CORRELATIONS OF LABORATORY AND FIELD DATA

by WOODLAND G. SHOCKLEY*

INTRODUCTION

The original procedure for compacting laboratory specimens for the Marshall stability test had produced densities that were comparable to those obtained in the construction of pavements on the few airfields investigated. As has been noted in the discussion of tracking operations on the asphalt test section, it became apparent, from results of tests on cored samples, that compaction of the pavement was taking place under the traffic applied. The increased density of the pavement reduced the void space and allowed the asphalt to fill the voids more completely. In the event the pavements contain sufficient asphalt to overfill the voids when the density is increased by traffic, the pavements may flush and become unstable. Some indication of increased density had been obtained in previous laboratory tests in which the compactive effort was varied. An increase in the compactive effort resulted in higher densities and a lower optimum asphalt content. Therefore, it was decided to investigate the possibility of increasing the compactive effort in the laboratory test to obtain densities approximating those attained under traffic, such that the lower optimum asphalt content would provide a pavement design which would not have an excess of asphalt as a result of compaction at any time during the life of the pavement.

During the progress of the studies reported in this paper, a number of different compactive efforts were used in establishing the proper effort to be used in preparing laboratory specimens for the design and construction control of asphalt pavements. Inasmuch as it is rather difficult to keep in mind all of the factors involved in the compaction procedures, they are summarized in the following tabulation. Also shown are abbreviated designations by which the various procedures are called in this paper. (Table, page 66.)

STUDIES FOR SELECTION OF LABORATORY DESIGN COMPACTION PROCEDURE

The data from the 9 principal mixes used in the test section were plotted as test property curves for several intervals of traffic coverages. Values of 500, 1000, and 1500 or 3500 coverages were selected for analysis to cover the range of traffic experienced in the test section. The major changes in the pavement properties had occurred before 500 coverages, as explained in a previous paper of this symposium. Based on a preliminary analysis of the traffic data, an optimum asphalt content was selected for each mix at each interval of coverage. The results of this study, including the criteria used for selection of optimum asphalt content, are shown on Table 1. In the laboratory the same aggregate materials corresponding to the test section mixes were prepared with a range of asphalt contents and compacted at three compactive efforts; namely, 40, 55, and 75 blows with the modified AASHO hammer. The optimum asphalt content for each compactive effort was selected using the same test properties criteria as for the traffic data; these values are also shown on Table 1. Inspection of the table shows that for a given mix there was very little difference in field optimum asphalt content at any specific coverage for all three lanes; thus, it was proper to select an average value of optimum asphalt on data from all

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Compactive Effort	Terminology used in this paper
15 blows on top of specimen with Modified AASHO hammer (10-lb. weight 18-in. drop, 1.95-in. diameter foot) plus 5,000-lb. static load	Original procedure
40, 55, or 75 blows on both top and bottom of specimen with Modified AASHO hammer plus 500-lb static leveling load	40, 55, or 75 blows with Modified AASHO hammer
8, 10, 15, 20, 25, or 50 blows on both top and bottom of specimen with 12.5-lb. hammer, 18-in. drop, 3-7/8 in. diam. foot	8, 10, 15, 20, 25, or 50 blows with 12.5-lb. hammer, 3-7/8-in. foot
15, 40, or 50 blows on both top and bottom of specimen with 10-lb. hammer, 18-in. drop, 3-7/8 in. diam. foot	15, 40 or 50 blows with 10-lb. hammer, 3-7/8-in. foot

three lanes for each mix as representing the field condition. The optimum asphalt contents for specimens compacted with 55 blows were reasonably comparable to the values selected from the traffic tests for all mixes. On the basis of these comparisons, a compactive effort of 55 blows with the modified AASHO was tentatively selected as closely approximating the results obtained by traffic at from 500 to 1500 coverages of the wheel loads used in the test.

The laboratory compaction procedure tentatively selected involved considerably more work to prepare specimens for test than did the original procedure using 15 blows of the hammer. In addition, it was noted that some degradation was occurring in the compacted aggregates near the surface of the specimen. For these reasons a laboratory study was initiated in an effort to achieve the same results in compaction with less effort on the part of laboratory technicians and to eliminate the degradation of aggregates. A detailed discussion of the investigation is beyond the scope of this paper; however,

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the various methods tried and the final results of the study are presented.

