METHOD OF TEST FOR PREPARATION OF MARSHALL SPECIMENS

1. SCOPE

1.1 This method describes a procedure for the preparation of Marshall test specimens used in the design of bituminous mixtures, as well as specimens from field samples required for the determination of Marshall properties of dense and open-graded bituminous pavement mixtures.

2. RELEVANT DOCUMENTS

2.1 ASTM D6926-10

2.2 Asphalt Institute MS-2

3. APPARATUS

3.1 METAL CONTAINERS: Of sufficient capacity, required for heating aggregates in the oven.

3.2 MARSHALL MOULDS: Conform to details shown in Figure 1.

3.3 COMPACTION HAMMER: Hand Type. Total mass of 7853 ± 16 g with a sliding weight mass of 4536 ± 9 g (including finger guard) free falling 457 ± 1.5 mm onto a flat circular tamping foot. Hammer shall conform to Figure 2 and dimensions in Table 1. The hammer foot shall be flat with square (not rounded) edges.

3.4. COMPACTION PEDESTAL: For hand compaction, a hardwood block (having an average dry weight of 0.67 to 0.77 g/ml), nominal size 203.2 mm x 203.2 mm x 457.2 mm high, capped with a 304.8 mm x 304.8 mm x 25 mm thick steel plate (Figure 3) and equipped with a compaction mould holder (not shown) secured to the top plate to position and hold the mould during compaction. The hardwood block shall be secured to a concrete block of nominal size 457.2 mm x 457.2 mm x 228.6 mm, which in turn shall rest on a 50.8 x 50.8 x 25.4 mm cork and neoprene pad at each corner.

3.5 MECHANICAL COMPACTION: Instead of a hand-operated hammer, a mechanically-operated hammer may be used provided that it has been calibrated to give results comparable to the hand - operated hammer. A typical mechanical compactor set-up is shown in Figure 5. Other makes/models may differ.

3.6 METAL TROUGH: Round bottom, of suitable size to charge moulds with hot mix.

3.7 OVENS: Of suitable capacity and capable of maintaining the specified temperatures for drying and heating aggregates, and heating compaction moulds and paving mixtures.

3.8 HOT PLATE / OVEN: Thermostatically controlled and capable of heating asphalt cement to a temperature range of 100 to 180°C, and to maintain the required temperature at ± 3°C.

3.9 METAL GARDEN TROWEL: Rounded end, slightly curved blade, 180 mm long, approximately 75 mm wide at the top, and 50 mm wide at the bottom.

3.10 SPATULA: Rounded end, rigid blade, about 250 mm long and 25 mm wide.

3.11 MIXER: A mechanical mixer, capable of producing a well-mixed, homogeneous mixture of the required amount in the allowable time. See Figure 6 for an example.

3.12 KETTLE / CONTAINER: Of sufficient capacity to hold approximately 4.5 L of asphalt cement.

3.13 BALANCE: 5 kg capacity, accurate to 0.1 g.

3.14 METAL SCOOP: Flat bottomed - for batching aggregates.

3.15 THERMOMETERS / ELECTRONIC TEMPERATURE PROBES: Suitable for measuring temperature of aggregates, asphalt and bituminous mixtures in the range of 10 to 204°C with sensitivity of ± 1°C.

3.16 THERMOMETER / TEMPERATURE PROBES: Suitable for measuring water bath and air bath temperatures with a range from 20 to 70°C with accuracy of ± 0.2°C.

3.17 GLOVES: Heat resistant for handling hot equipment.

3.18 STOP WATCH OR TIMER: With an accuracy of ± 0.1 second.

3.19 MIXING BOWL: For hand mixing. Of sufficient capacity to mix material required for preparing the Marshall specimen.

3.20 FLAT PANS: Approximately 350 mm x 250 mm x 60 mm deep for drying and batching of aggregates.

3.21 PAPER DISCS: Made of non-absorbent material, cut to the proper size to fit in the Marshall mould (Premanufactured paper discs are acceptable).

3.22 METAL OR WOODEN BAR: To be placed across the top diameter of the mould for aligning and supporting two thermometers or probes in the proper location in the uncompacted mixture in the mould in order to measure the temperature prior to compaction. Two holes are drilled in order that the two thermometers or probes are 25 mm from the inside wall of the mould with the lower tip of the stem approximately 40 mm into the loose mixture.

