Transport Roads & Maritime Services

NSW GOVERNMENT

# Test method T154

## Resilient modulus of road construction materials stabilised by foamed bitumen (blended in the laboratory)

**DECEMBER 2013**

# Revision Summary

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Note that Roads and Maritime Services is hereafter referred to as 'RMS'.

The most recent revisions to Test method T154 (other than minor editorial changes) are indicated by a vertical line in the margin as shown here.

# Test method T154

# Resilient modulus of road construction materials stabilised by foamed bitumen (blended in the laboratory)

## 1. Scope

This test method sets out the procedure to determine the resilient modulus of foamed bitumen stabilised material using specimens prepared and cured in the laboratory.

*NOTE: Where the binder content is to be determined for pavement design, the test is to be repeated for a range of binder contents as required by the pavement designer.*

## 2. General

(a) This method tests a specimen of granular material mixed in the laboratory with foamed bitumen and a suitable secondary binder.

(b) Moulded specimens are tested to determine:

(i) Initial Modulus after curing at 25°C for 3 hours.

(ii) Cured Modulus after curing at 40°C for 3 days.

(iii) Soaked Modulus after soaking for 24 hours.

(c) For each mix design to be tested, 6 samples are required to be prepared, 3 for initial modulus and 3 for cured and soaked modulus.

*NOTE: Testing of samples with initial curing only may cause damage to the sample which will influence cured and soaked modulus assessment.*

*NOTE: Typically to optimise a mix design 3 different mixes are required to be assessed which required a total of 18 samples to be prepared.*

(d) The following documents are referred to in this test method:

(i) T100 Sampling road construction materials (soil, gravel, sand, aggregate, rock and recycled products).

(ii) T105 Preparation of samples for testing (soils).

(iii) T106 Coarse particle distribution in road construction materials (by dry sieving).

(iv) T107 Fine particle distribution in road construction materials.

(v) T108 Liquid limit of road materials.

(vi) T109 Plastic limit and plasticity index of road construction materials.

(vii) T111 Dry density/moisture relationship of road construction materials.

(viii) T120 Moisture content of road construction materials (standard method).

(ix) T153 The half-life and expansion ratio of foamed bitumen.

(x) T602 Compaction of Test Specimens of Asphalt – Marshall Procedure.

(xi) AS 1289.3.6.1 Methods of testing soils for engineering purposes Soil classification tests—Determination of the particle size distribution of a soil—Standard method of analysis by sieving.

(xii) AS 1984 Vernier callipers (metric series).

(xiii) AS 2193 Calibration and classification of force-measuring systems.

(xiv) AS 2891 Methods of sampling and testing asphalt:

- AS 2891.2.1 Sample preparation–Mixing quartering and conditioning of asphalt in the laboratory.
- AS 2891.2.2 Sample preparation–compaction of asphalt test specimens using a gyratory compactor.
- AS 2891.5 Determination of stability and flow–Marshall procedure.
- AS 2891.9.3 Determination of bulk density of compacted asphalt–Mensuration method.
- AS 2891.13.1 Determination of the resilient modulus of asphalt–Indirect tensile method.

## 3. Apparatus

(a) An invertible cylindrical metal mould with 150 mm ± 2 mm or 100mm ± 2mm diameter.

*NOTE: A suitable mould is specified in AS 2891.13.1.*

(b) Marshall compaction equipment (removable baseplate, collar and spacer to produce a specimen 75 mm ± 5mm high.

(c) Specialised laboratory bitumen foaming machine incorporating temperature controls and water addition for foaming.

(d) A testing machine and data logging equipment as described in AS 2891.5.

(e) Mixing and quartering equipment (as specified in AS 2891.2.1).

(f) Suspension device, water container and suspension bridge (as specified in AS 2891.9.2).

(g) Loading jig and strips (as specified in T602).

(h) Temperature controlled water bath capable of maintaining temperature of 25 ± 2°C.

(i) Balance of not less than 5 kg capacity readable to 1 g and with a limit of performance of ± 0.5g.

(j) Thermostatically controlled air environment with good air circulation and capable of:

(i) Maintaining temperatures at 25 ± 0.5°C.

(ii) Maintaining temperatures at 40 ± 3°C.

(k) (Optional) A humidity cabinet maintaining temperatures at 25 ± 0.5°C

(l) Thermometer, or other suitable temperature measuring device, covering the range of 0°C to 100°C graduated in 1°C.

