"COMPACTION OF FLEXIBLE PAVEMENTS"

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Introduction

If the various layers of a flexible pavement structure are not compacted adequately during construction, they will compact further under traffic, or under the weight of the overlying layers. The additional compaction will result in settlement of the surface. Generally, settlement under traffic does not produce a total disruption of the surface, but settlement sufficient to require leveling is a common condition at bridge approaches, culverts, and occasionally in the traffic wheel paths. Another reason for compacting subgrades and other layers is to obtain the highest strength practical and thus obtain an economical design. Generally the strength increases with density and by compacting the soil to the highest density that can be obtained practicably and that will be retained in the structure during its life, the thinnest and most economical design will result. This paper presents information on the density that develops in soils under traffic, and a summation of the compaction capabilities of various types of equipment.

The asphalt paving mixture must also be compacted to provide a smooth, stable, water-tight surface, and to a degree that future compaction under traffic will not be detrimental.

The paper is based primarily on data collected by the U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss., as a part of their studies on the development of flexible pavement design criteria for Air Force and Army Airfields.

Most of the relationships in this paper are presented by schematic diagrams rather than actual presentations of test data. The trends indicated by the schematic diagrams are in most instances supported adequately by published data and references are given to indicate the source of the data. In some instances the schematic diagrams represent the author's estimate; these cases are indicated.
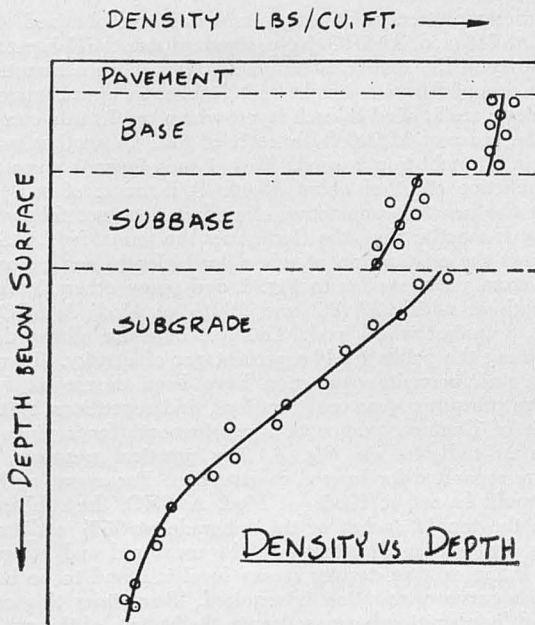
Subgrades, Subbases, and Base Courses

In order to have a logical design procedure, the density that will attain in each layer from initial compaction, traffic compaction, and expansion and shrinkage due to variation in moisture, should be known. Unfortunately, there is little information available on the ultimate density of subgrades, subbases, and base courses.
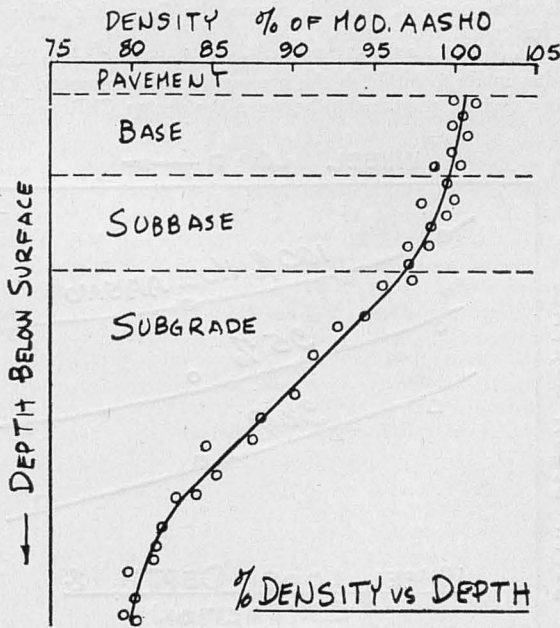
Required Density

Studies of accelerated traffic test sections and airfield pavements that have been subjected to a heavy concentration of traffic have indicated a definite tendency for densities to be higher in the upper levels and to decrease with depth. Fig. 1 is a schematic diagram of a typical group of measurements..* Density is plotted in lbs/cu ft versus depth from the surface. The density in lbs/cu ft varies with the specific gravity of the particles, as well as the degree of compaction; however, by expressing the density in a percentage of that produced in a standard laboratory compaction test the effect of specific gravity is eliminated

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* Refer to items in list of references.

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DENSITY LBS/CU. FT. ⟶

PAVEMENT

BASE

SUBBASE

SUBGRADE

DEPTH BELOW SURFACE ⟶

DENSITY vs DEPTH

NBCA 2605   FIGURE 1

DENSITY % OF MOD. AASHO

75   80   85   90   95   100   105

PAVEMENT

BASE

SUBBASE

SUBGRADE

DEPTH BELOW SURFACE ⟶

% DENSITY vs DEPTH

NBCA 2606   FIGURE 2

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and a more orderly pattern of density versus depth is obtained as illustrated in Fig. 2. Both ASTM and AASHO have standardized the laboratory compaction test. In one variation the sample is compacted in a 4 inch diameter mold with a 5.5 lb hammer dropped from a height of 12 inches in approximately 1½" layers. A total of 25 blows are applied to each layer, which results in a computed compactive effort in the order of 12,000 ft/lb/cu ft of soil. In another variation a 10 lb hammer with an 18 inch drop is used. Each 1 inch layer is given 55 blows for a computed compactive effort of about 56,000 ft/lb/cu ft of soil. The Corps of Engineers uses the heavier compactive effort but does not follow the ASTM or AASHO standards exactly; thus, the Corps uses the term Mod. AASHO.

