Louisiana Highway Research

COMPACTION HAMMER CORRELATION

Louisiana Department of Highways - Research Unit

SYNOPSIS

The Mechanical Marshall Hammer Correlation Study is an attempt to correlate a new, more easily operated, mechanical hammer with the standard manual hammer presently in use. The new device is designated as hammer No. 2 and the older, hammer No. 1.

Briquettes molded of pugmill mixes on three separate projects located in different areas of the State showed that when varying the number of blows with hammer No. 2 from 75 to 105 on Projects II and III the density and Marshall stability did not reach the values obtained using 75 blows of the manual hammer.

Bituminous mixtures were also molded in the laboratory using aggregates from six different sources. Five of these were gravel mixes and the other expanded clay aggregate. In addition to hammers 1 and 2, another mechanical hammer (No. 3) was introduced into the study. The only noticeable difference between the design of hammers No. 2 and 3 was that hammer No. 3 had an improved lift mechanism.

In attempting to correlate these three hammers, results indicated that the manual hammer gave the highest density and Marshall stability. Between the two mechanical hammers, No. 3 was far superior to No. 2. It operated more efficiently and trouble - free and the results showed a closer correlation to those obtained using the manual hammer.

CORRELATION OF THE MANUAL COMPACTION HAMMER WITH MECHANICAL HAMMERS FOR THE MARSHALL METHOD OF DESIGN FOR ASPHALTIC CONCRETE

During the past several years, Louisiana Department of Highways and many other agencies have increased their compactive effort for Bituminous Concrete Pavements by incorporating high intensity pneumatic rollers in hot mix construction. This increase in compactive effort not only aids in obtaining higher roadway density and stability but also minimizes rutting caused by in service densification due to traffic. Along with this increase of compactive effort in the field, it is necessary to increase the design compactive effort. This was accomplished in Louisiana by increasing the number of blows of the Marshall hammer from 50 to 75 for each face of the briquettes. Due to the additional effort needed it was necessary to use a mechanical hammer to minimize injuries and excessive employee fatigue. For this reason a study was undertaken by the Louisiana Department of Highways in cooperation with the Bureau of Public Roads to attempt to correlate the mechanical and the manual hammers. The hammers consisted of two mechanical hammers and one manual hammer.

To avoid confusion during this study, the hammers were numbered as follows: manual hammer - No. 1, mechanical hammer - No. 2, and mechanical hammer - No. 3. Mechanical hammer No. 3 was the newest type hammer purchased from Marshall Consulting and Testing Laboratories, and the only difference between the two was the lift mechanism.

Although both mechanical hammers weighed 10 lbs. and each had an 18 inch drop, it was observed during preliminary testing that hammer No. 3 gave higher densities and stabilities on laboratory made briquettes. The reason for this difference in test results is undetermined, but it should be mentioned that the lift mechanism on hammer No. 2 has been troublesome at times during this study. However, other than frequent breakdown of the lift mechanism hammer No. 2 operated properly. All three hammers are illustrated in Figures 1 through 3.

CORRELATION OF THE MANUAL COMPACTION HAMMER WITH MECHANICAL HAMMERS FOR THE MARSHALL METHOD OF DESIGN FOR ASPHALTIC CONCRETE

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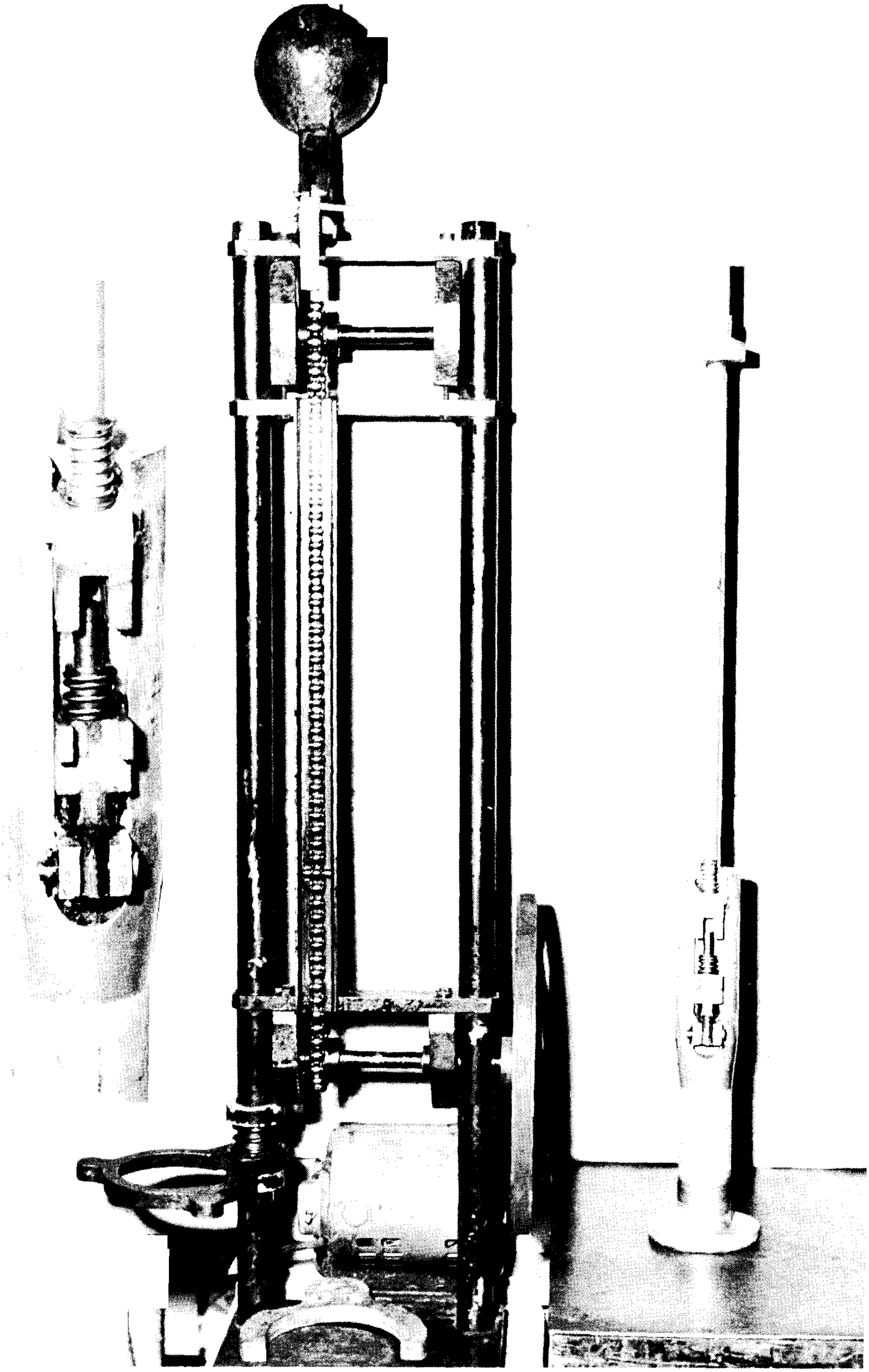

Figure 2 - Mechanical Hammer, With Insert of Old Lift Mechanism, Hammer No. 2.

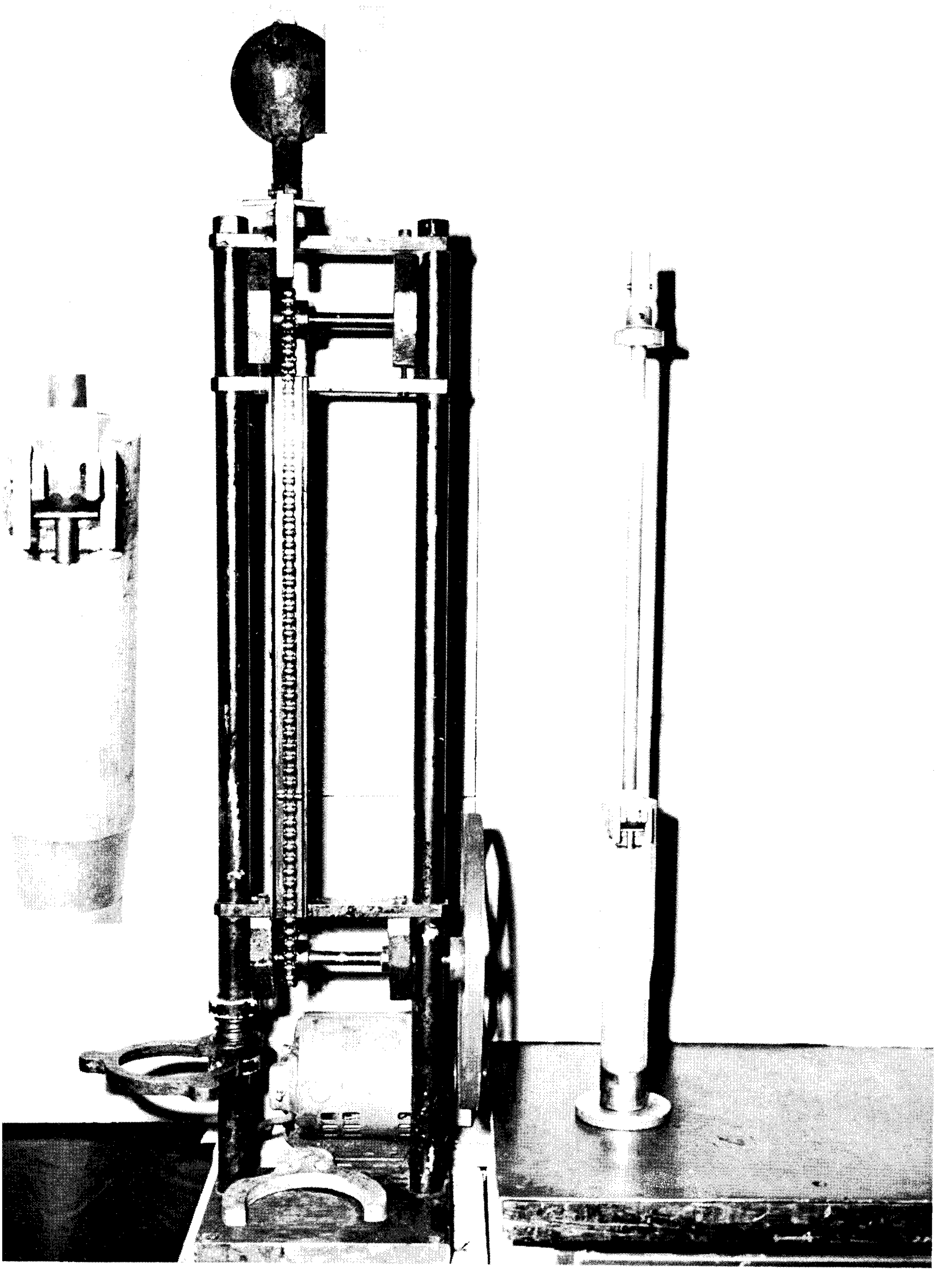

Figure 3 - Mechanical Hammer With Insert of Improved Lift Mechanism, Hammer No. 3.

Purpose of Study

The purpose of this investigation was to establish, through a series of correlations, the compactive effort (number of blows) needed using the mechanical hammers to yield similar physical properties obtained with 75 blows of the manual hammer.

Scope of the Study

This study was initiated in March 1963, as a research project and consisted of two phases:

1. Correlation of manual hammer No. 1 and mechanical hammer No. 2 on briquettes made from wearing course material taken out of the pugmill.

2. Correlation of manual hammer No. 1 and mechanical hammers No. 2 and 3 on laboratory made briquettes using a wearing course mix.

Phase one consisted of three construction projects in which briquettes were molded varying the compactive effort using mechanical hammer No. 2 and keeping a constant compactive effort of 75 blows using the manual hammer.

Phase two consisted of six mixes from different sources; where five of these were gravel mixes and the other expanded clay aggregate. Laboratory briquettes were molded with each mix using hammers 1, 2, and 3 and the compactive effort was varied to cover the needed range for a satisfactory correlation.

PROCEDURE

Field Investigation

Field results consisted of making briquettes at three hot mix plants during construction, using pugmill mixed material. These three projects were located in different areas of the State. The sequence of operation was as follows:

> Briquettes were molded in sets of two at each compactive effort using material discharged directly from the pugmill into the truck. The purpose of molding in sets of two rather than all from the same truck load of material was to eliminate the possibility of compacting a mix which was below the optimum temperature and to keep the molding temperature as constant as possible. Five briquettes were molded

at a compactive effort of 75 blows using the manual hammer. These results were used as the control. This was followed by varying the compactive effort in increments of 10 from 65 to 105 blows for the top and bottom of each briquette, with the use of mechanical hammer No. 2. The objective of this operation was to establish the compactive effort needed using mechanical hammer No. 2 to equal the results obtained with the 75 blows of the manual hammer. Eight briquettes were molded in sets of two for each compactive effort using this hammer.

In order to investigate the possibility of a variation in material from beginning to end of this operation, five additional briquettes were molded at a compactive effort of 75 blows using the manual hammer.

Laboratory Investigation

Bin samples were obtained from six different plants located in various parts of the State. These samples were then separated into individual sizes and recombined with the exception of the fine bin samples.

For each source, three briquettes were molded varying the compactive effort in increments of 5 blows using hammers 1, 2, and 3. The asphalt content was kept at optimum for each respective mix. Unlike the field investigation, the same procedure was repeated for the manual hammer.

All briquettes for both field and laboratory investigations were tested for the following properties using the methods indicated:

Specific Gravity	LDH Designation TR 304-62
Marshall Stability and Flow	LDH Designation TR 305-62

These test procedures are shown in Appendix D.

DISCUSSION OF TEST RESULTS

Field Results

The bituminous mixtures for each of the three projects consisted of a combination of gravel, sand and mineral filler. All field results are given in Appendix A.

Project I, located in the north central part of the State, is represented by Figures 4 and 5 for Marshall stability and density. Points number 1 and 1A

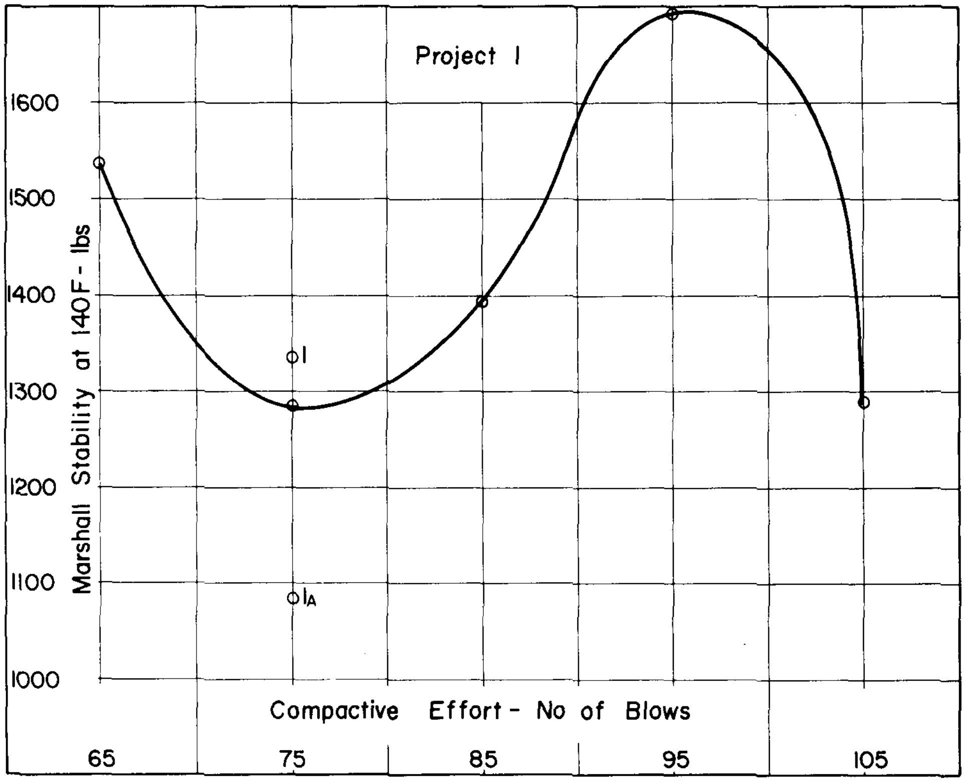

Figure 4 - Marshall Stability - Compactive Effort Relationship Comparing Manual Hammer 1 and Mechanical Hammer 2 on Pugmill Mixed Material.

