Preparation of Aggregate Samples for Dynamic Testing

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A compaction device was developed that permits aggregate samples to be compacted by using the dynamic test equipment. Use of the device eliminates the need to move the specimen after it has been prepared. Tests were conducted to establish compaction procedures and to determine whether specimens compacted with the device experienced moisture or fines migration. The tests demonstrated that the method can be used to compact dense-graded aggregate materials to the modified Proctor (AASHTO T 180) maximum density without creating segregation or moisture migration. However, fines and moisture migration were observed when dry material and material significantly wetter than optimum were used. Recommendations are presented for preparing samples for dynamic testing using the device developed. Also included is an engineering drawing of the compaction device.

Aggregate samples for dynamic testing (i.e., resilient modulus and rapid shear strength) are normally compacted by vibratory methods. Typically, this involves the use of a small vibratory hammer equipped with a flat, cylindrical compaction head that fits within the compaction mold. The sample is compacted with the mold assembled on the triaxial cell base plate (Figure 1). After the sample is compacted, it is necessary to move the sample and base plate to the test machine.

DEVELOPMENT OF METHOD

The University of Arkansas, Department of Civil Engineering, developed an alternate method of sample preparation. The development was instigated because the department did not have the type of vibratory compaction equipment normally used. Also, the researchers wished to eliminate the need to move the sample after it was compacted. Therefore, this alternate method involves compacting the specimen by using dynamic test equipment.

Dynamic test equipment is a closed loop, hydraulic cyclic loading machine manufactured by MTS Systems Corporation, Minneapolis, Minnesota. The initial development attempt involved mounting a flat, cylindrical compaction head on the MTS load piston and then applying a vibratory force in essentially the same manner as was normally used with the vibratory hammer. However, several attempts with this approach by using various vibration frequencies failed to produce the target sample density. The target sample density was the maximum density determined by the modified Proctor test, AASHTO T 180 (*1*).

Subsequently, a modified compaction head (Figure 2) was developed that is able to produce the target density. The modification consists of attaching a ⅝-in. square bar across the diameter of the compaction head and then inserting a spring in the loading shaft. During compaction, the head is manually rotated. The square bar provides a concentration of the compactive effort and, during rotation, causes a reorientation of the aggregate particles. Although the bar protrudes into the top of the material during compaction, a uniform top surface is achieved by gradually raising and rotating the compaction head at the conclusion of compaction so that the bar "finishes" the surface during the final rotations.

The compaction head is mounted on the MTS loading shaft (Figure 3) in place of the load cell. The system is operated in strain control with the applied load limited by the maximum shaft movement and the spring in the compaction head. By using the strain control setting the maximum shaft movement is limited to 0.7 in. (18 mm). The head position is adjusted during compaction so that it lifts slightly above the aggregate at the top of each stroke to permit the manual rotation. As a result, the load spring is typically compressed between 0.4 and 0.5 in. (10 to 13 mm) during each compaction stroke.

It was determined through trial and error that the target density in a layer could be achieved by the MTS system being operated at a loading frequency of 10 Hz for 2 min. Five compaction layers were used for the 6-in. (152 mm) diameter by 12-in. (305 mm) high samples of crushed stone. Some adjustment in the time and frequency of loading may be necessary for other aggregates.

TESTING PROGRAM

Once a method had been established that produced the desired density, questions remained regarding the efficiency of the method and the uniformity of the resulting sample. Operational concerns involved the number of compaction layers, the vibrational frequency, and the compaction time. The uniformity concerns centered around potential problems of moisture and fines migration during compaction. A testing program was conducted to answer those concerns (*2*).