Fig. 3 shows the relationship of wheel load, depth, and percent compaction as determined from pilots similar to Fig. 2 and many other similar plots. From Fig. 2 the depth at which 90, 95, and 100% of Mod. AASHO occurred are plotted on Fig. 3 against wheel load. This was done for all the data and curves were drawn joining the points for like percentages of density. These relationships of load, depth and percent compaction have been developed for a range of wheel loads, tire pressures, gear configurations, and repetitions by the Corps.

The Corps of Engineer compaction requirements for a given airplane load can be shown as indicated in Fig. 4. For practical purposes, however, the requirements are separated for layered construction. For example, the requirement for the base would be set at 103% of Mod. AASHO, the subbase at 100% of Mod. AASHO, the top 12 inches of the subgrade at 95% and any fill at 90% In cut sections the existing density would be measured and compared with the requirements. If the existing density at any level is found to be below the value indicated on the curve compaction is required. Sometimes this compaction can be accomplished by operating heavy rollers in the bottom of the cut, in other cases material must be excavated and the layer compacted.

In the majority of cases studied by the Flexible Pavement Laboratory, cohesionless sands plotted at about 5 points higher on the percent density scale than materials with cohesion. For this reason, the Corps has different compaction requirements for cohesionless sands.

A publication of the Flexible Pavement Laboratory[1] summarizes the result of all the studies made to establish the compaction requirements. This report also shows there is a definite relationship between the design CBR and the compaction


WHEEL LOAD, DEPTH, & % COMPACTION

NBCA 2607   FIGURE 3

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DENSITY % OF MOD. AASHO

TYPICAL COMPACTION REQUIREMENTS
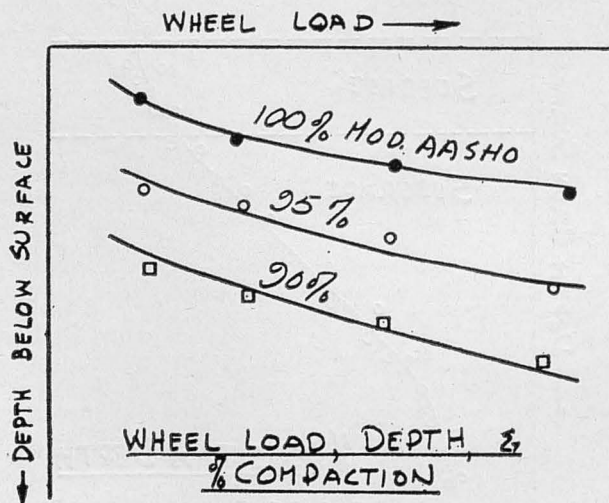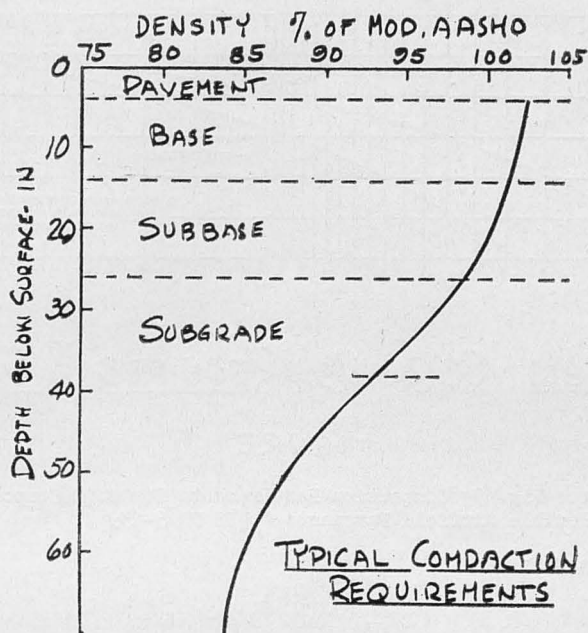
NBCA 2608   FIGURE 4

requirement specified by the Corps. In this relationship the design CBR is used merely as a parameter for integrating the effect of variations in wheel load, gear configuration, tire pressure, depth from the load to the layer being considered, and repetitions. The relationships between the design CBR and the required percentage of compaction given in reference 1 are shown in Fig. 5. The position of the curves is based on in-place densities measured in pavements that had been subjected to heavy traffic tempered with judgment. A point of explanation is in order concerning the density values in excess of 100% of Mod. AASHO. Since these values are typically found in gravelly materials there was considerable scatter of the data due to the inherent difficulties of sampling and determining proper reference densities. For this reason the Corps of Engineers has never specified densities in excess of 100% of Mod. AASHO although for extremely heavy loading proof rolling has been superimposed on the usual requirements to produce densities in the range of 102 and 103% of Mod. AASHO. Information is sorely needed for highway conditions on the densities required in base courses and subgrades. It is believed that the method suggested in reference 1 can be applied to highway conditions and also that the data developed for airfield loadings represents a good starting point for highways. Figs. 6 and 7 illustrate the methods suggested by reference 1. The method is illustrated for the following condition:

Traffic   : Kentucky EWL Group X
Surfacing : Asphalt pavement—4" thick
Base   : Crushed aggregate, 80 CBR or better,
                 cohesionless—8" thick
Subbase : Sandy gravel, 50 CBR or better, cohesionless
Subgrade : Silty sand, design CBR, as selected from lab-
                 oratory tests, 12, cohesive material; natural
                 densities as indicated by circles and dashed
                 line on Fig. 7.