3.23 BRIQUETTE EXTRUDER: Steel, in the form of a disk with a diameter not less than 100 mm and 13 mm thickness. The extruder shall be any device, either electrically or hand operated that will force the briquette from the mould at a uniform rate without causing any deformation to the specimen.

3.24 HOT PLATE/ELECTRIC PAN: Thermostatically controlled and capable of heating to a temperature of 135°C± 5°C required to heat compaction hammers (Placing the hammer upright on a sand pad approximately 12 mm deep in an electric frying pan has been found to be satisfactory for this purpose).

3.25 FLAT PANS: Approximate dimensions 400 mm x 300 mm x 50 mm for heating field samples. Smaller pans (approximate dimensions 200 x200 x 50) are suitable for heating briquette sized portions.

3.26 ALUMINUM FOIL OR SUITABLE COVER: For covering pans during mix heat-up process.

3.27 RIFFLE SPLITTER: For splitting hot mix samples. Recommended width of the individual chutes is approximately 38 mm for all types of paving mix.

4. PREPARATION OF MIX DESIGN SAMPLES

4.1 The following assumes that the desired blend of aggregates has been determined, and a weigh card prepared. Also, the aggregates have been dried, and split into sieve fractions.

4.2 Arrange the individually sized coarse aggregate(s) and fine aggregate(s) in bags or in suitable containers on a bench, in order of decreasing sieve sizes. The pass 2.36 mm from the coarse aggregate(s) and from the fine aggregate(s) shall be placed in separate flat-bottomed pans of appropriate size. Using the flat-bottom scoop, weigh up into separate pans for each test specimen a sufficient quantity of oven-dried sample of the selected aggregates, so that the total mass will result in a compacted briquette 63.5 ± 2.5 mm in height. The quantity of material will have to be adjusted if the mixing is for preparing more than one specimen. Trial briquettes may have to be completed in order to determine the proper material weight for each mix. Place the aggregates in an oven maintained at a temperature not exceeding 28°C above the mixing temperature specified by the proprietor of the asphalt cement product (see Note 1). Heating time shall be a minimum of 16 hours, normally overnight.

Note 1: The mixing and compaction temperatures for asphalt cements are typically supplied by suppliers or proprietors of the asphalt cement. For refinery run products, these are obtained from the temperature-viscosity chart for the selected asphalt cement. For engineered asphalts and some polymer modified products, the suppliers of these products must be consulted for their mixing and compaction temperature recommendations. Suppliers typically specify the mixing and compaction temperatures each as a range. The midpoint of the range shall be used for these procedures. See Figure 4 for an example of details.

4.3 Preheat the metal trough and Marshall moulds in the oven to a temperature of 135°C±5°C.

4.4 Preheat the mixing bowl in the same oven as the aggregate.

4.5 Preheat the metal trowel and spatula on the hot plates or in the same oven as the Marshall moulds.

4.6 Heat the asphalt cement to the mixing temperature specified by the proprietor of the asphalt cement using either an oven or hot plate. The asphalt cement should not be held at mixing temperatures for more than 1 hour prior to compaction. Suitable shields, baffle plates or sand pads shall be used on the surface of the hotplate to prevent localized overheating.

4.7 When the asphalt cement has reached the desired temperature, remove the container of aggregate from the oven and quickly place it in the mixing bowl that has been previously tared on the balance. If the aggregate mass is not within ±1 g of the originally batched mass prior to overnight

heating adjust the batch by the addition of preheated pass 2.36 mm material from the primary fine aggregate. Using the mixer, dry mix the aggregate for 15 seconds.

4.8 After dry mixing, form a crater in the centre of the aggregate in the bowl, quickly add in the required amount of asphalt cement to give the required asphalt cement content, and mix 45 seconds or until the aggregate is coated. Do not mix longer than 1.5 minutes. Report any mixing problem such as coating of aggregate or balling of mix.

Note 2: The asphalt content is calculated as a percentage by mass of total mix, e.g. for a total mass of 1180 g of aggregate and A.C. content of 5.0 %

$$\text{Mass of A.C. required} = \frac{1180 \times 5}{100 - 5} = 62.1 \text{ g}$$

Total mix = 1180 g + 62.10 g = 1242.1 g

4.9 At the end of the wet mixing cycle, using the pre-heated spatula, scrape as much of the mix as possible from the mixing paddle and scraper blade.

