

# Australian/New Zealand Standard™

## Methods of sampling and testing asphalt

### Method 5: Compaction of asphalt by Marshall method and determination of stability and flow— Marshall procedure

AS/NZS 2891.5:2015

#### PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee CE-006, Asphalt and Sprayed Surfacing, to supersede AS 2891.5—2004, *Methods of sampling and testing asphalt—Determination of stability and flow—Marshall procedure*.

The term ‘informative’ has been used in this Standard to define the application of the appendices to which it applies. An ‘informative’ appendix is only for information and guidance.

#### METHOD

#### 1 SCOPE

This Standard sets out the method for preparing specimens of asphalt (either produced in the laboratory or at a mixing plant) by the Marshall procedure and determining stability and flow values of the specimens using the Marshall apparatus. It is applicable to asphalt mixes not exceeding 20 mm nominal size.

#### 2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS	
2008	Bitumen for pavements
2193	Calibration and classification of force-measuring systems
AS/NZS	
2891	Methods of sampling and testing asphalt
2891.1.1	Method 1.1: Sampling—Loose asphalt
2891.2.1	Method 2.1: Sample preparation—Mixing, quartering and conditioning of asphalt in the laboratory
2891.9.1	Method 9.1 Determination of bulk density of compacted asphalt—Waxing procedure
2891.9.2	Method 9.2: Determination of bulk density of compacted asphalt—Presaturation method
2891.9.3	Method 9.3: Determination of bulk density of compacted asphalt—Mensuration method

Austrroads  
 AGPT/T190 Specification framework for polymer modified binders  
 New Zealand Transport Agency  
 NZTA M/1 Specification for roading bitumens

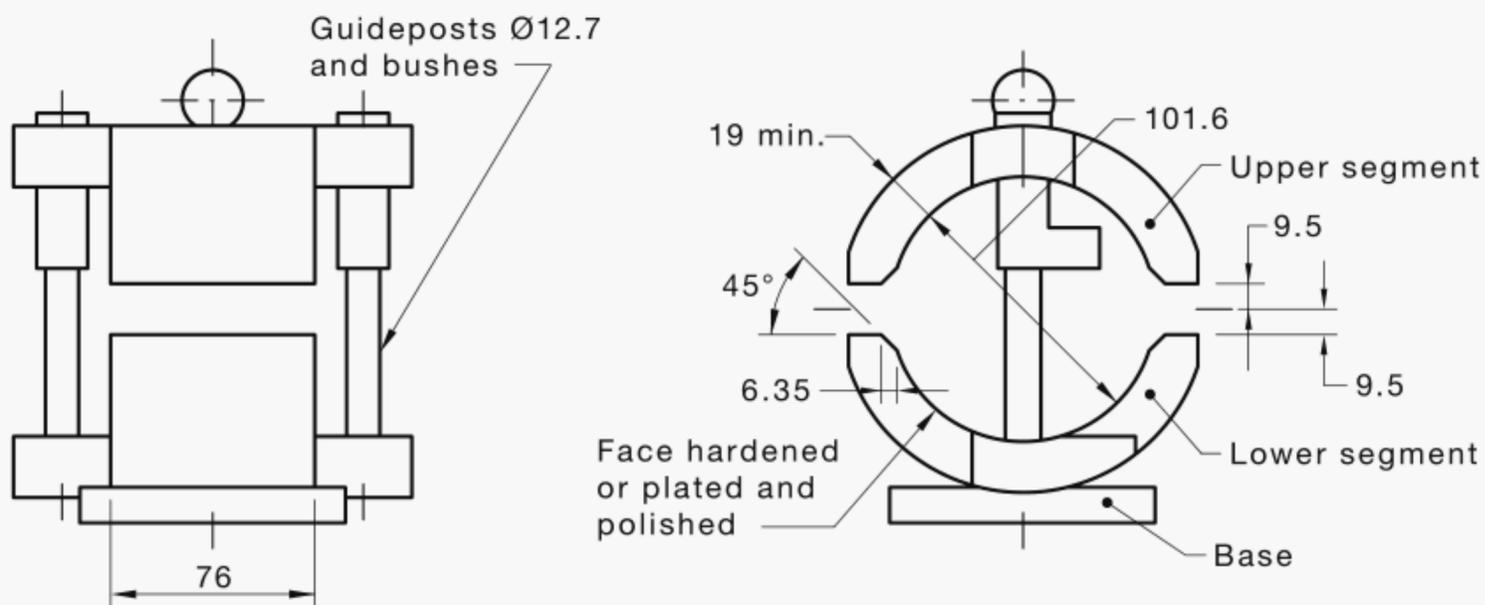
### 3 DEFINITIONS

For the purpose of this Standard, the definitions in AS/NZS 2891.1.1 apply.