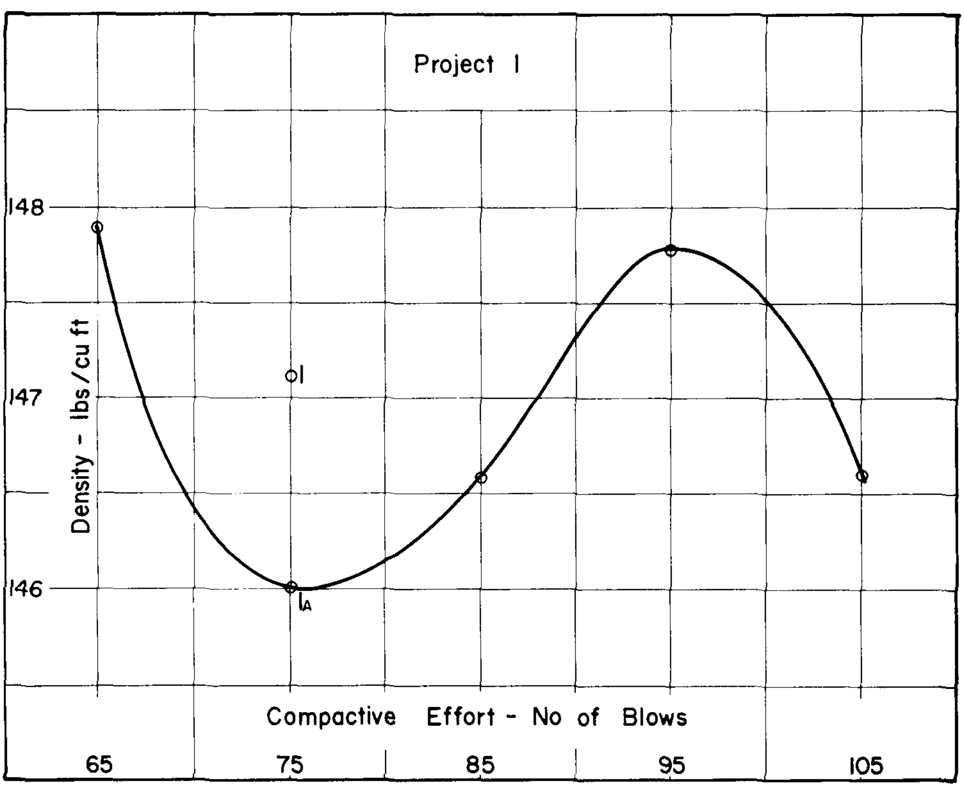

Figure 5 - Density - Compactive Effort Relationship Comparing Manual Hammer 1 and Mechanical Hammer 2 on Pugmill Mixed Material.

represent the Marshall stability and density using manual hammer No. 1 at the beginning and end of each field operation respectively. Similar points will be seen in each of the curves for Projects I, II, and III.

Figure 4 shows that Point 1, representing the manual hammer, correlates fairly well with hammer No. 2 at 75 blows, but Point 1A shows a drop of 200 lbs. in stability from hammer No. 2.

Figure 5 shows the same trend for density as in Figure 4 for stability. However, Point 1 shows a one pound difference in density and Point 1A correlates with hammer No. 2.

It should again be mentioned that these briquettes were molded in sets of two and there was some variation between sets which was probably due to changes in the mix or temperature during the operation.

Project II, located in the southeast part of the State and represented by Figures 6 and 7, indicates that both Marshall stability and density results for hammer No. 1 were excessively higher than the results obtained using hammer No. 2, even when the compactive effort was varied from 75 to 105 blows.

Project III, which is also located in the southern part of the State is represented by Figures 8 and 9. The results are similar to those shown for Project II.

The inconsistency of the results obtained on these three projects necessitated a closer control of the variables involved. Therefore, the field work was discontinued.

Laboratory Results

These results were obtained on briquettes mixed and molded in the laboratory. There were six aggregates involved, each of which was obtained from a different source. For convenience, the aggregates were identified "A" through "E" for gravel, sand and filler mixes and "F" for the expanded clay, coarse sand, fine sand, and mineral filler. All proportions and gradations for each individual aggregate along with the average test results for each aggregate are given in Appendix B.

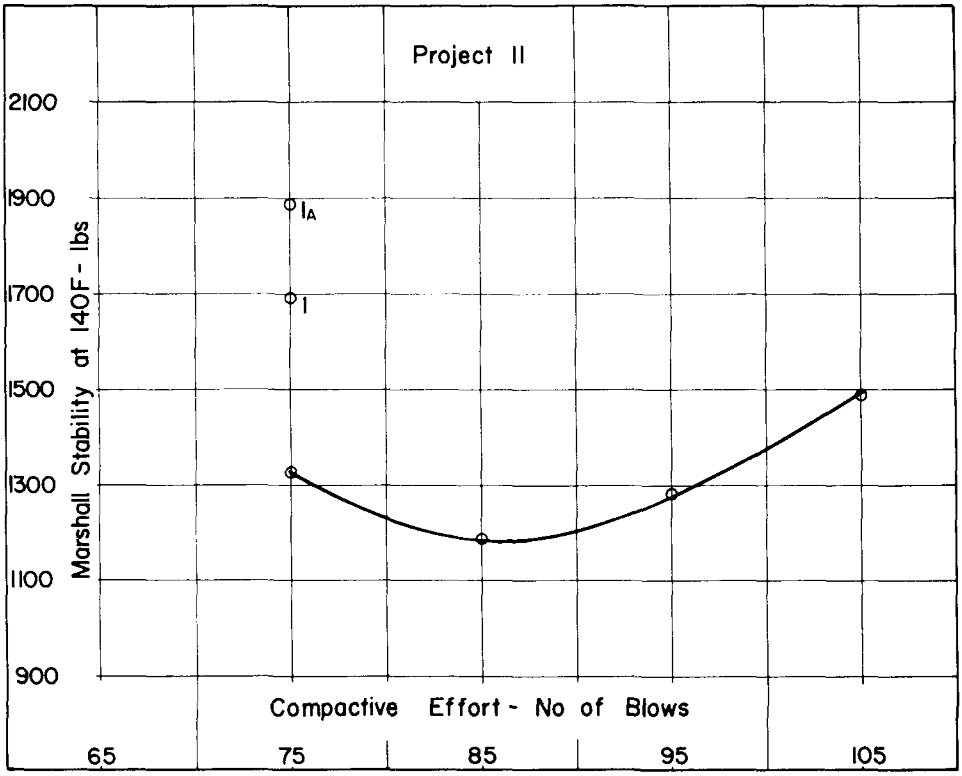

Figure 6 - Marshall Stability - Compactive Effort Relationship Comparing Manual Hammer 1 and Mechanical Hammer 2 on Pugmill Mixed Material.

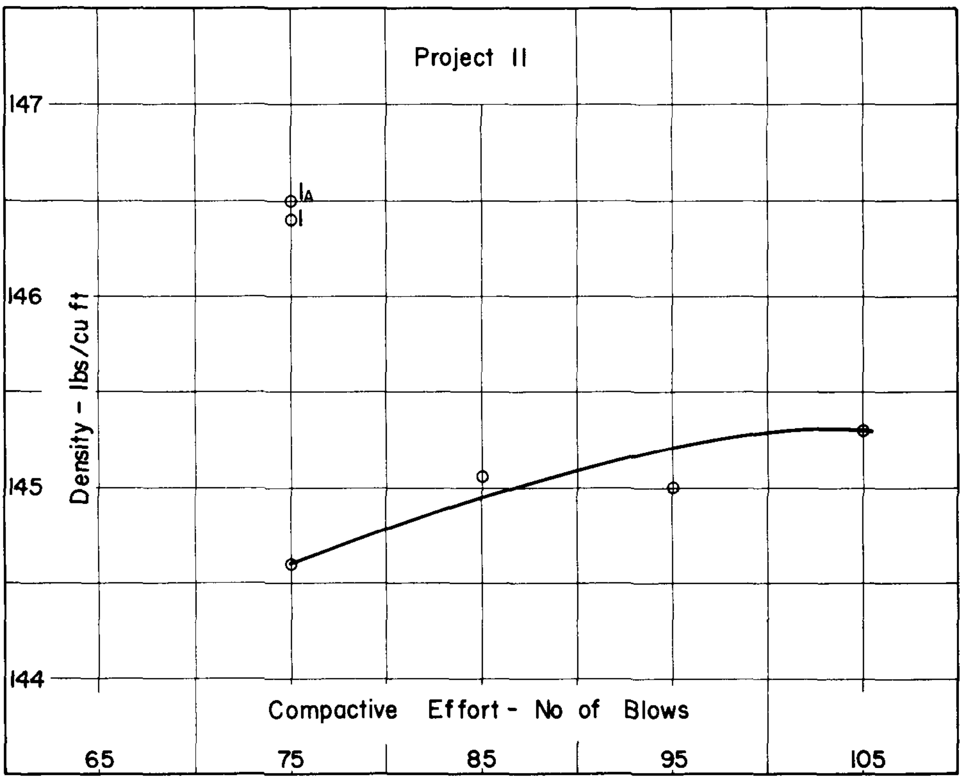

Figure 7 - Density - Compactive Effort Relationship Comparing Manual Hammer 1 and Mechanical Hammer 2 on Pugmill Mixed Material.

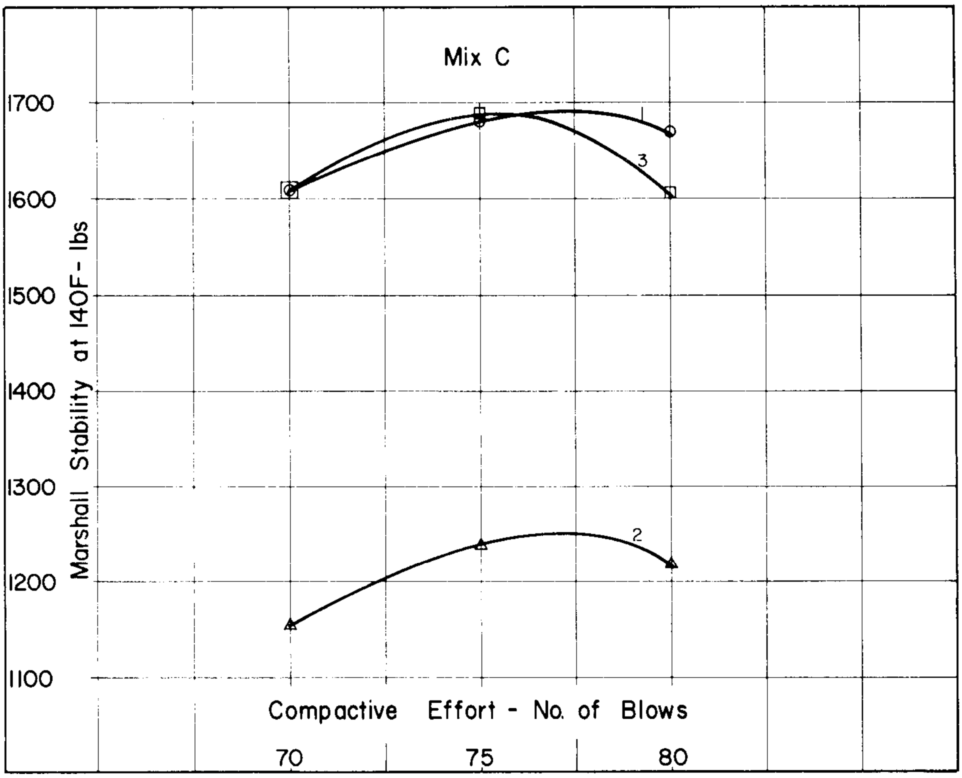

Figure 14 - Marshall Stability - Compactive Effort Relationship Comparing Manual Hammer 1 and Mechanical Hammers 2 and 3 on Laboratory Mixed Material.

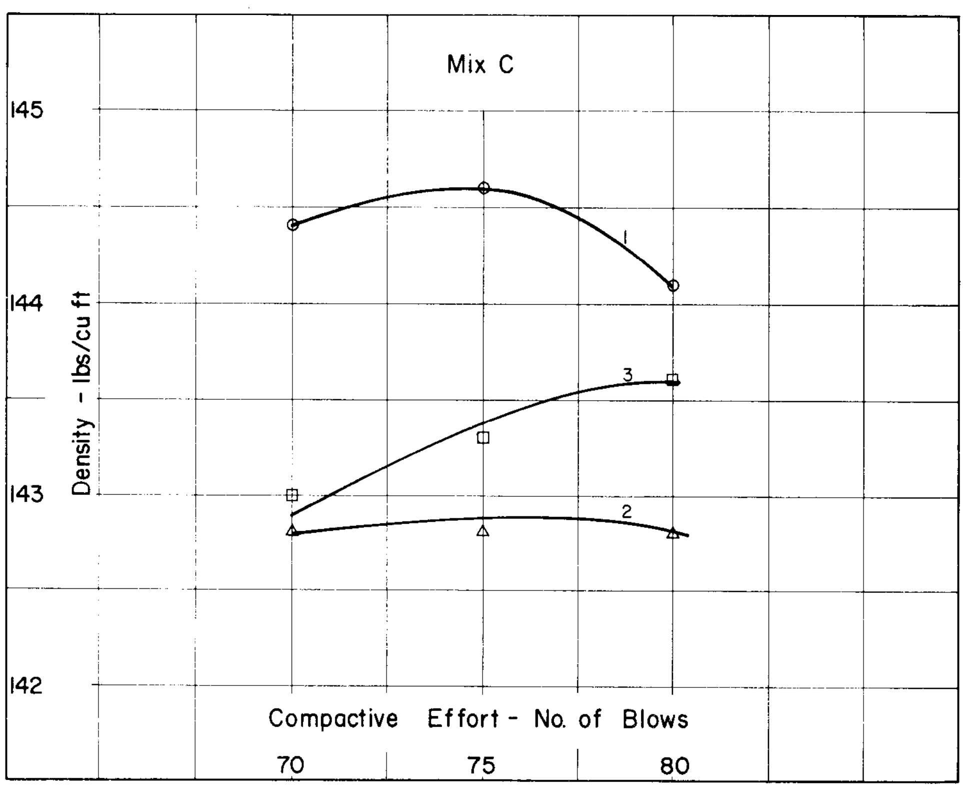

Figure 15 - Density - Compactive Effort Relationship Comparing Manual Hammer 1 and Mechanical Hammers 2 and 3 on Laboratory Mixed Material.