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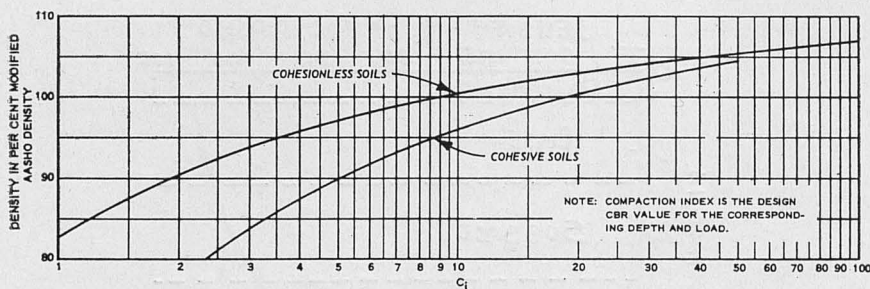
DESIGN CBR VS. REQUIRED % COMPACTION

FIGURE 5

Source Fig. 9 "Compaction Requirements for Soil Components of
  Flexible Airfield Pavements," WES TR 3-259

NBCA 2611

Fig. 6 is a typical CBR–thickness design chart; in this case the curve represents Kentucky's EWL group X loading. This is the heaviest loading used by Kentucky and was selected for illustration purposes to give a farily thick pavement section. The compaction requirements from Fig. 5 are superimposed on Fig. 6 by vertical arrows. To avoid confusion, only the requirements for cohesive soils are shown. As a specific example, the compaction index for 95% of Mod. AASHO density (Fig. 5) is 8.6. A compaction index of 8.6 occurs for any condition of loading and depth that requires a CBR of 8.6. As shown on Fig. 7, this occurs for Kentucky EWL group X loading at a depth of almost 19 inches. In a similar manner, depths are determined for other percentages of density and used to plot the curves shown in the left part of Fig. 7. These curves represent the depths to which the various percentages of compaction are indicated as necessary for Kentucky EWL X loading. The right hand part of Fig. 7 is the pavement section for the specific conditions set forth in the example. Arrows are drawn from the contacts of the various layers to intersect the respective compaction-depth curve.

It can be seen that the compaction indicated as necessary for the base and subbase courses is in excess of 100% of Mod. AASHO density. As noted previously, specification requirements for more than 100% of Mod. AASHO have not been used although proof rolling has been used to produce densities in the order of 102 to 103% of Mod. AASHO. The Corps of Engineers has experienced no significant difficulty with traffic compaction under airplanes under these circumstances. It remains to be seen whether densities in excess of 100% of Mod. are needed in bases and subbases for highways.

Values for the natural densities of the subgrade have been plotted at the depth they will occur in the finished section. It can be seen that compaction of traffic will produce densities higher than the natural density down to a depth of about 28 inches. The indicated requirement would be 95% of Mod. AASHO density in the top 6 inches and 90% in the next 4 inches. In practice this latter figure would normally be increased to a nominal lift thickness, say 6 inches. In cut sections, no compaction would be needed below this depth. In fill sections, general practice in the Corps of Engineers is to require 90% of Mod. AASHO (in cohesive soils) in the lower levels.

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Compaction During Construction

In compacting subgrades and foundations for fills, it is necessary that organic soils, roots, vegetation, and other material that will decompose or develop extremely low strength be removed before operations are started. Five years ago the author would have considered this statement trit; however, during investigation of isolated areas of settlement in an airfield some four years ago, logs, roots, and grass were found at the contact between the subgrade and the subbase. The areas of settlement were exactly on 100' centers and when pits were excavated the grade stakes were still in place. The general conditions suggested that the area around each 100' station stake was not stripped adequately, further it appeared that logs and debris picked up from adjacent areas were piled around the grade stakes. As recently as this past summer, the author was shown a job where the base course contractor encountered numerous buried stumps during fine grading of the subgrade.

In addition to the obvious item of stripping, it is necessary that the fill and subgrade be compacted to the design density. In cohesive soils it is also necessary that they be compacted at the design moisture content because the future strength of a cohesive soil depends as much on the moisture content at which it is compacted as on the moisture content it finally adjusts to.

In cohesive soils, densities in the order of 95% of standard AASHO can be obtained with practically any of the current rollers and tampers; however, vibrators
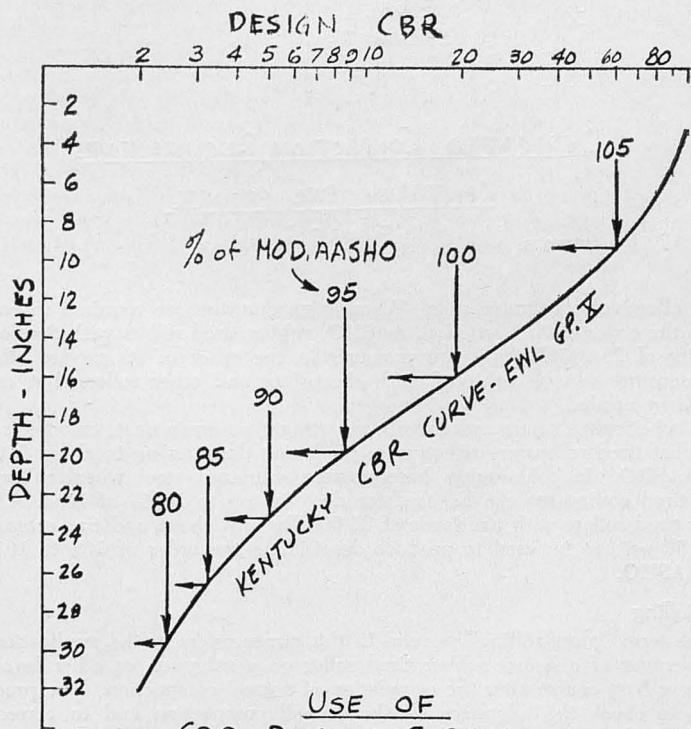
USE OF
CBR DESIGN CURVE IN
DEVELOPING COMPACTION REQUIREMENTS

