

Field Control of Hot Bituminous Mixtures By the Marshall Method

Lab Experiment #11

Submitted to:

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CE 361: Highways Materials Laboratory

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II. Results

Table 2.1: Data, Calculations, and Relative Compaction of BYU Asphalt Parking Lot Pavement.

Test #1: Wet Density (lb/ft ³)	Test #2: Wet Density (lb/ft ³)	Test #3: Wet Density (lb/ft ³)	Average Density (lb/ft ³)	Density of Laboratory Compacted Specimen (lb/ft ³)	Relative Compaction (%)
131.60	124.40	120.20	125.40	135.00	92.89

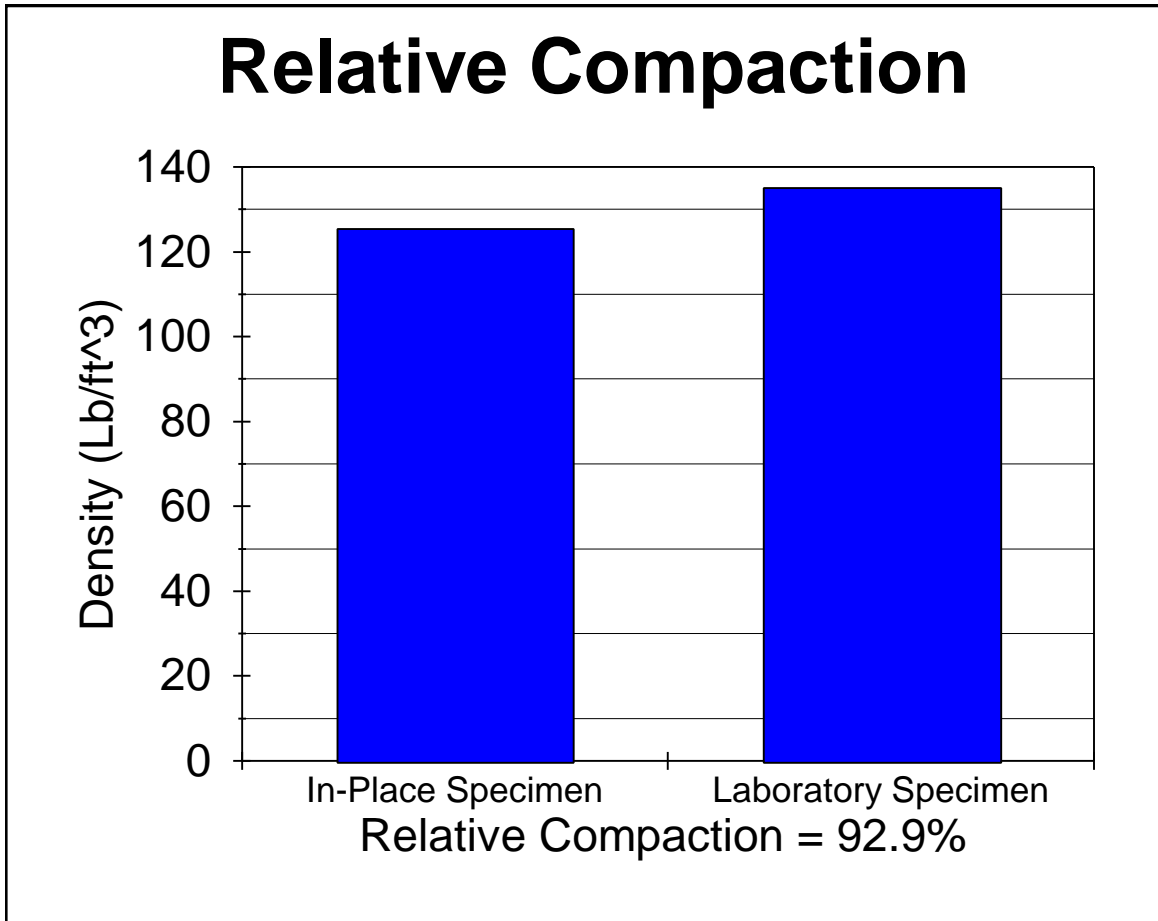


Figure 2.1: Relative Compaction of the In-Place Paving Mixture

In table 2.1 and figure 2.1, one may observe the data and calculations from the laboratory. The relative compaction of the in-place material at the BYU parking lot was determined to be 92.9%, assuming that the compaction of the laboratory specimen would be 135 lb/ft³.