### 4 APPARATUS

The following apparatus is required:

- (a) *Balance* Of suitable capacity with a limit of performance not exceeding  $\pm 0.5$  g.
- (b) *Breaking head* Consisting of upper and lower cylindrical segments having an inside cylinder face accurately machined. The lower segment is to be mounted on a base having two perpendicular guide rods or posts extending upwards. Guide bushes on the upper segment are to be in such a position as to direct the segments together without binding or loose motion of the guide rods. The breaking head shall have an internal diameter of  $101.6 \pm 0.2$  mm. A typical breaking head is shown in Figure 1.



NOTE: Frequent checks on the inner radius of segments and on the alignment of guideposts are necessary as high loads may permanently distort the breaking head.

DIMENSIONS IN MILLIMETRES

FIGURE 1 TYPICAL BREAKING HEAD

- (c) *Compaction hammer* Mechanical or hand and consisting of a 98.5 mm diameter flat circular tamping face and a  $4.53 \pm 0.02$  kg sliding weight with a free fall of  $457 \pm 1$  mm. A suitable design for a hand compaction hammer is shown in Figure 2. Designs for mechanical compaction hammers may vary as long as the essential dimensions are met.

NOTE: Although the design, dimensions, mass and height of mass drop for hammers may comply with this specification, variations in efficiency may mean density achieved in compacted specimens with the same number of blows may vary between compaction apparatus. It is up to individual users to ensure the compaction apparatus is operating correctly and efficiently. This may be achieved through inter laboratory assessments or proficiency testing schemes.

