixtures.

5. A comprehensive study of both type and quantity of filler materials is required prior to any changes in bituminous base mixture specifications.