FOAM

Duurzame funderingen door in situ recycling met schuimbitumentechnologie

INSTRUCTIONS FOR THE MIX DESIGN

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INSTRUCTIONS FOR THE MIX DESIGN

The most applicable binder, filler, parent material (aggregate), and quantity required to meet the bitumen stabilised material should be determined through laboratory tests.

Details of the sampling and laboratory testing associated with the stabilisation mix design are described below.

1. Field Sampling and Sample Preparation

When undertaking a mix design for in situ stabilisation, the samples of pavement material selected for testing must represent the material to be stabilised. Therefore, the selection of representative samples for testing requires bulk samples to be classified according to a visual description and the results of standard laboratory classification tests. (EN 932-1)

This section is divided into two parts. The first part explains obtaining samples and the second part explains preparing samples for testing in the laboratory.

- Sampling from test pits

Test pits are commonly used for exposing and sampling foundation and construction materials. The test pit must be large enough to permit detailed examinations of the material in situ to be conducted or to obtain large, undisturbed samples as required by the investigation. Test pits are usually located in the outer wheel path of trafficked lanes.

A sample of sufficient size from each pavement layer should be placed in a separate container or thick plastic bags and sealed to avoid loss of moisture content. Every container / bag must be clearly labelled showing the appropriate information, e.g. test pit ID, the layer (e.g. upper subbase) and the thickness of the layer.

- Sampling from stockpile

Segregation often occurs when materials are stockpiled; therefore, it is difficult to ensure representative samples from stockpiles. Therefore, it is crucial to take the samples from different locations around the stockpile. Extracting samples must be placed into a sealed container or plastic bag. Samples should be stored in an area where contamination cannot occur.

2. Preliminary Testing

This section explains the procedure of preliminary tests on bitumen stabilised materials.

- Air Dry

The first step before starting the mixture design is air drying the samples obtained from test pits or stockpiles. The material (RAP) must be spread onto a clean dry surface protected from rain or wind. The thickness of the material spread for the air-dry procedure should be a maximum ± 3 cm. After drying to constant mass, material must be collected according to the quartering method to have the same gradation as in bulk samples. EN 932-2 procedure is followed for the quartering method.

- Moisture content and Hygroscopic Moisture Content (EN 1097-5)

Hygroscopic moisture content is a term that stands for the moisture content of air-dried material. It is an important step to determine the moisture content of the end material. Two air-dried samples, each approximately 1 kg, are used to determine the material's hygroscopic (air-dried) moisture content following the standard test procedure EN 1097-5 for moisture determination.

- Sieve Analysis to determine grading (EN 933-2)

Washed fine procedure must be followed on granular materials used as base course however, it is recommended to follow dry sieve analysis procedure when working with RAP.

- Atterberg Limits

The Atterberg limit test, according to NBN CEN ISO/TS 17892-12, is used to determine the plasticity of the parent material to be stabilised. RAP does not have plasticity, It is therefore Atterberg Limit tests on RAP material is not required.

- Modified Proctor Test (EN 13286-2)

The Proctor test is used to establish a relationship between moisture content and dry density. The results define the correct moisture content for optimum compaction; meaning the optimum water content and maximum achievable dry density. In addition the maximum dry density is used as a reference when determining the degree of compaction of a constructed layer. Maximum dry density (MDD) and Optimum moisture content (OMC) is defined by following EN 13286-2 Modified proctor test procedure.

3. The Foaming Unit (Wirtgen WLB 10 S)

This section explains how to produce foamed bitumen using WLB 10 S. Filling the water tank must be done when there is no air pressure in the system, in other words, before starting the internal compressor and connecting the external compressed air supply. The water tank of the WLB 10 S must be filled with adequate water (at least half of the water tank). This is carried out by opening the water valve at the back of the unit and pouring water into the funnel. The water level indicator on the right side of the unit shows when the water tank is full. Water valve must be closed after filling with water.

The points should be taken into account when working with the foaming unit:

- Regular draining of the entire water system is recommended to avoid corrosion in the water tank.
- Only clean potable water is to be used and the temperature of the water is recommended to be higher than 20 °C.
- The water filter should be checked and cleaned regularly.