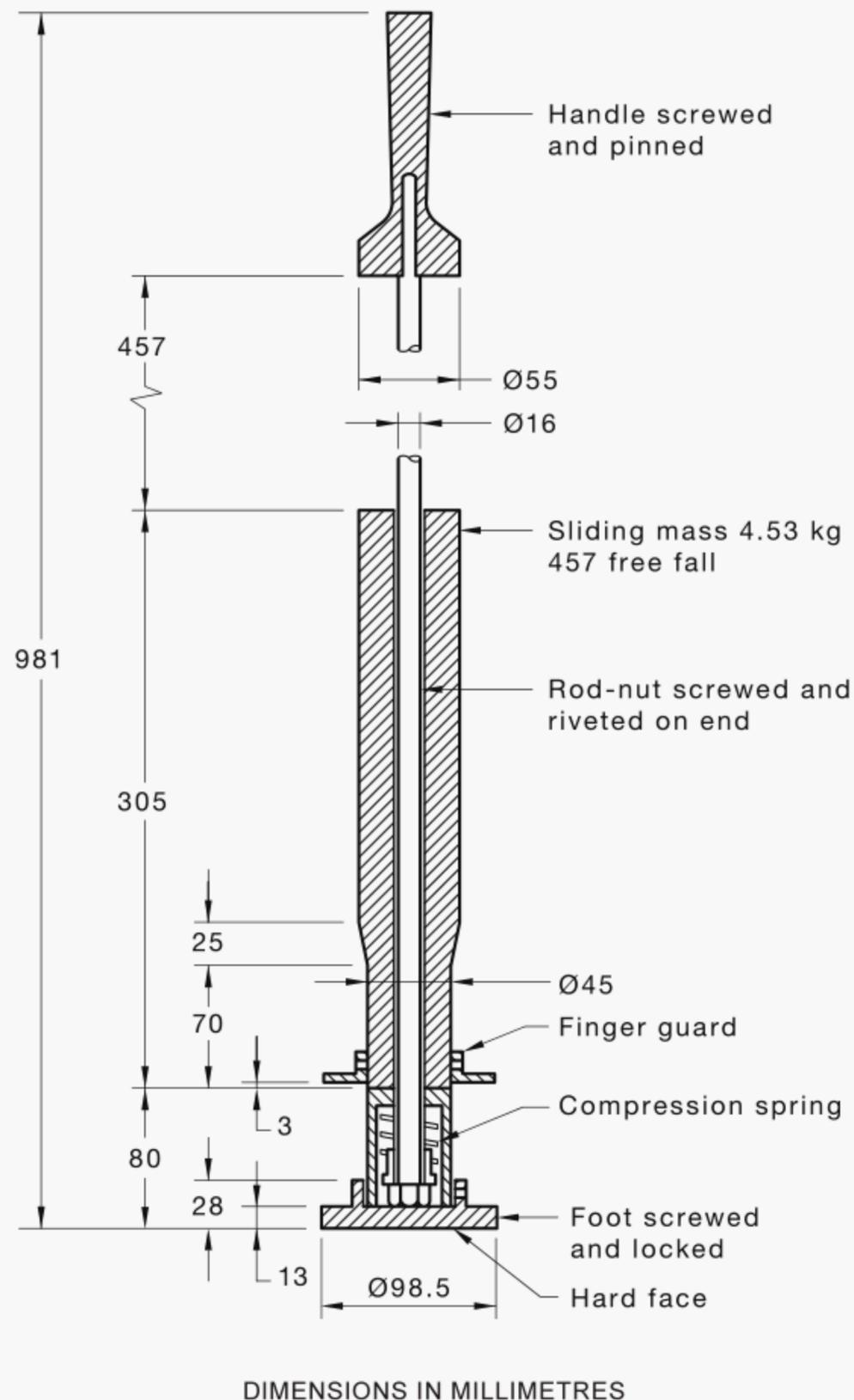


FIGURE 2 TYPICAL HAND COMPACTION HAMMER

- (d) *Compaction pedestal* Consisting of a wooden block approximately 200 mm × 200 mm × 450 mm capped by a steel plate approximately 300 mm × 300 mm × 25 mm. A typical compaction pedestal is shown in Figure 3. The air dry density of the wooden block shall be 670 kg/m<sup>3</sup> to 770 kg/m<sup>3</sup>. The plate shall be level and securely attached to the block, which in turn shall be secured to a solid concrete floor or slab. A suitable framework shall be secured to the pedestal to ensure that the compaction hammer is kept vertical. Wooden block dimensions for length may vary to accommodate multi-head compactors.

NOTE: Certain designs of dual head compactors are supplied fitted to a steel plate approximately 400 mm × 400 mm × 25 mm and are bolted directly to a dense concrete block approximately 400 mm × 400 mm × 450 mm which is secured to the solid concrete floor or slab. This type of pedestal has been found to be an acceptable alternative.