The measures of effectiveness used in the testing program were the achieved dry density and the migration of fines and moisture. The compacted samples were divided into top and bottom halves to check for fines and moisture migration. Each half was dried for moisture content and sieved for fines con-

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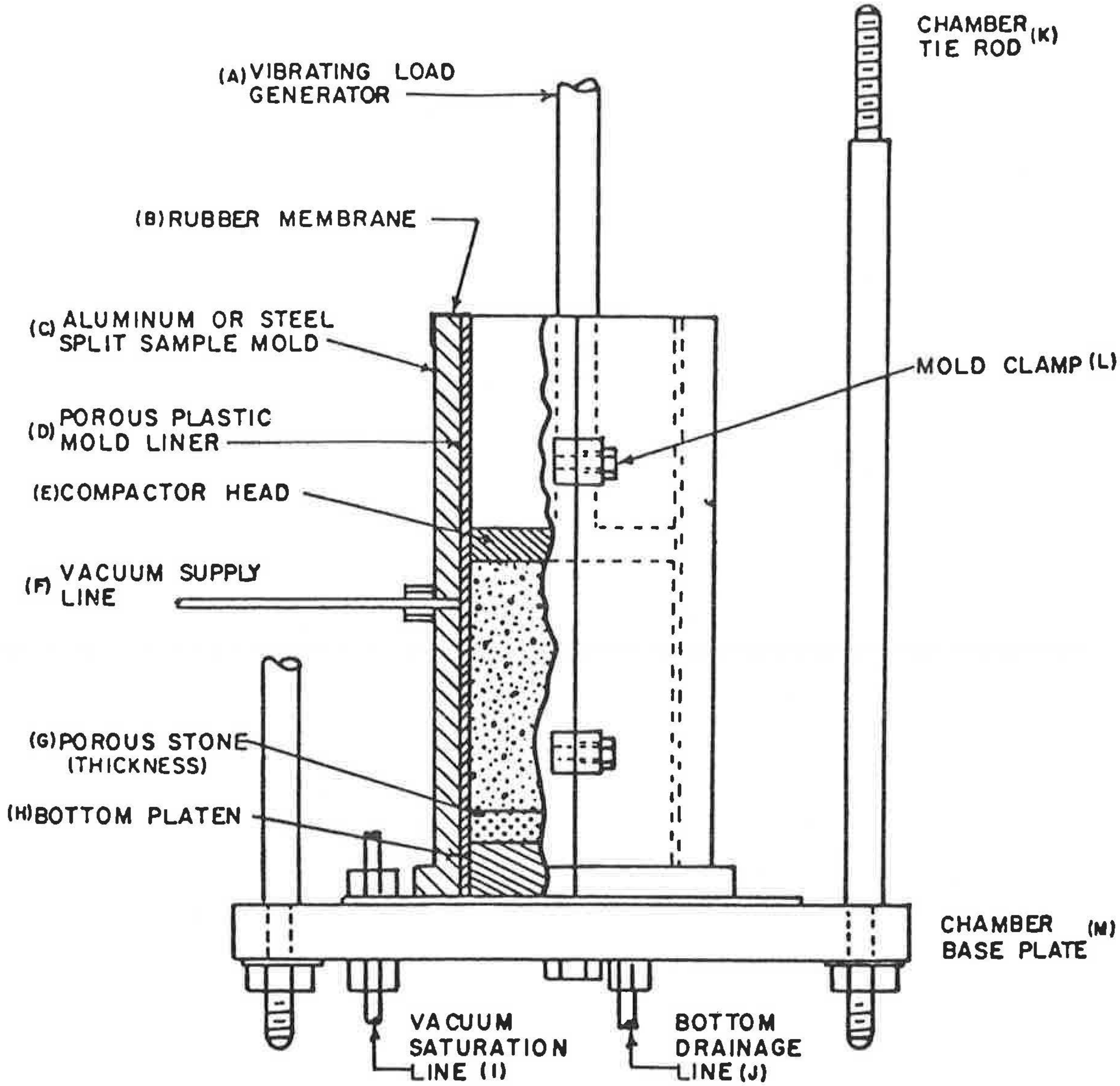

FIGURE 1 Vibratory compaction configuration from AASHTO T 180 (*1*).

tent. The ratios of top to bottom half contents provided a measure of migration.