III. Discussion

Procedure

Preparation of the specimens

Typically, three laboratory compacted asphalt specimens would be made which coincided with the plant mix asphalt concrete and aggregate mixture. The specific gravity of each of these specimens would be determined experimentally and the density in pounds per cubic feet would be calculated. The average densities of the three

tested specimens would then be determined. The density of the "in-place" mixture would then be determined. Using the density obtained from the laboratory compacted specimens and the density obtained from the "in-place" mixture, the relative compaction of the in-place asphalt with respect to the laboratory compacted specimens could be determined. But a laboratory compacted density of 135 lb/ft³ was assumed in this study, and the density of the in-place asphalt was determined by nuclear methods.

Methods used in determining the Relative Compaction of the "In-Place" Mixture

The density of the in-place asphalt concrete was determined by use of nuclear equipment, shown in figure 2.2. This equipment used gamma radiation to determine the density of the pavement surface. To obtain the density, the gamma radiation was emitted from the "source" and reflected toward the detectors. As the gamma radiation progresses from the source toward the detectors, the radiation collides with electrons located in the path, and *the higher the density of the material in the path of the radiation, the lower the number of particles which reach the detectors*. This was how the density was determined. The processor within the nuclear equipment calculated the density of the surface material from the amount of particles reaching the detectors from the source.

Figure 2.2: Nuclear Equipment used for Determining the Density of the In-Place Pavement, Showing the Backscatter and Direct Transmission Geometries.

The backscatter mode may be a slightly inaccurate method for determining the density of a pavement for 2 reasons. First, some of the radiation may have been transmitted *directly* from the source to the detectors, not even passing through the pavement and measuring its density. The amount of radiation not passing through the specimen being tested is assumed to be less than 10% of the total radiation emitted. (See information on the nuclear testing equipment, p. A-2). Second, the average energy of radiation reaching the detector in the backscatter mode is lower than the energy delivered in the direct transmission mode, also pictured in figure 2.2. This phenomenon may cause a higher density reading than the actual density of the pavement.

The density of the pavement was determined by applying the test for 1 minute in three different locations. The average of the densities from these tests was determined, and the average density was calculated to be 125.4 lb/ft³. Dividing this value by the assumed value of the laboratory compacted specimens, 135 lb/ft³, a relative compaction of 92.9% was determined. The relationship between the densities of the in-place and laboratory specimens may be observed in figure 2.1.

Answers to "Observations and Discussion"

1. Why is compaction important in constructing a pavement?

It is essential that a pavement is compacted properly when it is constructed because:

1. Compaction to the required density will increase the *strength* of the material.

2. Compaction to the required density will enhance the *resistance to settlement* and volume change in a pavement structure.

3. Proper compaction controls the number of air voids in a pavement. Adequate voids in the total compacted mixture must exist to permit a small amount of compaction when traffic load is applied without loss of stability, flushing, or bleeding. But at the same time low enough voids must exist in the pavement to prevent harmful penetration of air and moisture into the compacted mixture.

Proper compaction will ensure a durable pavement which is resistant to excessive settlement, bleeding and flushing, and environmental effects. Proper compaction is normally specified to be 90-95% of the laboratory compacted specimen (relative compaction). In this study, the relative compaction of the bituminous pavement was determined to be 92.9%.

2. How is "Relative Compaction" determined?

Relative compaction is obtained by first determining the density of three laboratory compacted specimens. After determining the average density of these three specimens, the density of a field specimen is obtained, either by experimentally determining the density of a core sample from the finished road or using nuclear equipment to determine the density.

After the average density of the laboratory specimens and the density of the in-place specimens are determined, the relative density may be obtained by dividing the density of the in-place pavement by the average density of the laboratory compacted specimens.

3. What factors determine the degree of compaction?

Six factors determine the degree of pavement compaction:

1. The compactive effort applied to the pavement when it is being laid.
2. The Quality of materials used.
3. The percent of asphalt cement contained in the pavement mixture.
4. The temperature of the pavement when it is laid.
5. The maximum density of the pavement mixture and the gradation of the aggregate used in the mix.
6. Environmental conditions in which the pavement is laid.