Hammer studies were conducted using various sizes of hammer face from 1 in. up to 3-7/8 in. in diameter. Different design of hammer face, such as bullet-nose, stair stepped, etc., were investigated. The hammer weight was increased from 10 lb. to 12½ and to 15 lb. In addition, the shape of the compaction mold base was varied in an effort to produce a kneading action in preparation of the test specimens. Finally, other types of compaction were tried; namely, static compaction and "drop mold" compaction wherein the mold was weighted and dropped a number of times through a definite distance. The results of these tests indicated that the static method of compaction used was not satisfactory and that none of the dynamic methods tried would materially reduce the work required in the laboratory to prepare specimens, although there was a difference in the efficiency of the hammers with the different face diameters. A 3-in. diameter was most efficient and the 3-7/8-in. diameter was slightly less efficient than the 1.95-in. diameter of the Modified AASHO hammer. However, the large diameter hammer face (3-7/8 in.) was effective in reducing degradation of aggregates and eliminated the necessity for moving the hammer in the mold after each blow. Therefore, the following procedure was adopted: the hammer face was increased to 3-7/8 in. diameter, the weight was increased to 12½-lb.,

TABLE 1

COMPARISON OF OPTIMUM ASPHALT CONTENTS TRAFFIC AND LABORATORY COMPACTION

Asphalt Test Section

Mix No	Type	Asphalt Contents Placed on Test Section	Optimum Asphalt, Traffic Compaction: 15,000-Lb Lane 500 Coverages	15,000-Lb Lane 1000 Coverages	15,000-Lb Lane 3500 Coverages	37,000-Lb Lane 500 Coverages	37,000-Lb Lane 1000 Coverages	37,000-Lb Lane 1500 Coverages	60,000-Lb Lane 500 Coverages	60,000-Lb Lane 1000 Coverages	60,000-Lb Lane 1500 Coverages	Average	Optimum Asphalt, Laboratory Compaction: Modified AASHO Hammer 40 Blows	Modified AASHO Hammer 55 Blows	Modified AASHO Hammer 75 Blows	12-½-Lb Hammer 3-7/8-In Foot 50 Blows
7	Sand Asphalt 7% Filler	8 5, 9 5, 10 6	8 6	8 5	8 5	8 4	8 4	8 5	8 5	8 6	8.4	8.5	8 5	8 3	8 1	8 3
8	Sand Asphalt, 13% Filler	7 0, 7 9, 8 8	6 9	6 8	6 9	7 3	7 5	7 5	7 2	7 2	7.5	7 2	7 2	6 8	6 7	6 9
9	Sand Asphalt, 19% Filler	6 4, 7 2, 8 0	6 3	6 0	6 3	6 5	6.3	6 2	6 3	6 3	6.3	6 3	6.5	6 4	5 9	6 3
10	Asphaltic Concrete, Crushed Limestone, 2% Filler	5 6, 6 3, 7 0	6 3	6 1	6 1	6 5	6.4	6 3	6 4	6 2	6.3	6 3	6.7	6 7	6 3	6 3
11	Asphaltic Concrete, Crushed Limestone, 5% Filler	4 8, 5 4, 6 0	5 2	5 2	4 9	5 4	5 5	5 3	5 5	5 5	5 5	5 3	5 5	5 3	5 0	5 3
12	Asphaltic Concrete, Crushed Limestone, 8% Filler	4 8, 5 4, 6 0	5 0	4 9	5 0	5 0	5 0	5 0	4 9	4 6	4 9	4 9	5 1	4 8	4 5	4 6
13	Asphaltic Concrete, Uncrushed Gravel, 4% Filler	6 0, 6 8, 7 5	6 1	6 0	6 0	6 2	6 1	6 1	6.2	6 2	6.2	6 1	6 1	6.0	6 0	6 0
14	Asphaltic Concrete, Uncrushed Gravel, 5% Filler	5 7, 6 4, 7 1	5 6	5 6	5 7	5 5	5 5	5 3	5 8	5 6	5.7	5 6	5 5	5 5	5 3	5 4
15	Asphaltic Concrete, Uncrushed Gravel, 9% Filler	4 5, 5 0, 5 5	5 0	5 0	4 7	5.0	5 0	4.8	5 0	5 0	5.0	4 9	4.8	4 9	4 9	4 4

NOTES

1 The criteria for determining optimum asphalt content were as follows

Property	Limit
Flow	15
Stability	Maximum
Unit Weight-Total Mix	Maximum
Unit Weight-Aggregate Only	Maximum
Percent Voids-Aggregate Only	Minimum
Percent Voids-Total Mix	5
Percent Voids Filled with Asphalt	75

2 A 500-lb static leveling load was used in addition to the hammer compaction

and the number of blows on each side of the specimen reduced to 50. The large hammer face also eliminated the necessity for a static leveling load on the specimen. The revised compaction method duplicated the test results obtained with the previously-used 55 blows of the Modified AASHO hammer.