(m) Calibrated timing device readable to ± 0.5 second.

(n) Vernier callipers conforming to AS 1984 and readable to 0.1 mm.

(o) Marking crayon.

(p) Damp cloths to wipe the specimens.

(q) Plastic cling wrap, aluminium foil, thick leak-proof plastic bags and tape to seal single specimens.

## 4. Preparation

(a) Prepare the sample according to T105. A sample of supplementary material that can be incorporated to adjust the particle size distribution (PSD) may also be required. Adjust the sample size to:

(i) Suit the capacity of the foamed bitumen mixing equipment.

(ii) Suit the size of mould being used.

(iii) Suit the range of bitumen and secondary binder contents specified by the pavement designer.

(iv) Have sufficient mix to prepare 6 samples for each mix design (3 for initial curing and 3 for cured and soaked curing).

*NOTE: The supplementary material should represent the material used on site.*

(b) Determine the PSD of the sample and any proposed supplementary material according to T106 and T107, if not already determined.

(c) Where the PSD is not within the specified range add supplementary material in accordance with pavement designer's requirements to achieve the range:

(i) Dry the supplementary material so that it can be crumbled.

(ii) Weigh out portions of the sample and the supplementary material as required by the designer and record the mass of each.

(iii) Thoroughly mix the two materials to form the sample.

(iv) Determine the PSD of the sample according to T106 and T107.

(v) Repeat from Step 4 (c) if the required range is not achieved.

*Note: Pavement designer is to provide direction on supplementary material to be added.*

(d) Sieve the sample to meet the maximum particle size permitted for the mould size (-19mm is suitable for 100 or 150mm mould, -37.5 mm is suitable for 150mm mould only).

(e) Determine the following properties of the sample:

(i) Determine the Plasticity Index according to T108 and T109.

(ii) Determine the OMC and Maximum Dry Density according to T111.

(f) Obtain samples of the materials to be blended and test that they meet the requirements of the appropriate specification listed in Table 1.

**Table 1 - Standard of materials added**

| Material | Specification |
|---|---|
| Bitumen binder | RMS 3253 |
| Bitumen foaming additive (where required) | RMS 3255 |
| Secondary binder | RMS 3211 |

## 5. Procedure

### 5.1 Foam bitumen Apparatus set up

(a) Prior to each day's use of the bitumen foaming machine and any time the bitumen type is changed, operate the apparatus to determine the bitumen flow rate.

(b) Heat the bitumen to a temperature of 175 ± 5°C unless otherwise specified, ensure all apparatus that influences the bitumen temperature before discharge through the nozzle is also heated so that the sprayed bitumen temperature is in the range specified.

(c) Discharge foamed bitumen for 10 s and measure the mass of bitumen discharged.

(d) Calculate the bitumen discharge rate in g/s of bitumen.

(e) Measure and record the bitumen foaming properties according to T153.

### 5.2 Mixing binder

(a) Measure out the quantity of water and secondary binder determined using T105 Process A.9 based on the target moisture content required to achieve a sample moisture content of 70% OMC.

*Note: The 70% OMC level relates to the material to be bound prior to incorporation of lime and bitumen (4(e)(ii)).*

(b) Combine the specified secondary binder and water to the sample, mix thoroughly and stand for one hour.

(c) Heat the bitumen to a temperature of 175 ± 5°C unless otherwise specified, ensure all apparatus that influences the bitumen temperature before discharge through the nozzle is also heated so that the sprayed bitumen temperature is in the range specified.

*NOTE: Temperature reading from the temperature meter on foaming machine.*

(d) Record the sample temperature prior to the addition of bitumen.

(e) Blend the foamed bitumen with the sample to achieve the required mix bitumen % specified by the pavement designer.

*NOTE: Mixing time and spray rate should replicate field practice as close as possible, mix design to be provided by pavement designer.*

(i) Weight the sample at 70% OMC

(ii) Determine the mass of bitumen to be applied based on the dry mass of the material to be bound(MTBB).

(iii) Based on apparatus bitumen discharge rate ( determined in step 5.1) determine the spray valve opening time required to deliver the required % of bitumen binder (Dry Mass x % of Bitumen to be added)/ Bitumen discharge rate).

(iv) Combine the foamed bitumen with the wet mix and mix to create a uniform distribution of binder throughout the mix.

(v) Remove mix, ensure all material is removed from the blending apparatus mixing blade and weigh the mix.

(vi) Determine the temperature of the mix.