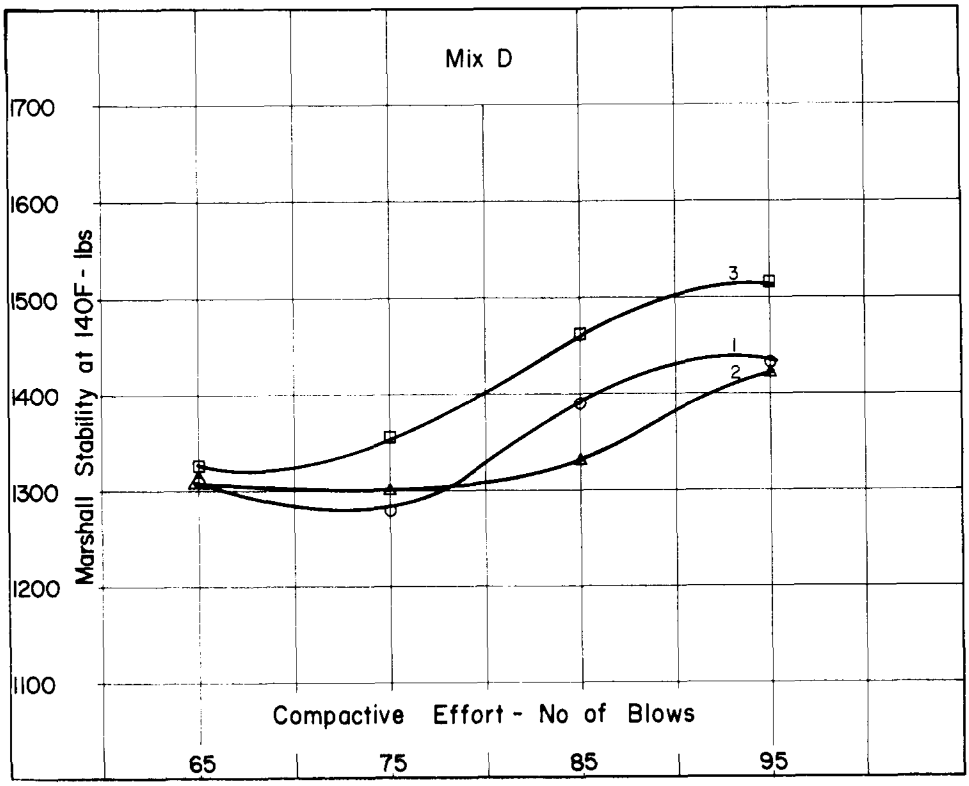

Figure 16 - Marshall Stability - Compactive Effort Relationship Comparing Manual Hammer 1 and Mechanical Hammers 2 and 3 on Laboratory Mixed Material.

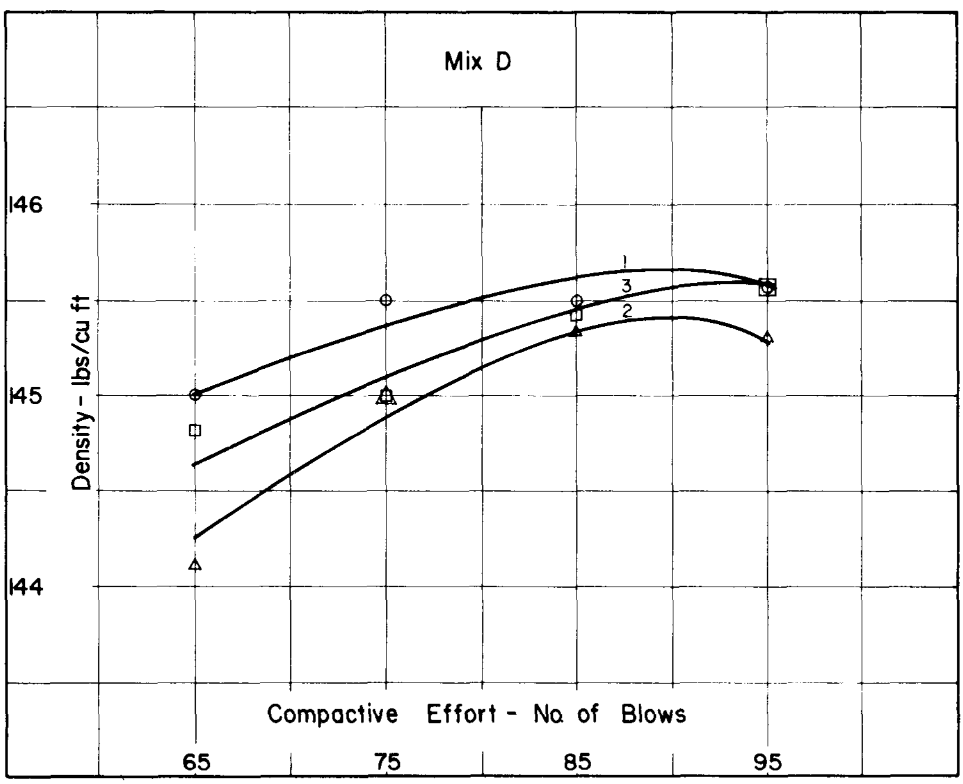

Figure 17 - Density - Compactive Effort Relationship Comparing Manual Hammer 1 and Mechanical Hammers 2 and 3 on Laboratory Mixed Material.

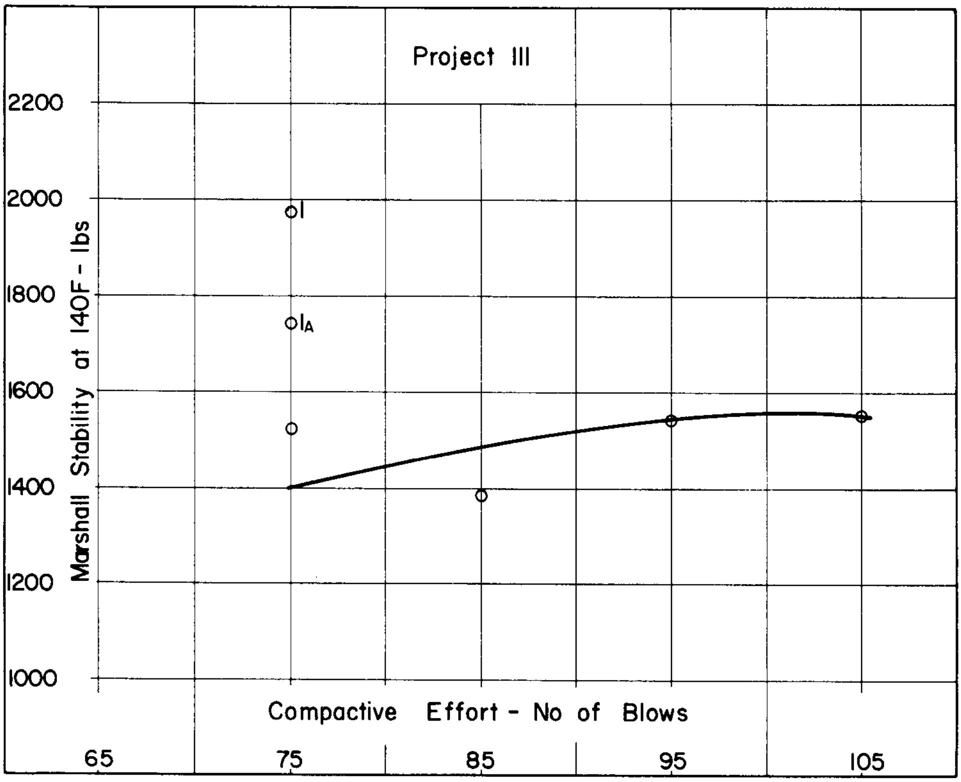

Figure 8 - Marshall Stability - Compactive Effort Relationship Comparing Manual Hammer 1 and Mechanical Hammer 2 on Pugmill Mixed Material.

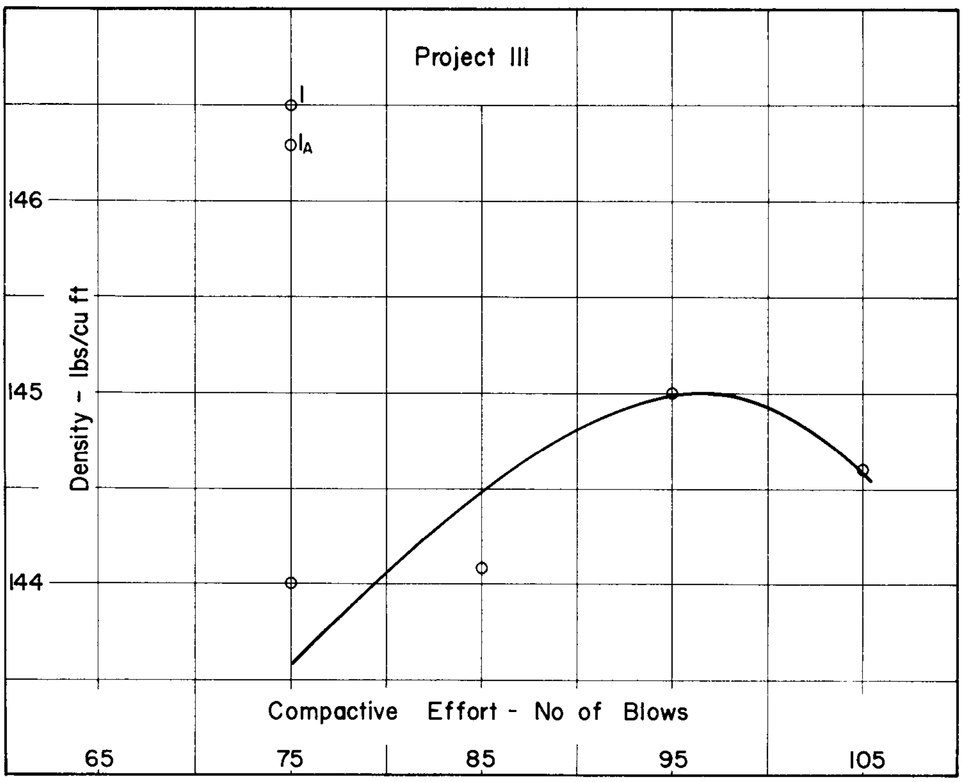

Figure 9 - Density - Compactive Effort Relationship Comparing Manual Hammer 1 and Mechanical Hammer 2 on Pugmill Mixed Material.

Mix A is represented by Figures 10 and 11 for Marshall stability and density. Figure 10 shows a very close correlation in stability between hammers No. 1 and 3. Hammer No. 2 shows a lower stability at each compactive effort. Figure 11 also indicates a very good correlation between hammers No. 1 and 3 with lower density results for hammer No. 2. As mentioned previously, the only design difference between mechanical hammers No 2 and 3 is the lift mechanism. The low results encountered with hammer No. 2 could have possibly been due to a binding or dragging of the lift mechanism during the process of compaction.

Mix B, which is represented by Figures 12 and 13, shows poorer correlation, between hammers, than Mix A. Figure 12 shows that at 65 and 75 blow compactive efforts, hammers No. 2 and 3 correlate very closely although both are lower than the manual hammer results. However, at 85 blows, hammer No. 3 gives a stability of nearly 200 lbs. higher than hammers No. 1 and 2. This variation in stability is probably due to the difference in the orientation of coarse aggregate within the briquettes. This problem will, however, have less effect on density as indicated by Figure 13.

Figures 14 and 15 represent Mix C. These show a very good correlation for stability between hammers No. 1 and 3. These curves were very similar to those given in Figure 10 for Mix A, which also indicated a very close correlation between hammers No. 1 and 3. The extremely low results for hammer No. 2 were not explained. Figure 15 shows that the density results are the highest for hammer No. 1, next is No. 3 and the lowest is hammer No. 2.

Mix D represented by Figures 16 and 17 shows a fairly close correlation in stability and density between hammers No. 1 and 3. Again hammer No. 2 produced the lowest results and hammer No. 1 the highest.

Mix E, represented by Figures 18 and 19, shows approximately the same trend as some of the other mixes with a little more variation between hammers.

The results of Mix F, expanded clay aggregate mix, is illustrated by Figures 20 and 21. They indicate that the highest density and stability results were obtained with hammer No. 1 followed by hammers No. 3 and 2.

Deviations in Stability and Density

In order to illustrate more clearly the deviation of results between mechanical hammers No. 2 and 3 and the manual hammer No. 1, per cent deviations of

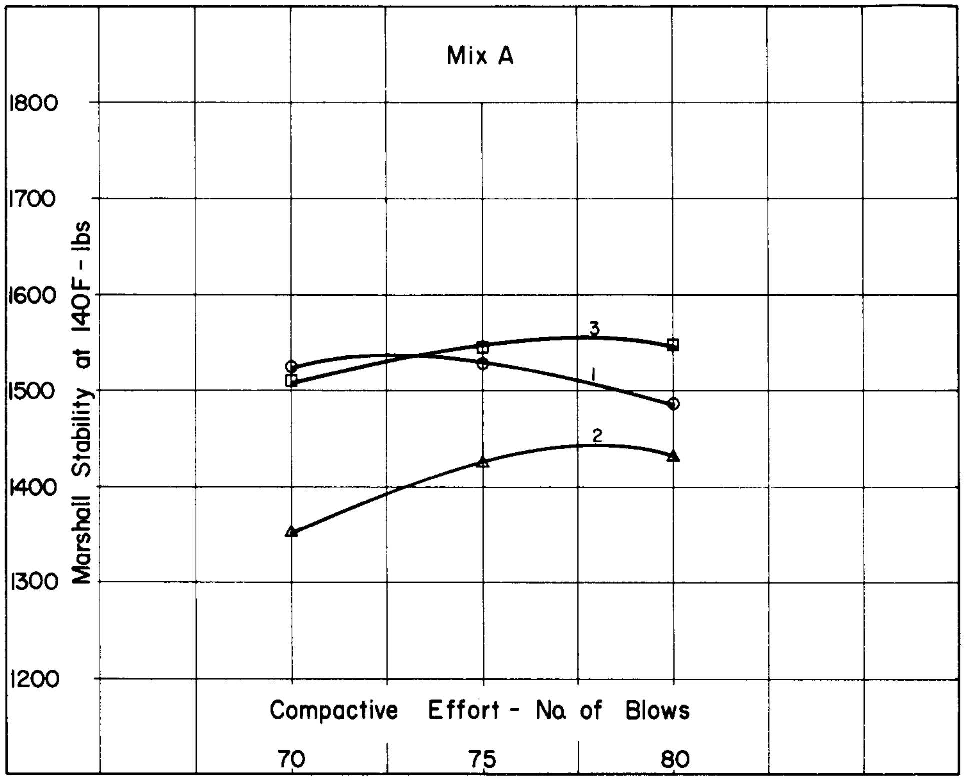

Figure 10 - Marshall Stability - Compactive Effort Relationship Comparing Manual Hammer 1 and Mechanical Hammers 2 and 3 on Laboratory Mixed Material.

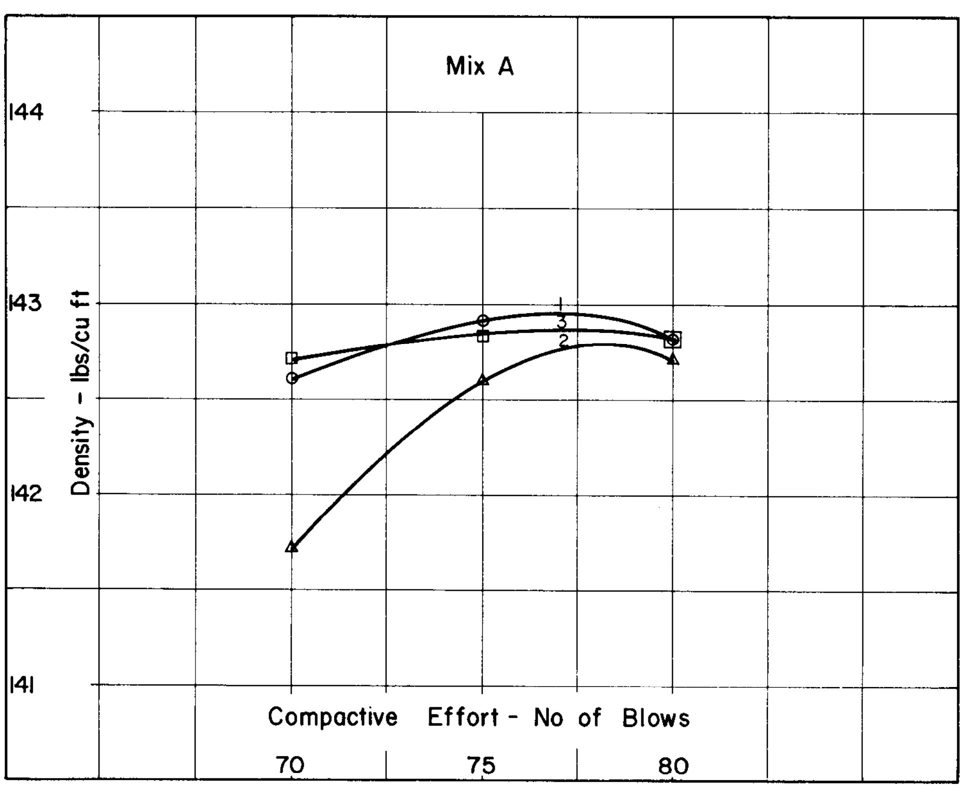

Figure 11 - Density - Compactive Effort Relationship Comparing Manual Hammer 1 and Mechanical Hammers 2 and 3 on Laboratory Mixed Material.