The foregoing revised procedure was used in the laboratory until the results of the final detailed analysis of the traffic data from the test section became available. This detailed analysis indicated that the optimum asphalt content selected by the revised compaction method just described was on the low side of the acceptable range of values as determined by traffic tests. In addition, it was recommended by the board of consultants that the compaction hammer weight be changed back to 10 lb. in order that it would more closely correspond to the Modified AASHO hammer. These changes necessitated further studies in the laboratory to establish a compactive effort that would produce reasonable agreement between field and laboratory optimum asphalt contents using the revised criteria.

To achieve this result, the data from 9 test section mixes used in the original compaction study were re-analyzed and new optimum asphalt contents were selected. These values were compared with the range of asphalt contents indicating satisfactory pavement behavior of the mixes in the test section, from which it was determined that 40 rather than 55 blows of the Modified AASHO hammer most nearly reproduced the desired optimum asphalt contents in the laboratory.

In order to correlate the compactive effort of 40 blows of the Modified AASHO hammer with the 10-lb. hammer, 3-7/8 in. foot, the following laboratory tests were conducted. Four of the 9 test section mixes, plus a mixture containing slag aggregate, were synthesized in the laboratory and optimum asphalt determined for 40 blows of the Modified AASHO hammer, as well as for 40 and 50 blows of the 10-lb. hammer with 3-7/8 in. foot. The results of these studies are shown in Table 2. Based on the analysis of these data it was determined that 50 blows of the 10-lb., 3-7/8-in. hammer should be used in compacting laboratory specimens as representing the proper design procedure for airfield pavements.

FIELD AND LABORATORY COMPACTION CORRELATION STUDIES

General - At various times throughout the investigation, information was obtained on the relationship between densities of bituminous pavements as constructed and the compactive effort required to duplicate those densities in the laboratory. In addition, data were available on a few satisfactory airfield pavements which had been subjected to considerable traffic and which could be compared with the laboratory compaction results.

It has been mentioned previously that the original compaction procedure produced densities that were approximately the same as those obtained in the construction of the airfield pavements investigated. It should be mentioned at this time that in order to expedite airfield construction the use of 8-ton roller, both three wheel and tandem types, was permitted during the national emergency. The current Corps of Engineers' specifications require the use of rollers weighing at least 10 tons for compacting bituminous pavements. However, the revised compaction procedure adopted for the laboratory design of asphalt paving mixtures produced densities in laboratory specimens that were higher than those obtained in field construction. This procedure, therefore, could not be used for control of rolling operations during construction. It was desired to obtain further information from field construction projects and to make laboratory compaction studies on the bituminous materials to see what improvement in correlation could be made between the laboratory and field compaction procedures.

Airfield Investigation - The airfield investigation program conducted by the Waterways Experiment Station has provided considerable information on bituminous pavements. In general, at each airfield investigated, samples of the pavement were obtained at the center and edge of the runways and taxiways. These samples were

TABLE 2

COMPARISON OF OPTIMUM ASPHALT CONTENTS - LABORATORY COMPACTION

Mix No.	Type	Asphalt Content Selected from Traffic Behavior	Optimum Asphalt Content - Laboratory Compaction: Original Mixes, Modified AASHO Hammer, 40 Blows	55 Blows	75 Blows	Laboratory Blends: Modified AASHO Hammer, 40 Blows	10-Lb Hammer, 3-7/8-Inch Diameter Foot, 40 Blows	50 Blows
7	Sand Asphalt, 7% Filler	7 6 - 8 5	8 5	8 2	8 0	-	-	-
8	Sand Asphalt, 13% Filler	6 3 - 7 0	7 1	6 8	6 7	7 3	7 4	7 2
9	Sand Asphalt, 19% Filler	6 4 - 7 2	6 4	6 3	6 1	-	-	-
10	Asphaltic Concrete, Crushed Limestone, 2% Filler	6 3 - 7 0	7 0	6 9	6 6	-	-	-
11	Asphaltic Concrete, Crushed Limestone, 5% Filler	5 4 - 6 0	6 0	5 8	5 5	5 6	6 0	5 7
12	Asphaltic Concrete, Crushed Limestone, 8% Filler	4 8 - 5 4	5 5	5 2	5 1	-	-	-
13	Asphaltic Concrete, Uncrushed Gravel, 4% Filler	6 0 - 6 8	6 7	6 6	6 4	-	-	-
14	Asphaltic Concrete, Uncrushed Gravel, 5% Filler	5 7 - 6 4	6 0	5 9	5 9	5 3	5 5	5 4
15	Asphaltic Concrete, Uncrushed Gravel, 9% Filler	5 0 - 5 5	5 3	5 2	5 4	-	-	-
-	Asphaltic Concrete, Slag, 8% Filler	-	-	-	-	5 3	5 6	5 3

