ANALYSIS OF REFUSAL DENSITY USING THE VIBRATORY HAMMER, FOR SPECIFICATION PURPOSES OF SITE COMPACTION

1 APPARATUS

1.1 A steel split mould 152mm in diameter and 125mm in height with an extension piece and clasps to fix the mould to the base of the frame.

1.2 Three circular papers with diameter of 152mm.

1.3 Non-stick spray e.g. non stick cooking spray purchased at any supermarket.

1.4 A 10kg surcharge load.

1.5 A Vibratory Hammer with the following Specifications (see note 4.3):

Table Error! No text of specified style in document.**-1: Specifications of vibratory hammer for compaction**

Specification	Criteria
Power rating	1500 W
Frequency	900 to 1890 beats/min (15 – 31.5Hz)
Point Energy	25 J

The vibratory Hammer should be mounted on two guide rods; one on either side of the hammer. A mounting head should be fitted to the vibratory hammer to allow a surcharge of 10kg to be mounted to the vibratory hammer. There should be a pulley system connecting the frame and mounting head. This allows for easy lifting and lowering of the vibratory hammer.

The total mass of vibratory hammer, surcharge and mounting head should be 30kg ± 1.5kg.

1.6 A 150mm tamping foot.

1.7 Material Scoop (90mm Φ x 85mm h).

1.8 Specimens are compacted in 2 Layers.

1.9 Suitable marker e.g. permanent marker.

1.10 Adjustable spanner to fasten and loosen surcharge load to the vibratory hammer.

1.11 Steel ruler of length >150mm.

1.12 Chisel for tamping layers.

1.13 Drill with drill bit of 150mm with a point marked off 10mm from the tip of the bit.

2 PROCEDURE

2.1 Preparation of the material

Preparing the sample of material for initial Moisture Curve

Determine the grading curve of the aggregate (TMH 1) and reconstitute the material to produce samples that will be used for refusal density analysis for the specification of site compaction levels.

Preparing the sample of material for vibratory hammer compaction

From the grading curve reconstitute the material to the produce a sample of 7kg (see note 4.1) of aggregate with a maximum particle size of 19mm. Three samples of around 7kg are required.

The aggregate is prepared as follows:

1. Obtain the OMC of the untreated material from Compaction protocol 1. This OMC is used to specify the moisture content of the BSM. A moisture content of 84% of the OMC of the untreated material is added to the sample (see Section 3 for calculations)
2. Should cement or lime need to be added to a specific mix, add these first (before the moisture) to the sample:

4. For BSM-emulsion, the moisture content of the bitumen emulsion needs to be calculated out of the physical mass of water that is added. An example of this calculation is as follows:

   Assumptions made for the example:

   - OMC of untreated material from Compaction protocol 1 = 6.15%.
   - Target moisture content = 85% of 6.15% =5.23%;
   - The bitumen emulsion content of the mix is 3%;
   - The bitumen emulsion is a 60/40 emulsion;

   For a 60/40 emulsion, 40% of the emulsion is water. Therefore of the 3% bitumen emulsion to be added to the mix, 40% of it is water. Therefore the fraction of water being added to the mix from the emulsion is 40% x 3%÷100 = 1.2%

   The fraction of water that is to be added to the mix in order to obtain a moisture content of 5.166% is now 5.23%-1.2% = 4.03%. The physical mass of water to be added to the mix in order to give a target moisture content of 5.23% when the bitumen emulsion is added is now 4.03% of the mass of the sample.

   First add the physical mass of water to the material and allow to stand for 40 – 60 minutes. After this time add the bitumen emulsion to the mix and also allow to stand for 40-60 minutes to allow breaking of the bitumen emulsion.

5. For the BSM-foam, the fraction of moisture added is equivalent to the target moisture content, e.g. Target moisture content is 5.166%, the moisture added to the material prior to stabilisation would therefore be 5.166%.

2.2 Compaction Procedure

2.2.1 Prepare the mould and vibratory hammer

Preparing the vibratory hammer

Fix the Mounting Head to the vibratory hammer and fit hammer onto the guide rods. Place the 10kg surcharge load onto the mounting head and fasten tightly – see separate drawing for Mounting Head, Subsection 5 Compaction protocol 1 (Kelfkens, 2008). Using the pulley system raise the vibratory hammer to the maximum height it can be raised or to an adequate height that will allow the operator to work beneath the vibratory hammer.

Preparing the Mould

Make sure the mould is clean and then spray the interior of the mould with the non-stick spray. After a specimen has been compacted and removed from the mould, the mould should be cleaned by wiping of excess material from the mould walls (this should be done prior to the compaction of subsequent specimens). Fix the mould to the base of the frame directly below the foot piece of the vibratory hammer using the clasps. Place two of the circular paper sheets at the base of the mould.

Lower the vibratory hammer into the mould, checking that the vibratory hammer is perpendicular to the base of the mould i.e. the tamping foot is flat on the base with no point of the foot slightly raised. Allow the vibratory hammer to rest in the mould with no material present. Where the lower end of sleeve of the mounting head rests on the guide rod mark that position clearly on the vertical guide using the suitable marker. Raise the vibratory hammer and measure up from the initial mark 125mm and mark this clearly (non-erasable).