4.10 Spread the mixture into the metal trough using a back and forth motion. Scrape all the loose mixture in the bowl into the trough.

4.11 The temperature of the mixture immediately prior to compaction shall be that temperature specified by the proprietor for the asphalt cement being used. Specimens below the minimum temperature requirement shall be discarded. In no case shall the mixture be reheated.

5. PREPARATION OF FIELD SAMPLES

5.1 Use a sample obtained in accordance with approved methods.

5.2 In order to be consistent, any material received in the laboratory from the paving site in a hot condition, i.e. >100°C, shall be allowed to cool to room temperature and then reheated.

5.3 REDUCING FIELD SAMPLE TO TESTING SIZE: Large field samples shall be reduced to the appropriate size for testing. Two methods of reducing the field sample to the testing size are acceptable: quartering or splitting using a riffle splitter.

5.3.1 Quartering: Warm the field sample to achieve sufficient workability for quartering. A convectional or forced air oven, maintained at 110°C, or a microwave oven (see Note 3) may be used for this purpose. The surface upon which the sample is to be reduced should be flat, non-abrasive, non-absorptive and of sufficient area to provide for uniform quartering. Heat lamps may be used to keep the surface warm (see Note 4). The sample shall be mixed on the surface until uniform, then quartered, and opposite quarters removed. This process is to be repeated until the testing size is obtained.

Note 3: Caution: Frequent mixing may be necessary to prevent localized overheating when using a microwave oven to heat paving mixtures. Also, the presence of metal particles in some mixtures may render the microwave oven unsafe for the heating of these mixtures.

Note 4: If required, 'Pam' or equivalent used in minimal quantities has been found suitable in preventing the sample from adhering to the surface. Motor oils must not be used for this purpose.

5.3.2 Riffle Splitter: Warm the field sample to achieve sufficient workability for splitting. A convectional or forced air oven, maintained at 110°C, or a microwave oven (see Note 3 above) may be used for this purpose. The mix may agglomerate if it is too cold or stick to the splitter if too hot. A temperature range of 90°C to 110°C has been found to be generally satisfactory. Heat lamps may be used to keep the walls of the splitter box warm (see Note 4 above). Chutes shall be cleaned after each split. The use of a putty knife or a 25 mm diameter wire brush used to clean glassware has been found suitable.

5.4 Obtain from the sample by the splitting/quartering, sufficient material (approximately 4000 g) in order to prepare 3 Marshall briquettes.

Optional procedure for working with briquette sized batches: If desired, the 4000 g may be further reduced to 3 batches at this point, each to a size which will yield the briquette of the desired height (see Note 8 below). Care should be taken to ensure that the batches are of uniform composition, i.e., visually consistent.

Note 5: Materials required for other testing such as MRD and extraction can be obtained at the same time.

5.5 Spread the mixture in a flat pan (see Section 3.25), cover with aluminium foil or suitable cover and heat in an oven to a temperature not more than 5°C above the desired compaction temperature. A microwave oven shall not be used for this purpose. During heating the sample may be stirred and temperature checked by forming a mound and measuring with a temperature probe. The compaction temperature for the reheated loose paving mixture shall be supplied by the proprietor of the asphalt cement and/or the mix supplier.

Note 6: For field samples, keep the mix in the oven only long enough to achieve the desired compaction temperature. Preparation of multiple specimens will require that the oven be charged sequentially to ensure that all specimens are in the oven for approximately the same duration.

5.6 When the desired temperature has been reached, transfer the mix to a metal trough.

Note 7: For testing field samples, the moulds, trough and hammer are heated to the same temperature as in the preparation of mix design samples, i.e., 135 ± 5°C.

6. COMPACTION PROCEDURE

6.1 Remove the mould assembly from the oven and place on a non-conducting surface (19 mm plywood has been found suitable) and then place a paper disc in the mould. Using the metal trowel remove the mix from the trough. Place the mixture into the mould, ensuring that the bottom of the trowel is in contact with the bottom of the trough so that the mixture is not removed in layers.

For field mixes which are still around 4000 g in mass (i.e., not reduced to briquette sized portions) , divide the mix into three approximately equal portions on the trough, and charge three moulds with the required amount of mix, taking care not to segregate the mix in the process (see Note 7). When using a single compaction set up, return two of the moulds to the oven to prevent mix cool down.

