4.4 Heavy Compaction using 4.5 kg Rammer

4.4.1 Scope. This type of compaction is widely used for pavement materials and also for earthworks and sub-grades if a high standard of compaction is specified.

This method may be carried out in the 1L compaction mould or in a CBR mould.

4.4.2 Apparatus, sample preparation and test procedure. The test is similar to the standard compaction (2.5 kg rammer) as described earlier, the only differences being that the sample is compacted in 5 equal layers with the 4.5 kg rammer dropping from a controlled height of 450 mm. The 4.5 kg rammer is shown in Figure 4.4.1. As previously each layer still receives 27 blows / layer for a 1L mould and 62 blows / layer for a CBR mould. Calculation and reporting of results are identical to those for 2.5 kg rammer compaction test.

4.5 Vibrating Hammer Method

4.5.1 Scope. This test is applicable to granular soils containing no more than 30% by mass of material retained on the 20 mm sieve, which may include some particles retained on the 37.5 mm sieve. It is not generally suitable for cohesive soils. The principle is similar to that of the rammer procedures except that a vibrating hammer is used instead of a drop-weight rammer, and a larger mould (the standard CBR mould) is necessary.

4.5.2 Apparatus

a) Cylindrical metal mould, internal dimensions 152 mm diameter and 127 mm high (CBR mould). The mould can be fitted with an extension collar and base-plate. The mould is shown in Figure 4.3.3.
b) Electric vibrating hammer, power consumption 600-800 W, operating at a frequency in the range 25-60 Hz. For safety reasons the hammer should operate on 110V and an earth-leakage circuit breaker (ELCB) should be included in the line between the hammer and the mains supply.
c) Steel tamper for attaching to the vibrating hammer with a circular foot 145 mm diameter (see Figure 4.5.1 a) and b)).
d) A balance readable to 5 g.
e) 20 mm and 37.5 mm BS sieves and receiver.
f) A straightedge, e.g. a steel strip about 300 mm long, 25 mm wide and 3 mm thick, with one beveled edge.
g) Depth gauge or steel rule reading to 0.5 mm.
h) Apparatus for the determination of moisture content.
i) Laboratory stop-clock reading to 1 s.
j) A corrosion-resistant metal or plastic trays with sides, e.g. about 80 mm deep of a size suitable for the quantity of material to be used.
k) A scoop.
l) Apparatus for extracting compacted specimens from the mould (optional).
Vibrating Hammer Assembly

Figure 4.5.1 (a)

Tamper for Vibrating Hammer Compaction Test

Figure 4.5.1 (b)
4.5.3 **Calibration of apparatus**

4.5.3.1 **General.** The vibrating hammer shall be maintained in accordance with the manufacturer’s instructions. Its working parts shall not be badly worn.

The calibration test described in 4.5.3.3 below shall be carried out to determine whether the vibrating hammer is in satisfactory working order, and able to comply with the requirements of the test.

4.5.3.2 **Material.** Clean, dry silica sand, from the (geological) Woburn Beds of the Lower Greensand in the Leighton Buzzard district of the UK. The grading shall be such that at least 75% passes the 600 µm sieve and is retained on the 425 µm sieve. Dry and not previously used sand shall be used. This sand shall be sieved through a 600 µm test sieve and the coarse fraction shall be discarded.

*Note.* This is the standard sand as described in the British Standard. Advice on suitable suppliers can be obtained from BSI in the UK. Advice should be sought from BRRL as to whether a suitable sand is available locally, to reduce dependence on costly imports.

4.5.3.3 **Calibration test**

a) Take a 5±0.1 kg sample of the specified in 4.5.3.2, which has not been used previously and mix it with water in order to raise its moisture content to 2.5±0.5%.

b) Compact the wet sand in a cylindrical metal mould of 152 mm diameter and 127 mm depth, using the vibrating hammer as specified in the section on apparatus above.

c) Carry out a total of three tests, all on the same sample of sand, and determine the mean dry density. Determine the dry density values to the nearest 0.002 Mg/m³.

*Note.* The operator can usually judge the required pressure to apply with sufficient accuracy after carrying out the check described in 4.5.4 below.

d) If the range of values in the three tests exceeds 0.01 Mg/m³, repeat the procedure. Consider the vibrating hammer suitable for use in the vibrating compaction test if the mean dry density of the sand exceeds 1.74 Mg/m³.

*Note.* Advice should be sought from BRRL if a locally available replacement for the Leighton Buzzard sand is used and the replacement does not achieve a mean dry density of 1.74 Mg/m³.

4.5.3.3 **Calibration of operator.** Before being allowed to carry out the test the operator must practise with the apparatus in order to achieve the correct downward pressure required in the test. The downward force, including that resulting from the mass of the hammer and tamper should be 300-400 N. This force is sufficient to prevent the hammer bouncing up and down on the soil. The correct force can be determined by standing the hammer, without vibration, on a platform scale and pressing down until a mass of 30-40 kg is indicated. With experience the pressure to be applied can be judged, but an occasional check on the platform scale is advisable. If the hammer-supporting frame is used, the hand pressure required is much less but should be carefully checked.

4.5.5 **Sample preparation.** The procedure to be adopted depends on the grading zone into which the sample falls (see Table 4.2.1), and whether the soil is susceptible to crushing. Full details of sample preparation methods are given in Tables 4.2.2 to 4.2.5. The quantities of soil required are indicated in Table 4.2.1.
4.5.6 **Preparation of apparatus.** See that the component parts of the mould are clean and dry. Assemble the mould, base-plate and collar securely, and weigh to the nearest 5 g ($m_1$). Measure the internal dimensions of the assembly to 0.5 mm and calculate the internal volume. The nominal dimensions of the mould give an area of cross-section of 18, 146 mm$^2$ and a volume of 2304.5 cm$^3$ (say 2305 cm$^3$) but these may change slightly with wear. The inside height of the mould with collar is recorded ($h_1$ mm).