FIGURE 6
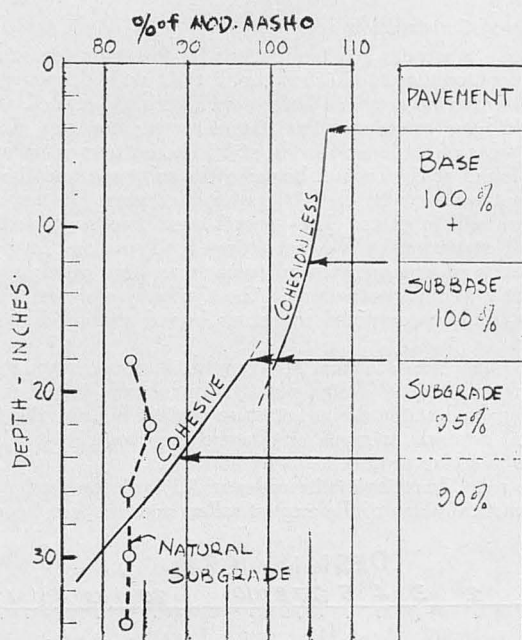
% of MOD. AASHO

INDICATED COMPACTION REQUIREMENTS

KENTUCKY EWL GROUP X

FIGURE 7

NBCA 2613

are not effective in cohesive soils. Where high densities are required in cohesive soils, in the order of 95% of Mod. AASHO, rubber tired rollers with tire loads in the order of 25,000 lbs and tire pressures in the order of 90 psi are effective. These densities can be achieved with sheepsfoot and other rollers, but extreme care will be needed.

In cohesionless sands and gravels, vibrating type equipment, crawler tractors, and rubber tired rollers are effective in producing densities up to about 100% of Mod. AASHO. In cohesionless base courses, vibrators, steel wheel rollers, and rubber tired equipment can be used for densities up to 100% of Mod. AASHO. Rubber tired rollers with tire loads of 30,000 lbs and above and tire pressures of 90 to 150 psi can be used to produce densities in the order of 102 to 103% of Mod. AASHO.
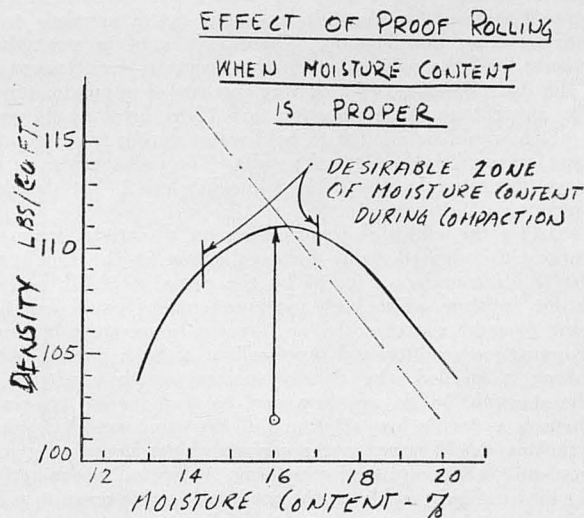
Proof-Rolling

The term "proof-rolling" as used in this paper refers to the application of a few coverages of a heavy rubber tired roller on a subgrade or other layer of a subbase or base course after the completion of normal compaction. The procedure is used to check the adequacy of the normal compaction and to correct any deficiencies that may exist. In recent months several states have incorporated proof-rolling requirements into their specifications for heavy-duty pavements. Proof-rolling is an excellent tool that will assist materially in the construction of adequate pavements, but there is a growing tendency to look on proof-rolling as a panacea for all compaction problems, even to the extent of relaxing on inspection

and construction control testing where proof-rolling is being used. Proof-rolling will accomplish the intended purpose only when the moisture content is near optimum. This is illustrated as follows:
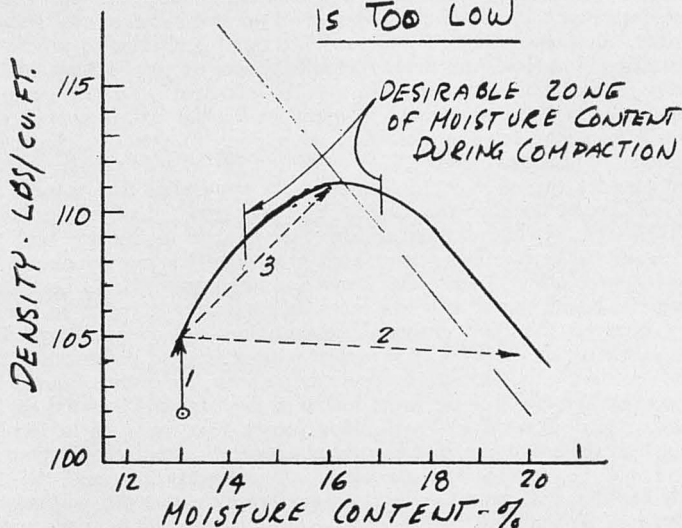
Fig. 8 illustrates the case where the moisture content is near optimum but for some reason the density obtained is well below that specified. This condition is illustrated on Fig. 8 by the circle shown at 16 percent moisture and 102-lb per cu ft density. It is assumed that this condition exists just prior to proof-rolling. As proof-rolling is applied, the density increases; and as proof-rolling continues, the density reaches the maximum that can be obtained with the compaction effort. Since the moisture was about at optimum for the compaction effort, the strength will be adequate even after field saturation. In this case, proof-rolling accomplished the intended purpose.