(vii) Determine the actual mass of bitumen binder added (Sample taken after added bitumen – Sample taken before added bitumen).

(viii) Calculate the actual % of binder added as a % of the sample dry mass prior to adding any binder.

(f) Determine the required moulding sample size using T105 Process A.11 and adjusted to include effect of added binders. Remove the foamed bitumen sample from the mixing bowl and divide the sample into moulding sizes using T105 Process A9 and place each in a sealed container in an oven preheated to a temperature of 40 ± 3°C.

(g) Immediately after heating and within 60 min of mixing, compact the samples according to Step 5.3.

## 5.3 Compacting samples

(a) Sufficient samples are to be prepared to allow all testing of samples from a homogeneous batch.

(b) Assemble the mould, base-plate, spacer and collar, and place the assembly on the rigid foundation.

(c) Place the sample in the mould in one layer and compact using 50 blows (75 blows if the sample is indentified as HD material) from a Marshall hammer for 100 mm diameter mould and 110 blows for 150 mm diameter mould.

(d) Free the material from around the collar and then carefully remove the collar.

(e) Level the specimen to the top of the mould by means of the straightedge. Patch any holes developed in the surface by replacing coarser particles with smaller sized material.

(f) Invert the mould, remove spacer and place the assembly on the rigid foundation.

(g) Compact the inverted sample in the mould using a further 50 blows from a Marshall hammer for 100 mm diameter mould and 110 blows for 150 mm diameter mould.

(h) Carefully eject the specimen from the mould and determine the following:

(i) By mensuration the average diameter ($D_0$) and average height ($h_0$) of the specimen in mm in accordance with AS 2891.9.3(6). Calculate the volume of each specimen ($V_{sn}$).

(ii) The mass of each specimen ($M_0$).

(i) Calculate the sample density and relative compaction achieved relative to the MDD determined from step 4.e.ii.

(j) Wrap the specimen to prevent moisture loss and carry out initial curing in a controlled environment at 25 ± 0.5°C for 3 h ± 5 min.

(k) Repeat Steps 5.3(a) to (i) for each additional specimen.

## 5.4 Initial modulus

(a) After the period of initial curing in Step 5.3(i) of 3h:

(i) Remove each specimen to be tested for initial modulus from the controlled environment and remove the wrapping.

(ii) Determine the mass of each moulded specimen ($M_i$) in g.

*NOTE: The 'i' subscript denotes initial.*

(b) Test the resilient modulus ($E_{Ri}$) of each specimen according to Step 5.7.

## 5.5 Cured modulus

(a) After the period of initial curing (Step 5.3(j)) unwrap each sealed specimen to be tested for cured modulus and cure in an oven set at 40°C and capable of maintaining this temperature within ±3°C for 3 d ± 1 h.

(b) Remove each cured specimen after the required time.

(c) When cooled to 23 ±2°C carry out the following:

(i) Record any defects in the specimens.

(ii) Determine the mass of each specimen ($M_c$) in grams.

(iii) Test the resilient modulus ($E_{Rc}$) of each specimen according to Step 5.7

*NOTE: The 'C' subscript denotes cured.*

(d) Immediately after testing commence soaked curing.

## 5.6 Soaked modulus

(a) After cured modulus testing, condition each sample by soaking each unsealed specimen using a water bath:

(i) Place the specimen in the water bath at a temperature of 25° ±0.5°C and

(ii) Soak for 24 h ± 1.0 h.

(b) Remove the saturated specimen without shaking the specimen. Wipe the saturated specimen with a damp cloth to bring the specimen to a saturated surface dry condition.

(c) Within 5 min of the specimen being removed from the apparatus complete the measurements and commence testing:

(i) Determine the mass of the saturated specimen in air ($M_s$) in grams.

*NOTE: The 's' subscript denotes soaked.*

(ii) Record any defects in the specimens.

(iii) Test the resilient modulus ($E_{Rs}$) of each specimen according to Step 5.7.

## 5.7 Testing resilient modulus

(a) Test each specimen using the apparatus and method detailed in AS 2891.13.1. Record the resilient modulus of each specimen ($E_{Rx}$).

*NOTE: The 'x' subscript denotes the conditioning: where i=initial, c=cured, s=soaked*

(b) Inspect and record any damage to the specimen.

(c) Rotate each sample 90 deg and repeat steps a and b.