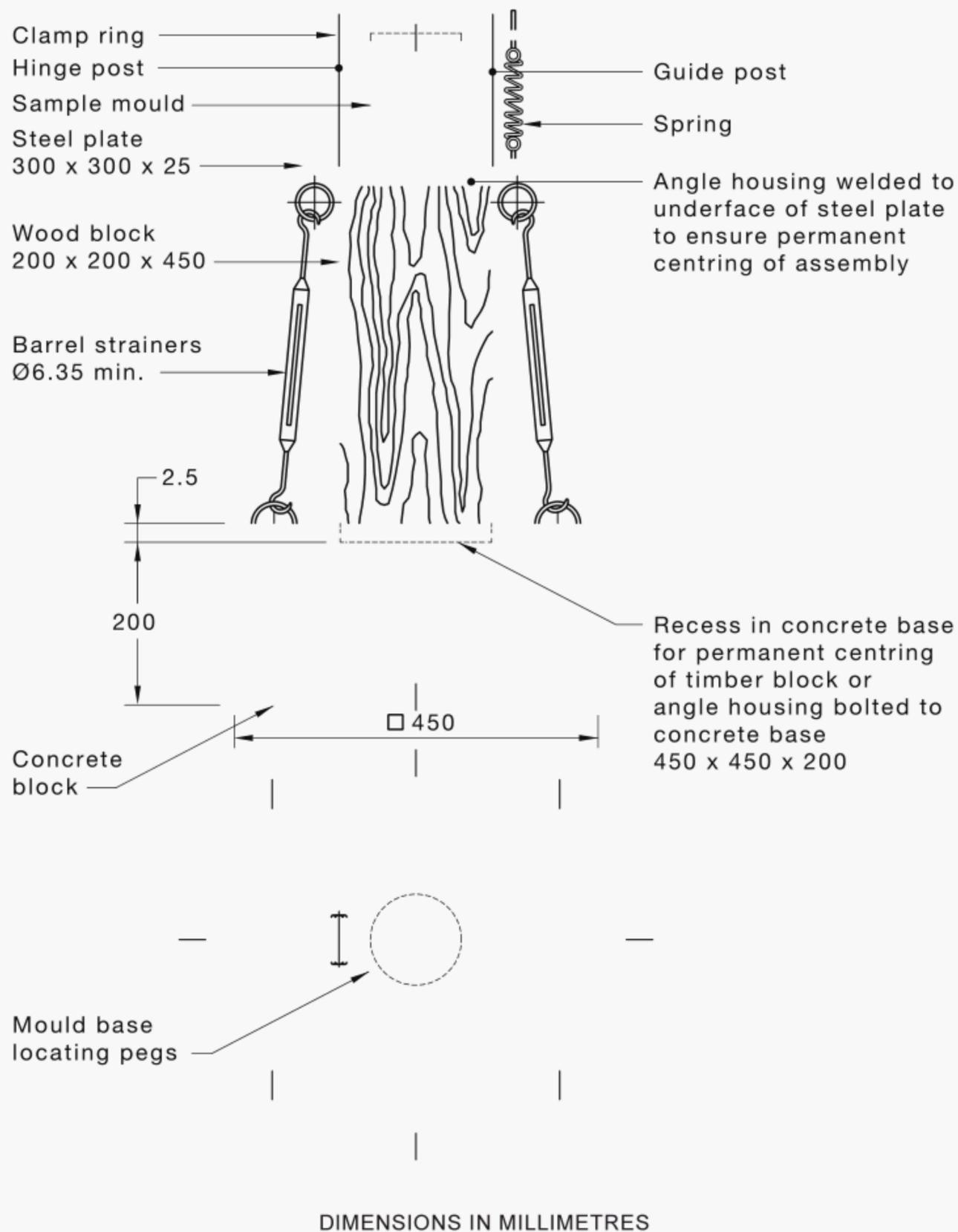
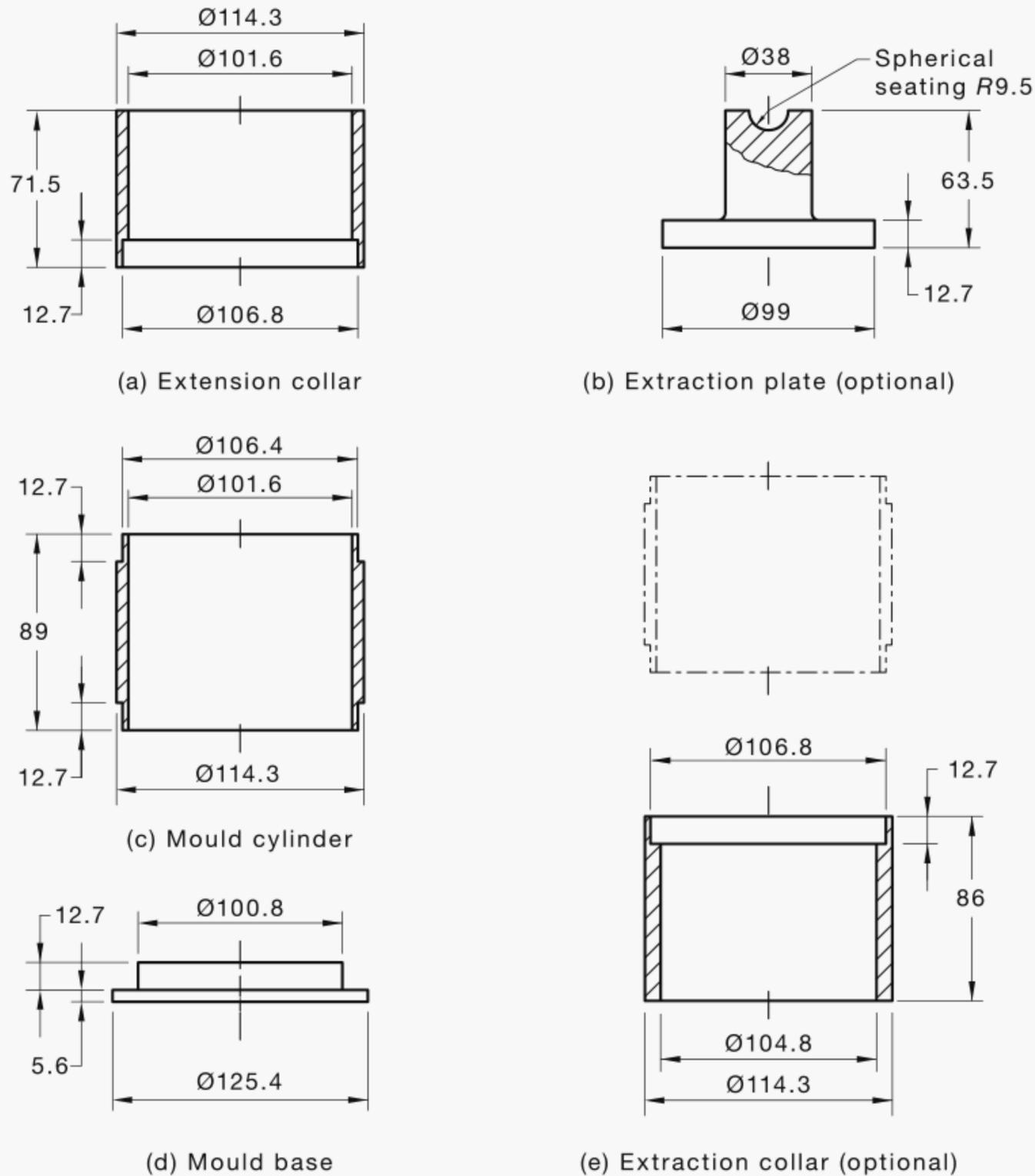


FIGURE 3 TYPICAL COMPACTION PEDESTAL

- (e) *Mixing apparatus* Such as steel tray, steel trowel, spatulas and scoop.
- (f) *Oven* Forced draught, thermostatically controlled, capable of maintaining temperatures up to 200°C within 3°C of the set temperature.
- (g) *Circular paper discs* Cut to fit the mould.
- (h) *Specimen mould assembly* Consisting of a mould base, a mould cylinder and an extension collar made of material that will not deform. The mould cylinder and extension collar shall have a diameter of  $101.6 \pm 0.2$  mm and a height suitable to produce specimens with a conforming height. Typical dimensions of a mould assembly are shown in Figure 4.