NOTES

1 A 500-lb static leveling load was used in addition to the hammer compaction for the Modified AASHO hammer only

tested for density, stability, and flow, and the other test properties were computed. From the same locations as the cored samples, disturbed pavement samples were also obtained and tested in the laboratory. The samples were reheated and compacted with 10 blows and 50 blows of the 12.5-lb. hammer, 3-7/8 in. foot. These efforts were selected on the basis of preliminary studies that indicated the 10-blow compaction would approximate construction rolling densities, whereas the 50-blow compaction had been tentatively selected for design of asphalt pavements. It may be well to mention here that the 12.5-lb. hammer with 3-7/8 in. foot was used in these studies since they were concurrent with the analysis of the asphalt test section data and the final hammer design (10-lb., 3-7/8 in. foot) was not selected until a later date.

It has been determined from other investigations that the major portion of airplane traffic is concentrated in the center portion of runways and taxiways, whereas the edges receive very little traffic. Table 3 shows for several airfields the unit weights of pavements at the center of runways and taxiways compared with the 50-blow laboratory compaction results. It will be noted that the pavement densities at the center of runways average about 6 lb. per cu. ft. less than the 50-blow laboratory value, whereas the unit weights at the center of taxiways average about 2 lb. per cu. ft. below the 50-blow laboratory values. These data tend to show that the laboratory design compaction have considerably higher densities than were obtained on runways and slightly higher than were obtained on taxiways. This would indicate that the laboratory compaction procedures might be somewhat conservative for design purposes.

In order to determine the relationship between field as-built and laboratory compaction, a comparison was made between the unit weights at the edges of runways, assumed to approximate the as-constructed condition, and the 10 blow laboratory compaction. Table 4 shows these data. A comparison of the unit weights of the 10-blow laboratory compaction with the runway edge densities shows that in only two cases (Camp Campbell and La Junta, Pits 4 and 5) did the unit weight exceed that of the laboratory specimens. It would appear from this comparison that 10 blows of the 12.5-lb. hammer, 3-7/8 in. foot on laboratory specimens would be a little severe to use as a criterion to establish densities to be attained in construction.

TABLE 3

Comparison of Field and Laboratory Densities - Runway and Taxiway Centers-Airfield Studies

Field	Unit Weight -- Lb Per Cu. Ft: Runways Center	Runways 50 Blow Laboratory	Taxiways Center	Taxiways 50 Blow Laboratory
Lawson Field, Ga.	-	-	139	143
	-	-	138	143
Jackson AAB, Miss.	141	139	-	-
Camp Campbell, Tenn.	136	143	-	-
Berry Field, Tenn.	136	147	-	-
	143	147	-	-
Bergstrom Field, Tex.	147	148	147	148
Dodge City, Kans.	-	-	144	146
Woodward, Okla.	-	-	138	142
La Junta, Colo.	138	147	148	146
	141	148	-	-
Rocky Ford, Colo	136	142	-	-
Pueblo, Colo.	139	146	144	146
	138	145	-	-

TABLE 4

Comparison of Field and Laboratory Densities Runway Edges - Airfield Studies

Field	Unit Weight -- Lb. Per Cu Ft: Runway Edge	Laboratory
Bergstrom Field, Tex.	142	144
Berry Field, Tenn	135	140
Camp Campbell, Tenn.	135	134
Jackson AAB, Miss.	134	140
La Junta, Colo.		
Pits 1 and 2	136	143
Pits 4 and 5	134	132
Pueblo, Colo.		
Pits 3 and 6	134	140
Pits 5 and 4	136	138
Rocky Ford, Colo.	134	137

Field Rolling Studies

Eglin Field, Florida - The Waterways Experiment Station, in conjunction with the Mobile District, Corps of Engineers, conducted a rolling study at Eglin Field, Florida, in September 1946. The pavement was an asphaltic concrete in which a 1-in. maximum size slag was used as the coarse aggregate. The fine aggregate was a local sand and the filler was limestone