Note 8: The actual mass required shall be sufficient to produce a compacted briquette 63.5 ± 2.5 mm in height. Refer to mix design for determining the mass required to yield this height.

6.2 Rod the mixture in the mould with the spatula 25 times, 15 times around the outside, 10 around the centre. When rodding around the outside, keep the spatula blade flat against the inside of the mould. When rodding around the centre, do not change direction of the blade. After rodding smooth the surface to a slightly rounded shape.

6.3 Place the metal or wooden bar on the top of the collar, and insert the two thermometers or probes into the pre-drilled holes so that the bottom of the thermometers or probes are approximately 40 mm into the centre of the mixture.

6.4 When the average mix temperature as indicated by the two thermometers or probes is in accordance with Section 4.11 (for mix design work) or Section 5.5 (for field samples), remove the probes and the bar.

6.5 When cooling to compaction temperatures, the mould(s) shall remain on the wooden board to minimize excessive temperature gradients.

6.6 Place the second paper disc on top of mix and place the mould assembly on the compaction pedestal in the mould holder. Compact the specimen by applying 75 blows per side at a rate 60 ± 5 blows per minute (see Note 9). The drop mass shall be allowed to hit and rebound with a secondary hit between drops. During compaction, the operator shall hold the axis of the compaction hammer as nearly perpendicular as possible to the base of the mould assembly (see Note 10). After compaction remove the base plate, collar and paper disks. Then allow the mould to cool until warm to the touch (approximately 40°C). Fans may be used when more rapid cooling is desired. Cooling by submerging in water is not permitted. For each additional briquette repeat the process.

Note 9: For mechanical compactors, it will be necessary for the laboratory to establish the mechanical equivalency for the equipment as compared to 75 blows per side of the hand hammer. This equivalency may be unique for each mix tested.

Note 10: The handle of the compaction hammer should be held freely by one hand in as nearly a vertical position as possible. This will result in some wobbling of the handle about the vertical during compaction. This wobbling provides a desirable kneading action of the specimen during compaction. Consequently, no mechanical device or other support shall be used to restrict or support the handle in the vertical position during compaction.

Note 11: When a significant number of samples are to be prepared, it is recommended that compaction of each briquette be performed by two technicians, alternating technicians on each face.

6.7 Remove the specimen from the mould by means of an extrusion jack or other compression device, and then place flat side down on a smooth, level surface until ready for testing.

6.8 Allow the extruded briquettes to stand on a smooth flat surface at room temperature for a minimum of one hour before any further testing is performed. Test for Marshall Stability requires the briquettes to sit at room temperature a minimum of 12 hours.

7. GENERAL NOTES AND PRECAUTIONS

7.1 To ensure consistency during hand compaction, place an empty mould in the compaction mould holder and rest the hammer in the mould. While standing, the operator's eye level should be the same height as the bottom of the hammer handle. If the eye level is below, place a step stool adjacent to the compaction pedestal to adjust the operator's height accordingly.

7.2 Mechanical mixing is preferred in the preparation of mix design samples.

7.3 The concrete block shall be restrained against lateral movement.

7.4 Handle all hot equipment with heat resistant gloves.

7.5 Always use the hand guards with the hand hammers.

7.6 Wear proper protective safety gear for each operation.

7.7 For mechanical compaction with the bevelled tamping foot, the position of the foot (i.e. the thick edge to the front, sides or back) may change the level of compaction. Therefore, the foot must be positioned the same way for all briquettes made for the same mix.

7.8 The manual hammer shall meet the following additional requirements: the major hammer parts (foot, handle, sliding mass) shall bear unique identifying number(s), either etched or stamped to make the marking indelible and permanent. The manufacturer of the hammer shall provide a dated document certifying that the assembled hammer bearing the unique identifying number(s) complies with the requirements of Table 1. The document shall also provide the total weight of the hammer and the weight of the sliding mass at manufacture, including the weight of the finger guard.

7.9 Compaction Proficiency Testing: It is recommended that laboratories conduct regular checks to ensure the proficiency of the laboratory's compaction set-up and procedures. This can be done by preparing Marshall specimens of a mix whose bulk relative density has been established through multi-laboratory testing. As a minimum, this proficiency testing should be done/repeated whenever

(a) there is a change in, or repair to, any major equipment used (hammer, pedestal, ovens etc.);

(b) there is a change is personnel conducting the test;

(c) routinely every 100 sets of briquettes;

(d) whenever a laboratory is physically moved; and/or

(e) at start-up (e.g. after winter shutdown)

Records of such proficiency testing should be maintained as part of the laboratory's quality manual.