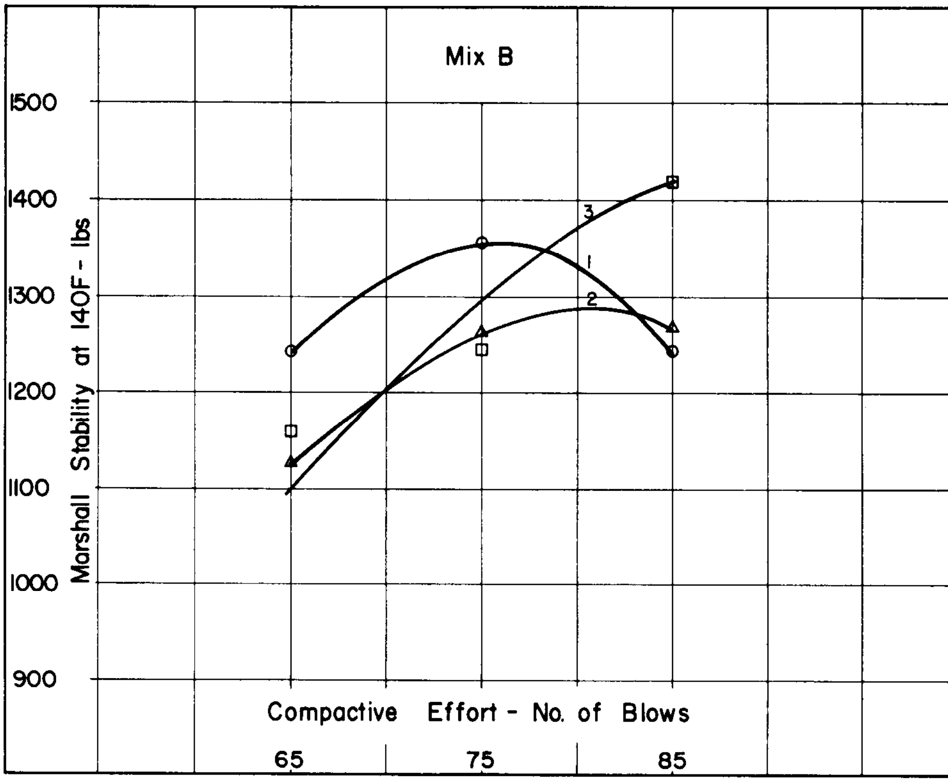

Figure 12 - Marshall Stability - Compactive Effort Relationship Comparing Manual Hammer 1 and Mechanical Hammers 2 and 3 on Laboratory Mixed Material.

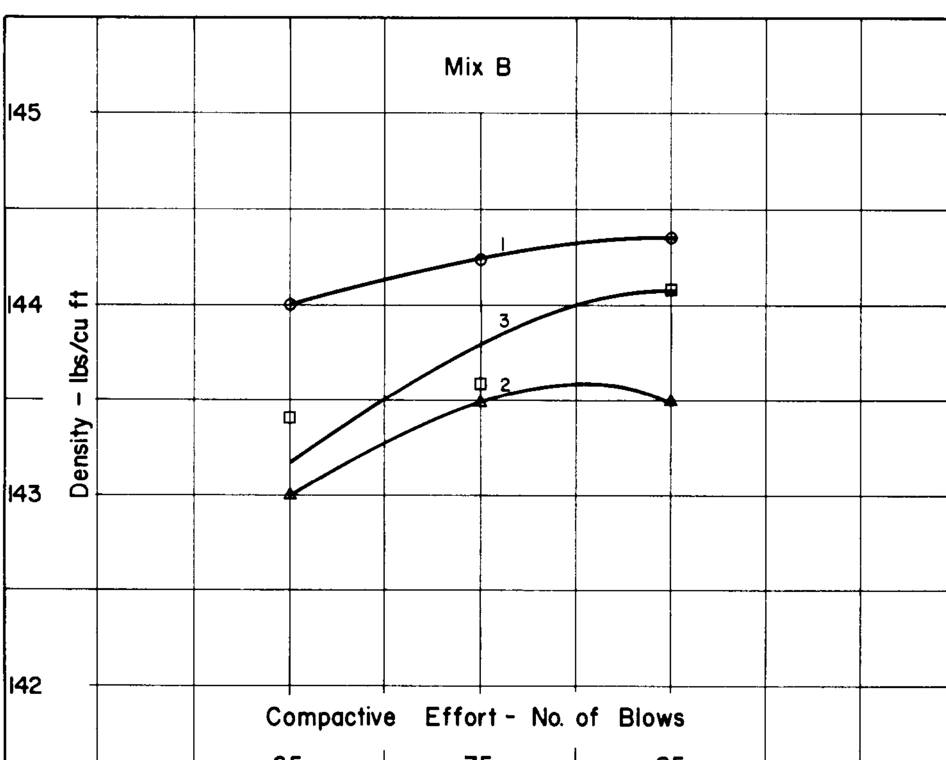

Figure 13 - Density - Compactive Effort Relationship Comparing Manual Hammer 1 and Mechanical Hammers 2 and 3 on Laboratory Mixed Material.

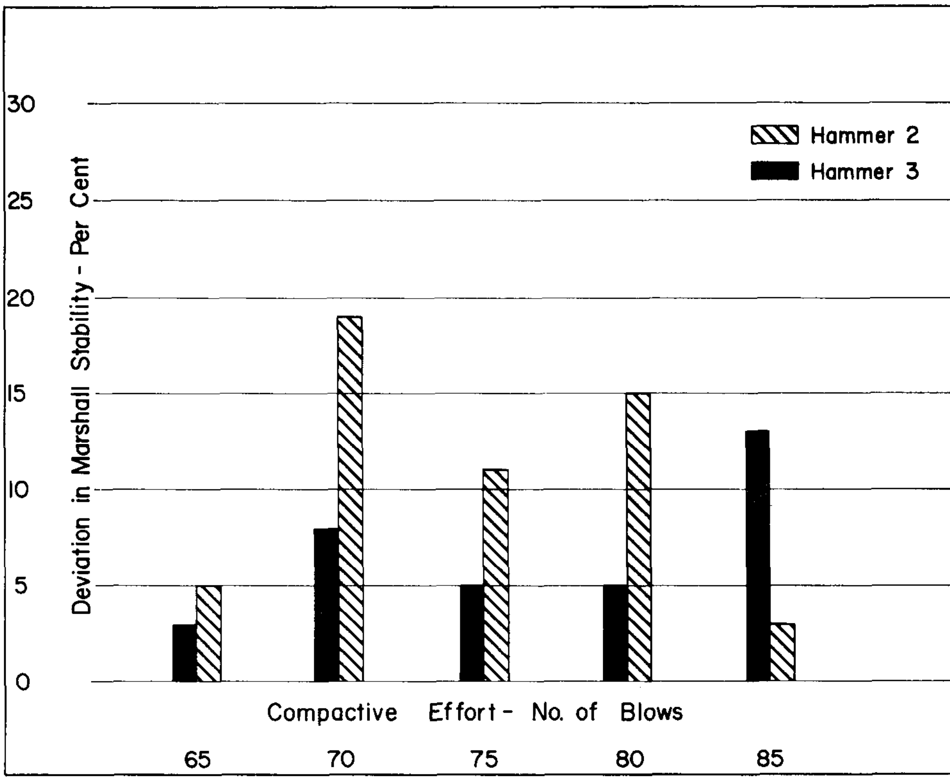

Figure 24 - Comparison of Deviation in Marshall Stability for Various Compactive Efforts With Hammers 2 and 3.

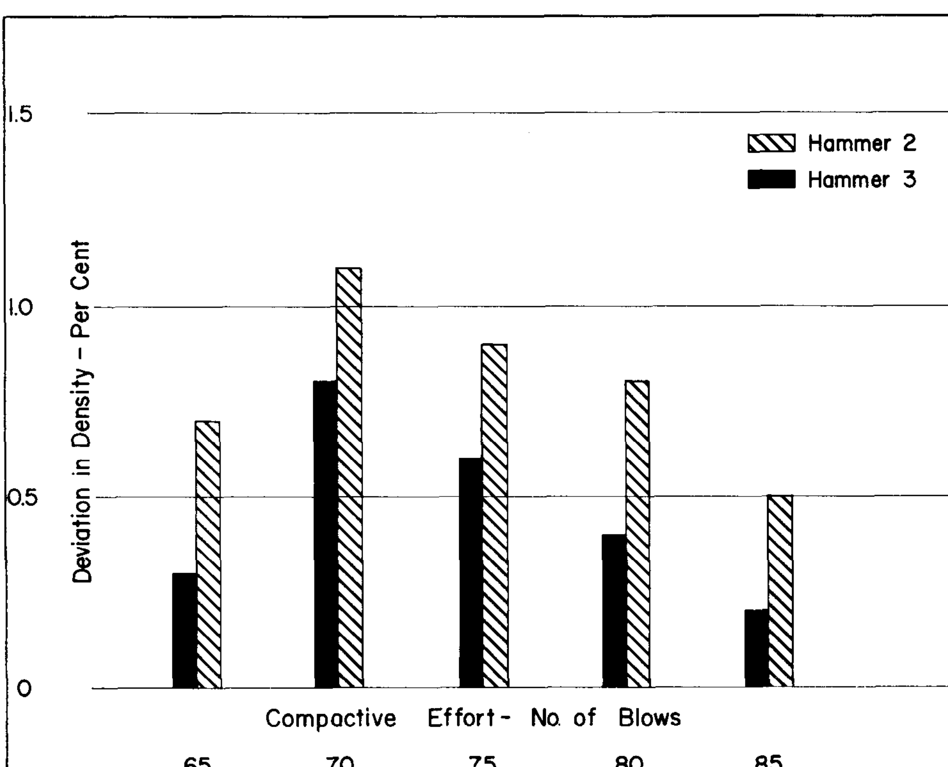

Figure 25 - Comparison of Deviation in Density for Various Compactive Efforts With Hammers 2 and 3.

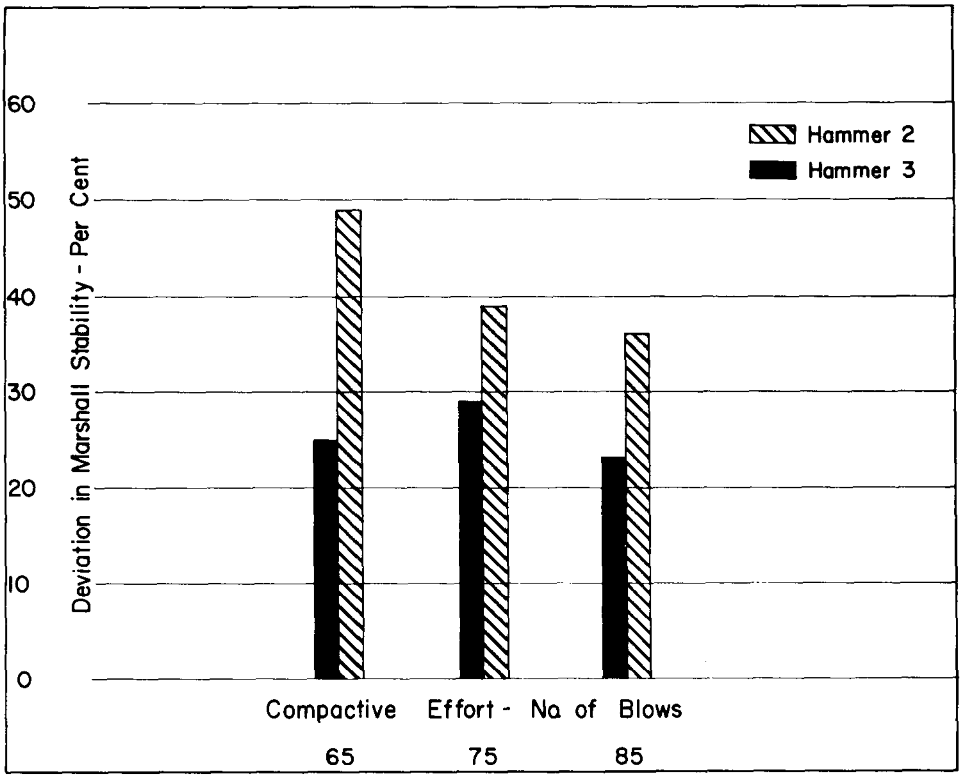

Figure 26 - Comparison of Deviation in Marshall Stability for Various Compactive Efforts With Hammers 2 and 3 on Expanded Clay Aggregate Mix.

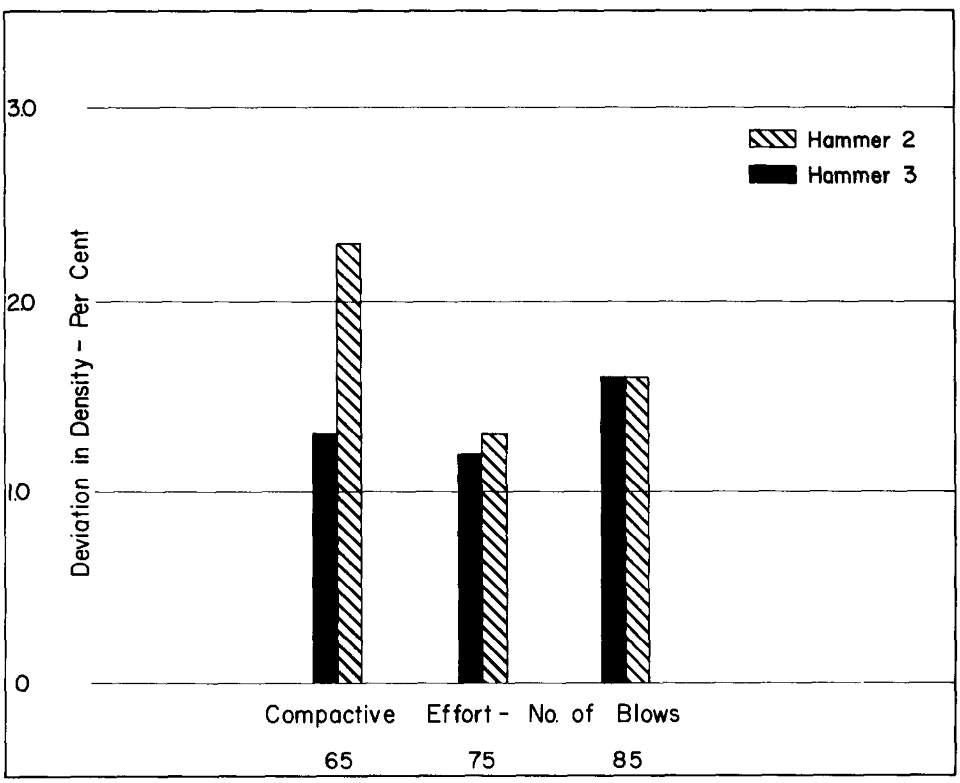

Figure 27 - Comparison of Deviation in Density for Various Compactive Efforts With Hammers 2 and 3 on Expanded Clay Aggregate Mix.

the mean values were calculated for stability and density for hammers 2 and 3 as based on the mean values of the manual hammer. These average deviation percentages were computed without regard to algebraic sign and are shown in Appendix C

Figure 22 illustrates the per cent deviation of Marshall stability for each mix with the exception of Mix F which is expanded clay aggregate and is shown separately. All deviations are based on the manual hammer results being used as the zero line or the base line for illustrating the percentage of deviation. Figure 22 indicates that Mix C gives the highest per cent deviation in stability of all the mixes used. Hammer No. 3 shows closer correlation to the manual hammer than does hammer No. 2. Figure 23, which illustrates the per cent deviation in density for each mix clearly indicates that hammer No. 3 gives a closer correlation with the manual hammer than hammer No. 2. This is also evident in Figures 24 and 25, which illustrates per cent deviation in stability and density respectively, versus compactive effort (No. of blows). Figure 24, for hammer No. 3, shows that the maximum per cent deviation in stability is approximately 12 per cent at 85 blows and only 5 per cent at 75 blows. These variations, as mentioned previously, can be expected and are not considered to be excessive. Figure 25 shows that the maximum per cent deviation in density for hammer No. 3 is 0.8 per cent and the maximum deviation for hammer No. 2 is 1.1 per cent.

