

# Design of Asphalt Mixes (Marshall Method)

## 1. Scope

This method covers the combination of component materials, the preparation of asphalt mixes, the compaction of test specimens using Marshall compaction and the determination of the strength and volumetric properties of asphalt.

The criteria for selection of a design mix, extracted from VicRoads specifications are also included.

Reference to the latest specification for the type of asphalt being designed shall be made prior to designing mixes to ensure the criteria for grading, strength, volumetric properties and binder content shown in this method meet the specification requirements.

## 2. Component Materials

- (a) Obtain samples of the aggregates and filler(s) in accordance with AS 1141.3.1
- (b) Determine the particle size distribution of the aggregates and fillers in accordance with AS 1141.11 and AS 1141.12, as appropriate.
- (c) Determine the particle density on a dry basis of the fine and coarse aggregates in accordance with AS 1141.5, AS 1141.6.1 or AS 1141.6.2, as appropriate, including determination of the Saturated Surface Dry State mass of aggregates as detailed in Note 1. (See also Note 2)
- (d) Determine the apparent particle density of the filler(s) in accordance with AS 1141.7. (See also Note 2)
- (e) Obtain a sample of bitumen and determine its density in accordance with AS 2341.7 and its viscosity in accordance with AS 2341.2. (See also Note 2)
- (f) Select an appropriate grading target within the specification range for the asphalt required, taking into account the variability of each component, so that during production of asphalt the grading shall not fall outside the tolerance limits (see also Note 3).

*Note: For VicRoads works, reference to the grading of mineral matter for each size of asphalt is shown in Note 4.*

- (g) Combine the gradings of the individual aggregates and filler(s) to obtain a grading as near as possible to the grading selected in step (f) above.

## 3. Trial Mixes

Manufacture trial batches of asphalt using at least three binder contents within the specified range of binder contents in accordance with the following procedure:

### 3.1. For each batch

- (a) Manufacture asphalt in accordance with AS 2891.2.1, of sufficient amount to provide the samples required.

Measure the temperature of the asphalt mix.

The temperature of the asphalt mix shall be as required in AS 2891.5 clause 6.1, unless otherwise specified, prior to proceeding further.

- (b) Sample in accordance with AS 2891.5. Sample in order:
  - 1 sub-sample for a Marshall cylinder
  - 1 sub-sample for maximum density determination
  - 1 sub-sample for a Marshall cylinder
  - 1 sub-sample for maximum density determination;followed by any additional sub-samples for additional Marshall cylinders.

A sub-sample for determination of binder content and particle size distribution may be sampled, if required, e.g. at the mid-point of the binder contents added.
- (c) Condition the sub-samples which are to be compacted at a temperature appropriate to the asphalt type for one hour prior to compaction in accordance with AS 2891.2.1.
- (d) Using the appropriate sub-samples, compact at least two Marshall cylinders in accordance with AS 2891.5.
- (e) Determine the maximum density of the appropriate sub-samples in accordance with AS 2891.7.1 (see Note 5).
- (f) When the compacted specimens have cooled, extract them from the moulds (see Note 6).
- (g) Determine the bulk density of each compacted specimen in accordance with AS 2891.9.1 or AS 2891.9.2 for dense graded asphalts, or AS 2891.9.3 for open graded asphalts.

- (h) Determine the stability and flow of each compacted specimen in accordance with AS 2891.5, with the exception of open graded asphalts.

### 3.2. Selected binder content

If the selected binder content (see Clause 5) is not within  $\pm 0.3\%$  of the binder content at the mid-point of the binder contents added in step 3.1, manufacture a batch of the asphalt with a binder content selected in Clause 5.

Obtain a sub-sample from this batch and determine the binder content and grading of the sub-sample in accordance with AS 2891.3.3.

### 3.3. Reference Bulk Density

For the purpose of determination of the reference bulk density for calculation of Density Ratio under Code of Practice RC 500.05, the following procedure shall be followed.

- Prepare three Marshall cylinders from the sample prepared under step 3.1(b) above at the selected binder content determined in step 3.2 above.
- Determine the bulk density of each cylinder and record the method (step 3.1(g)).
- Determine reference bulk density by calculating the mean bulk density from the three results determined in step 3.3(b).

## 4. Calculations

Calculate the following for each batch :

- The mean bulk density of the specimens for each batch. If the range of the values of bulk density exceeds  $0.02 \text{ g/cm}^3$ , the batch should be repeated.
- The mean stability and the mean flow of the specimens.
- The mean maximum density of the results obtained in step 3.1 (d) above.
- The bulk density of the combined mineral aggregates in accordance with AS 2891.8.
- The air voids, percentage by mass of binder absorbed, proportion by mass of effective binder and voids in the mineral aggregate in accordance with AS 2891.8 using the mean values obtained above.
- The specific area in  $\text{m}^2/\text{kg}$  of the combined mix using the combined grading as selected in step 2(g), but substituting the value of percentage passing the  $75 \mu\text{m}$  sieve obtained in step 3.2 (see Note 7).
- Using the mean values of maximum density and bulk density obtained in steps 4(c) and 4(d), calculate the film thickness ( $T_F$ ) ( $\text{m}^2/\text{kg}$ ) of binder from:

$$T_F = \frac{B_e}{100 - B} \times \frac{1}{\rho_b} \times \frac{10^3}{SSA}$$

where :

$B_e$  = effective binder content (%) calculated or determined in step 4(e)

$B$  = the added binder content for the batch

$\rho_b$  = the density of the binder ( $\text{t/m}^3$ ) determined in step 2(e)

$SSA$  = the specific surface area ( $\text{m}^2/\text{kg}$ ) of the combined mineral matter as calculated in step 4 (f)

## 5. Selection of Design Mix

- Plot the values of stability, flow, percent air voids, bulk density and percent voids in the mineral aggregate and film thickness against binder content.
- Select the value of binder content at or near the midrange of the percent voids in the specification for that particular asphalt. Check that the other properties of film thickness, stability, flow and percent voids in the mineral aggregates meet the specification requirements. If all values meet the specification requirements, the binder content, properties, mix grading and proportions of each aggregate and filler are designated the design mix.
- For mixes which are derived from the base mix selected in this section, e.g. "SF" asphalts which have a binder content 1.0% greater than "SI" asphalts, properties such as bulk density and film thickness may be read from the curves produced provided the binder content is not more than 0.3% nor less than 0.3% from the upper and lower binder contents respectively of those used in the trial batches.

