

PROCEDURE FOR COMPACTION OF TEST SPECIMENS USING THE VIBRATORY HAMMER

1. SCOPE

The mix design procedure of BSM's require different size of specimens to carry out the tests specified at the different phases of the mix design procedure, as indicated below.

Phase	Level 1	Level 2	Level 3
Road Category	C and D	B and C	A and B
Cumulative Traffic (million E80's)	< 3	3 to 6	> 6
Minimum Test requirements	ITS dry and soaked	ITS and UCS at equilibrium moisture content	Triaxial testing at equilibrium moisture content
Specimen Size	diameter 101mm height 65mm	diameter 152mm height 125mm	diameter 152mm height 300mm

2. APPARATUS

2.1. A vibratory hammer with the following specifications;

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. The total mass of vibratory hammer, surcharge and mounting head should be 30kg ± 1.5kg. There should be a pulley system connecting the frame and mounting head. This allows for easy lifting and lowering of the vibratory hammer.

2.2 A 10kg surcharge weight, to mount onto vibratory hammer (except for 100mm diameter specimens, where 5kg is required)

2.3 Steel split moulds with the dimensions indicated below, with detachable collar and base plate. A spacer plate can be used with the proviso that with the spacer plate inside the mould the effective height shown below shall be maintained.

Phase	Level 1	Level 2	Level 3
Test	ITS	ITS and UCS	Triaxial
Diameter of mould	101 ± 1mm	152 ± 1mm	152 ± 1mm
Minimum height of mould (excluding height of spacer plate)	65 mm	125mm	300mm

2.4 A 100mm diameter and/or 150mm diameter tamping foot.

2.5 A steel rule or vernier caliper, minimum length 300mm.

2.6 A balance to weight up to 15kg, accurate to 1g.

- 2.7 A balance to weigh up to 2kg, accurate to 0.1g.
- 2.8 Suitable air-tight containers, approximately capacity 15 to 20 litres.
- 2.9 A mixing basin, approximately 500mm in diameter.
- 2.10 A mixing trowel.
- 2.11 A chisel or spatula, approximate length 200mm.
- 2.12 Suitable containers to hold 1kg of material for moisture content determination.
- 2.13 A force draft drying oven, thermostatically controlled and capable of maintaining a temperature of 105 to 110 °C.
- 2.14 A 1000 mℓ measuring cylinder.
- 2.15 Filter paper, 100mm and/or 150mm in diameter.
- 2.16 Lubricating grease or non-stick spray.
- 2.17 A sample extruder to remove sample from the mould, if split mould is not used.
- 2.18 Material Scoop (90mm Φ x 85mm h)
- 2.19 Suitable marker e.g. permanent marker
- 2.20 Adjustable spanner to fasten and loosen surcharge load to the vibratory hammer.

3. **SAMPLE PREPARATION**

Samples shall be blended and reconstituted as outlined in Appendix A2. The following minimum sizes of samples are required.

Phase	Level 1	Level 2	Level 3
Test	ITS	ITS and UCS	Triaxial
Minimum mass of sample required per bitumen content	10kg per or as per mixer manufacturers recommendations	30kg per or as per mixer manufacturers recommendations	60kg per or as per mixer manufacturers recommendations
Minimum number of specimens per bitumen content	6	4	4

All prepared samples to be placed in air-tight containers. Determine the hygroscopic moisture of the air-dried blended material (See Equation 1).

4. Mixing

4.1 BSM-Emulsion Stabilised Material

The cement or lime, if required, is added to the air-dried material and mixed thoroughly. The optimum fluid content (OFC) is added to each sample but the emulsion content is varied such that samples are tested at a minimum of 4 residual bitumen contents at intervals of 0.25%. The following ranges of residual bitumen are recommended for the following material types;

Material	Grading Modulus	CBR @ 100% modified AASHTO	Residual Bitumen Range
Reclaimed Asphalt Pavement (RAP)	n/a	n/a	1.75 – 2.50
Graded Crushed Rock	> 2.0	> 80	2.25 – 3.00
Granular Material or Blends	> 2.0	> 45	2.50 – 3.25
Granular Material or Blends	< 2.0	> 20	2.50 – 4.00 (0.5% increments)