DIMENSIONS IN MILLIMETRES

FIGURE 4 TYPICAL SPECIMEN MOULD ASSEMBLY

- (i) *Specimen extraction equipment* Such as that shown in Figure 4, together with an extraction jack.
- (j) *Testing machine* Gear driven at a constant speed to give a rate of travel of plates of  $51 \pm 3$  mm/min when the force is being applied and capable of applying forces up to at least 22 kN. The machine shall be fitted with one or both of the following measurement systems:
  - (i) Load measuring device meeting the readability, accuracy and repeatability requirements of a Class B device as required in AS 2193.
  - (ii) A flow gauge placed on a guide post of the breaking head capable of measuring the vertical deformation of the specimen from the onset of load to 0.1 mm. Alternatively, a revolution counter reading directly from the drive shaft may be used in conjunction with the appropriate calibration factor for the drive pulley, provided compensation is allowed for deflection in the load measuring device.
- (k) *Water bath* At least 150 mm deep with a perforated shelf about 50 mm from the bottom, with mechanical agitator, maintained at a temperature of  $60 \pm 1^\circ\text{C}$ .

- (l) *Water bath thermometer* Or other suitable temperature-measuring device capable of measuring a temperature of 60°C, readable and accurate to 1°C or less.
- (m) *Thermometer* Or other suitable temperature-measuring device, covering the range 0°C to 200°C readable and accurate to 1°C or less.
- (n) *Steel ruler or external vernier callipers* To measure the height of specimens for the stability test.

## 5 COMPACTION TEMPERATURES

Unless otherwise specified, the temperatures for the mix to be compacted shall be in accordance with Tables 1, 2 or 3.

NOTE: Refer to Appendix A and Appendix B for guidance in establishing compaction temperatures for binders not included in Tables 1, 2 or 3 or for warm mix asphalt.

**TABLE 1**  
**COMPACTION TEMPERATURES FOR AS 2008 BINDERS**

Class	Stone mastic asphalt	Dense graded asphalt	Open graded asphalt
C170	N/A	142 ±3°C	N/A
C320	150 ±3°C	150 ±3°C	125 ±3°C
C450	150 ±3°C	150 ±3°C	N/A
C600	N/A	155 ±3°C	N/A
M1000	N/A	155 ±3°C	N/A

**TABLE 2**  
**COMPACTION TEMPERATURES FOR AUSTROADS**  
**AGPT/T190 BINDERS**

Binder class	Stone mastic asphalt	Dense graded asphalt	Open graded asphalt
A10E	160 ±3°C	160 ±3°C	135 ±3°C
A15E	160 ±3°C	160 ±3°C	135 ±3°C
A20E	160 ±3°C	160 ±3°C	135 ±3°C
A25E	N/A	160 ±3°C	135 ±3°C
A35P	N/A	160 ±3°C	135 ±3°C

**TABLE 3**  
**COMPACTION TEMPERATURES FOR NZTA M/1 BINDERS**

Bitumen grade	Stone mastic asphalt	Dense graded asphalt	Open graded asphalt
40–50	157 ±3°C	157 ±3°C	118 ±3°C
60–70	150 ±3°C	150 ±3°C	113 ±3°C
80–100	142 ±3°C	142 ±3°C	107 ±3°C

## 6 SPECIMEN PREPARATION

### 6.1 Laboratory prepared mix

Laboratory prepared mix shall be prepared as follows:

- (a) Preheat the specimen mould assembly in the oven.

- (b) If required, prepare a sample of asphalt in the laboratory in accordance with AS/NZS 2891.2.1.
- (c) Remove the specimen mould assembly from the oven and place a paper disc in the bottom of the mould.
- (d) Obtain a representative test portion of the asphalt of sufficient mass to obtain a compacted specimen height of approximately 63.5 mm but within the allowable range of 57 mm to 70 mm. Place the test portion in the mould and spade the asphalt with a heated spatula 15 times around the perimeter and 10 times over the interior.

NOTE: The expected bulk density of the compacted asphalt may be used to calculate the mass necessary to give the desired specimen height.

- (e) Place the mould in the oven for sufficient time for the test portion to reach the specified compaction temperature. If the test portion has not reached the specified temperature within 60 minutes discard the test portion.