Peak results for hammers 2 and 3 show the same trend, but again hammer No. 3 indicates a closer correlation to the manual hammer than hammer No. 2.

Figures 26 and 27 illustrate per cent deviations of stability and density for Mix F which consists of expanded clay aggregate, sand and mineral filler. As can be seen hammer No. 3 shows a closer correlation to the manual hammer than hammer No. 2.

However, it is also evident that the per cent deviations for stability and density are somewhat higher for expanded clay mix than for gravel mix. This is probably due to the breaking up of the expanded clay aggregate under the hammer, which would cause greater deviations in results.

CONCLUSION

As based on the results of this study the following conclusions are warranted:

1. Hammer No. 3 showed a closer correlation to hammer No. 1 and, therefore, it is recommended that 75 blows with hammer No. 3 be used in lieu of hammer No. 1.

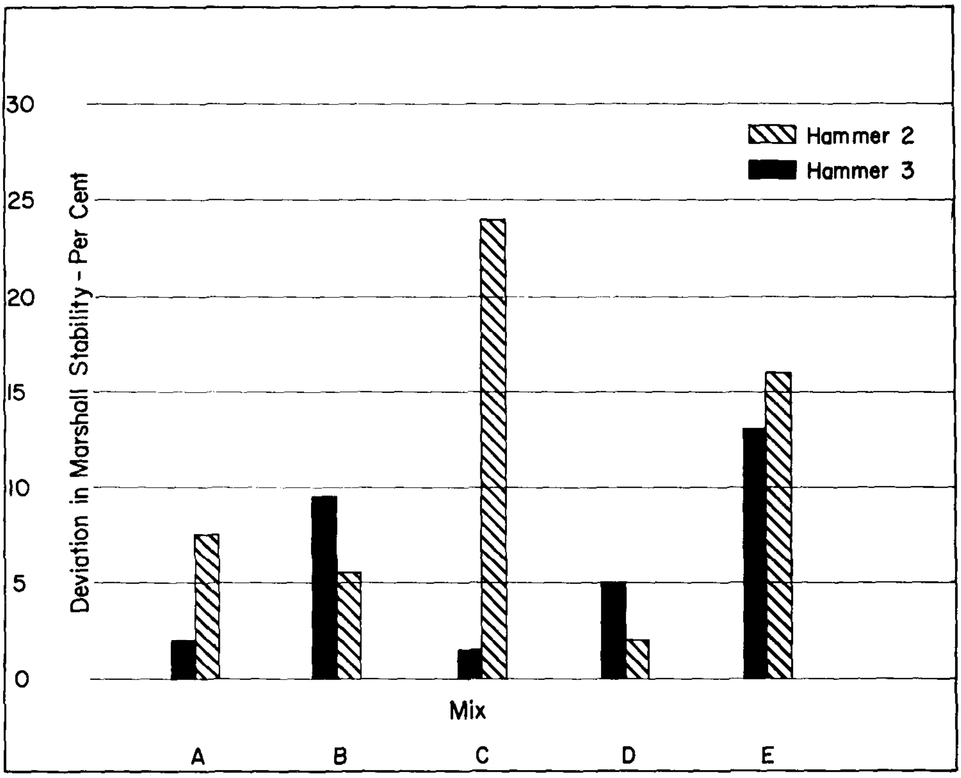

Figure 22 - Comparison of Deviation in Marshall Stability for Various Mixes With Hammers 2 and 3

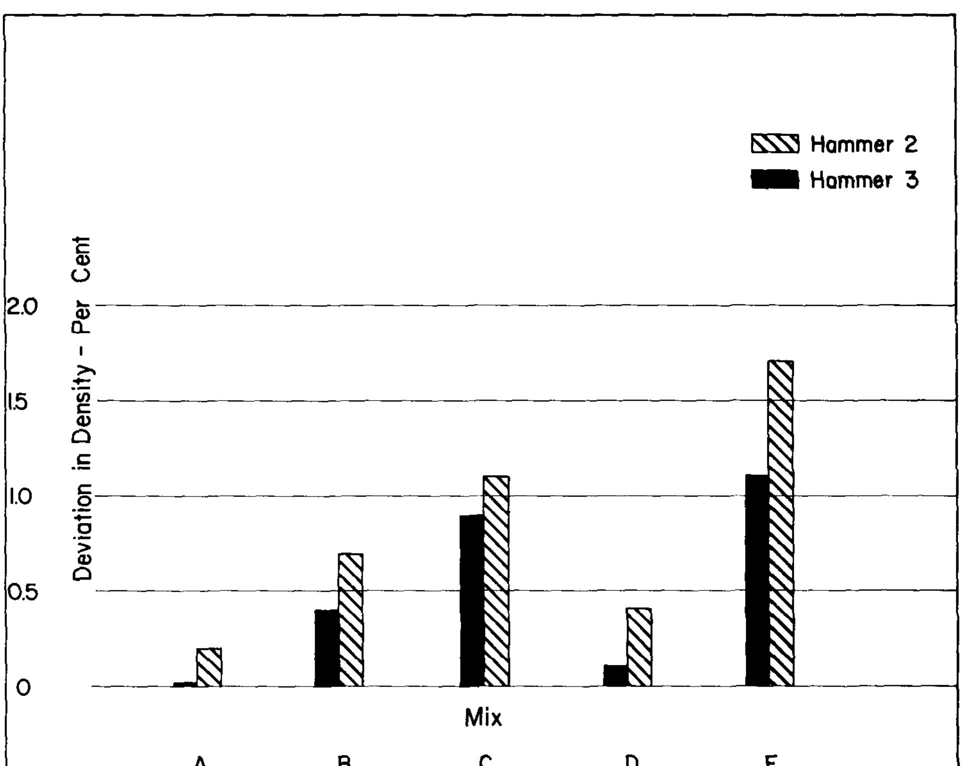

Figure 23 - Comparison of Diviation in Density for Various Mixes with Hammers 2 and 3.

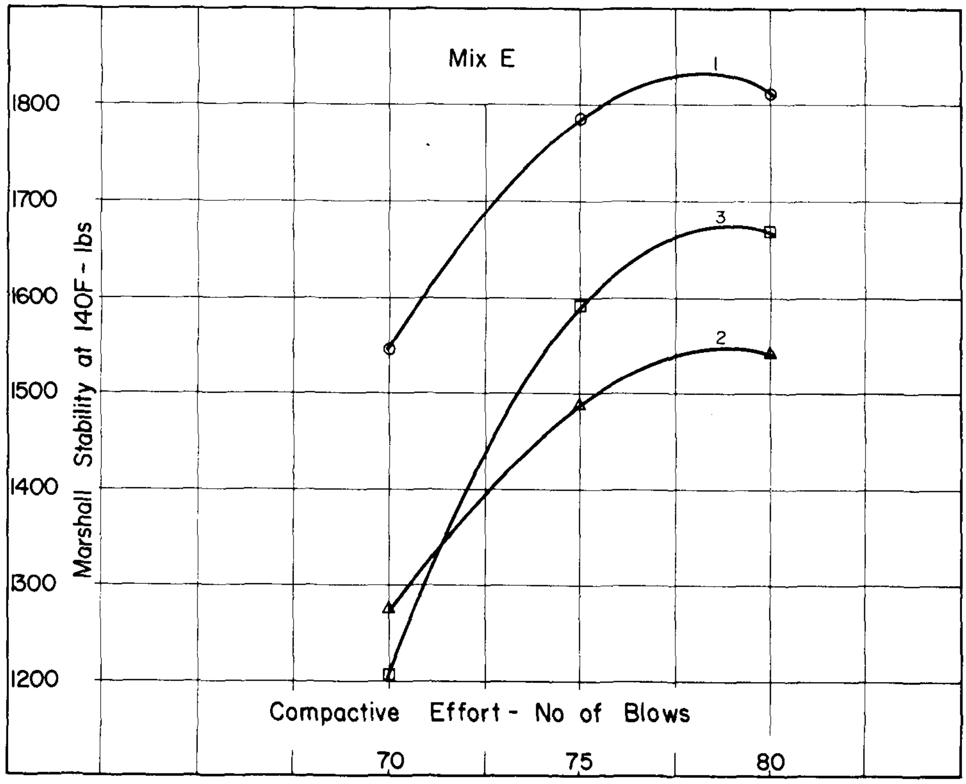

Figure 18 - Marshall Stability - Compactive Effort Relationship Comparing Manual Hammer 1 and Mechanical Hammers 2 and 3 on Laboratory Mixed Material.

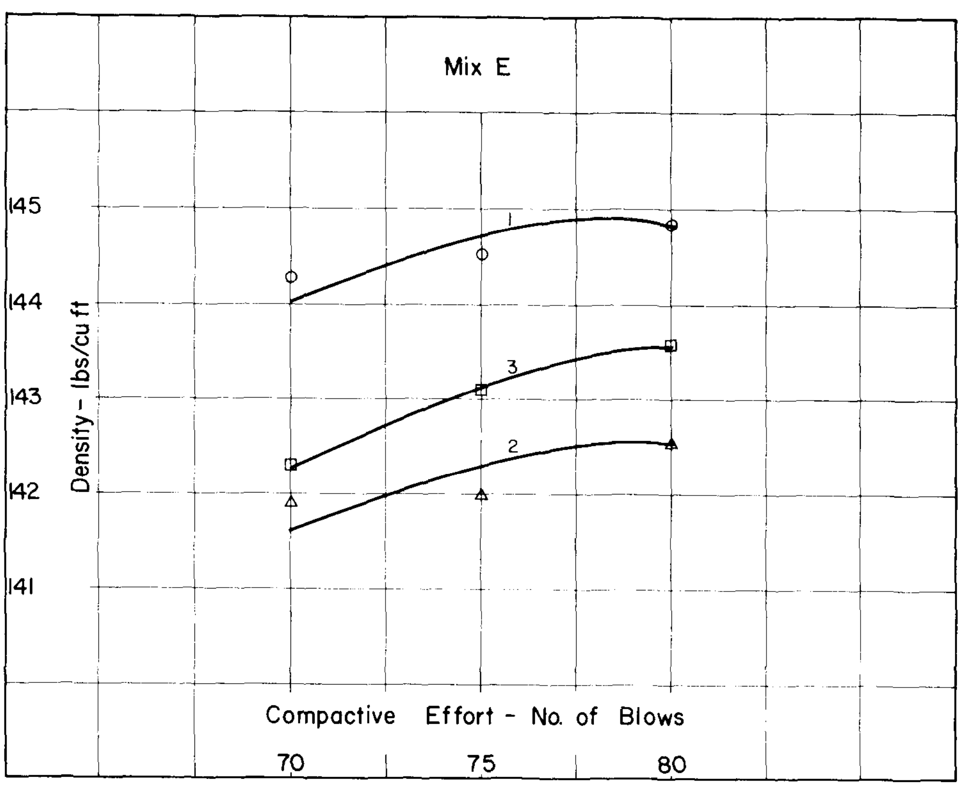

Figure 19 - Density - Compactive Effort Relationship Comparing Manual Hammer 1 and Mechanical Hammers 2 and 3 on Laboratory Mixed Material.

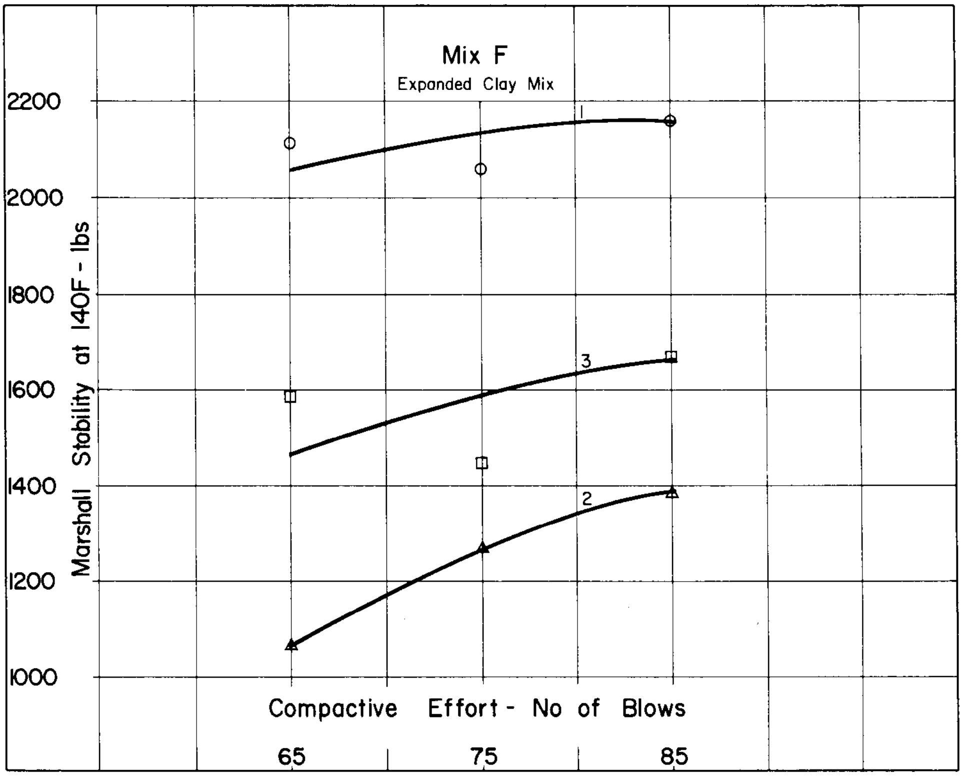

Figure 20 - Marshall Stability - Compactive Effort Relationship Comparing Manual Hammer 1 and Mechanical Hammers 2 and 3 on Laboratory Mixed Material.

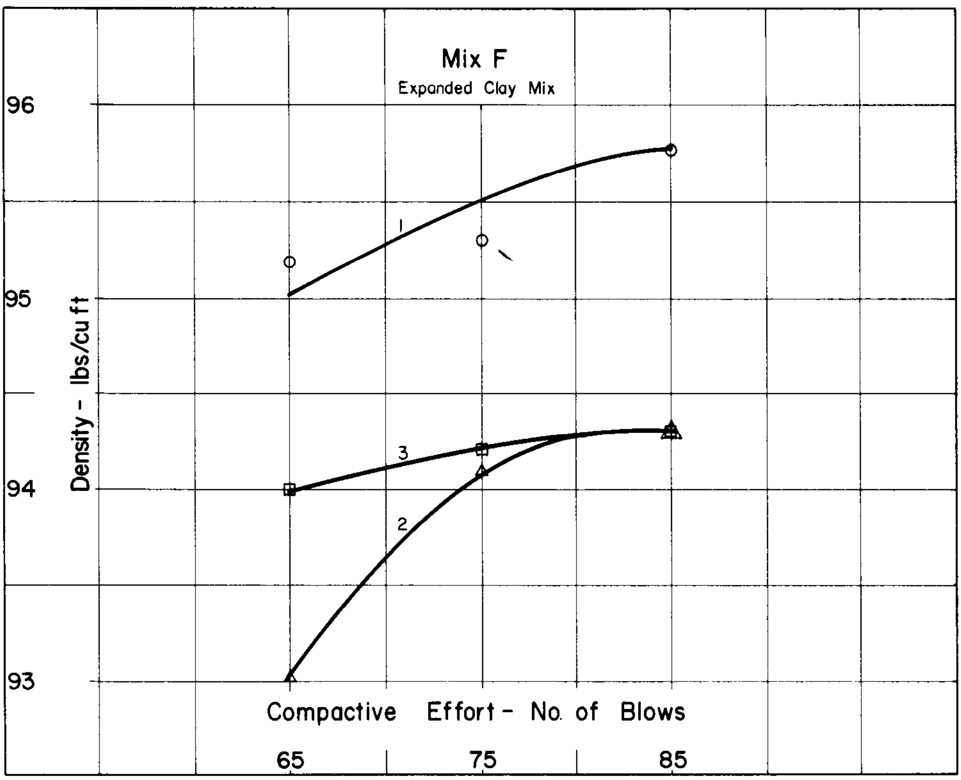

Figure 21 - Density - Compactive Effort Relationship Comparing Manual Hammer 1 and Mechanical Hammers 2 and 3 on Laboratory Mixed Material.