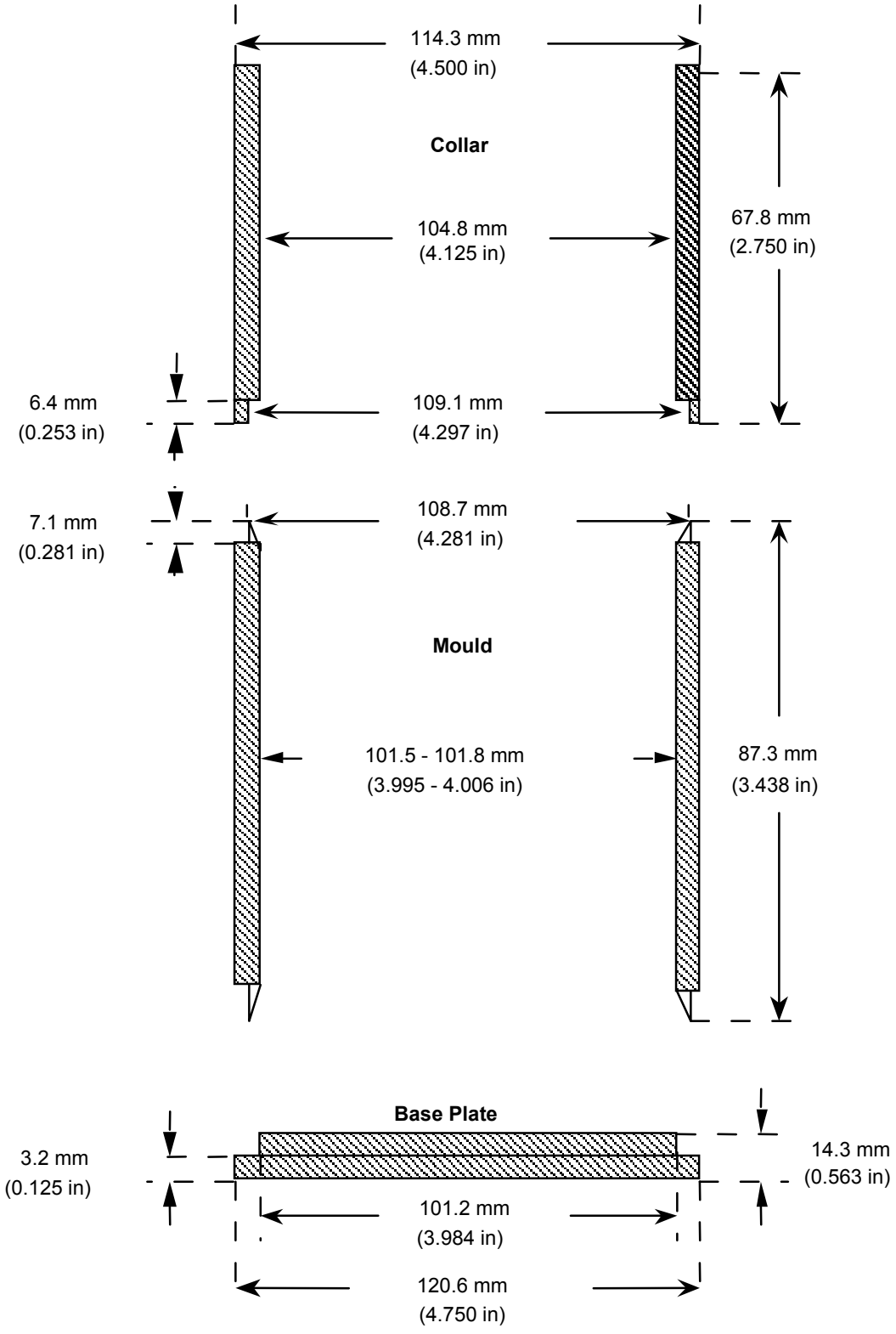


Figure 1

Dimensions for 4" Compaction Mould

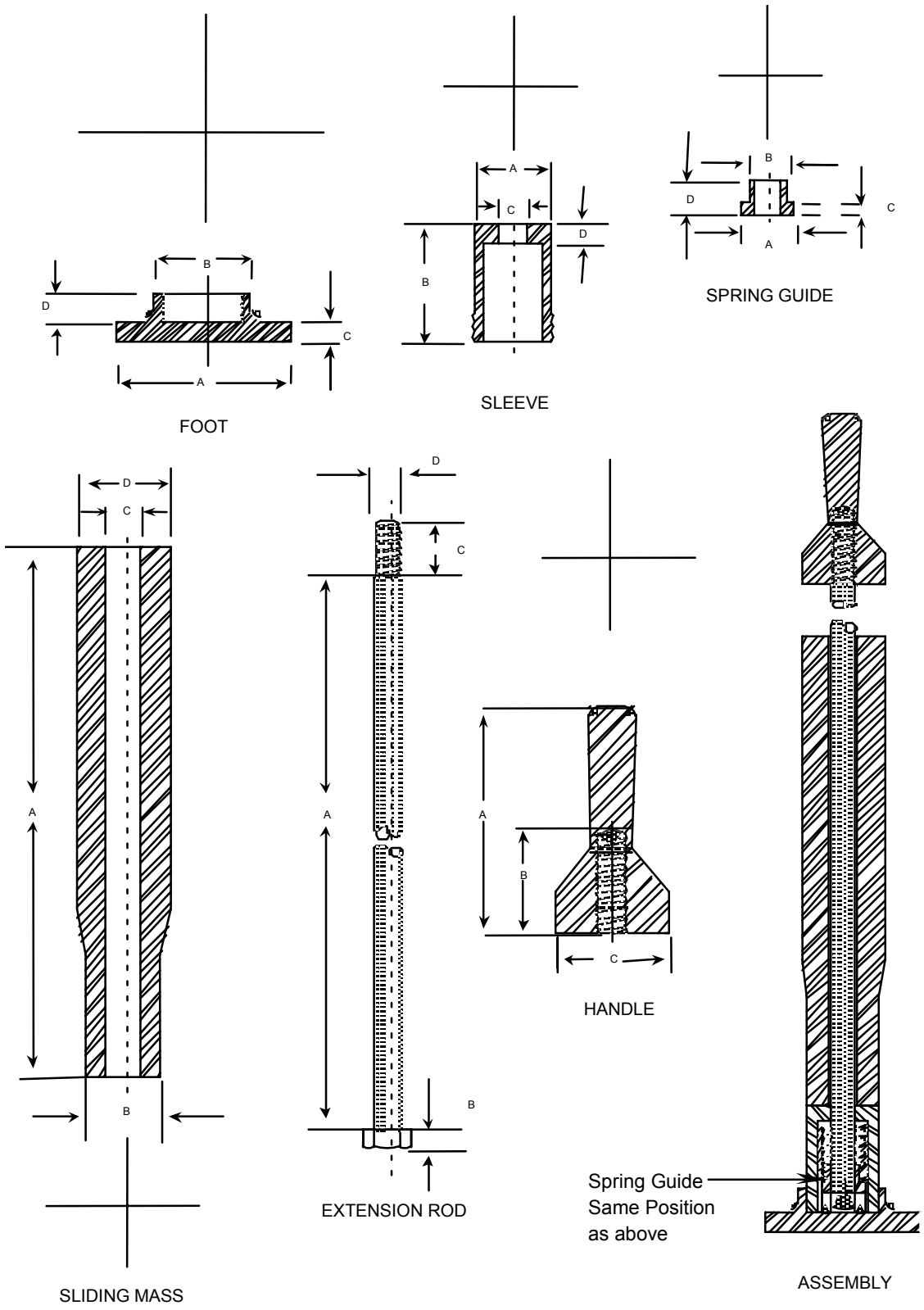


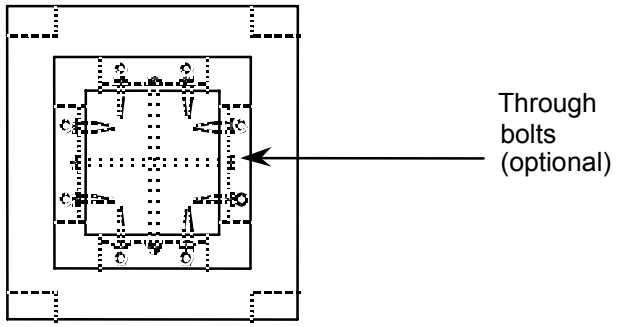
Figure 2

Dimensions for Manual Marshall Compaction Hammer

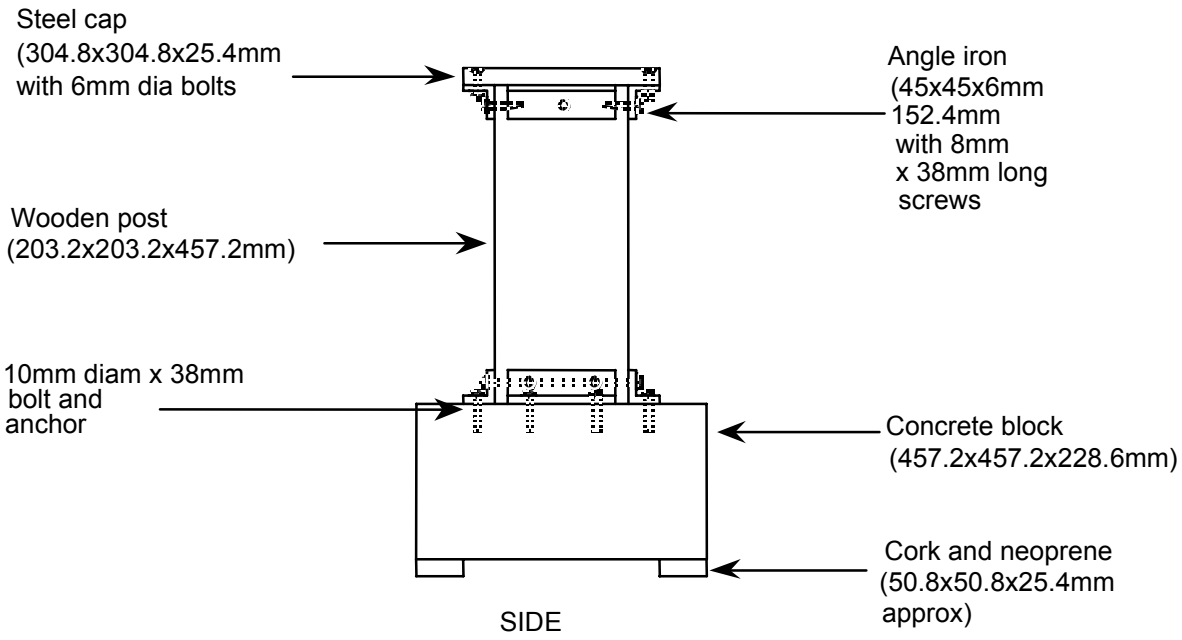
Table 1
Dimensions for Marshall Manual Compaction Hammer (1)

Measurement Location*	Specifications (3)				
	inches	Tolerance (in)	mm	Tolerance (mm)	grams
Handle					
A	5.25	± 0.50	133.3	± 12.7	-
B	2.00	± 0.50	50.8	± 12.7	-
C	2.25	± 0.25	57.2	± 6.4	-
Foot					
A	3.880	± 0.010	98.6	± 0.3	-