The material used in the testing program was a dense-graded crushed limestone base material with the fraction larger than 0.75 in. (19 mm) replaced by material smaller than 0.75 in. (19 mm) but larger than the No. 4 (4.75 mm) sieve. Figure 4 presents a grain size curve of the gradation used in the testing. The laboratory maximum density and optimum moisture content for this material was 133 pcf (2130 kg/m^3) and 7.5 percent, respectively. The aggregate was sieved into five size fractions and recombined for each layer to the proper gradation and moisture content to ensure uniformity of the material for each compaction layer.

Number of Layers

To examine the possibility of using fewer compaction layers samples were prepared by using one, three, and five layers. The material for each layer was prepared to the proper gradation and the optimum moisture content.

The density of each layer was monitored by checking the compacted thickness. For the one- and three-layer samples, the compaction time per lift was increased to more than 2 min in an effort to achieve the target density. Nevertheless, the target density was not achieved for those specimens. The dry densities achieved were 121.9 pcf (1953 kg/m^3) for one layer, 123.5 pcf (1978 kg/m^3) for three layers, and 133.9 pcf (2145 kg/m^3) for five layers.

In addition to low density, the one-layer sample also showed serious moisture and fines migration (Figures 5 and 6). There was no evidence of significant migration for the three- and five-layer samples.

Compaction Time

Samples were prepared by using total compaction times of 6 min. per layer to investigate the significance of compaction time. The layer and sample thicknesses were checked periodically during compaction. There was no significant decrease in layer and sample thickness (i.e., increase in density) after