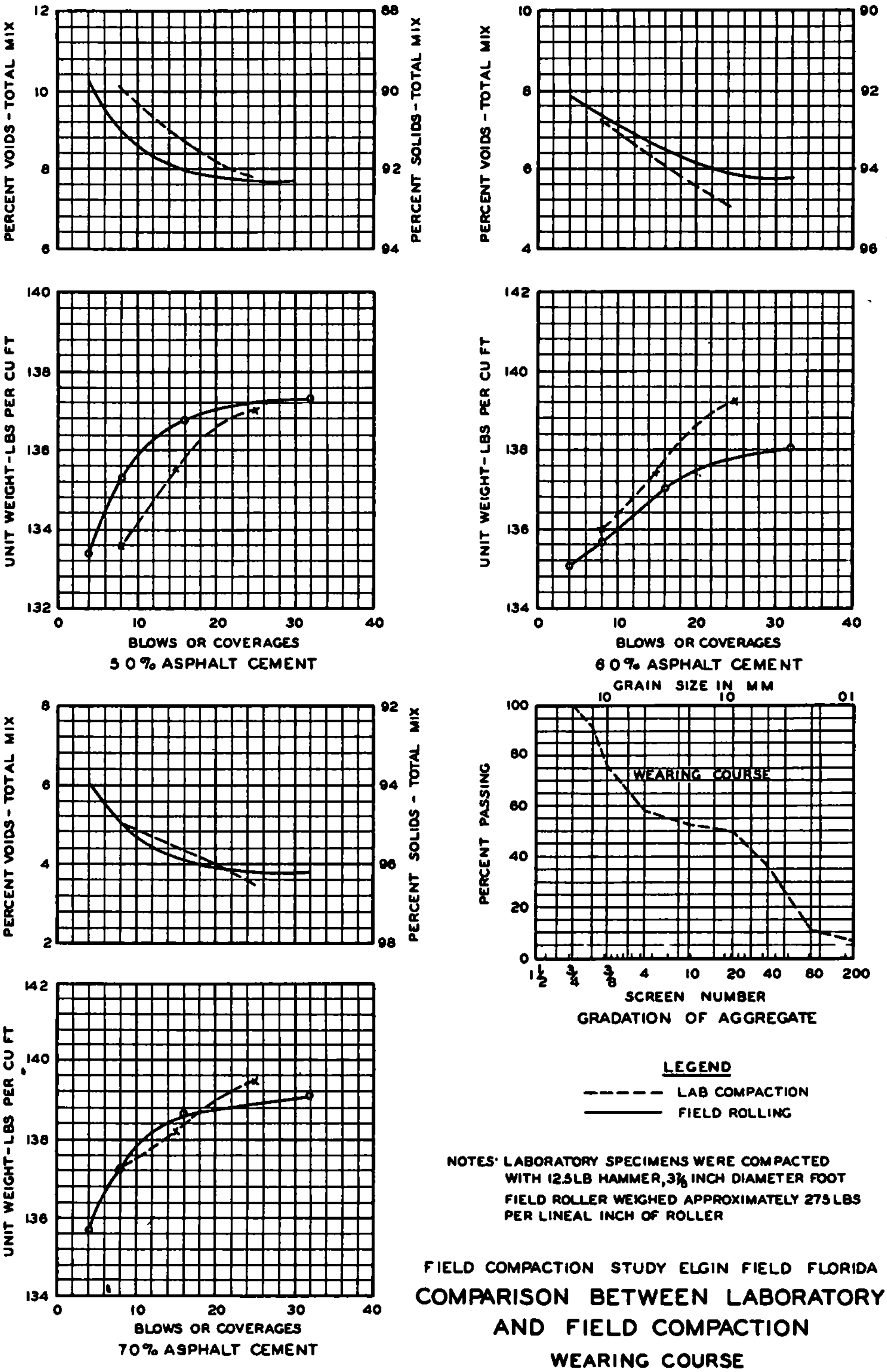

PERCENT VOIDS - TOTAL MIX
PERCENT SOLIDS - TOTAL MIX
UNIT WEIGHT-LBS PER CU FT
BLOWS OR COVERAGES
5.0% ASPHALT CEMENT
6.0% ASPHALT CEMENT
7.0% ASPHALT CEMENT
GRAIN SIZE IN MM
WEARING COURSE
PERCENT PASSING
SCREEN NUMBER
GRADATION OF AGGREGATE
LEGEND
LAB COMPACTION
FIELD ROLLING
NOTES: LABORATORY SPECIMENS WERE COMPACTED WITH 12.5LB HAMMER, 3⅞ INCH DIAMETER FOOT
FIELD ROLLER WEIGHED APPROXIMATELY 275 LBS PER LINEAL INCH OF ROLLER
FIELD COMPACTION STUDY ELGIN FIELD FLORIDA
COMPARISON BETWEEN LABORATORY AND FIELD COMPACTION
WEARING COURSE

Figure 1

dust. Ten-ton tandem rollers which produce approximately 275 lb. pressure per lineal inch of roller were used. Sections of pavement were placed at three percentages of asphalt and compacted with 4, 8, 16, and 32 passes of the rollers. Samples were cored from the completed pavements and tested. Samples were also taken of the plant-mixed asphaltic concrete for each section and specimens were compacted in the field laboratory using 8, 15, and 25 blows, each side, using the 12.5-lb. hammer, 3-7/8 in. foot. All specimens were tested for density, stability and flow.