Next consider the effect of proof-rolling on a material that is well below optimum (13 percent) moisture during the time that proof-rolling is being accomplished. The circle indicated on Fig. 9 at 13 percent moisture and 102-lb per cu ft density is the case being considered. The density is low because of faulty rolling or for some other reason. The lower moisture content could be the result of the material being placed at a low moisture content or it could be the result of drying between the time of normal compaction and proof-rolling. In cohesionless materials, the time between normal compaction and proof-rolling is very critical because not only does drying occur but a loss of moisture from drainage can also occur. The effect of the proof-rolling in this case is illustrated on Fig. 9 by the solid line designated 1. Proof-rolling brings the density up to 105-lb per cu ft, which is the maximum that can be obtained with that compaction effort. Strength would be very high immediately after construction, and the job is apparently one that will stand forever. Assume, however, that this particular road is completed in the late fall but the road cannot be opened to traffic until the following summer because shoulder work or some other leement is not complete. In the meantime, the moisture content increases during the wet winter weather and approaches the compaction curve on the wet side. This change in moisture content is indicated on Fig. 9 by the dashed line labeled 2. The line is slanted downward because almost always some swelling will occur upon saturation. A large decrease in strength will occur. With continuous traffic on the pavement,

EFFECT OF PROOF ROLLING

WHEN MOISTURE CONTENT IS PROPER

DESIRABLE ZONE OF MOISTURE CONTENT DURING COMPACTION

DENSITY LBS/CU FT.

MOISTURE CONTENT - %

FIGURE 8

25

EFFECT OF PROOF ROLLING
WHEN MOISTURE CONTENT
IS TOO LOW

NBCA 85911   FIGURE 9

distress in the form of cracking or displacement will develop quickly. In this case, the proof-rolling was wasted and, further, it produced a false sense of security.

The case illustrated on Fig. 9 by the dashed line labeled 3 results when the moisture content increases moderately to about optimum while traffic is being applied, with resulting densification. There is a gain in strength as moisture content increases, and the only effect on the structure is settlement in the wheel paths. For the case illustrated, the density increase is approximately 6 lb, or 5.7 percent. This percentage of densification in a 12-in. layer would produce 0.7-in. settlement, which would be enough to hold water during rains. Again, the proof-rolling did not accomplish the desired results. The deficiencies are not as severe as in the case illustrated by the dashed line labeled 2, but the deficiency will require correction.

Next, consider the effect of proof-rolling on a material when the moisture content is above the desired value for compaction at the time proof-rolling is started. This is illustrated on Fig. 10 by the circle at 102-lb per cu ft density and 19 percent moisture. The high moisture content could be caused by the material being placed too wet or by an increase in moisture from rain between the time of normal compaction and proof-rolling or by a ground-water condition. As proof-rolling is applied, the density increases with coverages. As density increases the strength builds up; however, as the density crosses the line of tptimum, there is a drastic loss of strength. Weaving would develop under the roller and cracking would occur in the surface of the layer being rolled. In this case, the proof-rolling accomplished something. It located wet material that would subsequently have caused trouble on the road and in this sense it was not wasted.

From the discussions given above, the following statements are considered applicable to proof-rolling:

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a. If the moisture content is in the proper range for compaction, proof-rolling will correct compaction deficiencies.

b. If the moisture content is well on the wet side of optimum, proof-rolling will locate this condition and thus permit correction of the condition during construction.

c. If the moisture content is on the dry side of the proper range for compaction, proof-rolling gives a false sense of security, because the layer looks firm and hard; but as moisture increases, the layer will either lose strength drastically or will compact further under traffic.
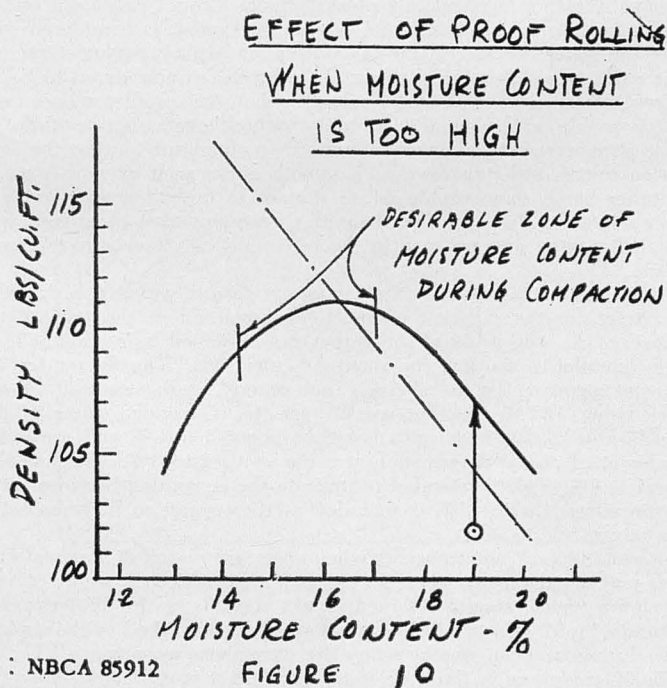
Compaction of Bituminous Mixtures
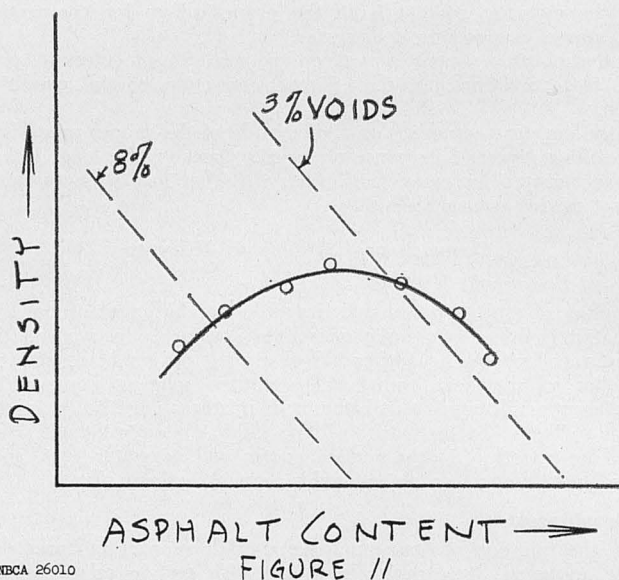
Why Compact Bituminous Mixtures