2. Hammer No. 2 due to excessive deviation in the Marshall stability results, should not be used.

3. Field results showed a wide variation between briquettes possibly because of a change in gradation or change in temperature of the mix. For this reason more weight was put on laboratory conclusions.

4. The maximum per cent deviation in stability and density for hammer No. 3 were 12 and 0.8 respectively as compared to 19 and 1.1 for hammer No. 2 at a given number of blows.

5. Results for expanded clay aggregate mixes showed higher deviations than for gravel mixes which is primarily due to the breaking up of the aggregate during laboratory compaction.

6. When using mechanical hammer No. 2, generally, regardless of the number of blows stability cannot be increased to approach the manual hammer.

APPENDIX C

TABLE VII

AVERAGE PER CENT DEVIATION IN MARSHALL STABILITY FOR VARIOUS COMPACTIVE EFFORTS

Compactive Effort - No. of Blows 65

Average Marshall Stability @ 140°F-Lbs.			Per Cent Deviation in Stability from the Manual Hammer			
Mix	B	D	Mix	B	D	Average Deviation - %
Manual Hammer No. 1	1237	1312	Mechanical Hammer No. 2	8.4	0	4.2
Mechanical Hammer No. 2	1132	1311	Mechanical Hammer No. 3	5.5	0.8	3.2
Mechanical Hammer No. 3	1169	1322				

Compactive Effort - No. of Blows 70

Average Marshall Stability @ 140°F-Lbs.				Per Cent Deviation in Stability from the Manual Hammer				
Mix	A	C	E	Mix	A	C	E	Average Deviation - %
Manual Hammer No. 1	1527	1606	1548	Mechanical Hammer No. 2	11.2	28.5	17.8	19.1
Mechanical Hammer No. 2	1356	1149	1273	Mechanical Hammer No. 3	0.7	0.8	22.4	8.0
Mechanical Hammer No. 3	1516	1619	1202					

Compactive Effort - No. of Blows 75

Average Marshall Stability @ 140°F-Lbs.						Per Cent Deviation in Stability from the Manual Hammer						
Mix	A	B	C	D	E	Mix	A	B	C	D	E	Average Deviation - %
Manual Hammer No. 1	1527	1353	1684	1276	1780	Mechanical Hammer No. 2	6.9	5.6	26.8	2.0	16.6	11.6
Mechanical Hammer No. 2	1422	1269	1233	1301	1484	Mechanical Hammer No. 3	1.0	8.1	0.4	6.0	10.3	5.2
Mechanical Hammer No. 3	1543	1243	1691	1353	1597							

Compactive Effort - No. of Blows 80

Average Marshall Stability @ 140°F-Lbs.				Per Cent Deviation in Stability from the Manual Hammer				
Mix	A	C	E	Mix	A	C	E	Average Deviation - %
Manual Hammer No. 1	1485	1674	1810	Mechanical Hammer No. 2	4.0	27.4	15.5	15.6
Mechanical Hammer No. 2	1426	1215	1530	Mechanical Hammer No. 3	4.4	4.2	7.8	5.5
Mechanical Hammer No. 3	1550	1604	1669					

Compactive Effort - No. of Blows 85

Average Marshall Stability @ 140°F-Lbs.			Per Cent Deviation in Stability from the Manual Hammer			
Mix	B	D	Mix	B	D	Average Deviation - %
Manual Hammer No. 1	1243	1390	Mechanical Hammer No. 2	2.5	4.3	3.4
Mechanical Hammer No. 2	1274	1330	Mechanical Hammer No. 3	14.8	9.5	12.2
Mechanical Hammer No. 3	1427	1462				

APPENDIX C

TABLE VIII

AVERAGE PER CENT DEVIATION IN DENSITY FOR VARIOUS COMPACTIVE EFFORTS

Compactive Effort - No. of Blows 65

Mix	Average Density Lbs/Cu.Ft. B	D
Manual Hammer No. 1	144.0	145.0
Mechanical Hammer No. 2	143.0	144.1
Mechanical Hammer No. 3	143.4	144.8

Mix	Per Cent Deviation in Density from the Manual Hammer B	D	Average Deviation - %
Mechanical Hammer No. 2	0.7	0.6	0.7
Mechanical Hammer No. 3	0.4	0.1	0.3

Compactive Effort - No. of Blows 70

Mix	Average Density Lbs/Cu.Ft. A	C	E
Manual Hammer No. 1	142.6	144.4	144.5
Mechanical Hammer No. 2	142.2	142.8	141.9
Mechanical Hammer No. 3	142.7	143.0	142.3

Mix	Per Cent Deviation in Density from the Manual Hammer A	C	E	Average Deviation - %
Mechanical Hammer No. 2	0.3	1.1	1.8	1.1
Mechanical Hammer No. 3	0	1.0	1.5	0.8

Compactive Effort - No. of Blows 75

Mix	Average Density-Lbs/Cu.Ft. A	B	C	D	E
Manual Hammer No. 1	142.9	144.5	144.6	145.5	144.5
Mechanical Hammer No. 2	142.6	143.5	142.8	145.0	142.0
Mechanical Hammer No. 3	142.8	143.6	143.3	145.0	143.1

Mix	Per Cent Deviation in Density from the Manual Hammer A	B	C	D	E	Average Deviation - %
Mechanical Hammer No. 2	0.3	0.7	1.2	0.4	1.7	0.9
Mechanical Hammer No. 3	0	0.6	0.9	0.3	1.0	0.6

Compactive Effort - No. of Blows 80

Mix	Average Density-Lbs/Cu.Ft. A	C	E
Manual Hammer No. 1	142.8	144.1	144.9
Mechanical Hammer No. 2	142.7	142.8	142.6
Mechanical Hammer No. 3	142.8	143.6	143.6

Mix	Per Cent Deviation in Density from the Manual Hammer A	C	E	Average Deviation - %
Mechanical Hammer No. 2	0	0.9	1.6	0.8
Mechanical Hammer No. 3	0	0.3	0.9	0.4

Compactive Effort - No. of Blows 85

Mix	Average Density-Lbs/Cu.Ft. B	D
Manual Hammer No. 1	144.7	145.5
Mechanical Hammer No. 2	143.5	145.3
Mechanical Hammer No. 3	144.2	145.4

Mix	Per Cent Deviation in Density from the Manual Hammer B	D	Average Deviation - %
Mechanical Hammer No. 2	0.8	0.1	0.5
Mechanical Hammer No. 3	0.3	0	0.2

A P P E N D I X   B

TABLE IV (CONT.)

MIX E

COMPOSED OF GRAVEL AND A COMBINATION OF SAND AND MINERAL FILLER

Mineral Aggregate	95.0%
Asphalt Cement	5.0%

Laboratory No.	Specific Gravity	Proportions
746625 (Fine Bin)	2.646	50.0
755022 (1/2" - 3/8")	2.620	5.0
755020 (3/8" - No. 4)	2.626	37.0
755021 (No. 4 - No. 10)	2.624	4.0
746628 (Limestone Dust)	2.734	4.0
770633 (80-100) Shell Oil Co.	1.020	5.0

Gradation

U.S. Sieve	Per Cent Passing					
	746625	755022	755020	755021	746628	Composite
3/4 Inch						100
1/2 Inch		100				100
3/8 Inch		-	100			95
No. 4	100		-	100		58
No. 10	85			-		47
No. 40	59				100	34
No. 80	40				96	24
No. 200	17				81	12

Manual Hammer No. 1

Compactive Effort-No. of Blows	70	75	80
Specific Gravity	2.315	2.310	2.322
Density - Lbs/cu.ft.	144.5	144.5	144.9
Marshall Stability @ 140°F-Lbs.	1548	1780	1810
Flow 1/100 Inch	11	10	13

Mechanical Hammer No. 2

Compactive Effort-No. of Blows	70	75	80
Specific Gravity	2.274	2.276	2.286
Density - Lbs/cu.ft.	141.9	142.0	142.6
Marshall Stability @ 140°F-Lbs.	1273	1484	1530
Flow 1/100 Inch	8	9	7

Mechanical Hammer No. 3

Compactive Effort-No. of Blows	70	75	80
Specific Gravity	2.281	2.294	2.302
Density - Lbs/cu.ft.	142.3	143.1	143.6
Marshall Stability @ 140°F-Lbs.	1202	1597	1669
Flow 1/100 Inch	8	8	7

MIX F

COMPOSED OF EXPANDED CLAY AGGREGATE,
COARSE SAND, FINE SAND AND MINERAL FILLER

Mineral Aggregate	93.0%
Asphalt Cement	7.0%

Laboratory No.	Proportions
773745 (1/2" - 3/8")	17.0
773746 (3/8" - No. 4)	25.0
773796 (Coarse Sand)	33.0
773795 (Fine Sand)	20.0
697061 (Silica Dust)	5.0
752212 (80-100) Humble Oil Co.	7.0

Gradation

U.S. Sieve	Per Cent Passing					
	773745	773746	773796	773795	697061	Composite
3/4 Inch						100
1/2 Inch	100					100
3/8 Inch		100	100			83
No. 4			94			56
No. 10			82	100		52
No. 40			40	99		38
No. 80			7	96	100	26
No. 200			1	25	99	10

Manual Hammer No. 1

Compactive Effort-No. of Blows	65	75	85
Specific Gravity	1.526	1.527	1.536
Density - Lbs/cu.ft.	95.2	95.3	95.8
Marshall Stability @ 140°F-Lbs.	2116	2062	2163
Flow 1/100 Inch	8	8	9

Mechanical Hammer No. 2

Compactive Effort-No. of Blows	65	75	85
Specific Gravity	1.490	1.508	1.511
Density - Lbs/cu.ft.	93.0	94.1	94.3
Marshall Stability @ 140°F-Lbs.	1061	1261	1380
Flow 1/100 Inch	6	6	6

Mechanical Hammer No. 3

Compactive Effort-No. of Blows	65	75	85
Specific Gravity	1.507	1.510	1.512
Density - Lbs/cu.ft.	94.0	94.2	94.3
Marshall Stability @ 140°F-Lbs.	1593	1448	1674
Flow 1/100 Inch	4	7	6

A P P E N D I X   B

PROPORTIONS, GRADATIONS AND TEST RESULTS OF LABORATORY MIXED BRIQUETTES

TABLE IV

MIX A

COMPOSED OF GRAVEL AND A COMBINATION OF SAND AND MINERAL FILLER

Mineral Aggregate 94.5%
Asphalt Cement 5.5%

Laboratory No.	Specific Gravity	Proportions %
765375 (Fine Bin)	2.648	50.0
765376 (1/2" - 3/8")	2.601	5.0
765377 (3/8" - No. 4)	2.618	35.0
765378 (No. 4 - No. 10)	2.627	5.0
697061 (Silica Dust	2.670	5.0
770633 (80-100) Shell Oil Co.	1.020	5.5

Gradation

U.S. Sieve	Per Cent Passing 765375	765376	765377	765378	697061	Composite
3/4 Inch						
1/2 Inch		100				100
3/8 Inch		-	100			95
No. 4	100		-	100		60
No. 10	93					52
No. 40	62					36
No. 80	34					22
No. 200	11				100	10

Manual Hammer No. 1

Compactive Effort-No. of Blows	70	75	80
Specific Gravity	2.286	2.290	2.289
Density - Lbs/cu.ft.	142.6	142.9	142.8
Marshall Stability @ 140°F-Lbs.	1527	1527	1485
Flow 1/100 Inch	14	11	12

Mechanical Hammer No. 2

Compactive Effort-No. of Blows	70	75	80
Specific Gravity	2.279	2.286	2.287
Density - Lbs/cu.ft.	142.2	142.6	142.7
Marshall Stability @ 140°F-Lbs.	1356	1422	1426
Flow 1/100 Inch	6	9	17

Mechanical Hammer 3

Compactive Effort-No. of Blows	70	75	80
Specific Gravity	2.287	2.288	2.288
Density - Lbs/cu.ft.	142.7	142.8	142.8
Marshall Stability @ 140°F-Lbs.	1516	1543	1550
Flow 1/100 Inch	8	12	8

MIX B

COMPOSED OF GRAVEL AND A COMBINATION OF SAND AND MINERAL FILLER

Mineral Aggregate 94.5%
Asphalt Cement 5.5%

Laboratory No.	Specific Gravity	Proportions %
665607 (Fine Bin)	2.650	60.0
773358 (1/2" - 3/8")	2.629	10.0
773357 (3/8" - No. 4)	2.621	25.0
697825 (Silica Dust)	2.668	5.0
752212 (80-100) Humble Oil Co.	1.022	5.5

Gradation

U.S. Sieve	Per Cent Passing 665607	773358	773357	697825	Composite
3/4 Inch					
1/2 Inch		100			100
3/8 Inch		-	100		90
No. 4	100		-		65
No. 10	88				58
No. 40	49				34
No. 80	23				19
No. 200	8			100	10

Manual Hammer No. 1

Compactive Effort-No. of Blows	65	75	85
Specific Gravity	2.308	2.315	2.319
Density - Lbs/cu.ft.	144.0	144.5	144.7
Marshall Stability @ 140°F-Lbs.	1237	1353	1243
Flow 1/100 Inch	8	10	9

Mechanical Hammer No. 2

Compactive Effort-No. of Blows	65	75	85
Specific Gravity	2.292	2.299	2.299
Density - Lbs/cu.ft.	143.0	143.5	143.5
Marshall Stability @ 140°F-Lbs.	1132	1269	1274
Flow 1/100 Inch	7	7	6

Mechanical Hammer No. 3

Compactive Effort-No. of Blows	65	75	85
Specific Gravity	2.298	2.301	2.311
Density - Lbs/cu.ft.	143.4	143.6	144.2
Marshall Stability @ 140°F-Lbs.	1169	1243	1427
Flow 1/100 Inch	5	6	7

TABLE IV (CONT.)