The results of tests on the field and laboratory samples of the wearing course, together with the gradation of the pavement aggregates, are shown on Figure 1. Plotted on the figure are curves of density versus number of blows for laboratory compacted samples and density versus roller coverages for the field samples. It appears that in general the densities increase as the number of blows or coverages increase. It is assumed that 32 coverages constitutes excessive rolling and that satisfactory densities should be obtained with about 8 to 12 coverages. On this basis, a comparison of the laboratory data with field densities at 8 to 12 coverages indicated that 10 blows of the 12.5-lb. hammer, 3-7/8 in. foot produced laboratory densities that were in reasonable agreement with good field rolling.

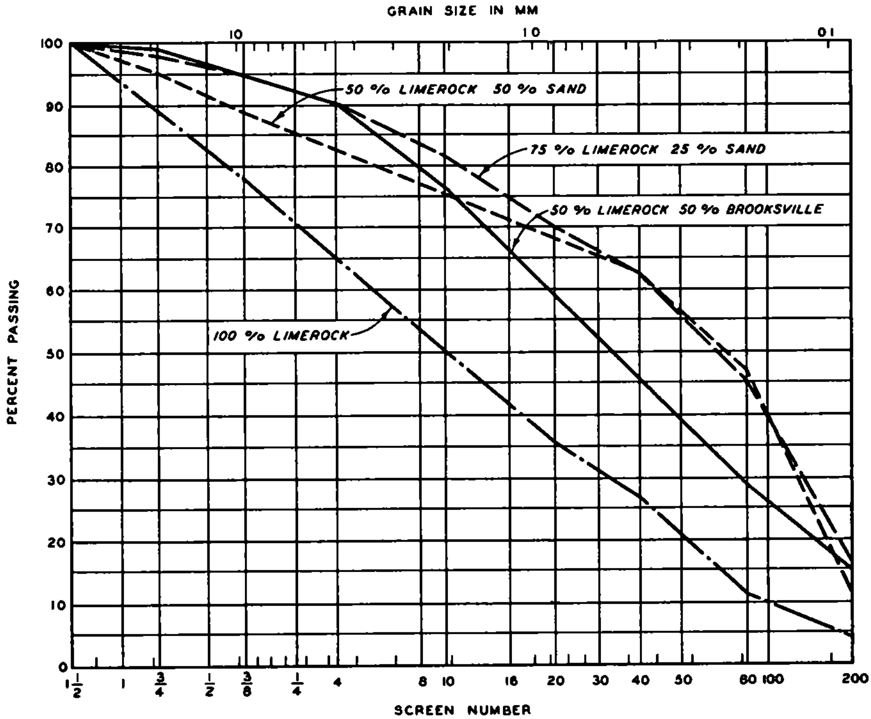
MacDill, Field, Florida - In June 1946, the Waterways Experiment Station was invited by the Savannah District, CE, to participate in the construction of four test sections at MacDill Field, Florida. The primary purpose of the tests was to determine the suitability of Florida limerock aggregate for construction of hot-mix bituminous pavements. However, only the features pertaining to field and laboratory compaction are discussed here. The four test sections each consisted of a different type of wearing course placed at various asphalt contents on a previously prepared base. The composition of the test sections is shown on Table 5. Gradations of the aggregates are shown on Figure 2. The wearing courses were approximately 1-3/4 in. thick and were compacted with 6 straight and 4 diagonal coverages of an 8-ton roller. Samples of the completed pavement were obtained from each of the sections and test properties were determined. Samples of the plant-mixed materials for each section were reheated and compacted in the laboratory with 10, 15, and 20 blows of the 12.5-lb. hammer with 3-7/8 in. foot.

Curves of density versus asphalt content for field and laboratory compacted samples for Section II, 50 percent limerock and 50 percent sand, are shown on Figure 3. These results may be considered comparable to those obtained on the other test sections. A comparison of the laboratory and field densities for the four test sections showed that 10 to 15 blows of

TABLE 5

Composition of Test Sections, MacDill Field, Florida

Section	Type of Aggregate	Asphalt Cement Percent
I	100 Percent Limerock	9, 10, 11, 12
II	50 Percent Limerock 50 Percent Local Sand	8, 9, 10, 11
III	75 Percent Limerock 25 Percent Local Sand	9, 10, 11, 12
IV	50 Percent Limerock 50 Percent Limestone Screenings	8, 9, 10, 11



