New Method for Laboratory Soil Compaction by Vibration

LARS FORSSBLAD, Head of Research Department, AB Vibro-Verken, Solna, Sweden

A laboratory compaction method based on the use of a vibrating tamper has been developed at the Concrete and Soil Laboratory of AB Vibro-Verken, Solna, Sweden. The weight and vibration data of the tamper have been selected to obtain with cohesionless soils the same maximum density as obtained with the modified AASHO method. For cohesive soil the vibration method has given somewhat lower values, compared with the modified AASHO method. The vibration method is quicker than the modified AASHO test. The vibrating tamper can also be used to compact test cylinders of soil-cement, asphaltic concrete, etc.

•A LABORATORY compaction method based on vibration has long been considered to have certain advantages. The following reasons may be stated:

1. In cases where the field compaction is performed by vibratory compactors a laboratory test by vibration should give best correlation with field results.
2. A laboratory compaction test based on vibration is more easily adaptable to a test mold of greater diameter than the 4-in. cylinder usually employed for laboratory compaction tests. In a larger mold, the tests can be carried out on samples containing material of a larger maximum size.
3. A laboratory compaction test based on vibration is less affected by the manual performance of the test compared with the ordinary Proctor compaction test. A method based on vibration is also quicker and involves less labor.

EARLIER VIBRATION METHODS

Laboratory compaction methods based on vibration of the soil have been tested previously (1, 2, 3). Best known is the Bureau of Reclamation method for determining the relative density of cohesionless free-draining soils (4). In its original version, the sample is vibrated in a container in a saturated state to obtain the maximum density. The Bureau has subsequently issued a modified test method in which a loading weight is placed on top of the material during vibration. The test is performed either on saturated material or on totally dry material. The mold is 6 in. in diameter and 0.1 cu ft in capacity or 11 in. in diameter and 0.5 cu ft in capacity. The method has been approved as ASTM Standard D 2049.

VIBRATING TAMPER TEST

The writer has previously reported (5) comparative tests using three variants of an apparatus for laboratory compaction by vibration: (a) vibration in an open mold fixed on a vibrating table; (b) vibration in a mold fixed on a vibrating table, with a loading weight on top of the material; and (c) vibration with a vibrating tamper working on the top surface of the material.

The use of a vibrating tamper for laboratory testing has been the subject of further studies at the Concrete and Soil Laboratory of AB Vibro-Verken. An advantage of the

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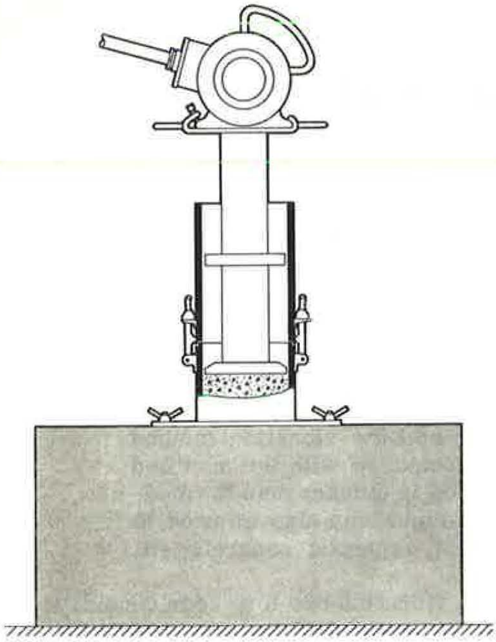

Figure 1. Apparatus comprising test mold with detachable collar and vibrating tamper; the mold is fixed by bolts to a concrete base.

Figure 2. Vibrating tamper, test mold and collar.

vibrating tamper is that a greater pressure is achieved during compaction than by either of the other two methods. The tamper thus gives compaction results that most closely agree with those obtained in the field. The compaction effect is determined by the dimensions of the mold, the layer thickness, the duration of vibration, the weight of the tamper, and the frequency and centrifugal force of the vibrator. These parameters can easily be standardized.

Study Stage 1

The first stage of continued investigations of the new laboratory compaction method concerned an apparatus with specifications as given below and shown in Figures 1 and 2.

(1a) Mold of 1 cu dm (0.035 cu ft) capacity

Diameter of mold 102 mm (4 in.)
Height of mold 123 mm (5 in.)
Weight of vibrating tamper 25 kg (55 lb)
Frequency 3000 vib/min, centrifugal force 225 kg (500 lb)

(1b) Mold of 2.5 cu dm (0.09 cu ft) capacity

Diameter of mold 152 mm (6 in.)
Height of mold 138 mm ($5\frac{1}{2}$ in.)
Weight of vibrating tamper 45 kg (100 lb)
Frequency 3000 vib/min, centrifugal force 400 kg (900 lb)

In a mold with 6-in. diameter the maximum particle size of the soil is 30 to 40 mm ($1\frac{1}{4}$ to $1\frac{1}{2}$ in.). The weights and the vibration data of the tampers have been selected to obtain with cohesionless soils the same maximum density as obtained with the modified AASHO method.