2.2.2 Compaction of the specimen

Addition of material to mould

Material is placed in the mould using the material scoop. Fill the scoop with the prepared material and level off the scoop and place it in the mould. Add four scoops of material. Using the chisel, work the material around in order to evenly distribute it in the mould; try to distribute the particles evenly as well i.e. not too much fine material on top or to much coarse material on top, but rather a fair distribution of each i.e. un-segregated. Make sure the material is as level as possible before lowering the vibratory hammer till the foot piece comes to rest on the material.

Compaction of individual layers

Specimens are compacted according to set times for each layer. This is to produce specimens that have densities close to or at refusal density. The compaction times for the individual layers of a specimen according to the type of Bitumen Stabilized Material is provided in **Error! Reference source not found.**:

TABLE ERROR! NO TEXT OF SPECIFIED STYLE IN DOCUMENT.**-2: COMPACTION TIMES PER LAYER TO ACHIEVE REFUSAL DENSITY**

Mix type	Compaction Time per layers of specimens (Sec)
Untreated	180
BSM-emulsion	180
BSM-foam	180

After the material of a layer has been compacted for the allocated time, raise the vibratory hammer. Using the drill, scarify the entire surface area of the top of the compacted layer to a depth of ± 10mm (see Note 4.2).

After the surface of a respective layer has been scarified, add the material for the next layer and compact accordingly.

*The extension piece (collar) must first be fitted to the mould before adding the material for the final layer. After adding the material for the final layer place a circular sheet of paper on top of the material and then lower the vibratory hammer into position; the paper helps prevent material of the final layer from sticking to the tamping foot. Before raising the vibratory hammer the final height of the specimen must be measured, once this is done the vibratory hammer may be raised and the specimen removed.

Measuring the final height of the specimen

After the final layer has been compacted and prior to raising the vibratory hammer take the steel rule and measure the distance from the zero line to the bottom end of the sleeve. This distance is taken as the final height of the specimen.

Removing and handling the compacted specimen

Raise the vibratory hammer and remove the extension piece (collar). Disassemble the mould entirely. Place a plastic bag over the specimen and remove it taking care to pick the specimen up from the bottom end. Weigh the specimen after compaction to check the final mass of the specimen.

Checking the moisture content of the specimen

Take a small amount (750-950 gm) of BSM either just prior to, during or after compaction and determine the moisture content using the standard oven drying method.

Determining the final Dry Density

From the moisture content determined, the final mass of the compacted specimen and the final height measured, the final Dry Density of the specimen may be determined. This Dry Density is determined for all three specimens and is averaged out. This average Dry Density is used to specify compaction levels for site.

2.3 Compaction specifications for site compaction

The average Dry Density obtained from the refusal density compaction is used to specify site compaction levels (See Note 4.8). The table below provides the compaction levels:

Table 6-4: Specifications for the level of site compaction

Material Type/Quality	Level of Site Compaction (% Refusal Density)		
	Untreated	BSM-emulsion	BSM-foam
G2 (High Quality)	93.5 to 95.3	93.5 to 95.3	90.1 to 91.1

3 CALCULATIONS

3.1 Addition of lime or cement

Cement or lime content (C/L)

C/L (gm) = C/L (%) × 14000 ÷ 100

3.2 Addition of water for untreated material

Water (gm) = (target moisture content (%))/100× mass of sample (gm)

3.3 Addition of stabilizer and water to Bitumen Stabilized Material (BSM)

BSM-emulsion

Mass of bitumen emulsion

Emulsion mass (gm) = Emulsion content (%)/100 × aggregate dry mass (gm)

Moisture contents

MC in BSM from emulsion (%) = (MC_e (%))/100 × emulsion content (%)

Mass of water added to BSM = (ΔMC) × mass of sample (gm)) ÷100

MC_e = Moisture content of the bitumen emulsion

ΔMC = X (%) - MC in BSM from emulsion (%)

X = target moisture content of the mix

Moisture added = target moisture content of the mix

3.4 Dry Density

Volume of the specimen = $\pi \times 0.005625 \times$ Fh

Fh = Final height of the specimen

Dry Density = (Fm ÷ (1+ (MC/100)) ÷ Volume of the specimen

Fm = Final Mass of the specimen (kg)

MC = Moisture Content (%)

4 NOTES

4.1 For a final specimen of 125mm high a sample mass of 7kg is recommended when preparing the BSM. This mass is influenced by the achieved Dry Densities and as a result will vary with the type of material being compacted.

4.2 Layers should not be scarified deeper than 10mm. The result of scarifying deeper than10mm is that the layer being compacted does not bond adequately well to the previous layer and hence there is an increase in voids at this interface.

4.3 Should the vibratory hammer not meet the specifications provided and where no suitable alternative compaction hammers can be sourced, then a vibratory hammer with a point energy of 25 Joule ± 2 Joule should be used. If the weight of the hammer deviates from the specifications by more than 5%, then calibration tests need to be made.

4.4 After a specimen has been compacted and removed from the mould, the mould should be cleaned by wiping off excess material from the mould walls. This should be done prior to the compaction of the next specimen.

4.7 Should 7 ply shutter board not be obtainable then a wooden base with material properties as close to those of the 7 ply shutter board should be used.

4.8 The compaction specifications for site compaction need to be revisited as compaction data from sites become available.