The correct bitumen nozzle must be screwed in before start working. It is easier to screw the nozzles in and out once the heating circuit for the bitumen nozzle has been heated up. The bitumen to be foamed must be preheated in a suitable oven to a temperature of at least 120 °C before adding into the bitumen tank. The required amount of bitumen is approximately 3-5 liters. The required air and water pressures can now be read off at the corresponding pressure gauge (factory setting: air pressure 5 bar / 73 psi and water pressure 6 bar / 87 psi) and adjusted if necessary using the adjuster screws. Starting with the foaming unit steps as follows:

1. Once the power supply is connected, the foaming unit can be switched on by using the red main circuit. The heater and the pump should still be switched off at this time.
2. Each heating circuit can be set at the desired temperature using the multi-function display. The value of each heating circuit should not exceed 100 °C, while the pump is turned off, meaning before the bitumen circulation starts.
3. The heating circuit can now be switched on at the set temperature. And, the illuminated LEDs indicate that the heating circuit in question is heating up to the set temperature. The LED fades out when the set temperature has been reached. The unit is ready to start working on.

4. When the temperatures reaches 100 °C then the preheated bitumen (3-5 liters) can be added into the bitumen tank of WLB 10 S. And the lid is closed. It is important to take precaution while working with hot bitumen such as facial protection, heat resistant gloves, and laboratory clothes.
5. The temperature can be set at 130 °C to start the bitumen circulation. When the heating circuit of the pump reaches a temperature higher than 130 °C, and the bitumen circulation can start switching on the pump button. The pump should only be started once the added bitumen is in liquid faze.
6. It is recommended to check always pressure gauge to make sure the circulation is not prevented by cold bitumen (blockage) within the system. In this case, it is necessary to heat up the system for a longer period before starting the circulation. Free circulated bitumen does not produce backpressures, therefore, If the bitumen pressure gauge shows pressure during circulation which means there is a blockage inside the system and the pump immediately must be switched off.
7. The temperature of each heating circuit now can be set at a working temperature (160 °C - 180 ±5 °C). The duration to reach the set temperature depends on the initial bitumen temperature and the quantity of the added bitumen. To check whether the set temperature has been reached or not can be checked on display or by the LED lights. If the LED lights go out, it means that the set temperature has been reached. Once the working temperature reaches, the foaming unit is ready to produce foamed bitumen.

Calibrating Flow Rates

The flow rates of bitumen and water should be checked every time the unit is turned on.

Bitumen flow rate

For the calibration and checking bitumen flow rate, it is important to make sure the correct nozzle is screwed and the water valve is closed before start working. After closing the water valve, pressing the water and air buttons simultaneously will ensure that no water is left in the system. The empty bucket should be placed under the bitumen nozzle, and the bucket tare must be set to zero. The required amount of bitumen is set on the display . Principally, 500 g of bitumen should be selected for calibration. Pressing the bitumen flow button results in the required amount of bitumen to be pumped through the nozzle into the bucket. Then, the bitumen in the bucket can be weighted (before weighing the bucket tare must be set to zero). The flow rate can be adjusted using the rotary knob if required.

Water flow rate

The empty bucket should be placed under the bitumen nozzle and the water valve should be open. The scaled lines on the flow-through meter show the flow rate in liters per hour. Table I.1 shows the water flow rates (liters per hour) for different foaming water content (%) and bitumen flow rate (50 g/sec. and 100 g/sec.).

Table I.1. Conversion of water flow rate from % to l/h

Bitumen flow rate (g/sec.)	**Amount of water added [%]**								
	1	1.5	2	2.5	3	3.5	4	4.5	5
	Water flow rate [l/h]								

100	3.6	5.4	7.2	9.0	10.8	12.6	14.4	16.2	18
50	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9

Water and air buttons must be pressed simultaneously to make settings and, the adjuster screw for the flow-through meter can be operated by free hand until it the float remains steadily in the required position

4. Determining the Foaming Properties (Expansion Ratio and Half-life)

The Expansion Ratio (ER) and Half-life (HL) are two characteristics that determine bitumen's suitability to be used. The Expansion Ratio (ER) is the maximum volume of foam relative to the original volume. And, The Half-Life (HL): is the time the foam takes to collapse to half of its maximum volume. These characteristics depend on:

- Bitumen type
- Bitumen temperature
- Bitumen water quantity
- Air and water pressure