A guiding aim has been to make the new testing procedure as quick and as simple as possible. Filling and vibration in only two layers has been found feasible. The duration of vibration was set at 1 min per layer and the weights and centrifugal forces were selected to give the desired compaction effect under these conditions.

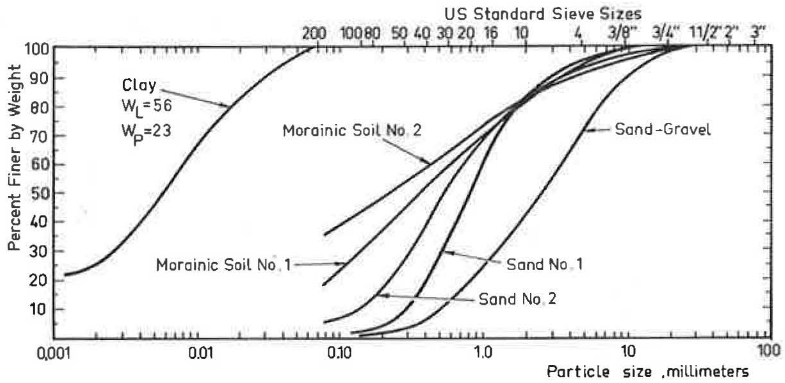

Figure 3. Grading curves for soils used for compaction tests.

The studies have also shown that granular soils can be vibrated with good results in a saturated condition, again filling and vibrating in two layers, each for 1 min. The mold was partly filled with water when the material was placed.

After compaction, and with the surface of the material somewhat above the upper edge of the cylinder, the collar is removed and the material leveled off. As an alternative, it is also possible to compact the material so that its surface is somewhat lower than the upper edge of the mold cylinder, and then measure the distance from this edge. The volume of the compacted material is then calculated on the basis of this measurement.

Grading curves of the soils used for the laboratory compaction tests described are shown in Figure 3. The results of the tests on these materials are shown in Figure 4.

Tests of cohesionless soils have shown good agreement with the results of tests by the modified AASHO method. The highest densities were obtained in vibration tests on dry and saturated materials. Examples of the relationships between the dry density and time of vibration are shown in Figure 5.

Tests of cohesive soils by the new method have given somewhat lower density values than obtained by the modified AASHO method. For clay, the maximum density obtained by vibration was about 10 percent lower than the maximum density obtained by modified AASHO (Fig. 4). In field compaction, it has very often been found impossible to achieve a high degree of compaction for cohesive materials, when compared with the maximum dry density obtained with the modified AASHO procedure. Thus the vibration method in this case gives better agreement with field results.

Practical Application of the Method

The new laboratory compaction method can, of course, be used in the same way as ordinary Proctor tests, that is, by subjecting a given material to a series of tests at various water contents. On many working sites, however, the grading of the soil varies considerably. This means that field density tests must be supplemented by a large number of laboratory compaction tests. Furthermore, the soils often contain gravel or stones in a greater or lesser amount; thus, it is necessary to make the laboratory compaction test with the larger particles removed. Density figures are then corrected with respect to the stone content of the soil, which introduces an element of uncertainty. These problems are eliminated by the following procedure, which is useful for sand, gravel and other granular soils containing a maximum of between 10 and 20 percent of material smaller than 0.074 mm grain size (No. 200 sieve).

Density determinations in the compacted fill are carried out in the ordinary way, e.g., with the water balloon method. At each testing point a soil sample is taken. The sample is vibrated in a saturated state by the laboratory method described previously, and a density value is obtained which in most cases closely agrees with the maximum density obtained by compaction according to the modified AASHO method. This density value is directly comparable with the density value determined in the field.