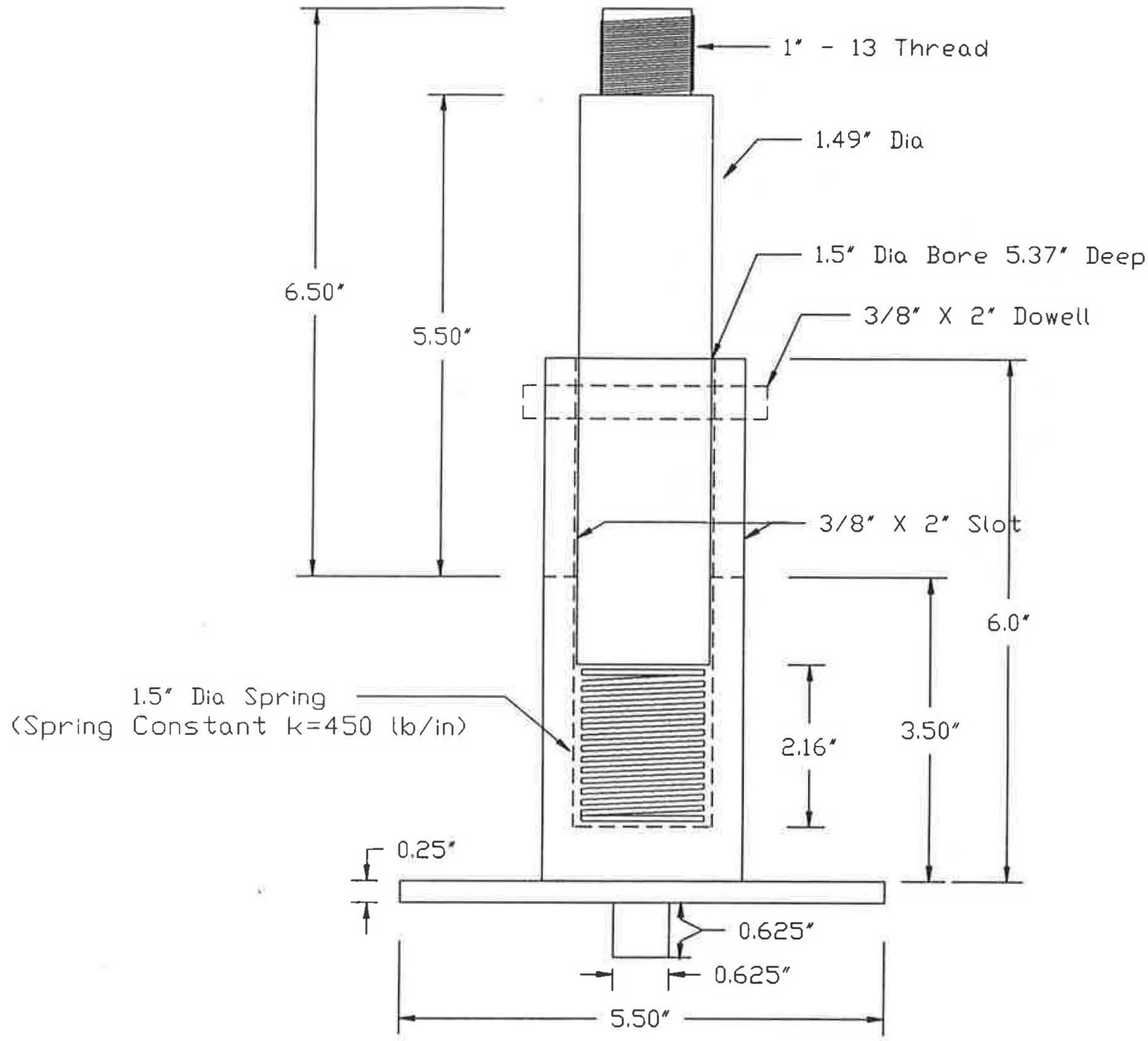

FIGURE 2 Engineering drawing of compaction device.

the first 2 min. Therefore, sample density for the aggregate tested is not significantly increased by using compaction times greater than 2 min per layer.

Vibration Frequency

The 10-Hz vibration frequency was selected through trial and error. To check whether other frequencies might be used, samples were prepared by using 5, 10, and 30 Hz. The target density could not be achieved except at the 10-Hz frequency.

Fines Content

Tests were also conducted to determine the effect of varying the fines and moisture content. The effect on fines and moisture migration was the primary interest in those tests.

To investigate the effect of fines content, samples were prepared with fines contents (percent passing the No. 200 sieve) of 3, 6, and 10 percent. The other gradation percentages were unchanged, and the moisture content was held at 7.5 percent. The samples were prepared by using five layers, 2 min of compaction per layer, and a 10-Hz vibration frequency.

The densities achieved were 122.0 pcf (1954 kg/m^3) at 3 percent fines, 133.9 pcf (2145 kg/m^3) at 6 percent fines, and 134.8 pcf (2159 kg/m^3) at 10 percent fines. None of the samples showed evidence of significant moisture or fines migration (Figures 7 and 8).

Moisture Content

Similar tests were conducted to examine the effect of moisture content. Three samples were prepared by using the normal gradation (Figure 4) and moisture contents of 0, 5, 7.5, and 10 percent. The samples were prepared by using five layers, 2 min of compaction per layer, and a 10-Hz vibration frequency.

The sample densities were found to increase when moisture content increased. The dry densities achieved were 124.5 pcf at 0 percent moisture, 128.1 pcf (2052 kg/m^3) at 5 percent moisture, 133.9 pcf (2145 kg/m^3) at 7.5 percent moisture, and 136.4 pcf (2185 kg/m^3) at 10 percent moisture. Fines migration was found in both the 0 and the 10 percent moisture content