The following procedure aims to determine the bitumen temperature and percentage of water addition required to produce the best foam bitumen with the largest expansion ratio and with the longest possible half-life for a particular source of bitumen. The test has been repeated at three (3) different bitumen temperatures (ranging between 160 °C and 180 °C) to determine the percentage of water added to achieve the optimum foaming characteristics. The procedure to determine the expansion ratio and half-life is followed by:

1. The foaming unit WLB 10 S should be prepared by following sections 3.
2. Set the bitumen temperature at 160 °C.
3. Prepare a stopwatch to measure the HL, the bitumen bucket (20 liters) and the measuring rod (dipstick) that are matched can be used to measure ER and HL. The measuring rod supplied by the Wirtgen WLB 10 S which is calibrated for a steel drum of 257 mm in diameter and 500 g of bitumen.
4. Prepare a stopwatch (to measure the half life) and a dipstick (to measure the expansion ratio).
5. Set the water flow rate of 100 g/sec. (This means spraying time of 5 seconds). The water flow meter is normally set to inject 2% of water by mass of bitumen for the first testing cycle.
6. Then, the foamed bitumen can be discharged into a preheated (±75 °C) steel drum for a calculated spray time for 500 g of bitumen. Immediately after the foam discharge stops, start a stopwatch. Note the spraying time, and immediately continue measuring the time.
7. Use the dipstick to estimate (to the nearest whole number) the maximum height that the foamed bitumen reaches in the container and record it as the maximum Expansion Ratio (ER = h1).
8. Measure the time that the foam takes to dissipate to half of its maximum volume in the container. When this point is reached, stop the stopwatch. Record the elapsed time to the nearest second as the foamed bitumen's half-life (t1).
9. Empty the container and repeat the steps above 3 times. And record each readings (h1, h2, h3, t1, t2, t3). Then calculate the average values.
10. Repeat the steps above (Step 1 to Step 8) for a range of at least three water injection rates, typically 1%, 2%, 3% and, 4% by mass of bitumen.

11. Repeat the steps above (Step 1 to Step 8) for the bitumen at two higher temperatures, typically 170 °C and 180 °C. It is important to note that the bitumen should NOT be heated above 190 °C.
12. Select the optimum water injec
13. Select the optimum water injection rate and bitumen temperature that matching with the requierements given in Table I.2.

Table I.2. ER and HL requierements

Aggregate Temperature	**15 °C to 25 °C**	**> 25 °C**
Expansion Ratio, ER (times)	≥ 10	> 8
Half-life, HL (secs)	≥ 8	≥ 6

- Calculation of the bitumen discharged in 5 seconds.

$M_b=(M_{bc}-M_c)$ where:

M_b : Mass of bitumen discharged in 5 seconds (g)

M_c : Mass of empty container (g)

M_{bc} : Mass of container and bitumen (g)

- Preparation of a chart to plot expansion ratio and half life at three different water injection percentages acoording to Table I.3.

Table I.3. Guideline to prepare a chart to plot ER and HL (TG2)

	Horizontal Axis	**Vertical Axis**	
	Water injection rate	**Left Ordinate: ER**	**Right Ordinate: HL**
Unit	Percentage (%)	Times expansion	seconds
Scale	20 mm = 0.5%	5 mm = 1 time	5 mm = 2 seconds

Example of the chart shown in Figure I.1.:

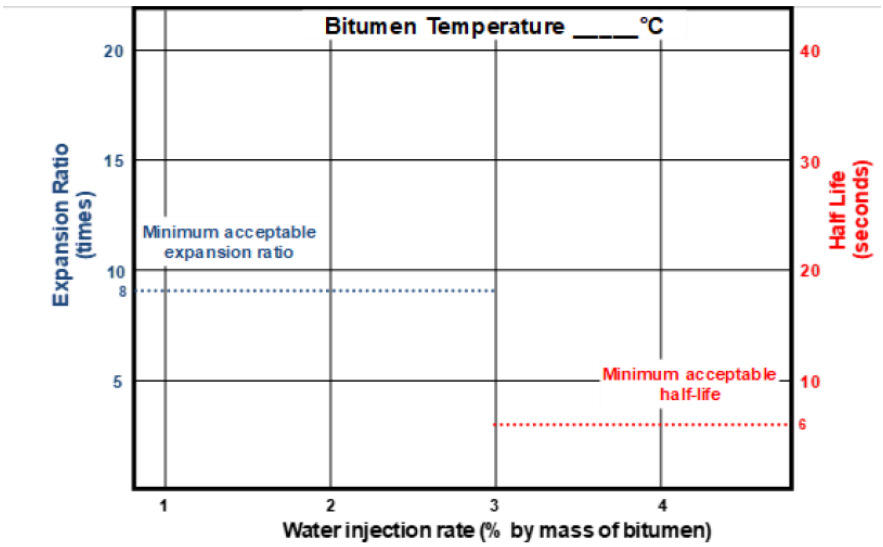

Figure I.1. Chart to plot ER and HL as a template (TG2)

Once the optimum water addition has been defined in relation to the type of bitumen used and the bitumen temperature, it is now possible to start mixing materials.

5. Mixing

The amount of bitumen, active filler, and water to be added to air-dried material (RAP) is calculated based on dry mass of the material. The Wirtgen pug mill mixer (WLM 30) is recommended to achieve a homogenous mixture. When working with WLM30, using at least 20 kg of material for one mix is recommended.

The oven-dried mass of the material used in the mix (aggregate) is calculated as follows:

$$M_{OD} = \frac{M_{AD}}{1 + (W_{AD}/100)}$$

M_{OD} : oven-dried mass of material to be mixed (g)

M_{AD} : air-dried mass of material to be mixed (g)

W_{AD} : Water content of the air-dried material (% of the oven-dried mass)

The required amount of active filler or foamed bitumen to be added to the mixture is calculated as follows:

$$M_{AF} = P_{AF} . \frac{M_{OD}}{100}$$

$$M_{FB} = P_{FB} . \frac{M_{OD}}{100}$$

M_{OD} : oven-dried mass of material to be mixed (g)

P_{AF} : percentage of active filler to be added (%)

M_{AF} : mass of active filler to be added (g)

M_{FB} : mass of foamed bitumen to be added (g)

P_{FB} : percentage of foamed bitumen to be added (%)

The required amount of water to achieve OMC in the BSM-Foam mix is calculated as follows:

$$M_W = \frac{OMC \times (M_{OD} + M_{AF} + M_{FB})}{100} - (M_{AD} - M_{OD})$$

OMC : optimum moisture content of the parent material (%)

Mw : amount of water required to achieve OMC

The sample to be mixed shall be prepared as described:

1. Add the air-dried material (temperature is between ±15°C and ±25 °C) along the length of the mixer and distribute the active filler (e.g. cement) over the surface of the added material at ambient temperature.
2. Start the mixer (WLM 30) at 25-30 % of the maximum speed for 30 seconds.

3. The mass of the first addition of water is calculated to achieve 60% of OMC. In this stage, slowly pour the first addition of water while the mixer is running at 90% of maximum speed. Mix for 30 seconds. After mixing is completed, check if the moisture content of the material is consistent. If variable colour is observed, mix for a further 30 seconds to achieve consistency.
4. Move the mixer under WLB10S foaming plant, cover must be correctly placed under the foaming nozzle. Start the mixer at maximum speed. Once the mixer is running at full speed, inject the foamed bitumen (the injection temperature ± 100 °C after foaming completed). Let the mixer run for 30 seconds. Foamed bitumen in the material ranges between 1.8 % - 3% in total mass. Therefore, the material temperature is slightly increasing (± 25 °C).
5. Reduce the mixing speed to 90% of the maximum and slowly pour the remaining water to achieve 100% of OMC. Let the mixer run for 30 seconds. Check the material consistency; if the appearance is not uniform, run the mixer for a further 30 seconds.
6. Remove the material from the mixer by rotating the mixer to let the material fall into the cover. The material taken from the mixer is immediately transferred to a sealed container and used to manufacture the test specimens within 30 minutes. In exceptional circumstances, the maximum time delay between mixing and manufacturing test specimens is four (4) hours, and the material must be protected in a sealed bag.

The mixing process for foamed bitumen stabilised materials are shown in Figure I.2..