## 6.2 Plant produced mix

Plant produced mix shall be prepared as follows:

- (a) Unless otherwise specified, obtain a bulk sample of asphalt in accordance with AS/NZS 2891.1.1.
- (b) Preheat the specimen mould assembly in the oven.
- (c) Obtain a representative test portion of the asphalt of sufficient mass to obtain a compacted specimen height of approximately 63.5 mm but within the allowable range of 57 mm to 70 mm by either—
  - (i) sample division of freshly produced asphalt that is at a temperature to facilitate sample division; or
  - (ii) placing a sample container in an oven, at a temperature not exceeding 160°C to reheat the sample. The sample shall not be in the oven for more than 3 h in total. When the sample is at a temperature to facilitate sample division remove the sample container from the oven and transfer the sample to a mixing tray or bowl and prepare test portions.

NOTE: The expected bulk density of the compacted asphalt may be used to calculate the mass necessary to give the desired specimen height.

- (d) Place the test portion in the mould and spade the asphalt with a heated spatula 15 times around the perimeter and 10 times over the interior.
- (e) Place the mould in the oven for sufficient time for the test portion to reach the specified compaction temperature. If the test portion has not reached the specified temperature within 60 min discard the test portion.

## 7 COMPACTION OF SPECIMENS

The compaction procedure shall be as follows:

- (a) Remove the mould from the oven. Place a thermometer in the mould and verify that the temperature of the asphalt in the mould is within the tolerance for the compaction temperature specified in Tables 1, 2 or 3. Record the temperature.
- (b) Place a circular paper disc on top of the asphalt and transfer the mould assembly to the compaction pedestal.
- (c) At a rate of 60 to 70 blows per minute, compact the mix using the specified number of blows of the compaction hammer with the hammer axis held vertically. Invert the mould and apply the same number of blows to the other end of the specimen.

## NOTES:

- 1 Where the number of blows is not specified, 50 blows is commonly used.
  - 2 Some laboratories that use dual head automatic hammers invert and swap the two moulds such that each mould receives the same compaction energy averaged between two hammers.
  - 3 Where hand compaction is used the sliding mass of the compaction hammer should be raised to its highest position without lifting the face of the hammer from the surface of the asphalt. Immediately after the sliding mass has reached the bottom of its free fall it should be caught such that it does not bounce on to the specimen creating additional compactive effort.
- (d) Repeat Steps (a) to (c) to produce a minimum of two specimens, these operations being continuous to minimize heat loss.
  - (e) Retain the specimens in the moulds and remove the paper discs from their faces. Mark the top of each specimen with an identification number.
  - (f) Remove the specimens from the moulds using the specimen extraction equipment and allow the specimen to cool.

NOTE: Care should be taken to ensure that the specimen has cooled sufficiently to ensure that it does not deform when removed from the mould.

## 8 STABILITY AND FLOW OF PREPARED SPECIMENS

The procedure shall be as follows:

- (a) Remove any lip formed around the edges of the specimen without damaging the specimen. Perform either of the following:
  - (i) Measure the height, to the nearest millimetre, of each specimen at four points evenly spaced around the specimen and average these values. Record the mean height of each specimen to the nearest millimetre.
  - (ii) Record the volume of the specimen to the nearest  $1 \text{ cm}^3$  where its compacted density has been determined using AS/NZS 2891.9.2 or AS/NZS 2891.9.3 (dense graded mix only).
- (b) Discard any specimen having a mean height outside the range 57 mm to 70 mm or a volume outside the range  $459 \text{ cm}^3$  to  $572 \text{ cm}^3$ . Replace any discarded specimen with an additional specimen prepared in accordance with Clause 6 to Clause 8(a).
- (c) Place the specimens in the water bath for 30 min to 40 min.
- (d) Remove a specimen from the water bath and place it centrally on its side in the lower segment of the breaking head. Place the upper segment of the breaking head on the specimen and place the complete assembly centrally on the testing machine. Once the specimen has been removed from the water bath, the test shall be completed within 30 s.

## NOTES:

- 1 If it becomes apparent that the test cannot be completed within 30 s of removal from the water bath and no load has yet been applied to the specimen, immediately replace the specimen into the water bath for a further 10 min and repeat Step (d). This process should only be carried out once for a specimen.
  - 2 The breaking head should be maintained at a temperature in excess of  $20^\circ\text{C}$  prior to the test.
- (e) Apply the load to the specimen until the load begins to decrease. Record the maximum load reading and the flow reading.
  - (f) Repeat Steps (d) and (e) for each of the remaining specimens.

NOTE: Between tests the breaking head faces should be wiped to remove residual binder that may adhere to the surfaces.

## 9 CALCULATIONS

### 9.1 Stability

Calculate as follows:

- (a) The load ( $L$ ) to the nearest 0.1 kN, applied to each specimen at failure using—
- (i) the recorded dial gauge reading and the calibration factor for the proving ring; or
  - (ii) the recorded load cell reading and the applicable calibration factor.
- (b) The stability ( $S$ ) of each specimen from the following equation:

$$S = LF \quad \dots 9.1$$

where

$S$  = the stability of each specimen, in kilonewtons

$L$  = load at failure, in kilonewtons (kN)

$F$  = correction factor from Table 4 according to the height or volume of the specimen

- (c) The average stability of the specimens to the nearest 0.1 kN.