## 6. Test Report

Report the following at the selected binder content:

- The type of asphalt,
- The values of stability (to the nearest 0.1 kN), flow (to 0.1 mm), percent air voids (to 0.1%), percent voids in the mineral aggregate (to 1%), film thickness (to 0.1  $\mu\text{m}$ ) and bulk density (to  $0.001 \text{ t/m}^3$ ) of the mix at the selected bitumen content,
- The combined grading of the mix as calculated with suitable adjustment made to the amount passing the  $75 \mu\text{m}$  sieve from the sieve analysis performed in step 5(b),
- The individual test results on the components and the percentage of each component used, as required in those methods referred to in this method,
- The temperature in  $^\circ\text{C}$  of each batch prior to compaction of specimens to the nearest 1,
- The reference bulk density (to  $0.001 \text{ t/m}^3$ ) as described in step 3.3 above, and
- Reference to this test method.

## 7. Notes

### Note 1

For determination of the Saturated Surface Dry State (SSDS) mass ( $m_2$  in AS 1141.5, AS 1141.6.1 and AS 1141.6.2) of aggregates for Particle Density, the following method shall be used:

**Principle :** Samples are weighed in trays at fixed intervals of time (nominally 1 minute) until it is considered that the SSDS has been passed. The sample masses are then plotted against the time of mass determination.

The mass of sample for SSDS is obtained at the change of slope of the mass versus time line - that is, the mass at the time when evaporation slows down because there is no longer free surface water within the whole sample, but water is only present within pores, cracks and vesicles of the aggregate.

**Laboratory Procedure :** In preparing the aggregates for measuring SSDS mass, the following process shall be followed, on a pair of samples :

- (a) Weigh (or tare) an empty tray sufficient to hold a sample and record the mass;
- (b) Decant water from the covered sample and place wet sample into the weighed tray and record the mass;
- (c) Place the tray with the wet sample under a current/draft/flow of warm air (fan type heater is useful);
- (d) Gently stir the sample in the tray and weigh at 1 minute intervals, recording the mass at each interval;
- (e) Continue the process until the loss of mass for each minute is consistent and near zero (e.g. 0.1 - 0.2 grams per minute for at least three minutes);
- (f) Plot the recorded mass, minus the mass of tray if appropriate, for each weighing;
- (g) SSDS mass is defined as the mass, the mean of the two determinations, at the intersection of a line drawn through the masses obtained a higher evaporation rate with a line drawn through the masses obtained later at a lower evaporation rate.

**Application:** The above must be validated for each aggregate by the laboratory against the AS 1141 methods.

### Note 2

When a NATA certificate for these tests results is available for these values for the batch of binder being used in the trial mix, the values on such a certificate may be used.

### Note 3

Preparing trial batches of asphalt using different combinations of aggregates and filler and a binder content at the mid-point of the specified binder contents assists in the selection of the most appropriate target grading.

### Note 4

For VicRoads works, the grading of mineral matter for each size of asphalt is shown in:

VicRoads Code of Practice RC 500.01, Table 5 (dense graded)

VicRoads Standard Specifications:

Table 404.061 (Stone Mastic Asphalt)

Table 417.061 (Open Graded Asphalt)

Table 421.061 (Bitumen Crumbed Rubber Asphalt)

These tables are subject to change and reference shall be made to the job specification or the latest edition of VicRoads Standard Specifications or contract specific clauses.

### Note 5

Plot the maximum density and the binder content to check that a relatively linear relationship over the range of binder contents has been obtained.

### Note 6

Compacted asphalt specimens should be allowed to cool to ensure that they do not deform when extracted from the moulds. Normally two hours in the mould in the laboratory is sufficient. Specimens should be allowed to stand for 24 hours prior to further testing.

### Note 7

Calculate the specific surface area (SSA) by:

- (a) multiplying the percentage passing each sieve by the appropriate factor in Table 1;
- (b) summing the values obtained in (a) and dividing this sum by 100; and
- (c) Multiplying the value obtained in (b) by 2.65 and dividing the result by the bulk particle density of the combined mineral matter obtained in step 4(d).

**Table 1 Grading Factors**

AS Sieve (mm)	Factor	Comment
Max Size	0.41	100
4.75	0.41	Mix Grading (see step 2(g))
2.36	0.82	
1.18	1.64	
0.600	2.87	
0.300	6.14	
0.150	12.29	
0.075	32.77	From step 3.2

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**VicRoads Test Method - Revision Summary**

**RC 201.01 – Design of Asphalt Mixes (Marshall Method)**

Date	Clause	Description of Revision	Authorised by
October 2016	Full document 3(c)	Re-branded Deleted reference to specific asphalt types	Manager – Construction Materials
March 2014	Cl 2  2(f) 3(a) 3(c) 4 (g) 6 Throughout	Note 2 created, AS 2341.2 & .7 specifically noted (Notes re-numbered) .... tolerance limits Aligned to RC 201.12 Conditioning for asphalt types Correction to Be source and minor editorials Added tolerances, reference to method Aligned to RC 201.12	Manager – Construction Materials