Uses of the test

The determination of the degree of pavement compaction is essential in determining whether the density of the pavement has been optimized. Normally, the density of a specimen is specified at 90-95% of the density of the optimum laboratory compacted specimen. If the relative compaction is between 90 and 95 percent, the pavement will have some additional room for compaction when vehicle loads are applied to it. In addition, if the relative compaction is to specifications, the strength of the pavement will be optimized throughout its design life.

Advantages/Disadvantages

Advantages:

The nuclear method of determining the density of asphalt pavements is highly advantageous since it is easy to use and takes a relatively short time. In this method, it is not necessary to remove a core specimen from the in-place road to determine its density.

The laboratory method of determining the density of asphalt pavements is quite a bit more cost effective as the equipment required for the nuclear method may require many thousands of dollars. In addition, if the laboratory method is performed correctly, the results obtained may be more accurate than the results from the nuclear test.

Disadvantages:

The nuclear method may not be practical because of the high initial capital investment involved in purchasing the equipment. In addition, the results obtained *in the backscatter mode* may not be completely accurate because some of the radiation emitted from the source may not pass through the material being tested.

The conventional laboratory method for determining density can be time consuming. In addition, it is necessary to remove a sample of pavement from the in-place road in order to test it. This pavement must then be brought to a field laboratory or another laboratory for testing. This "destructive" method can be avoided by using the "non-destructive" nuclear method.

Possible Errors

The possible errors include the following:

1. As was mentioned in the section, ***Methods used in determining the Relative Compaction of the "In-Place" Mixture***, the backscatter mode of the nuclear method may be inaccurate. First, some of the radiation may have been transmitted directly from the source to the detectors, not passing through the pavement. This phenomenon would cause the density reading to decrease. Second, the average energy of the radiation reaching the detector may be lower than if the test were performed in the direct transmission mode. This phenomenon would cause the density reading to increase. The net effect of the two sources of error is a slightly inaccurate density reading.

2. Second, temperature variations may have existed between the tested in-place pavement specimens and the laboratory compacted specimen. An increase in temperature would cause expansion of the pavement and a decrease in density. Thus, the density of the warmer specimens outside may be higher when tested at the same temperature as the specimen inside the laboratory.

3. Finally, error may have occurred if the thickness of the pavement was not sufficient for using the backscatter mode to test the material. For example, if the pavement were only 2 inches thick, the density of the base material below the pavement would be measured by the tester as well, resulting in an inaccurate measurement. But if the pavement were 4 to 6 inches thick, the measurement would be mostly that of the surface material.

Limitations of this Lab

The main limitation of the nuclear method compared with other methods is the high initial cost involved in purchasing the nuclear equipment. In addition, the accuracy of the readings is questionable. But empirical correction factors may be used if they are required to adjust the density obtained from the nuclear method. If high accuracy is required, the most appropriate method may be in a controlled laboratory situation using **ASTM D 2726** to determine the density of a cored pavement specimen.

IV. Conclusions

Properties of the Tested Material

The average density of the in-place pavement was calculated to be 125.4 lb/ft³. The standard density of the laboratory compacted specimen was given as 135.0 lb/ft³. These two values resulted in a relative compaction of 92.89%. This percentage of relative compaction indicates that the pavement mixture was compacted to the required relative compaction of 90-95%. If the laboratory value of 135.0 lb/ft³ was an optimum density, the paving material will have an optimum strength and will perform well by resisting settlement, bleeding and flushing, and penetration of water.

Engineering Significance of this lab

This laboratory may be used by a materials or a highway engineer to determine if the construction of the surface layer of a pavement structure is being performed according to specifications. The relative compaction is specified in construction. The pavement must then be constructed using this degree of compaction to insure that the pavement has optimum strength and resistance to weathering. If the pavement is not being constructed to the

specified degree of compaction, corrective measures should be taken to insure that the pavement is constructed to specifications. So the chief purpose of this test is used to control the compaction of pavement in the field. The densities may be obtained either from cored specimens or by nuclear methods.

V. Appendix

The following books were used for reference:

American Society for Testing and Materials. *1978 Annual Book of ASTM Standards*. Part 15. American Society for Testing and Materials, 1978.

Garber, Nicholas and Lester A. Hoel. *Traffic and Highway Engineering*. West Publishing Company, 1988.