The rolling of asphalt pavements is such a standard part of the construction practice that it is difficult to force oneself to consider why we roll them. The very earliest recollections the author has of asphalt pavement construction are of a steam roller rolling sheet asphalt. The author believes, however, that most paving engineers would agree that bituminous mixtures must be compacted during construction so that: (1) the mixes will be stable under traffic, (2) the finished surface will be smooth, (3) the surface course will be water-tight, and (4) the mixtures will not compact an objectionable amount under traffic.

Density Requirements

Before the question of how much we should compact mixtures during construction is answered, it is desirable to establish certain relationships between density, asphalt content, and behavior.

Fig. 11 is a typical curve showing the relationship of density versus asphalt content that is obtained in a laboratory compaction test[2,3] when samples are com-

EFFECT OF PROOF ROLLING WHEN MOISTURE CONTENT IS TOO HIGH

: NBCA 85912   FIGURE 10
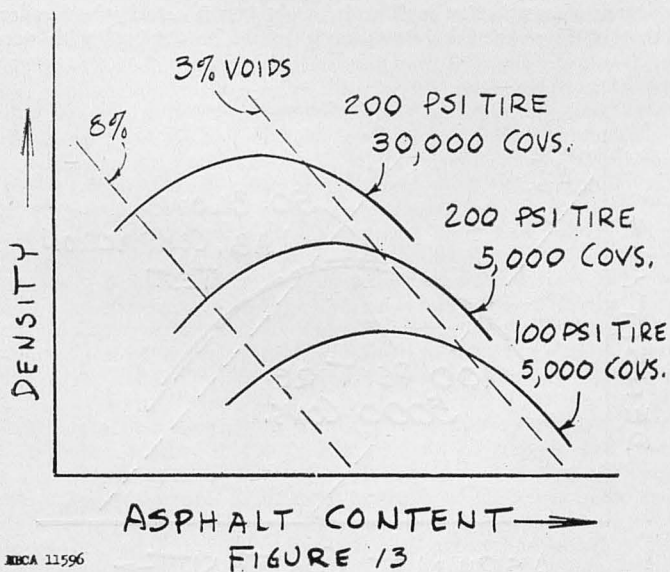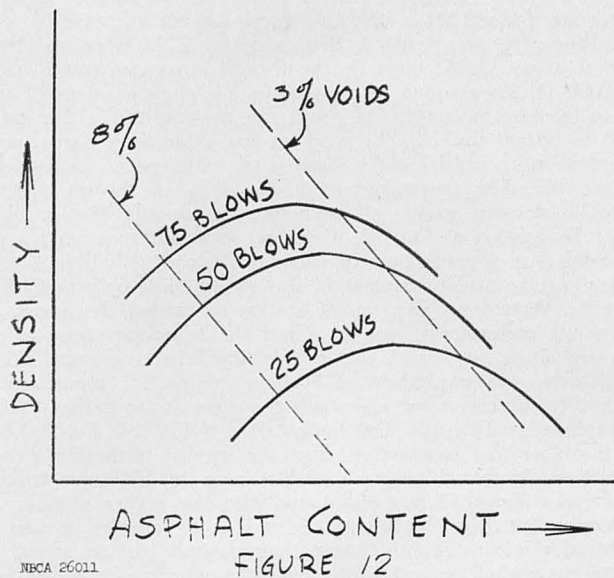
27

ASPHALT CONTENT →

FIGURE 11

NBCA 26010

pacted at increasing asphalt contents with a constant compactive effort. Density increases with increasing asphalt content up to a certain point after which density decreases with further increases in asphalt content. The relationship is quite similar to that obtained in a soil compaction test if the asphalt is considered the liquid in lieu of the water. In fact many relationships in asphalt paving mixtures follow the same pattern as soil-water mixtures if the asphalt is considered to be a liquid. In one respect the problem is more complex than soil problems because asphalt cement has such a wide change in viscosity with change in temperature. For this reason, it is necessary to maintain a uniform temperature during the laboratory compaction test in order to develop a smooth curve such as shown on Fig. 11. On the other hand, some problems are simpler in asphalt paving mixtures than soil-water mixtures. For example, there is no accumulation of asphalt with time in an asphalt paving mixture such as the accumulation of moisture that occurs in a subgrade.
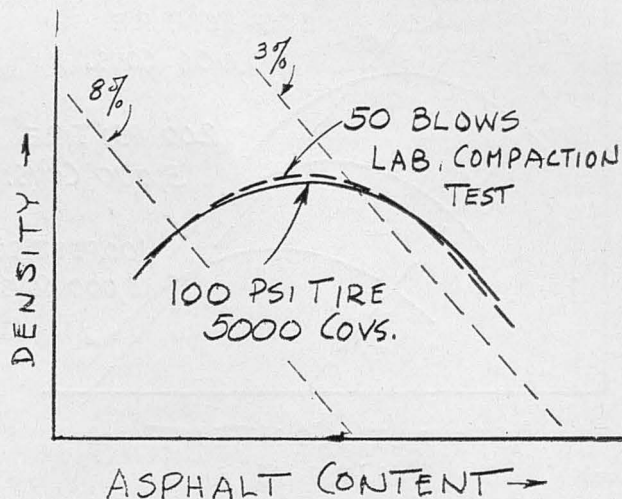
If the compactive effort in the laboratory test is varied the density versus asphalt curves for the different compactive efforts fall in the typical pattern[2,4] shown in Fig. 12. The peaks of the curves can be joined by a straight line which is roughly parallel to the line for about 4% air voids. The figures for air voids used in this paper refer to relatively non-porous aggregates and to air voids computed using ASTM apparent specific gravity. Generally, mixes of this type are considered water-tight at voids less than about 8 to 9% and are stable from the standpoint of plastic deformation at voids above 2 to 3%. The line shown on the figures at 3% voids is intended to indicate the separation between satisfactory and plastic mixes; that at 8% is intended as the separation between satisfactory and lean mixes.