MACDILL FIELD

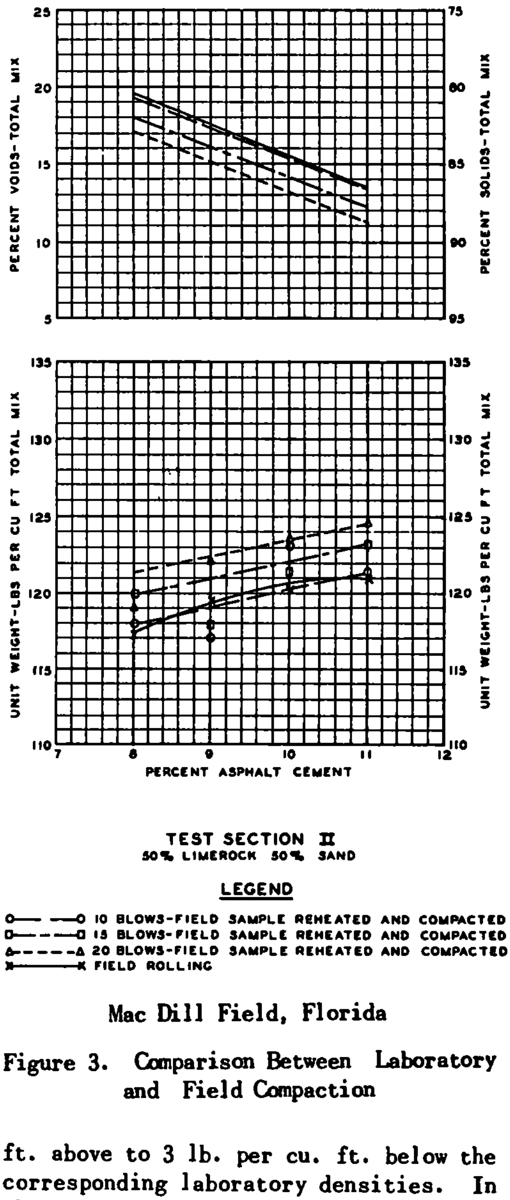
GRADATION OF PAVEMENT AGGREGATES

Figure 2

12.5-lb. hammer, 3-7/8 in. foot were required to produce densities in the laboratory that were comparable to those obtained in field construction.

Stockton Test Section No. 2 - During the construction and operation of Test Section No. 2 for very heavy wheel loads at Stockton, California, the Sacramento District, CE, furnished the Waterways Experiment Station with samples of the pavement for testing purposes. Of especial interest are the cores representing the as-constructed condition of the pavement. Six basic designs were used in constructing the wearing and binder courses for the test sections. Materials used in the bituminous mixtures were crushed granite, crushed river gravel, sand, sandy loam, and limestone dust. The pavement was placed in courses and each course was initially rolled with a 3-wheeled roller and finished with a 10-ton tandem roller. It is not known how many coverages were applied, but an effort was made to obtain high densities in construction. Cores were cut from the completed pavement outside of the traffic lanes and tested for density, stability and flow. Samples of the unmixed pavement aggregates were also furnished the Waterways Experiment Station. The six pavement designs were duplicated in the laboratory and specimens were compacted using 50 blows of the 12.5-lb. hammer, 3-7/8 in. foot. Test properties were determined for the laboratory specimens.

Table 6 shows a comparison of unit weights for the field and laboratory specimens for the six pavement designs. It may be seen from the tabulation that for the binder courses the unit weights of the field samples ranged from 7 lb. per cu.



Mac Dill Field, Florida

Figure 3. Comparison Between Laboratory and Field Compaction

ft. above to 3 lb. per cu. ft. below the corresponding laboratory densities. In the wearing courses the unit weights of the field samples ranged from equal to 6 lb. per cu. ft. below the laboratory densities. Since the laboratory compactive effort was 50 blows of the 12.5-lb. hammer, 3-7/8 in. foot, and not the lesser 10-blow effort which approximated construction densities in the other projects investigated, it is apparent that in practically all cases the pavement densities were relatively high. This may have been due to the use of 10-ton rollers on the project or, in part, to compaction by casual traffic over these areas.

Summary - Investigations at seven airfields throughout the country showed that in the majority of cases 10 blows of the 12.5-lb. hammer with 3-7/8 in. foot procuded higher laboratory densities than were obtained in the construction of the pavement, but in two cases the laboratory density was exceeded in the field. Further information was obtained at two carefully controlled rolling studies at Eglin Field and MacDill Field, Florida, which indicated that it was possible to obtain pavement densities equivalent to those obtained in the laboratory with 10 blows of the 12.5-lb. hammer, 3-7/8 in. foot. Data from Stockton No. 2 test section also indicated that high pavement densities might be obtained in construction.