Add the water (See Equation 2) to the material and mix thoroughly and allow to stand in an air-tight container for 15 to 30 minutes. Add the emulsion (See Equation 3) and again mix thoroughly. Allow this emulsion treated material to stand for 40 to 60 minutes to allow breaking of the bitumen emulsion prior to compaction. All 4 samples can be prepared in this manner at least 15 minutes apart to allow for compaction time. Care should be taken to prevent loss of moisture when the materials are left to stand and during compaction.

4.2 BSM – Foamed Bitumen Stabilised Material

The air-dried material is placed into the mixer of the foamed bitumen laboratory unit. The cement or lime, if required, is added to the air-dried material and mixed thoroughly. Water is added to the material to bring the material to 60% of the OMC determined by vibratory hammer compaction for the treated material (added water + hygroscopic water) and mixed thoroughly. The mixed material should be completely moist with no dry material evident. The foamed bitumen is added at 0.25% increments for at least 4 samples within the residual bitumen range recommended in Subsection 4.1.

Place the foamed bitumen laboratory unit in position to spray the foamed bitumen into the moist material in the mixer. Set the laboratory unit to spray the required amount of foamed bitumen, start the mixer and inject the foamed bitumen into the mixer. Mix the foamed bitumen treated material for 30 seconds or until thoroughly mixed. Add the outstanding amount of water (remaining 40% of OMC) to bring the moisture content of the material to the OMC determined by vibratory hammer compaction.

Compaction can be started after mixing of all the samples and care should be taken to prevent loss of moisture when materials are left to stand and during compaction.

5. PREPARATION OF SPECIMENS

5.1 Preparing the vibratory hammer

Fix the mounting head and appropriate tamping foot to the vibratory hammer and fit hammer onto guide rods. Place 10kg surcharge weight onto mounting head and fasten tightly. Using the pulley system raise the vibratory to the maximum height it can be raised or to an adequate height that will allow operator to work safely beneath the vibratory hammer.

5.2 Preparing the mould

Clean the mould, collar and base plate. Lubricate the inside mould wall with a very light application of lubricating grease or non-stick spray. This allows for easy removal of the compacted sample and easy cleaning of the mould thereafter.

Fix the mould to the base of the compaction frame directly below the foot piece of the vibratory hammer. Place a sheet of circular filter paper at the bottom 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 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 (non-erasable).

5.3 Compaction

The prepared material should be mixed immediately prior to compaction and be compacted at a temperature between 22 and 25 °C.

The number of layers for each type of specimen required is shown below.

Phase	Level 1	Level 2		Level 3
Test	ITS	ITS	UCS	Triaxial
Sample diameter (mm)	101	152	152	152
Sample height (mm)	65	95	125	300
Approximate volume of compacted specimen – Vcs in Eq 4 (cm ³)	520	1725	2270	5445
Surcharge on Hammer	5kg	10kg	10kg	10kg
Number of layers	1	2	2	5
Compaction time per layer (secs)	(per side)			
BSM-emulsion	10	15	15	15
BSM-foam	10	25	25	25
Tamping foot diameter (mm)	100	150	150	150

The approximate quantity of material required for each layer will be the total quantity of material based on the maximum dry density, the optimum moisture content and volume of compacted specimen (See Equation 4). The quantity of material for each layer will be the total quantity of material divided by the number of layers. For multi-layer specimens slight adjustments might be necessary for consecutive layers to achieve the recommended height.

Material is placed in the mould using a material scoop. Use the chisel to work the material around in order to evenly distribute the material in the mould without segregating the sample. Ensure that the material is as level as possible before lowering the vibratory hammer until the foot piece comes to rest on the material. The operator should ensure that the tamping foot is kept clean and no material build-up is formed on the tamping face.

After compaction of the layer, raise the vibratory hammer and secure. Measure the compacted thickness of the layer.