B	2.250	± 0.005	57.2	± 0.1	-
C	0.500	± 0.005	12.7	± 0.1	-
D	0.630	± 0.010	16.0	± 0.3	-
Sleeve					
A	1.750	± 0.005	44.4	± 0.1	-
B	2.50	± 0.25	63.5	± 6.4	-
C	0.630	± 0.025	16.0	± 0.6	-
D	0.35	± 0.05	8.9	± 1.3	-
Spring Guide					
A	1.250	± 0.005	31.8	± 0.1	-
B	1.00	± 0.10	25.4	± 2.5	-
C	0.240	± 0.035	6.1	± 0.9	-
D	0.70	± 0.05	17.8	± 1.3	-
Extension Rod					
A	32.0	± 0.5	812.8	± 12.7	-
B	0.50	± 0.05	12.7	± 1.3	-
C	1.63	± 0.12	41.4	± 3.1	-
D	0.63	± 0.010	16.0	± 0.3	-
Sliding Mass					
A	12.00	± 0.01	304.8	± 0.3	4535 ±9**
B	1.75	± 0.10	44.5	± 2.5	-
C	0.675	± 0.025	17.1	± 0.6	-
D	2.25	± 0.15	57.2	± 3.8	-
Spring (2) -					
unconfined	2.1		53.3		-
confined	1.50		38.1		-
I/D coil	> 0.94***		> 23.88***		-
wire diameter	0.155		3.94		-
Overall Mass	-		-		7853 ±16**

* See Figure 2 for dimension locations.
** Including finger guard
*** Just slightly larger than .94" (23.88mm)
(1) See Section 7. General Notes and Precautions for additional requirements pertaining to hammers
(2) Spring: # of coils = 5
(3) Irrespective of the tolerances permitted for the various components, the free fall of the sliding mass shall be 457 mm ± 1.5 mm.