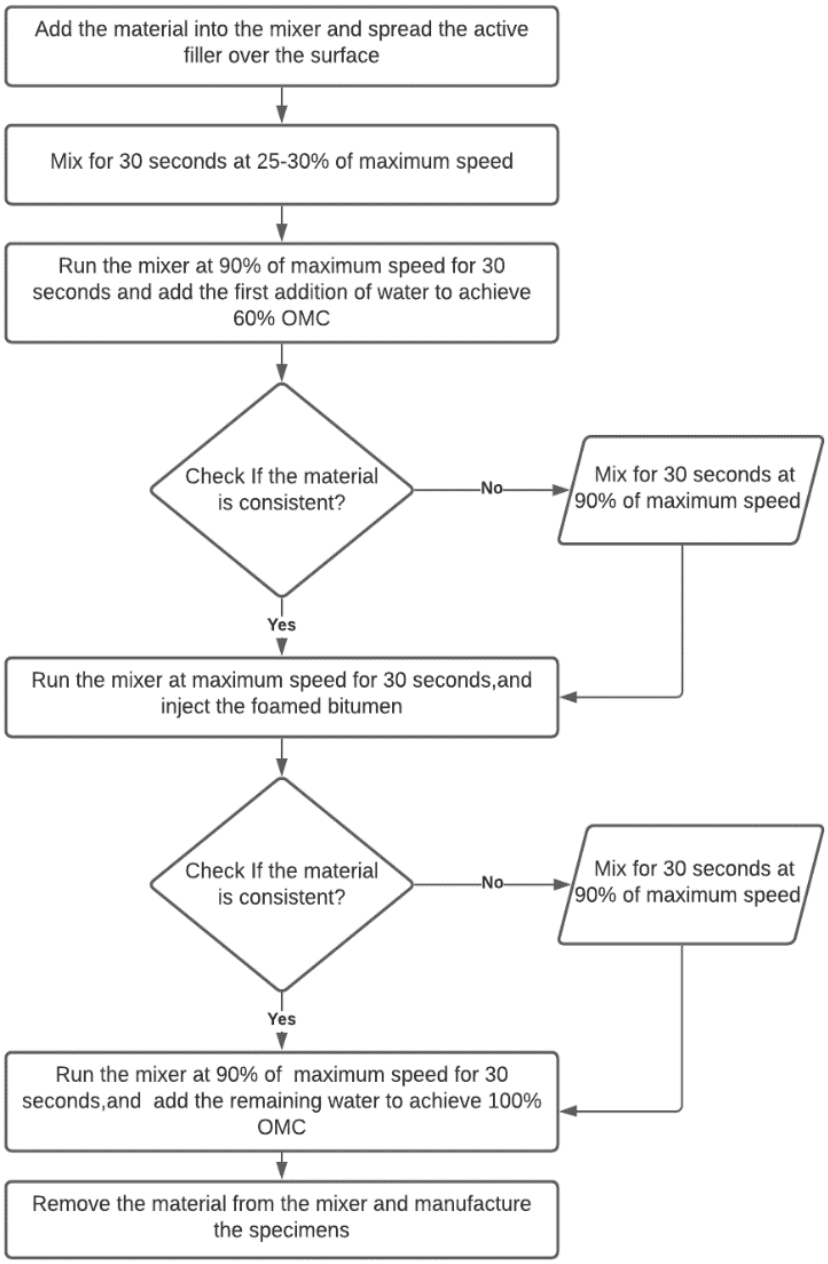

Figure I.2. Mixing procedure for BSM-Foam.

6. Compaction

A gyratory or vibrating hammer compaction method is recommended BSM-Foam mixes, depending on the availability of the equipment. Since both compaction methods have a different working mechanisms, the compaction procedure also differs.). Test specimens for mix design are manufactured at 100% of optimum moisture content (determined from the modified proctor test). It should be noted that the maximum allowed time delay between mixing the material with foamed bitumen and manufacturing test specimens is 4 hours (in a sealed bag).