(d) Repeat the test when the difference between tests at 0 deg and 90 deg differ by more than 15%. If after repeating the tests a second time the difference is still greater than 15 % record the result and note as 'miss representative result'

## 6. Calculations

(a) Calculate the resilient modulus for each specimen ($E_{Rx}$) as the average of the measured value at 0 deg and 90deg.

(b) Calculate the average Resilient Modulus (*RM*) for each set of specimens for each curing condition as follows:

$$RM_x = \frac{\sum E_{Rxn}}{n}$$

Where:

$RM_x$ : Average Resilient Modulus to the nearest 10 MPa.

$x$ : Conditioning group (i.e. i=initial, c=cured and s=soaked).

$E_{Rx}$ : Resilient Modulus of conditioned specimen (MPa)

$n$ : The number of specimens in the group.

(c) Calculate the Retained Resilient Modulus Ratio (*RMR*) rounded up to the nearest whole percent as follows:

*NOTE: The RMR is undetermined if one Resilient Modulus cannot be determined.*

$$RMR = \left(\frac{RM_s}{RM_c}\right) \times 100\%$$

Where:

$RMR$ : Retained Resilient Modulus Ratio rounded to the nearest whole %.

$RM_s$ : Average Soaked Resilient Modulus (MPa)

$RM_c$ : Average Cured Resilient Modulus (MPa)

(d) Plot the average Resilient Modulus against % Relative Compaction.

(e) Read and report the Resilient Modulus value corresponding to 100% relative compaction.

(f) Determine the bitumen content in each specimen by mass using the actual % of bitumen added in Clause 5.2 e (ix) and mass of each specimen in Clause 5.3 h(ii).

(g) Convert the bitumen content by mass in each specimen to bitumen content by volume *($v_{bn}$)* assuming the bitumen density 1.0334 T/m$^3$ (1033.4 kg/ m$^3$) at 25°C

(h) Calculate the percentage by volume of bitumen ($V_{bn}$%) in each specimen as follows:

$$V_{bn}\% = \left(\frac{v_{bn}}{V_{sn}}\right) \times 100\%$$

Where:

$V_{bn}$% % of bitumen by volume in the specimen

$V_{bn}$ : Bitumen content by volume in the specimen

$V_{sn}$ : Volume of the specimen

(i) Calculate the average percentage by volume of bitumen ($V_b$%) of all the specimens as follows:

$$V_b\% = \frac{\sum V_{bn}\%}{n}$$

Where:

$V_b\%$ Average percentage by volume of bitumen

$V_{bn}\%$ Percentage by volume of bitumen in each specimen

$n$ : Number of specimen

## 7. Reporting

Include the following data and results in the report:

(a) Identification and description of sample material.

(b) PSD and PI for the sample before mixing.

(c) OMC for the sample before mixing the secondary binder and bitumen.

(d) The moisture content ($w$) of the sample before mixing secondary binder and bitumen as a percentage of OMC.

(e) The following information about the foamed bitumen:

(i) The source and type of bitumen and the temperature (°C) of the bitumen before foaming.

(ii) The source, quantity and temperature (°C) of the water used in the foaming process.

(iii) If used, the source and quantity of the bitumen foaming additive used with the bitumen as a percentage of the bitumen mass and the timing of the incorporation of additive into the bitumen.

(iv) The quantity of bitumen as a percentage by weight of the dry mass of the mix.

(v) Average percentage by volume of bitumen of the compacted material ($V_b\%$)

(vi) The name and model number of the apparatus to produce the foamed bitumen.

(vii) Bitumen half life and expansion ratio (in accordance with T153).

(f) If used, the type, source and quantity of secondary binder as a percentage of the dry mass of the mix.

(g) Time of

(i) Mixing.

(ii) Compacting each sample.

(iii) Start/finish curing.

(iv) Modulus testing.

(h) The sample temperature (°C) just prior to the addition of bitumen.

(i) The sample temperature (°C) after mixing with foamed bitumen.

(j) Tabulate the following results for each mix tested:

(i) The average height ($h$), average diameter ($D$) and volume ($V$) of each specimen.

(ii) The resilient modulus ($E_{Rxn}$) results for each specimen and the Average Resilient Modulus ($RM_x$) to the nearest 10 MPa.

(iii) The Retained Resilient Modulus Ratio ($RMR$).

(iv) Average Resilient Modulus for each curing regime corresponding to 100% compaction.

(k) The daily calibrated bitumen discharge rate (g/s).

(l) Reference to this test method.