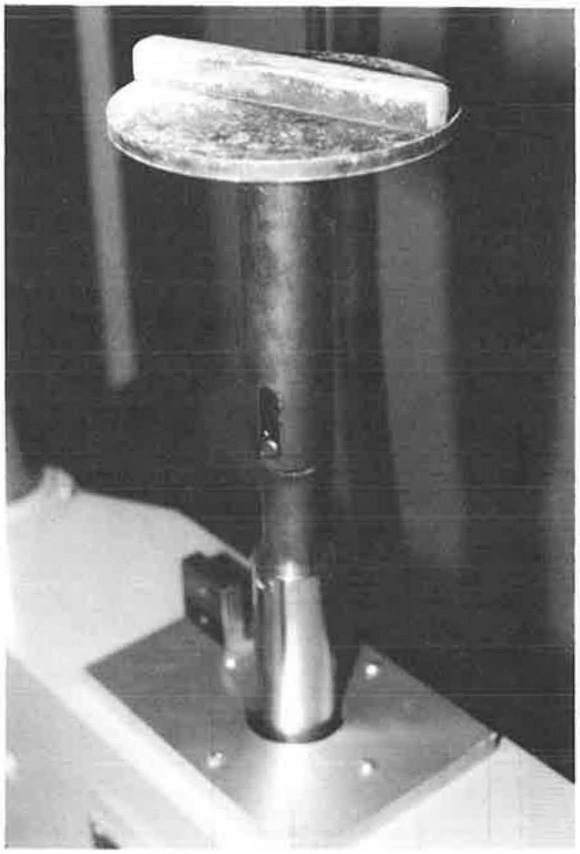

FIGURE 3 Compaction device mounted on MTS.

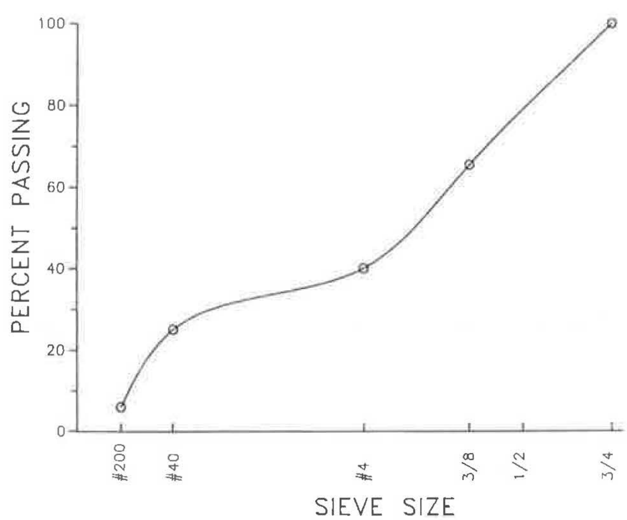

FIGURE 4 Gradation of aggregate used in test program.

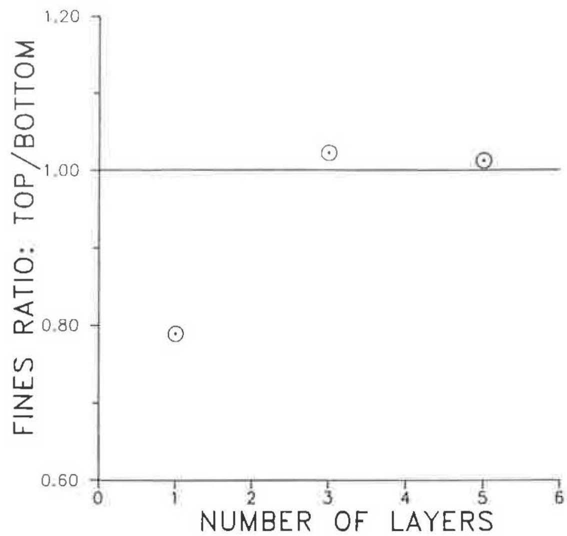

FIGURE 5 Fines migration results for 1, 3, and 5 layers.

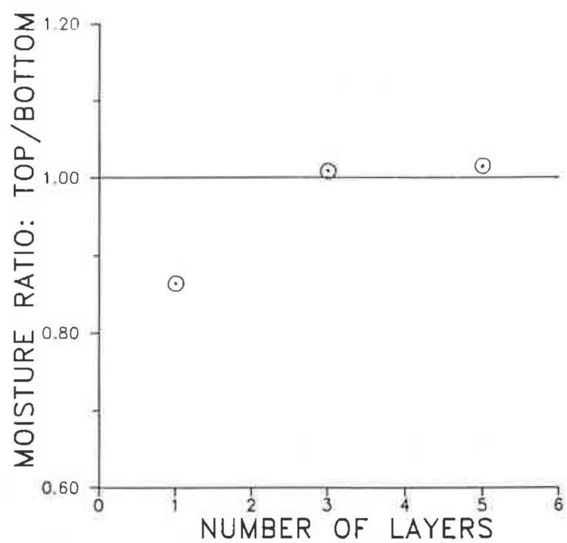

FIGURE 6 Moisture migration results for 1, 3, and 5 layers.

samples (Figure 9). The fines migrated to the bottom in the 0 percent sample and to the top in the 10 percent sample. The 10 percent fines sample showed a corresponding migration of moisture (Figure 10). There was no evidence of fines or moisture migration for the 5 and 7.5 percent moisture content samples.