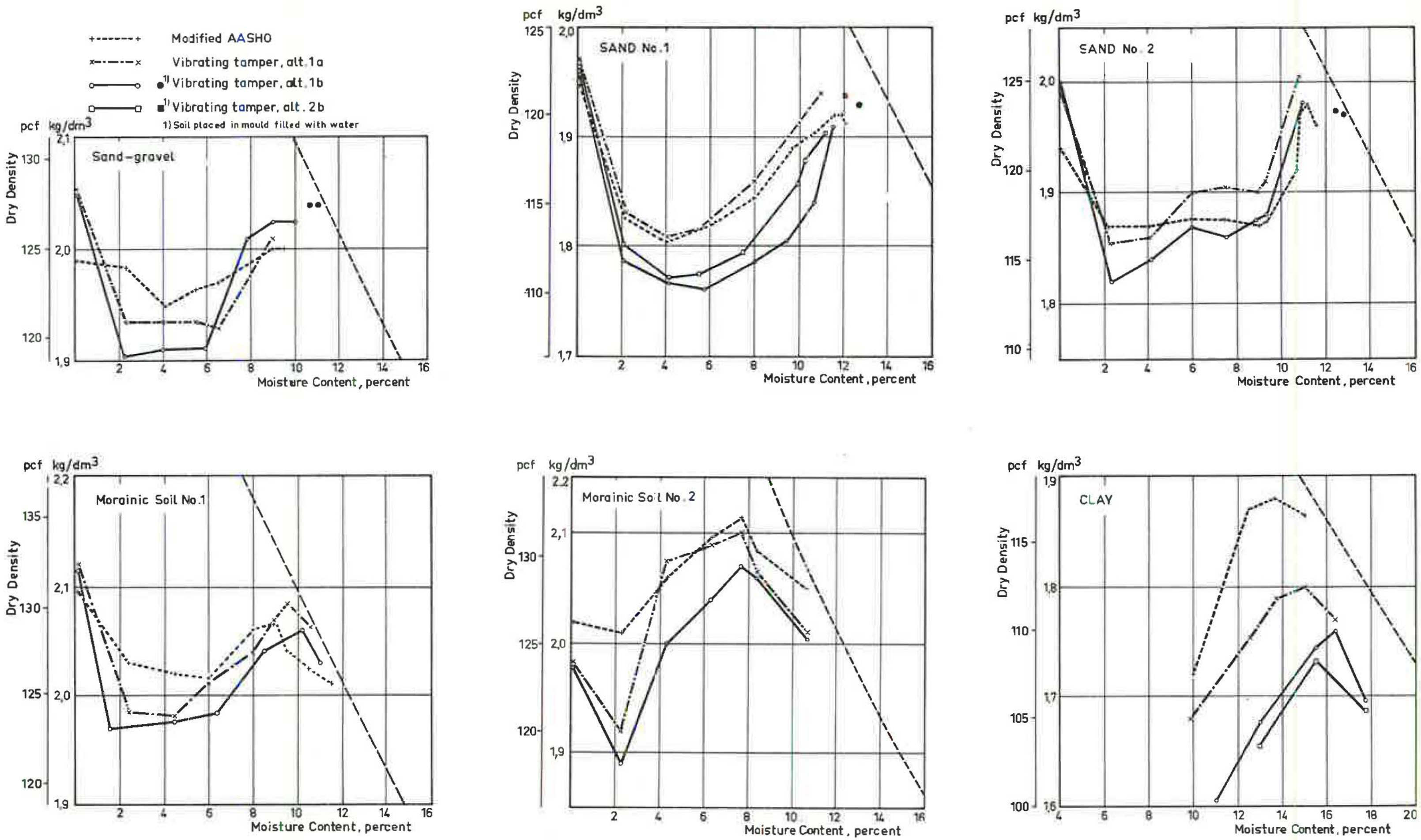

Figure 4. Results of laboratory compaction tests carried out by the modified AASHO method and the new method for laboratory compaction by vibration.

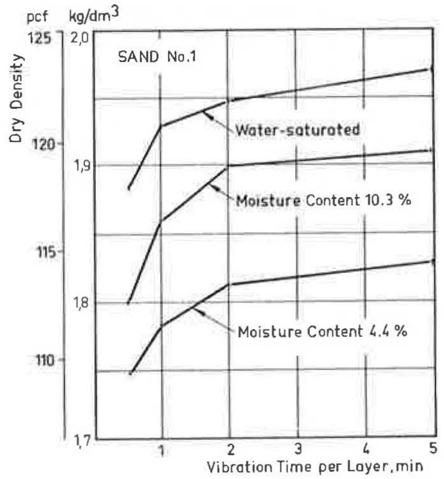

Figure 5. Relationships between dry density and vibration time obtained with apparatus defined in alternative 1b; vibration in two layers.

During the 1964 and 1965 working seasons this method was applied at the Håckren earth dam project in the northern part of Sweden. The part of the dam fill consisting of granular soils, 1.5 million cubic meters (2 million cu yd), varied from silty sand to gravelly stone. Density measurements were carried out in the compacted fill using a water balloon measure. A sample from each sampling point was vibrated in a saturated condition as described earlier under 1b. The density obtained in the laboratory tests was compared with the field density. The field densities averaged 96 percent of the lab values. Comparative tests by the modified AASHO method and the new laboratory method showed agreement to within ± 2 percent.