It is particularly important to ensure the lugs and clamps holding the mould assembly together are secure and in good condition, in order to withstand the effects of vibration. If the mould has screw-on fittings, the threads must be kept clean and undamaged. Avoid cross-threading when fitting the base-plate and extension collar, and make sure that they are tightened securely as far as they will go without leaving any threads exposed. Screw threads and mating surfaces should be lightly oiled before tightening.

Ensure that the vibrating hammer is working properly, in accordance with the manufacturer's instructions. See that it is properly connected to the mains supply, and that the connecting cable is in sound condition. The supporting frame if used, must move freely without sticking. The hammer should have been verified as described in 4.5.3.3.

The tamper stem must fit properly into the hammer adapter, and the foot must fit inside the CBR mould with the necessary clearance (3.5 mm all round).

4.5.7 **Test procedure**

4.5.7.1 Place the mould assembly on a solid base, such as a concrete floor or plinth. If the test is to be performed out of doors because of noise and vibration problems place the mould on a concrete paved area, not on unpaved ground or on thin asphalt. Any resilience in the base results in inadequate compaction.

4.5.7.2 For soils susceptible to crushing, prepare the soil to provide a sample of about 40 kg from which 5 (or more) separate batches of about 8 kg are obtained and made up to different moisture contents. It is not necessary, for soils not susceptible to crushing, to be divided into 5 separate batches. Add a quantity of soil to the mould, such that after compaction the mould is one-third filled. A preliminary trial may be necessary to ascertain the correct amount of soil. A disc of polyethylene sheet, of a diameter equal to the internal diameter of the mould, may be placed on top of the layer of soil. This will help to prevent sand particles moving up through the annular gap between the tamper and the mould.

4.5.7.3 Compact the layer with the vibrating hammer, fitted with the tamper for 60±2 s, applying a firm pressure vertically downwards throughout.

The downward force of 300-400 N should only be applied by a practised operator (see 4.5.4 above).

Repeat the above compaction procedure with a second layer of soil, and then with a third layer. The final thickness of the compacted specimen should be between 127 mm and 133 mm: if it is not, remove the soil and repeat the test.

4.5.7.4 After compaction remove any loose material from the surface of the specimen around the edge of the mould collar. Lay the straight-edge across the top of the collar, and measure down to the surface of the specimen with the steel rule or depth gauge, to an accuracy of 0.5 mm. Take readings at four points spread evenly over the surface, all at least 15 mm from the side of the mould. Calculate the average depth ($h_2$ mm). The mean height of the compacted specimen, $h$, is given by

$$h = (h_1 - h_2) \text{ mm}$$
where \( h_1 \) = Height of mould.

4.5.7.5 Weigh the mould with the compacted soil, collar and base-plate to the nearest 5 g (\( m_2 \)).

4.5.7.6 Remove the soil from the mould and place on the tray. A jacking extruder makes this operation easy if fittings to suit the CBR mould are available. However, sandy and gravelly (non-cohesive) soil should not be too difficult to break up and remove by hand.

4.5.7.7 Take two representative samples in large moisture content containers for measurement of moisture content. This must be done immediately after removal from the mould, before the soil begins to dry out. The moisture content samples must be large enough to give results representative of the maximum particle size of the soil. The average of the two moisture content determinations is denoted by \( w\% \).

4.5.7.8 For soils susceptible to crushing, repeat step 4.5.7.1 to 4.5.7.7 on each batch of soil in turn. For soil not susceptible to crushing break up the material on the tray and rub it through the 20 mm or the 37.5 mm sieve if necessary, mixing with the remainder of the sample. Add an increment of water so as to raise the moisture content by 1 to 2\% (150-300 ml of water for 15 kg of soil). As the optimum moisture content is approached it is preferable to add water in smaller increments.

4.5.7.9 Repeat stages 4.5.7.1 to 4.5.7.8 for each increment of water added. At least five compactions should be made, and the range of moisture contents should be such that the optimum moisture content is within that range. If necessary, carry out one or more additional test at suitable moisture contents.

Above a certain moisture content the soil may contain an excessive amount of free water, which indicates that the optimum condition has been passed.

4.5.8 Calculation and expression of results. The following stages apply to both the above procedures:

Calculate the bulk density \( \rho \) (in kg/m\(^3\)), of each compacted specimen from the equation

\[
\rho = \frac{m_2 - m_1}{Ah} \times 1000
\]

where, \( m_1 \) = mass of mould, collar and base-plate;
\( m_2 \) = mass of mould, collar and base-plate with soil;
\( h \) = height of compacted soil specimen = \( h_1 - h_2 \) mm;
\( A \) = circular area of the mould (in mm\(^2\)).

Calculate the density, \( \rho d \) (in kg/m\(^3\)), of each compacted specimen from the equation

\[
\rho d = \frac{100\rho}{100 + w}
\]

where, \( w \), is the moisture content of the soil.

The results of the required calculations, as determinations of dry density and moisture content, are plotted as described in Part 4.3.6 and illustrated in Form 4.1.1 to 4.1.4.

Calculations for air voids can be calculated if required as detailed in Part 4.3.6.

4.5.9 Report. The requirements for reporting are as detailed in 4.3.7.