One additional sample was prepared to examine the combined effect of low fines content (3 percent) and high moisture (10 percent). This sample also experienced fines and moisture migration (Figures 9 and 10). Interestingly, however, the fines and moisture migrated to the bottom in the low fines sample, opposite to the direction in the normal gradation sample (6 percent fines).

CONCLUSIONS

An alternate method for preparation of aggregate samples for dynamic testing has been developed. The method allows the sample to be prepared by using the dynamic test equipment, thus eliminating the need to move the sample after it is prepared. Visual examination of samples prepared by using the method showed the samples to be uniform.

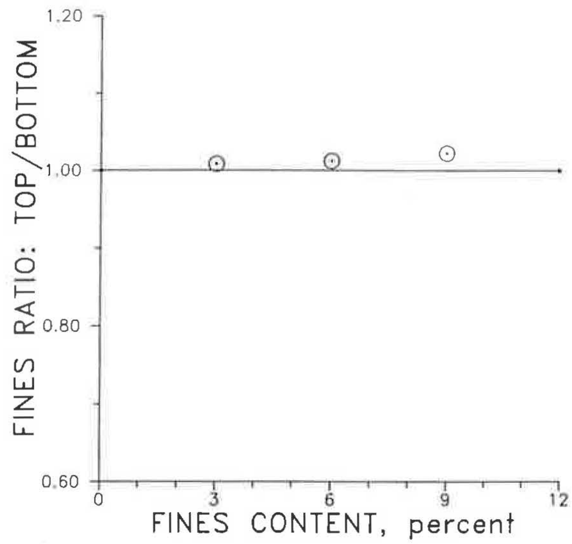

FIGURE 7 Fines migration for samples with varying fines content.

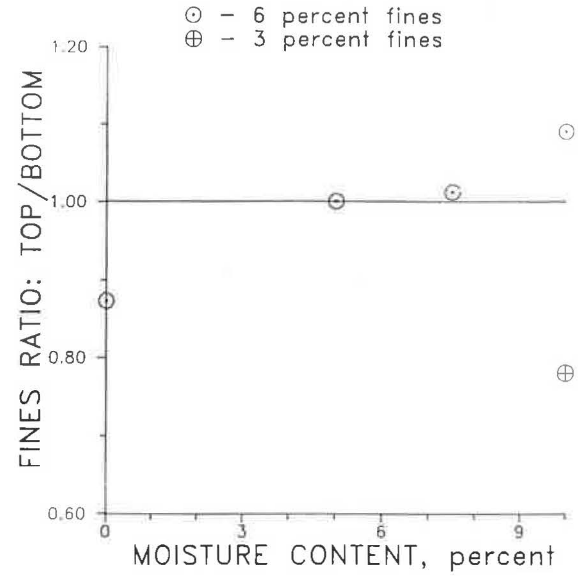

FIGURE 9 Fines migration at various moisture contents.

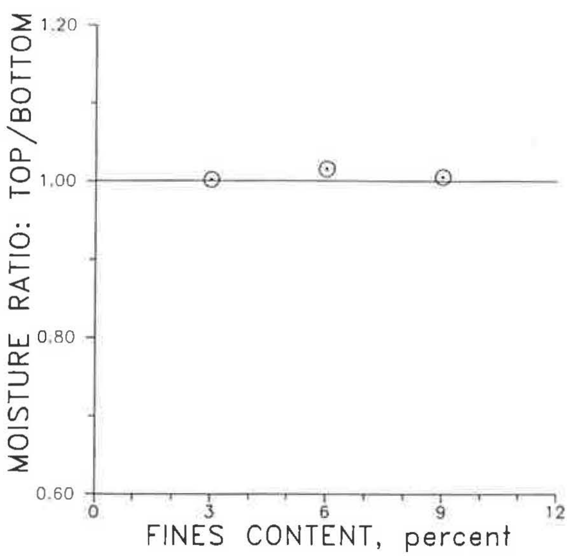

FIGURE 8 Moisture migration for samples with varying fines content.