For 2 and 5 layer specimens, if necessary, adjust for the amount of material to be added for the next layers such that the final compacted thickness is achieved. Using the chisel, scarify the entire surface area of the top of the compacted layer to a maximum depth of 10mm. Add the required amount of material and ensure the material is level as possible. For the final layer, place a sheet of circular filter paper on top of the material, lower vibratory hammer and compact.

After final compaction, prior to raising the vibratory, measure the distance from the initial position of rest of the lower end of the sleeve of the mounting head (without material in mould) to the final position of the lower end of the sleeve of the mounting head (after final compaction). This distance represents the final height of the compacted specimen and should be checked by measuring the samples after removal from the mould.

Compact the additional specimens for each bitumen content in the same manner.

5.4 Determination of moisture content

Two representative samples ($\pm 1000\text{g}$) are taken at different times during the compaction of all required specimens and placed in a suitable container for determination of moisture content.

The moist samples are weighed immediately to the nearest 0.1g and placed in an oven a 105 to 110 °C. The moisture content is determined to the nearest 0.1 percent.

5.5 Determination of the mass of compacted material

Raise the vibratory hammer and remove the collar. Remove the mould with the compacted material from the base plate and extract sample carefully from the mould. If sample is extruded from mould, the sample shall not distort during extrusion. The compacted material can now be weighed. This is the wet mass of the compacted specimen.

6. CALCULATIONS

6.1 Determine the moisture content of the sample using equation 1

$$MC = \frac{a - b}{b - c} \times 100 \quad \text{[Equation 1]}$$

where	MC	= moisture content expressed as a percentage of the dry sample [%]	
	a	= mass container and wet material	[g]
	b	= mass of container and dry material	[g]
	c	= mass of container only	[g]

6.2 Determine the quantity of water for BSM-emulsion using equation 2

$$Q_w = \frac{M_a}{100 + M_{Ch}} \times \frac{OFC - M_{Ch} - P_{em}}{100} \quad \text{[Equation 2]}$$

where

Q _e	= Quantity of emulsion	[g]
Ma	= mass of air-dried sample	[g]
MCh	= hygroscopic moisture of sample	[%]
OFC	= Optimum Fluid Content	[%]
P _{em}	= emulsion required	[%]

$$P_{em} = \frac{P_{rb} \times 100}{E_b}$$

where

P _{rb}	= residual bitumen required	[%]	and
E _b	= residual bitumen content in emulsion (eg 60%)	[%]	

6.3 Determine the quantity of emulsion using equation 3

$$Q_e = \frac{M_a}{100 + M_{Ch}} \times \frac{P_{rb} \times 100}{E_b} \quad \text{[Equation 3]}$$

6.4 Determine the total quantity of material for compacted specimen using equation 4

$$TMQ = \frac{D_{den} \times V_{cs}}{1000} \times \frac{100 + OMC}{100} \quad \text{[Equation 4]}$$

where

TMQ	= total material quantity	[g]
D _{den}	= maximum dry density	[kg/m ³]
V _{cs}	= volume of compacted specimen (See Section 6)	[cm ³]
OMC	= optimum moisture content	[%]

for emulsion treated samples OMC = OFC – residual bitumen content

6.5 Determine the dry density of the compacted sample using equation 5

$$D_d = \frac{M_w}{100 + M_{Ct}} \times \frac{100}{Vol} \times 1000 \quad \text{[Equation 5]}$$

where

D _d	= Dry density of compacted sample	[kg/m ³]
M _w	= mass of wet compacted sample	[g]
M _{Ct}	= moisture content of compacted sample	[%]

7. REPORTING

All specimens shall be clearly marked for easy identification, then cured and tested as necessary.

For each specimen the following shall be reported;

- The date of moulding;
- The dry density to the nearest 1 kg/m^3 ;
- The moulding moisture content to the nearest 0.1%;
- The final height of the specimen to the nearest 0.1mm;
- The diameter of the specimen to the nearest 0.1mm.

This information shall be included with the final strength test results of the specimens.