This same typical pattern occurs when mixes are placed at a range of bitumen contents, compacted during construction, and then subjected to prototype traffic. Fig. 13 shows typical results obtained in test sections at the Waterways Experiment Station in Vicksburg.[2,3] The sections were trafficked with airplane tires primarily during summer months when the pavements were warm. The application of 5,000 coverages in the accelerated traffic test is estimated to produce the

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DENSITY →

8%

3% VOIDS

75 BLOWS

50 BLOWS

25 BLOWS

ASPHALT CONTENT →

NBCA 26011

FIGURE 12

DENSITY →

3% VOIDS

8%

200 PSI TIRE
30,000 COVS.

200 PSI TIRE
5,000 COVS.

100 PSI TIRE
5,000 COVS.

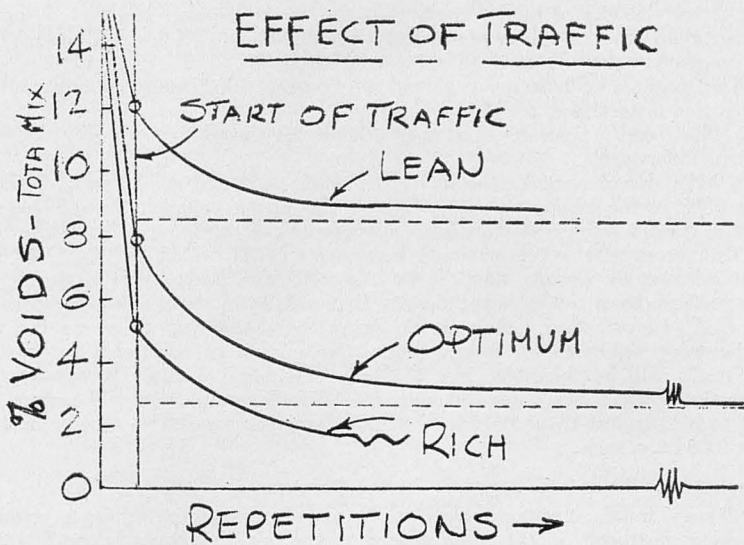ASPHALT CONTENT →

NBCA 11596

FIGURE 13

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same effect of 20 years of normal airfield traffic. It can be seen that increasing the tire pressure from 100 to 200 psi produced an increase in compactive effort[4,5,6] and the effect was similar to that produced in the laboratory by changing the number of blows. Also, when the number of coverages was increased from 5,000 to 30,000 (this was done to compensate for channelization of traffic) the effect was an increase in compactive effort. In these tests the tire loads ranged from 10,000 to 66,000 lbs.[7] In the work at the Waterways Experiment Station many pavements were placed and subjected to traffic primarily to develop this item. Also, considerable laboratory testing was done, on the same mixes placed under traffic, to develop means of predicting the density that would develop under traffic. By looking at Fig. 12, it can be seen that specifying a given percentage of voids (or a percentage of theoretical density) will not get the job done unless a specific asphalt content is also stated. The only method found in the work at the Waterways Experiment Station to predict the density that will develop in a mix under traffic was to adjust the laboratory compaction test to produce an asphalt-density curve that closely simulated the curve produced by traffic. The studies indicated that the 50-blow compaction procedure produced an asphalt-density curve that was essentially the same as the traffic of 5,000 coverages of tires inflated to 100 psi.[2] This is illustrated in Fig. 14. For 200 psi tires an increase in the laboratory compactive effort was needed to duplicate the increase in field densities. Increased numbers of blows up to 150 were tried, but the effect of increases above 75 was slight and also the higher numbers of blows produced degradation of the aggregate. It was finally decided to use 75 blows, which produced densities slightly lower than desired and to adjust the voids criteria to give the asphalt content which would be optimum for traffic compaction.

With a method available to predict the density that will develop under traffic, the designer is now able to consider the question of how much density he should require during construction. The obvious answer would be to require the ultimate density and be done with it. Prior to the advent of the rubber tired asphalt roller, this requirement would have been expensive. The Corps of Engineers specifies compaction during construction to a minimum of 98% of the laboratory density and this degree of compaction is difficult to obtain with steel wheel rollers. It is doubted that 100% of the laboratory density could be obtained with steel wheel

FIGURE 14

EFFECT OF TRAFFIC

% VOIDS - TOTAL MIX

14
12 — START OF TRAFFIC
10 — LEAN
8
6
4 — OPTIMUM
2 — RICH
0

REPETITIONS →

NBCA 1605

FIGURE 15

rollers. However, with the rubber tired rollers high densities can be obtained and the designer must consider the possible consequences of trying to compact to the ultimate density during construction.