The mass of each BSM-Foam specimen to be compacted is calculated as follows:

$$M_{BSM} = \frac{(\prod \times D^2)}{4 \times 10^6} \times H \times \left(MDD \times \left(1 + \frac{OMC}{100} \right) \right)$$

M_{BSM} : Mass of each BSM-Foam specimen at OMC (g)

MDD : Maximum dry density of parent material (kg / m^3)

OMC : Optimum moisture content of parent material (%)

D : Diameter of the mould/specimen to be compacted (mm)

H : Height of the specimen to be achieved after compaction (mm)

The required mass for each layer is calculated as follows:

$$M_L = \frac{M_{BSM}}{n}$$

M_L : mass of the BSM-Foam specimen for each layer (g)

n : number of layers to be compacted

Gyratory

The gyratory specimen requirements for ITS test and Triaxial test are shown in Table I.4.

Table I.4. Requirements for gyratory compaction

	ITS test	**Triaxial test**
Number of specimens per batch	6	10
Specimen diameter [mm]	150 ±2	150 ±2
Specimen height [mm]	95±1	2 * (150 ± 1)
Number of layers	1	1
Layer thickness [mm]	-	150

The recommended gyratory compaction settings are 0.82^0 angle of gyration, speed of 30 rpm and 600 kPa compaction pressure according to EN12697-31. The height limit is set at 95 mm for ITS specimens and 150mm for Triaxial specimens. Triaxial specimens are prepared as two separate specimens and tested as placed one on top of another to reach 300 mm height. The use of perforated moulds assists in completing the first curing stage of BSM-Foam mixtures.

The procedure to manufacture the test specimens is as follows:

1. Place the determined amount of material in the mould. Compaction with gyratory is made at one layer.
2. Set the gyratory settings on the software and start the compaction; compaction should end before reaching max. 200 gyrations.
3. If the compaction takes longer than 200 cycles, stop the compaction procedure and take the material out. Then, place half of the material in a mould and run the compaction at a height limit of 48 mm for ITS and 75 mm for Triaxial specimens. When the height is reached, remove the mould, add the second half of the material, and rerun the compaction for a height limit of 95 mm for ITS and 150 mm for Triaxial specimens. Ensure that the compaction for each layer takes less than 200 gyrations. If this happens, terminate the manufacturing procedure and ensure the Maximum Dry Density (MDD) used in the calculation is correct. It is also important

to note that, If water leakage from the mould is observed during compaction, stop the compaction procedure and repeat the Modified Proctor test to determine the correct MDD and OMC values. Then revised the mixing and compaction procedure using the correct values.

4. Once the compaction is completed, carefully place the mould and specimen on the ambient temperature room and record the mass and follow the curing instruction in Section 7.

Vibrating Hammer

The steps required to manufacture test specimens with WLV1 vibrating hammer are covered in this section. The vibrating hammer specimen requirements for ITS test and Triaxial test are shown in Table I.5.

Table I.5. Requirements for vibrating hammer compaction

	ITS test	**Triaxial test**
Number of specimens per batch	6	10
Specimen diameter [mm]	150 ±2	150 ±2
Specimen height [mm]	95±1	300±1
Number of layers	2	5
Layer thickness [mm]	47.5	60

If the required height cannot be achieved in 120 seconds with the vibrating hammer, compaction should stop and the layers may be increased to 3 layers for ITS test specimens and to 6 layers for triaxial test specimens. The vibrating hammer works in two different functions named distance measurement and time measurement. Distance measurement allows the vibrating hammer to run until a specific height is achieved. On the other hand, time measurement allows the vibrating hammer to run for a set time in seconds. For the compaction of BSM-Foam mixtures, distance measurement is selected in vibrating hammer. The procedure for compaction is as follows:

1. Ensure that the calibration is made for WLV 1. Clean the mould and base plate. Lubricate the inside of the mould with a light application of lubricating grease or non-stick spray. Fix the mould and base plate to the concrete block. Check the alignment of the mould and vibratory hammer by lowering the tamping foot into the mould. Check that the lifting system provides sufficient slack for the tamping foot to rest on the base plate.
2. Place the determined amount of material for the first layer in the mould. Then, Use the spatula to spread the material evenly in the mould avoiding segregation. Then use the Interlayer Roughening Device (IRD) to level the material inside the mould.
3. Lower the vibratory hammer until the tamping foot rests on the material. Ensure the lifting system is slack, allowing the hammer to slide downwards as the material compacts. Turn on the vibratory hammer and start the timer. When the height is reached for the first layer, the vibrating hammer will lift automatically. Record the time taken to compact the layer. When the compaction time for any layer exceeds 120 seconds, terminate the manufacturing procedure, increase the number of layers and start the procedure again. In the unlikely event of the problem persisting with an increased number of layers, terminate the manufacturing procedure and seal all the material in airtight containers. Repeat the Modified proctor test on a

new sample of the untreated material to determine the correct values for the MDD and OMC. Then start the procedure again using the revised MDD as the target density.