Despite the highly varied grading of the soil, the method allowed speedy and continuous checking of the degree of compaction of the fill. Granular soils containing varying quantities of stone are often used in bases and subbases for roads and airfields, and in fill used for building foundations. Thus there are several suitable applications for the new laboratory compacting method.

Study Stage 2

Experience during Stage 1 showed that the larger, 152-mm diameter (6 in.) mold is to be preferred, partly in view of the special usefulness of the method for stony cohesionless materials. Investigations of the effect of the time of vibration (Fig. 5) showed that a duration of 2 min instead of 1 min per layer gave closer agreement with the final results obtained in protracted vibration. The 2-min period is therefore preferable. Another aspect is that the 45-kg (100 lb) weight of the tamper made it difficult to handle. But if the duration of vibration is extended to 2 min per layer the weight of the tamper can be reduced; a further alternative was therefore studied.

(2b) Mold of 2.5 cu dm (0.09 cu ft) capacity

Diameter of mold 152 mm (6 in.)
Height of mold 138 mm ($5\frac{1}{2}$ in.)
Weight of tamper 35 kg (77 lb)
Frequency 3000 vib/min, centrifugal force 250 kg (550 lb)

Comparative tests as per 1b (1 min vibration per layer) and 2b (2 min vibration per layer) have shown good agreement in the results for granular materials tested at different water contents (Fig. 4). For the clay investigated, the light tamper gave a few percent lower maximum density than obtained with the heavy tamper. But this is no great disadvantage, and the light tamper, as in 2b, is to be preferred from the practical aspect.

CONCLUSIONS

A new laboratory compaction method based on vibration has been developed. The following equipment is recommended:

(2b) Mold of 2.5 cu dm (0.09 cu ft) capacity

Diameter of mold 152 mm (6 in.)
Height of mold 138 mm ($5\frac{1}{2}$ in.)
Weight of tamper 35 kg (77 lb)
Frequency 3000 vib/min, centrifugal force 250 kg (550 lb)

Vibration is in two layers, each layer vibrated for 2 min. In the United States and elsewhere with current of 60 cps, a vibrator with a frequency of 3600 vib/min is suitable. The corresponding centrifugal force must be tried out.

For granular materials, good agreement has been obtained between the new laboratory compaction method and compaction by the modified AASHO method. For cohesive materials, the new method gives somewhat lower figures. Sufficient basis exists for the recommendation of the method for practical use. The new procedure can also be used to compact test cylinders of soil-cement, asphaltic concrete, etc.

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Discussion

W. H. CAMPEN, Omaha Testing Laboratories, Inc.—This vibratory method of determining maximum laboratory density on noncohesive soils deserves consideration for two principal reasons: first, because methods are needed for the compaction of sands and gravels in the laboratory, and second, because this method may prove to be easier and more economical than the one which employs a vibrating table.

Although I believe this method has merit, I do not agree with some of the reasons Forssblad gives in its behalf. For instance, he emphasizes the good density correlation between his method and the modified AASHO method. If this were really true, it would detract from the method, since it is well known that the modified AASHO method is not suitable for round noncohesive soils because the material displaces under the foot, and consequently low density values are obtained. It would be well to correlate tests obtained by this method with those obtained by ASTM method D 2049, which is known to give very high density.

Forssblad also states that the method is good because density tests obtained with it correlate well with tests on sandy soils after compaction with vibratory field equipment. The reasoning appears to be faulty since it implies that density developed with field equipment is the basis for specifying maximum laboratory density. Maximum laboratory density, or some degree thereof, is used to indicate the structural strength of a compacted soil and is not related to the ease or difficulty with which it is developed in the field.

LARS FORSSBLAD, Closure—Campen agrees that a method for laboratory soil compaction based on vibration deserves consideration. He objects, however, to the correlations which are made between the new vibratory method and the modified AASHO method, but the author has not found any better method to correlate with the new method. An important reason is the common use of the modified AASHO method. With cohesive soils the new vibratory method has given lower values than the modified AASHO method. It is also likely that the agreement with the modified AASHO method will not be good for all types of cohesionless soils, as Campen indicates.

Campen's discussion contains the following sentence: "Forssblad also states that the method is good because density tests obtained with it correlate well with tests on sandy soils after compaction with vibratory field equipment." The following statement is made early in the report: "In cases where the field compaction is performed by vibratory compactors a laboratory test by vibration should give best correlation with field results." This sentence only indicates that a laboratory compaction method based on vibration is likely to give better results than other laboratory compaction methods when vibratory compactors are used for field compaction.