**TABLE 4**  
**FACTORS FOR CORRECTING THE MARSHALL STABILITY FOR SPECIMEN HEIGHT**

Height of specimen mm	Volume range of specimen cm <sup>3</sup>	Correction factor $F$
57	459–466	1.19
58	467–474	1.16
59	475–482	1.13
60	483–490	1.10
61	491–499	1.07
62	500–507	1.04
63	508–515	1.01
64	516–523	0.99
65	524–531	0.96
66	532–539	0.94
67	540–547	0.92
68	548–555	0.90
69	556–563	0.88
70	564–572	0.86

### 9.2 Flow

Calculate the flow as follows:

- (a) The flow of each specimen, to 0.1 mm at failure using—
- (i) the flow gauge reading; or
  - (ii) the recorder transducer reading and the applicable calibration factor.
- (b) The average flow of the specimens to 0.1 mm.

### 9.3 Marshall quotient

If required, calculate the Marshall quotient by dividing the average stability of the specimens by the average flow of the specimens.

## 10 TEST REPORT

The following shall be reported:

- (a) Average stability, in kN, to the nearest 0.1 kN.
- (b) Average flow, in mm, to the nearest 0.1 mm.
- (c) The number of blows.
- (d) The mix identification.
- (e) If the mix is a reheated bulk sample.
- (f) If required, the Marshall quotient, in kN per mm, to the nearest 0.1 kN per mm.
- (g) Reference to this Australian Standard, i.e. AS/NZS 2891.5.

APPENDIX A  
BASIS FOR COMPACTION TEMPERATURES  
(Informative)

In general terms, the asphalt compaction temperatures are derived from the binder viscosity. For dense graded asphalts, including stone mastic asphalt (SMA), the compaction temperature is the temperature where the bitumen binder has a viscosity of  $0.28 \pm 0.03$  Pa.s.

For NZTA M1 compliant binders, the basis for the compaction temperatures of open graded porous asphalt is  $2 \pm 0.2$  Pa.s.

Compaction temperatures for polymer modified binders compliant with AGPT/T190 are based on precedent.

It is recommended that, where appropriate, compaction temperatures are confirmed from time to time. Confirmation methods may include the following:

- (a) Determination of the viscosity of binders by laboratories.
- (b) Obtaining recent viscosity data from the binder supplier.

Compaction temperatures for polymer modified binders can be difficult to determine as the rheology of the modified binders can differ significantly from bitumen. It is recommended that—

- (i) guidance from the modified binder manufacturer be sought to determine compaction temperatures;
- (ii) viscosity testing be carried out to determine compaction temperatures; or
- (iii) a default conditioning and compaction temperature of  $160^{\circ}\text{C}$  for dense graded and stone mastic asphalt and  $135^{\circ}\text{C}$  for open graded asphalt be used.

The emergence of warm mix asphalt technologies adds further variability to asphalt compaction temperatures. Austroads research is examining techniques for determining appropriate temperatures for compacting warm mix asphalts and users of this document should consider the outcomes and recommendations of this research. Refer to Appendix B for more guidance.

APPENDIX B  
DETERMINATION OF EQUIVALENT COMPACTION TEMPERATURE  
(Informative)

**B1 SCOPE**

This method sets out a procedure for determining the equivalent compaction temperature for warm mix asphalt or mixes containing binders not listed in Tables 1, 2 or 3.

**B2 PROCEDURE**

The reference asphalt mix bulk density is determined by carrying out mix design tests on specimens of an asphalt mix using unmodified bitumen compacted at the standard temperatures listed in Tables 1, 2 and 3. An equivalent compaction temperature for the alternative asphalt mix is then determined by finding the temperature at which the bulk density of the alternative mix is equal to the bulk density of the reference mix.

Specimens of the reference mix are compacted at the standard compaction temperature for hot mix asphalt (e.g. 150°C), and a reference bulk density is calculated in accordance with relevant methods (i.e. AS/NZS 2891.9.1, AS/NZS 2891.9.2 or AS/NZS 2891.9.3). At least three specimens should be compacted to determine the average reference density. The temperature corresponding to this reference density on the density/temperature curve for the alternative asphalt mix is the relevant compaction temperature. This compaction temperature should be validated by compacting three alternative asphalt samples at this temperature and comparing the average density of these to the reference density.

Specimens for alternative mixes produced as warm mix asphalt should be prepared at several different temperatures (e.g. 110°C, 120°C, 130°C, 140°C and 150°C).