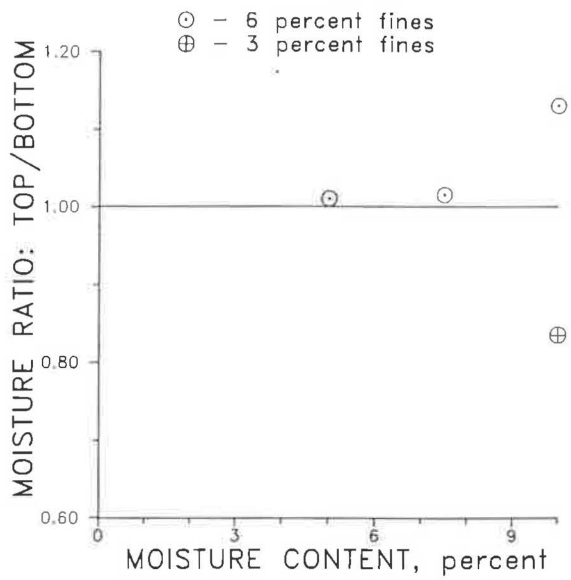

FIGURE 10 Moisture migration at various moisture contents.

A small test program confirmed that the method can compact dense-graded aggregate materials to densities equivalent to the AASHTO T 180 maximum density without creating segregation or moisture migration. However, when dry materials were used, problems were experienced in achieving the target density and fines migration was observed. Fines and moisture migration were also observed when the method was used with materials significantly wetter (10 percent versus 7.5 percent) than the optimum moisture content.

RECOMMENDED COMPACTION METHOD

What follows is the recommended method for preparing 6-in.-diameter by 12-in. high aggregate samples by using the compaction head developed at the University of Arkansas (Figures 2 and 3).

1. Determine the total amount of material needed on the basis of target density.
2. Weigh out and mix the proper amount of aggregate and water. To prevent fines and moisture migration, the moisture content should be from 2 percent below to 1 percent above optimum.
3. Compact the sample in five layers of equal thickness (2.4 in., 61 mm). The amount of material placed in the mold should be one-fifth the total amount needed for the sample on the basis of target density.
4. Mount the compaction head on the loading shaft of the dynamic test device.

5. Set the test device strain controls such that the maximum shaft movement is 0.7 in. (18 mm).

6. Set the operational frequency at 10 Hz. (Note: The test program used to develop the procedure was tried with frequencies of 5, 10, and 30 Hz. The target density could not be achieved except at 10 Hz. In some subsequent work, frequencies of 11 and 12 Hz were found to improve the compaction of some aggregates.)

7. For each sample layer, place the material in the mold and lower the compaction head so that the bar just touches the material.

8. During compaction, maintain the compaction head so that the head lifts slightly above the aggregate at the top of each vibrational stroke while manually rotating the load shaft (approximately 6 rpm) so as to rotate the compaction head.

9. Compact each layer for 2 min or until the appropriate layer height has been achieved. (Note: The test program used to develop the procedure was tried with only one aggregate. Although other aggregates have been compacted successfully in 2 min, some adjustment of the 2-min time may be necessary for other aggregates.)

10. To achieve a finished top surface, slowly raise the compaction head at the conclusion of the compaction time while continuing to operate and rotate the head. This should be done for the final layer and for any other layer for which the sample height is to be measured.

11. Measure the sample height by using the top of the mold as a point of reference to check the density achieved.

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Publication of this paper sponsored by Committee on Mineral Aggregates.