The field and laboratory correlations of as-constructed pavement densities were based on the original laboratory compaction procedure and on the laboratory procedure using the 12.5-lb. hammer, 3-7/8 in. foot. Inasmuch as neither of these procedures used the 10-lb., 3-7/8 in. foot hammer finally selected for the laboratory design test, it was necessary to correlate between the various compactive efforts in the laboratory. This was accomplished by preparing several bituminous mixtures, both sand asphalts and asphaltic concretes, at the approximate design optimum asphalt contents. Specimens of each mixture were compacted by (a) the original procedure, (b) by 10 blows of the 12.5-lb. hammer with 3-7/8 in. foot, and (c) by 10, 15, and 20 blows of the 10-lb. hammer with the 3-7/8 in. foot. The data for these tests are not presented here: however, from an analysis of the results it was concluded that 15 blows of the 10-lb., 3-7/8 in. hammer could be used for construction control of bituminous pavements.

As a final measure, it was considered that the 15-blow compactive effort (10-lb. 3-7/8 in. hammer) might be confused with the 50-blow compaction procedure (10-lb., 3-7/8 in. hammer) used in design. Also,

TABLE 6

Comparison of Field and Laboratory Densities
Stockton Test Section No. 2, California

Design Number	Course	Unit Weight -- Lb. Per Cu. Ft. Field	Laboratory
1	Binder	156	149
2	Binder	156	157
3	Wearing	151	151
4	Wearing	149	153
5	Binder	151	154
6	Wearing	146	152

TABLE 7

Correlation of Laboratory Densities,
15-Blow and 50-Blow Compaction

	Density: Per Cent Maximum Theoretical				Unit Weight Total Mix			
Identification	(1) 15-Blow Per Cent	(2) 50-Blow Per Cent	(3) Diff. Per Cent	(4) (1) / (2) Per Cent	(5) 15-Blow Lb	(6) 50-Blow Lb	(7) Diff. Lb	(8) (5) / (6) Per Cent
Sand Asphalt								
Blend A	92.0	94.7	2.7	97.1	136.9	141.0	4.1	97.1
Blend 3	90.3	93.4	3.1	96.7	133.9	138.5	4.6	96.7
Blend 4	94.5	96.1	1.6	98.3	142.3	144.8	2.5	98.3
Blend 5	93.1	95.2	2.1	97.8	141.7	144.8	3.1	97.8
Blend 8	91.6	93.9	2.3	97.6	137.7	141.1	3.4	97.6
Asphaltic Concrete								
Blend B (Gravel)	94.3	95.6	1.3	98.6	144.7	146.7	2.0	98.6
Blend B (Slag)	94.9	96.8	1.9	98.0	141.7	144.5	2.8	98.0
Blend B (Crushed Limestone)	93.6	95.5	1.9	98.0	148.2	151.3	3.1	98.0
Mix 11 (Crushed Limestone)	94.4	95.7	1.3	98.6	147.6	149.7	2.1	98.6
Blend 10 (Gravel)	92.8	94.6	1.8	98.1	142.5	145.2	2.7	98.1
Blend 12 (Gravel)	93.9	95.3	1.4	98.5	143.8	145.9	2.1	98.5
Approximate Average			2.0	98.0			3.0	98.0

the use of two compactive efforts requires additional laboratory work. Therefore, analyses were made which are intended to provide a method for the control of construction densities based entirely on the compaction effort used for design. Five sand asphalt and six asphaltic concrete mixtures were prepared in the laboratory at their design optimum asphalt contents. Specimens of each mixture were compacted using both 15 and 50 blows of the 10-lb. hammer, 3-7/8 in. diameter foot. The densities of compacted specimens from these tests are shown on Table 7, both as percent of maximum theoretical density and as unit weight in lb. per cu. ft. The difference in densities for the two compactive efforts on each mixture was obtained and expressed as a percentage of the 50-blow density used for design. Although the indicated percentage values vary somewhat, the variation is small. On the average, the density of a specimen compacted to 15 blows will be 98 percent of the density obtained with 50-blow compaction. It is considered therefore, that good construction rolling shall be stipulated as that amount which produces a density in the pavement equivalent to 98 percent of that determined by the 50-blow compactive effort used for design.

CONCLUSIONS

Based on the results of analyses and investigations presented in this paper, the following conclusions are made:

a. The laboratory compactive effort for use in design of asphalt paving mixtures should consist of 50 blows on each side of the specimen, using a 10-lb. hammer with 18 in. drop and a 3-7/8-in. diameter foot.

b. Good construction rolling can be considered that effort which produces a density in the asphalt pavement equal to 98 percent of that secured by the 50-blow laboratory compaction.