Fig. 15 illustrates the effect of traffic on asphalt paving mixtures as experienced in the several accelerated traffic tests conducted at the Waterways Experiment Station. As illustrated in Fig. 15, the mixes were compacted to a certain density (or percentage of voids) during construction. Traffic continued to compact the mixes, rapidly at first and at a decreasing rate as traffic continued. For very lean mixes neither construction rolling nor traffic produced a water-tight mix, indicated at somewhere between 8 and 9% voids, and ravelling could be expected. For mixes at optimum asphalt content, construction rolling produced a density that was adequate for water-tightness. Traffic produced additional compaction and in the accelerated traffic tests at Vicksburg densification continued as long as traffic was continued. Some data were collected from tests where traffic was delayed for a year and from airfields under actual traffic that indicate densification may not continue for the entire life of the pavement in actual service, however, the trend appears to be that densification continues for several years. The next case illustrated by the lower curve on Fig. 15 is for a mix on the rich side of optimum. Construction rolling produced a very water-tight mix. Traffic continued to produce densification to the point where the mix flushed, indicated at somewhere between 2 and 3% voids. After flushing occurred, successive sampling showed a scatter of points, but no further densification.

The evidence that compaction continues with traffic for several years is the basis of the author's belief that compaction should be stopped just short of the ultimate density. A small amount of data collected in one of the accelerated traffic tests at the Waterways Experiment Station indicated that traffic compaction occurred in mixes compacted during construction to low percentages of voids (ultimate density) and that these mixes flushed when possibly they would not have flushed if they had not been compacted to such a low percentage during construction. These findings plus the advent of the rubber tired roller, led to the adoption of a top density requirement by the Corps of Engineers. It is the

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intention of the Corps' requirements that the mixes be well compacted during construction (98% of laboratory density—usually about 7% or 6% voids) but that compaction stops short of "flushing" the mix.

The question of how much should we compact bituminous mixtures during construction is answered as follows:

a. We need a laboratory test that will predict the ultimate density that will develop under traffic.

b. We should compact the mix to be water-tight and stable, which will be about 98% of the laboratory value, but we should not compact the mix beyond 100% of the laboratory value because of danger of early flushing under traffic.

The intent of the compaction requirements is illustrated by Fig. 16. The curve indicates the density that can be expected from traffic. The circle off the chart at the bottom indicates the density that will be in the mat as the spreader moves off. Construction rolling should bring the density up to where the mix will be water-tight, stable, and to where the amount of additional compaction from traffic will be tolerable. For the case illustrated in Fig. 16, construction compaction reduces the voids to about 6% . Traffic compaction will reduce the voids to a little less than 4%. In a 3 inch layer this would be a settlement of about 0.06 of an inch.

Compaction of Bituminous Mixtures During Construction

There is much current emphasis on the use of rubber tired rollers to compact bituminous mixtures. In the usual procedure the mix is "knocked-down" with a steel wheel roller, compaction is applied with a rubber tired roller, and final smoothing is done with a steel wheel roller. The author's first experience in the use of rubber tired rollers was in connection with compacting "so-called" lean mixes for very heavy aircraft. These lean mixes check so badly under a steel wheel roller that they cannot be compacted with a steel wheel roller. They can be compacted with rubber tired rollers without further checking; in fact, rubber tired rolling apparently heals the check marks completely. In this case the rubber tired roller is a necessity.

FIGURE 16

32
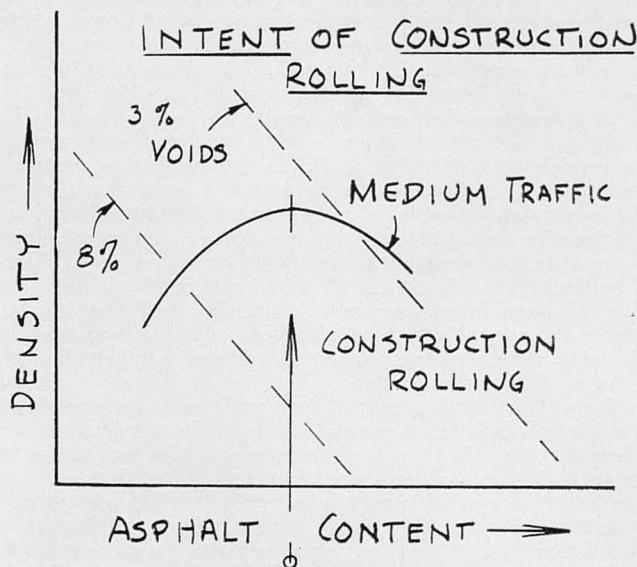
For conventional paving mixtures, however, the rubber tired roller is not a necessity since conventional pavements can be compacted to acceptable degrees of compaction by careful attention to details. It follows then that rubber tired rollers should be used on conventional pavements only if (1) they are more economical or (2) if they produce a better job. The author is convinced that rubber tired rollers are an efficient tool for compacting hot mixes but he is also convinced that the only possible method of determining which method of rolling is the more economical is by competitive bidding. The author also feels that rubber tired rolling will produce acceptable results under more unfavorable weather conditions than steel wheel rolling. At the present time the author recommends that rolling requirements be based on a percentage of laboratory density and the contractor permitted to use rubber tired rollers if he so desires. The author would also suggest that rubber tired rolling be required on jobs that must be done under unfavorable weather conditions.

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