4. Use the interlayer roughening device (IRD) to prepare the surface of the compacted layer inside the mould by applying sufficient pressure and rotating the IRD several times until the top of the compacted material is loosened. When the surface has been sufficiently roughened, proceed immediately with the next layer.
5. Place the material for the second layer and compact it as described in Steps 2 and 3. For Triaxial specimens, this step is repeated for 5 layers.
6. Once the compaction is completed, carefully place the mould and specimen on the ambient temperature room and record the mass and follow the curing instruction in Section 7.

7. Curing

The curing process allows BSM-Foam mixtures to acquire their strength by losing a significant amount of moisture in the mix. The curing process is essential in the short and long-term material characteristics. The curing of the specimens for ITS and Triaxial testing is different.

Curing of ITS specimens:

1. Once the compaction is completed, leave the specimens a minimum of 4 hours before removing them from their respective moulds and carefully placing each on a carrying plate.
2. And record the mass of specimens before placing them into an oven.
3. Place the six specimens on their carrying plates in the oven at a temperature of 40 ± 1 °C for a period of at least 72 hours. Ensure that there is a minimum air space of 25 mm between specimens.
4. After 72 hours, remove one specimen per batch from the oven and record the mass, then repeat this after 4 hours. The curing is completed when there is less than 10 g of loss. Take the specimens from the oven and record the weight of each specimen. And continue with measuring the height at three evenly spaced points around the circumference (h1, h2 and h3), calculate the average and record to the nearest 0.5 mm. And, measure the diameter at mid-height, at three evenly spaced points (d1, d2 and d3), calculate the average and record to the nearest 0.1 mm.
5. Then, place three of the specimen of each batch into a cooling chamber at 25 °C. And place the other three from each batch in the water bath and soak for 24 hours at 25 °C. Ensure that the specimens are covered by at least 25 mm of water.

Curing of Triaxial specimens

1. Leave all ten specimens overnight in their respective moulds covered with a moist hessian cloth.
2. Remove the specimens from their respective moulds the following morning.
3. Place the specimens in the oven at a temperature of 40 ± 1 °C for 8 hours. Ensure that there is a minimum air space of 25 mm between specimens. To avoid damage to the large specimens, exercise care when moving them. Specimens are always moved on their respective carrier plates.
4. Record the mass of each specimen before placing them into an oven.
5. After 8 hours curing at 40 ± 1 °C, remove all the specimens from the oven. Place each specimen in a loose-fitting plastic bag and seal the bag. Then, Place the specimens (in plastic bags) into the oven at a temperature of 40 ± 1 °C for 48 hours.

6. Remove the specimens from the oven after 48 hours and take them out of their respective plastic bags. Record the weight of each specimen. And continue with measuring the height at three evenly spaced points around the circumference (h1, h2 and h3), calculate the average and record to the nearest 0.5 mm. And, measure the diameter at mid-height, at three evenly spaced points (d1, d2 and d3), calculate the average and record to the nearest 0.1 mm.
7. Place the eight of the specimens in a dry loose fitting plastic bags and leave in the cooling chamber at 25 °C for a minimum 12 hours. Then, place two of the specimens under water for 24 hours in a soaking bath at a temperature of 25 °C.

8. Indirect Tensile Strength Testing

The ITS value for each specimen is first determined. The ITS_{DRY} and ITS_{WET} values are then calculated by averaging the results for the respective unsoaked and soaked specimens. It is important to maintain the temperature at 25 °C throughout the testing.

According to EN 12697-23, ITS is measured by applying a compression load along the diameter of a cylindrical specimen at a 50 ± 2 mm/minute constant rate using two steel strips on the specimen top and bottom to procreate tension zone passing through the centre of its loaded. The test is conducted at 25 °C temperature. The ITS of the specimen is calculated from:

$$ITS = \frac{2.P}{\pi \cdot D \cdot H}$$

Where ITS is the indirect tensile strength of the specimen (kPa); P is the peak load (kN); D is the specimen diameter (m); H is the specimen height (m).