MIX C

COMPOSED OF GRAVEL AND A COMBINATION OF SAND AND MINERAL FILLER

Mineral Aggregate	94.5%
Asphalt Cement	5.5%

Laboratory No.	Specific Gravity	Proportions
689776 (Fine Bin)	2.629	48.0
689778 A (1/2" - 3/8")	2.637	11.0
689777 A (3/8" - No. 4)	2.645	22.0
779434 (No. 4 - 10)	2.653	14.0
689824 (Silica Dust)	2.656	5.0
770633 (80-100) Shell Oil Co.	1.020	5.5

Gradation

U.S. Sieve	Per Cent Passing					
	689776	689778	689777	779434	689824	Composite
3/4 Inch						100
1/2 Inch		100				100
3/8 Inch		-	100			89
No. 4	100		-	100		67
No. 10	86			-		46
No. 40	49				100	29
No. 80	24				99.4	17
No. 200	13				81.0	10

Manual Hammer No. 1

Compactive Effort-No. of Blows	70	75	80
Specific Gravity	2.314	2.318	2.309
Density - Lbs/cu.ft.	144.4	144.6	144.1
Marshall Stability @ 140°F-Lbs.	1606	1684	1674
Flow 1/100 Inch	12	8	10

Mechanical Hammer No. 2

Compactive Effort-No. of Blows	70	75	80
Specific Gravity	2.289	2.289	2.288
Density - Lbs/cu.ft.	142.8	142.8	142.8
Marshall Stability @ 140°F-Lbs.	1149	1233	1215
Flow 1/100 Inch	7	9	10

Mechanical Hammer No. 3

Compactive Effort-No. of Blows	70	75	80
Specific Gravity	2.291	2.296	2.302
Density - Lbs/cu.ft.	143.0	143.3	143.6
Marshall Stability @ 140°F-Lbs.	1619	1691	1604
Flow 1/100 Inch	10	8	9

MIX D

COMPOSED OF GRAVEL AND A COMBINATION OF SAND AND MINERAL FILLER

Mineral Aggregate	94.5%
Asphalt Cement	5.5%

Laboratory No.	Specific Gravity	Proportions
779430 (Fine Bin)	2.632	60.0
762431 (1/2" - 3/8")	2.625	10.0
762432 (3/8" - No. 4)	2.615	25.0
779435 (Silica Dust)	2.644	5.0
766607 (60-70) Shell Oil Co.	1.038	5.5

Gradation

U.S. Sieve	779430	762431	762432	779435	Composite
3/4 Inch					100
1/2 Inch		100			100
3/8 Inch	100	-	100		90
No. 4	98		-		64
No. 10	82				54
No. 40	54			100	37
No. 80	17			98	15
No. 200	9			84	9

Manual Hammer No. 1

Compactive Effort-No. of Blows	65	75	85	95
Specific Gravity	2.324	2.331	2.332	2.333
Density - Lbs/cu.ft.	145.0	145.5	145.5	145.6
Marshall Stability @ 140°F-Lbs.	1312	1276	1390	1427
Flow 1/100 Inch	12	12	13	15

Mechanical Hammer No. 2

Compactive Effort-No. of Blows	65	75	85	95
Specific Gravity	2.309	2.323	2.328	2.328
Density - Lbs/cu.ft.	144.1	145.0	145.3	145.3
Marshall Stability @ 140°F-Lbs.	1311	1301	1330	1423
Flow 1/100 Inch	9	9	7	8

Mechanical Hammer No. 3

Compactive Effort-No. of Blows	65	75	85	95
Specific Gravity	2.321	2.324	2.330	2.334
Density - Lbs/cu.ft.	144.8	145.0	145.4	145.6
Marshall Stability @ 140°F-Lbs.	1322	1353	1462	1516
Flow 1/100 Inch	10	8	9	10

APPENDIX A

TEST RESULTS OF PLANT MIXED BRIQUETTES

TABLE I

Project I

Manual Hammer No. 1	1	1A
Compactive Effort-No. of Blows	75	75
Specific Gravity	2.357	2.340
Density - lbs/cu.ft.	147.1	146.0
Marshall Stability @ 140°F - lbs.	1339	1081
Flow 1/100 inch	11	7

Mechanical Hammer No. 2					
Compactive Effort-No. of Blows	65	75	85	95	105
Specific Gravity	2.370	2.334	2.349	2.369	2.350
Density - lbs/cu.ft.	147.9	146.0	146.6	147.3	146.6
Marshall Stability @ 140°F-lbs.	1536	1286	1394	1696	1289
Flow 1/100 inch	12	10	9	6	10

TABLE II

Project II

Manual Hammer No. 1	1	1A
Compactive Effort-No. of Blows	75	75
Specific Gravity	2.346	2.348
Density - lbs/cu.ft.	146.4	146.5
Marshall Stability @ 140°F - lbs.	1696	1889
Flow 1/100 inch	8	8

Mechanical Hammer No. 2				
Compactive Effort-No. of Blows	75	85	95	105
Specific Gravity	2.318	2.325	2.324	2.328
Density - lbs/cu.ft.	144.6	145.1	145.0	145.3
Marshall Stability @ 140°F-lbs.	1331	1190	1285	1494
Flow 1/100 inch	6	8	6	7

TABLE III

Project III

Manual Hammer No. 1	1	1A
Compactive Effort-No. of Blows	75	75
Specific Gravity	2.347	2.344
Density - lbs/cu.ft.	146.5	146.3
Marshall Stability @ 140°F - lbs.	1977	1751
Flow 1/100 inch	13	10

Mechanical Hammer No. 2				
Compactive Effort-No. of Blows	75	85	95	105
Specific Gravity	2.308	2.309	2.324	2.318
Density - lbs/cu.ft.	144.0	144.1	145.0	144.6
Marshall Stability @ 140°F-lbs.	1527	1395	1547	1554
Flow 1/100 inch	10	9	10	10

APPENDIX C

TABLE IX

AVERAGE PER CENT DEVIATIONS IN MARSHALL STABILITY AND DENSITY FOR EXPANDED CLAY AGGREGATE MIX

Mix F

	Average Marshall Stability @ 140°F-lbs.			Per Cent Deviation of Stability from the Manual Hammer		
Compactive Effort-No. of Blows	65	75	85	65	75	85
Manual Hammer No. 1	2116	2062	2163			
Mechanical Hammer No. 2	1061	1261	1380	49.9	38.8	36.2
Mechanical Hammer No. 3	1591	1448	1674	24.8	29.8	22.6

	Average Density-Lbs/cu.ft.			Per Cent Deviation of Density from the Manual Hammer		
Compactive Effort-No. of Blows	65	75	85	65	75	85
Manual Hammer No. 1	95.2	95.3	95.8			
Mechanical Hammer No. 2	93.0	94.1	94.3	2.3	1.3	1.6
Mechanical Hammer No. 3	94.0	94.2	94.3	1.3	1.2	0.9

APPENDIX D

Method of Test for

DETERMINATION OF SPECIFIC GRAVITY OF COMPRESSED BITUMINOUS MIXTURES

LDH DESIGNATION: TR 304-62

Scope

1. This method of test is intended to determine the bulk specific gravity of specimens of compressed bituminous mixtures. This is a modification of AASHO Designation: T-166 (ASTM Designation: D-1188). This method is to be used by the field plant laboratories.

Apparatus

2. (a) For laboratory made specimens, namely briquettes, the apparatus will consist of the following:

(1) A balance having a capacity of 2 kilograms or more and sensitive to 0.1 gram.

(2) A wire basket of No. 4 mesh or some other suitable device for holding the specimen.

(3) Container with overflow device for immersing the wire basket in water and maintaining a constant water level.

(4) Suspension apparatus for suspending the wire basket from center of scale pan.

(b) For samples taken from the pavement, namely roadway samples, the apparatus will consist of the following:

(1) Balance having a capacity of 5 kilograms or more and sensitive to 1 gram.

(2) A wire basket, container with overflow device, and suspension apparatus conforming to the requirements given in Section 2(a) items (2) through (4).

Samples

3. Samples of mixture made with aggregates of low absorption or dense grade mixtures such as regular wearing and binder course mixtures will be tested without paraffin coating.

Procedure Without Paraffin Coating

4. (a) The specimens, after they have stayed in air at room temperature for one hr. will be weighed in air. Laboratory prepared samples (briquettes) will be weighed to the closest 0.1 gram whereas the roadway samples will be weighed to the closest 1 gram.

(b) The specimens will then be placed on the wire basket and immersed in water and weighed. When weighing the samples in water, extreme care should be taken to remove all the air bubbles from the surface of the immersed briquette. *Balance should be checked prior to each weighing.* Briquettes will be weighed to the closest 0.1 gram whereas the roadway samples will be weighed to the closest 1 gram.

(c) The bulk specific gravity of uncoated samples will be computed by use of the following formula:

$$\text{Bulk Specific Gravity} = \frac{A}{A - B}$$

where:

A = weight in air in grams.

B = weight in water in grams.

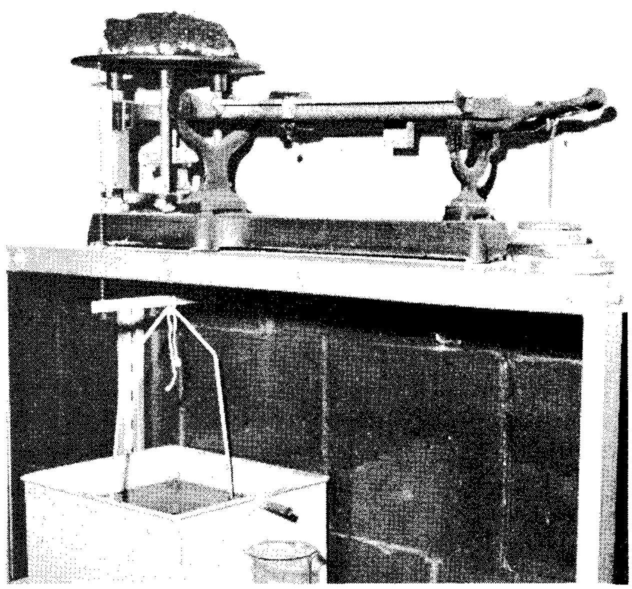

FIGURE 1

Apparatus for Weighing Roadway Samples in Air and in Water

Note: Briquettes being tested at a hot mix plant laboratory may be weighed to the closest gram.

Procedure With Paraffin Coating

5. (a) After samples have stayed in air at room temperature for one hr., they will be weighed as explained in Section 4 (a).

(b) The samples will then be coated with paraffin. Care should be taken to eliminate the presence of air pockets in the paraffin coating.

(c) The coated samples will be cooled to room temperature and then weighed in air as explained in Section 4(a).

(d) The coated samples will then be weighed in water as explained in Section 4(b).

(e) The bulk specific gravity of coated samples will be computed by use of the following formula:

$$\text{Bulk Specific Gravity} = \frac{A}{D - E - \frac{(D-A)}{F}}$$

where:

A = weight in grams of the dry uncoated specimen in air.
D = weight in grams of the dry specimen plus paraffin coating in air.
E = weight in grams of the dry specimen plus paraffin coating in water.
F = bulk specific gravity of the paraffin. (1)

(1) Whenever the actual specific gravity of paraffin is not available, 0.9 can be used for this purpose.

(f) After the test is completed, the paraffin coating should be removed from the briquettes if they are to be tested for stability. This can easily be accomplished by immersing the specimens in water at 120° F. for a few seconds and scraping the paraffin off by use of a spatula.

Reproducibility

6. Duplicate determinations shall check to within 0.02 in the case of roadway samples and to within 0.01 for laboratory samples or briquettes.

Report

7. The report shall include:

(a) For Briquettes:
(1) Specific Gravity.
(2) Theoretical Gravity.
(3) Percent Theoretical Gravity.
(4) Density--lbs. per cu. ft.
(5) Percent Voids in Total Mixture.
(6) Percent Voids Filled with Asphalt.
(7) Stability--lbs. @ 140° F.
(8) Flow--1/100".

(b) For Roadway Samples:
(1) Specific Gravity.
(2) Theoretical Gravity.
(3) Percent Theoretical Gravity.
(4) Average Briquette Specific Gravity.
(5) Percent Laboratory Briquette Gravity.

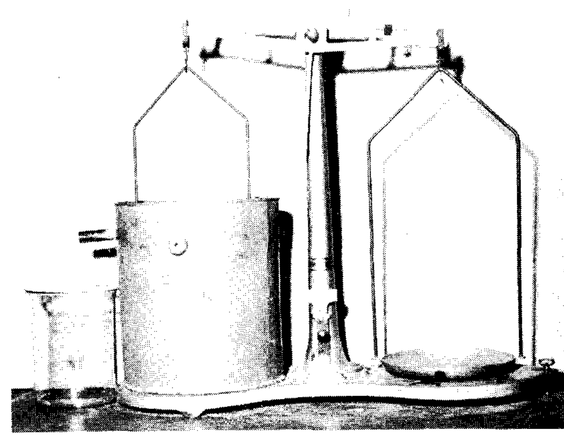

FIGURE 2

Apparatus for Weighing Briquettes in Water

(6) Thickness in inches.

Calculations

8. (a) *Percent of Theoretical Gravity* will be computed by use of the following formula:

$$\%\ \text{Theoretical Gravity (F)} = \frac{D \times 100}{E}$$

where:

D = specific gravity of briquette.
E = theoretical gravity of the mix.

(b) *Percent Voids-Total Mix* will be computed by use of the following formula:

$$\%\ \text{Voids} - \text{Total Mix (H)} = 100 - F$$

where:

F = % theoretical gravity.

(c) *Density* will be computed as follows:

$$\text{Density (lbs./cu.ft.)} = D \times 62.4$$

where:

D = specific gravity of compacted mixture.

(d) *Percent Voids Filled with Asphalt* (% V.F.A.) will be computed by use of the following formula:

$$\%\ \text{Asphalt by volume (I)} = \frac{D \times J}{K}$$

where:

D = specific gravity of mix.
J = percent asphalt in mix.
K = specific gravity of asphalt.

and

$$\% \text{ V. F. A.} = \frac{I}{H + I} \times 100$$

where:

I = % asphalt by volume.
H = % voids - total mix.

(e) *Percent of Laboratory Briquette Specific Gravity* will be computed by use of the following formula:

$$\% \text{ Laboratory Briquette Gravity} = \frac{P}{D} \times 100$$

where:

P = the specific gravity of roadway sample.
D = average specific gravity of briquettes for the same days run.

(f) All results shall be reported to the nearest whole number for:

Percent Theoretical Gravity.
Percent V.F.A.
Percent Voids.

All specific gravity results shall be reported to the nearest 0.01.

Normal Testing Time is 1 Hour

Method of Test for

THE STABILITY AND FLOW OF ASPHALTIC CONCRETE MIXTURES-MARSHALL METHOD

LDH DESIGNATION: TR 305-62

Scope

1. This method is commonly known as the "Marshall Method". It is intended in this method to determine the physical characteristics of asphaltic concrete or sand asphalt mixtures regarding the stability and flow.

Apparatus

2. (a) Marshall Testing Machine.
   (b) Marshall Hammer.
   (c) Compaction Pedestal (see Figure A-6.)
   (d) Compaction Mold Holder.
   (e) Two (2) Compaction Molds.
   (f) Stability Test Mold
   (g) Flow Meter with 1/100 inch divisions.
   (h) Hot Water Bath.
   (i) Dial Thermometer, 50-500° F., 5° F. divisions.
   (j) Bath Thermometer, 30-180° F., 1° F. divisions.
   (k) Mixing Spoon, Scoop, Containers, Etc.
   (l) A balance with 5 kilogram capacity and sensitive to 1 gram.

Samples

3. (a) *Samples mixed at a Hot Mix Plant*-When sampling a bituminous mixture, extreme care should be taken to obtain a truly representative sample of the material to be tested.

A composite sample shall be taken, portions of which shall come from the top, front and back of the load.

Immediately after sampling, the temperature of the mix shall be taken and recorded.

(b) *Laboratory Prepared Samples*-For mix design purposes, the mixture will be prepared as specified in "Method of Preparation of Hot Mix Samples for Mix Design" LDH Designation: TR-303.

Preparation of Test Specimens

4. (a) Prior to molding specimens, the molds will be placed in the water bath at 140° F. ± 1° F. for 5 min. This includes the base plate, the mold and the collar. This step should be accomplished prior to sampling in order to prevent the mixture from cooling. As soon as the mixture is ready to be compacted, the mold will be taken out of the bath, placed on the compaction pedestal and fastened tightly by means of the mold holder and the inside *will* be dried by use of a dry rag and a *light* application of kerosene made on the inside.

(b) The sample shall be transferred into the mold immediately after mixing. Losing too much time would cause the mix to cool and the necessary compaction cannot be secured. Prior to compaction, the temperature of the mix shall not be less than 275° F. The mixture shall be scooped to the bottom each time to prevent segregation of fine and coarse aggregates. After the mold is filled with the necessary amount of mixture to make a briquette 2½ ± 1/8 in. thick, (1150-1200 grams) the material shall be rodded exactly 25 times by use of a spoon to secure a uniform placement. The surface of the mixture shall be smoothened to a slightly rounded shape with the spoon.

(c) The sample will then be compacted by 75 blows of the compaction hammer. Extreme care should be taken in counting the number of the blows as most of the properties of the mixture is highly dependent on the degree of compaction applied. It is very important that the compaction pedestal used be in accordance with the requirements shown in Fig. 1.

Application of a light coating of kerosene to the base of the hammer will help to prevent the sticking of the hammer to the surface of the briquette.

(d) The base plate and collar shall be removed and the mold turned over and reassembled. Seventy-five blows shall then be applied to this side of the briquette. The base of the hammer should be cleaned by use of a rag dampened with kerosene prior to compaction, as in the first case.

(e) After compaction, the base plate and mold shall be removed and the mold and contents shall be placed in a cool water bath until the material has cooled to room temperature.