Specimens for alternative mixes produced as hot mix asphalt but using non-standard binders should be prepared at several different temperatures (e.g. 140°C, 150°C, 160°C, 170°C and 180°C).

The bulk density of the specimens is determined in accordance with the same method used for the reference mix (i.e. AS/NZS 2891.9.1, AS/NZS 2891.9.2 or AS/NZS 2891.9.3). The results are then plotted against the corresponding compaction temperatures to create a density/temperature curve as in Figure B1.

This method can also be adopted where viscosity modified binders are added to improve workability, regardless of whether there is a reduced temperature during laying.

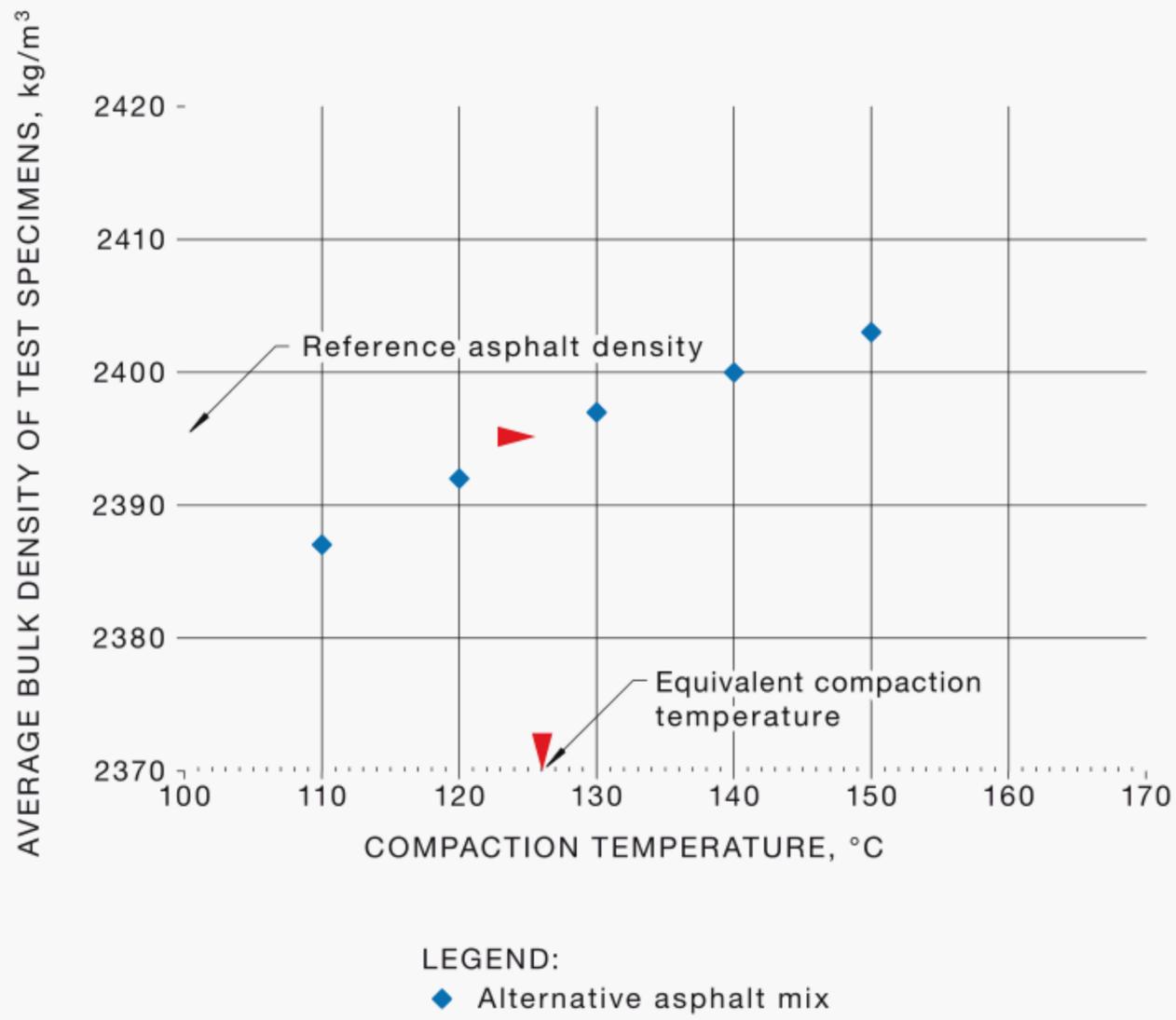


FIGURE B1 BULK DENSITY VS COMPACTION TEMPERATURE

NOTES

NOTES

This Australian/New Zealand Standard was prepared by Joint Technical Committee CE-006, Asphalt and Sprayed Surfacing. It was approved on behalf of the Council of Standards Australia on 9 April 2015 and on behalf of the Council of Standards New Zealand on 10 April 2015 and published on 24 April 2015.

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