Moisture sensitivity of the specimens is quantified by indirect tensile strength ratio (ITSR), defined as the percentage of the ITS of samples subjected to the submerged conditioning and those dry conditioned, based on the formula:

$$ITSR = \frac{ITS_{WET}}{ITS_{DRY}} .100$$

Where ITSR is the ratio of the indirect tensile strength calculated for the specimens under wet and dry conditions (%); ITS_{WET} is the average indirect tensile strength for wet specimens (kPa); ITS_{DRY} is average indirect tensile strength for dry specimens (kPa).

Once the test is completed, record the specimen identity, the maximum load applied (kN) and the displacement at break (mm). Immediately after the specimen has broken, remove it from the assembly and inspect the broken parts. Measure the temperature at the centre of the broken parts. For soaked specimens, estimate the extent of water penetration and record it as a percentage (e.g. ± 15% for the penetration. Break up one of the broken halves from each unsoaked specimen and combine them into a single sample. Separately, break one of the broken halves from each soaked specimen and combine them into a second sample. Extract a ±1kg representative sample from each (unsoaked and soaked) and determine the moisture content following the standard laboratory test procedure (i.e. overnight drying in an oven at 105°C).

9. Triaxial Testing

The purpose of performing triaxial testing is to determine the shear properties of BSM-Foam mixtures, cohesion (c) and friction angle (ϕ). The triaxial test is carried out on large specimens, each 150mm in diameter and 300mm high. Gyratory compacted specimens are tested placing two 150mm diameter specimens on top of each other, so 300mm height can be reached. Vibrating hammer allows to compact the specimens at 300 mm height, therefore the specimens are manufactured as 1 specimen. The test method calls for 2 soaked and 8 unsoaked specimens to be tested. The test involves subjecting a series of specimens to different levels of confinement and determining the magnitude of the applied load required to break the specimen under each different confining pressure. Confinement is achieved by placing the specimen in an inflatable rubber membrane that is placed inside a steel cylinder. The bladder is then inflated to the required at four confining pressure (0 kPa, 50 kPa, 100 kPa, 200 kPa). The steel cylinder prevents the bladder from expanding, thereby ensuring that the pressure is uniformly transferred to the circumferential face of the specimen. Based on the results (confining pressure and applied load), simplified Mohr-Coulomb theory is used to calculate the shear properties of the material (Cohesion and Angle of Internal Friction) which feed directly into the mechanistic / empirical method for designing pavement structures. It is important to keep the temperature at 25 ℃ throughout the testing. Triaxial testing is performed as follows:

1. Set the compression testing machine in displacement control mode at a rate of 3 mm/min. Ensure that the load and displacement readings are measured and recorded every second.
2. Apply the vertical load up to a displacement of 18 mm (6% strain), or sooner if the load starts to reduce from the maximum.
3. Unload the specimen by returning the actuator to its start position and release the confining pressure. Move the actuator clear of the top plate and remove the confining cylinder assembly from the loading frame. Dismantle the confining cylinder and carefully remove the specimen from the bladder. Immediately break the specimen and record the temperature in the centre and middle to the nearest 0.1 °C.
4. Take a sample of approximately 1 kg of material from the middle portion of the specimen and place in a sealed container. Determine the moisture content.
5. Repeat the procedure until all the specimens (unsoaked and soaked) have been tested at the confining pressures (0 kPa, 50 kPa, 100 kPa, 200 kPa).

10. Indirect Tensile Strength Modulus

Indirect tensile modulus (ITSM) is only used when the BSM material requires more than 1% active filler and/or > 3% bitumen addition. ITSM should be determined as the average of each four specimens for soaked and unsoaked conditions. This test is performed by following EN 12697-26 (both soaked and unsoaked conditions). ITSM samples are prepared with gyratory or vibratory hammer compaction having 150 ± 2 mm diameter and 60 ± 2 mm height. And ITSM is determined with the following parameters:

Test pulse period: 3000 ms

Pulse rise Time: 124 ms

Poisson ratio: 0.35

Target resilient strain: 50 microstrain

Test temperature: 25 ℃