(f) After the specimen has cooled, the mold shall be placed over the upper section of the collar resting on the compaction base. The specimen will then be forced out by a few light blows of the hammer into the collar which is of larger diameter.

(g) The specimens shall be 2½" ± 1/8 inch. in height; all those that do not meet this requirement shall be *discarded.*

Test for Specific Gravity and Computation of Density Characteristics

5. The specific gravities of the briquettes will be

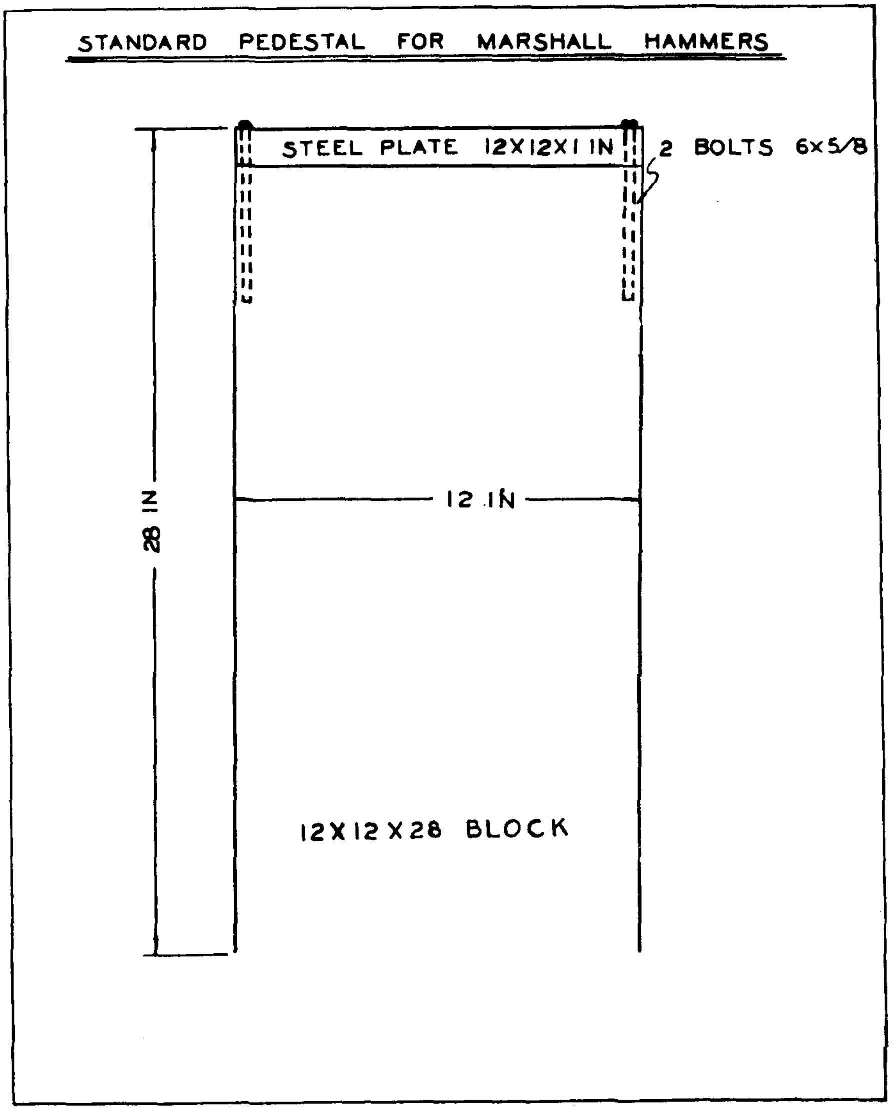

FIGURE 1

determined by use of "Determination of Specific Gravity of Compressed Bituminous Mixtures" LDH Designation: TR 304 and the density characteristics will be determined as explained therein.

Test for Stability and Flow

6. (a) After all the density characteristics have been computed, the specimens will be tested for stability and flow at 140° F. ± 1° F. This temperature of 140° ± 1° F. is very critical and should be closely adhered to since deviation from this value would greatly affect the stability of the Marshall specimens as illustrated in Fig. A-7.

The briquettes and the *testing mold* will be placed in a hot water bath for *twenty (20) min.* When placing the specimens in the bath, care should be taken to place them at leastone in.apart. In no event should the specimen touch the side or the bottom of the water bath or the thermometer.

(b) The inside surface of the testing mold and the guide rods shall be cleaned thoroughly prior to testing and the guide rods shall be well lubricated so that the upper part of the test mold can move freely.

(c) The testing mold and the specimen shall be removed from the water bath, placed in testing position with the upper part of the testing mold placed on the specimen and the complete assembly shall be transferred to the platform of the testing machine. The flow meter will then be placed on one of the guide rods and set to zero. Extreme care should be exercised to make sure that the movable "inner rod" in the flow meter is pulled out as far as it will go prior to placing the meter in testing position in order to insure

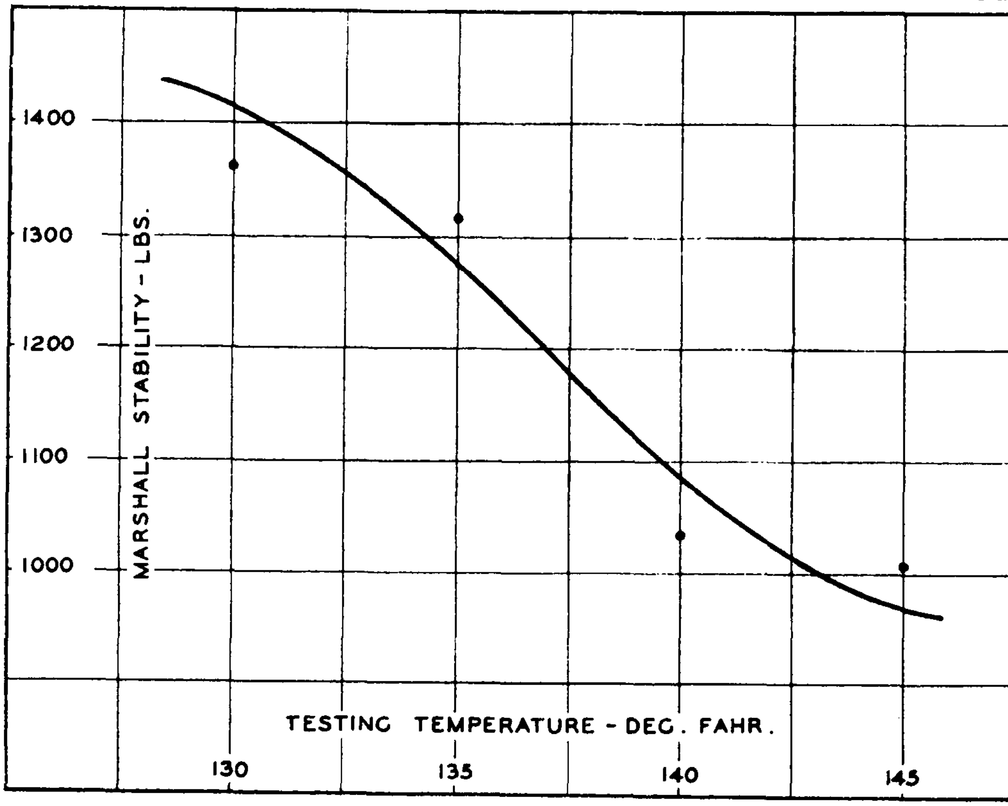

FIGURE 2 *Testing Temperature-Marshall Stability Relationship*

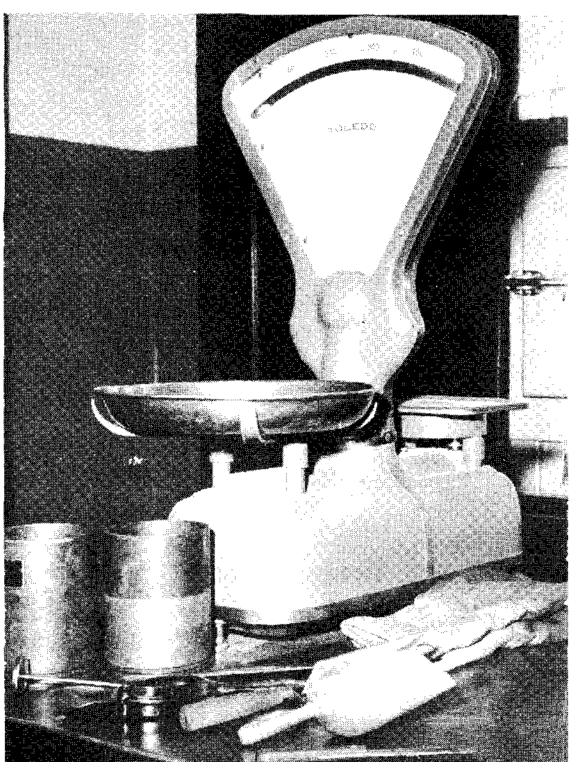

FIGURE 3 *Apparatus for Weighing, Mixing and Molding Aggregate - Asphalt Mixture*

a contact with the guide rod. Load shall then be applied to the specimen. During the application of the load, the flow meter should be held firmly against the top of the upper part of the testing mold. When the maximum load is reached on the stability dial, the flow meter shall instantly be released. It is very important that the flow meter be released upon reaching the failure point on the stability dial because after failure, even though the motor is stopped, there is a continuous flow. The dial reading and the flow values shall be recorded.

Since excessive cooling of the specimen causes an increase in stability and a decrease in the flow values, extreme rapidity of testing is necessary. The time that elapses between the removal of the specimen from the bath and the failure of the specimen should not be *over thirty (30) seconds*. Whenever more than *one* briquette is being tested, the testing mold should be rereturned to the water bath after each testing for a period of two minutes.

(d) Stability values varies directly with the thickness of the specimen; therefore, it is necessary to make a correction for the thickness. No correction is needed for flow values. The stability values will be corrected as follows:

(1) Volume of the briquette will be computed by

use of the following formula:

$$\text{Volume (cubic centimeters)} = A - B$$

where:

A = weight of the briquette in air.
B = weight of the briquette in water.

LOUISIANA DEPARTMENT OF HIGHWAYS
TESTING & RESEARCH SECTION

STABILITY CORRELATION RATIO
For Marshall Method

Revised September, 1958

Volume of Specimen in Cubic Centimeters	Approximate Thickness of Specimen in Inches	Correlation Ratio
200 – 213	1	0.18
214 – 225	1-1/16	0.20
226 – 237	1-1/8	0.22
238 – 250	1-3/16	0.24
251 – 264	1-1/4	0.26
265 – 276	1-5/16	0.28
277 – 289	1-3/8	0.30
290 – 301	1-7/16	0.33
302 – 316	1-1/2	0.36
317 – 328	1-9/16	0.40
329 – 340	1-5/8	0.44
341 – 353	1-11/16	0.48
354 – 367	1-3/4	0.52
368 – 379	1-13/16	0.56
380 – 392	1-7/8	0.60
393 – 405	1-15/16	0.64
406 – 420	2	0.68
421 – 431	2-1/16	0.72
432 – 443	2-1/8	0.76
444 – 456	2-3/16	0.80
457 – 470	2-1/4	0.84
471 – 482	2-5/16	0.88
483 – 495	2-3/8	0.92
496 – 508	2-7/16	0.96
509 – 522	2-1/2	1.00
523 – 535	2-9/16	1.04
536 – 546	2-5/8	1.08
547 – 559	2-11/16	1.12
560 – 573	2-3/4	1.16
574 – 585	2-13/16	1.21
586 – 598	2-7/8	1.24
599 – 610	2-15/16	1.28
611 – 625	3	1.32

Notes:
1. The measured stability of a specimen divided by the ratio for the thickness of the specimen equals the corrected stability for a 2-1/2 inch specimen.
2. Volume-thickness relation is based on a specimen diameter of 4 in.

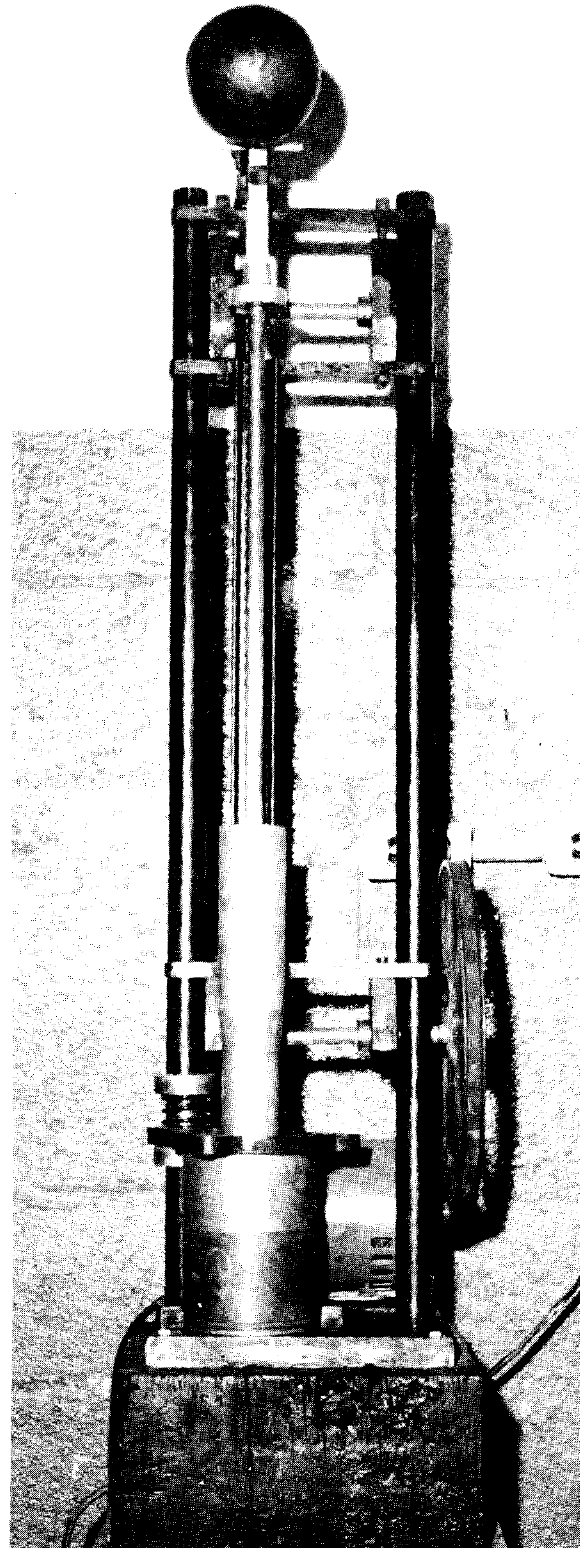

FIGURE 4

Test Specimen Ready for Compaction

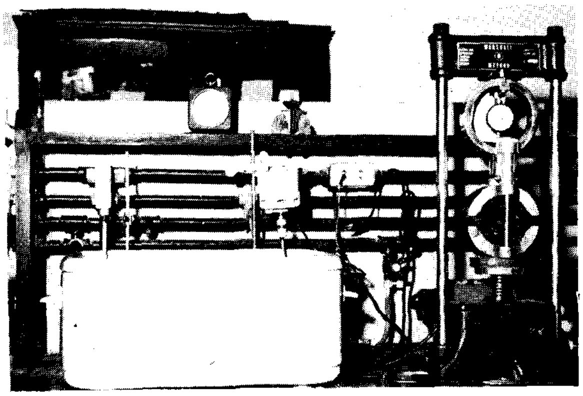

FIGURE 5

Hot Water Bath, Marshall Stability Machine and Flow Meter with Specimen in Place Ready for Test.

(2) Then from the "Stability Correction Chart" the "thickness" and the "correlation ratio" corresponding to the volume obtained above will be recorded.

(3) The original stability value will be divided by the correlation ratio to determine the "Corrected Stability Value".

(e) For mix design, a minimum of three (3) briquettes will be prepared and tested. For Daily Plant Control, a minimum of two (2) briquettes will be tested for each value reported. Under no circumstances, results obtained from just one briquette shall be reported.

Normal testing time (including preparation of specimens) - 6 hours.