TOP



SIDE

Note: Dimension Tolerances:

Concrete Block:	± 25 mm
Wooden post:	± 5 mm
Angle iron	± 5 mm, except thickness which is ± 1 mm

Figure 3

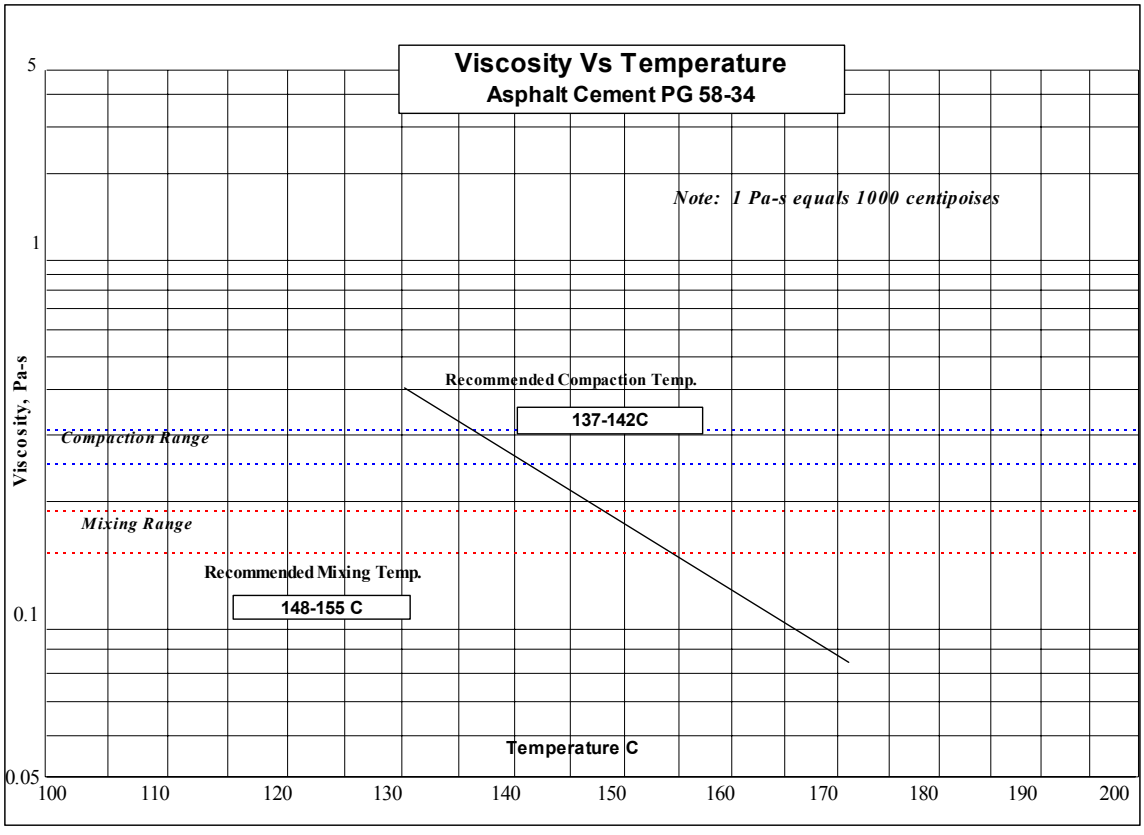
Compaction Pedestal (without mould holder)

Determination of the Laboratory Mixing and Compaction Temperatures of Hot Mix for Design of Pavement Mixtures

The viscosity temperature relationship of an asphalt cement is used as a guide for establishing the mixing and compaction temperature in the laboratory. The temperature to which the asphalt cement must be heated to produce a viscosity of 0.17 ± 0.02 Pa.s is the mixing temperature. The temperature to which the asphalt cement must be heated to produce a viscosity of 0.28 ± 0.03 Pa.s is the compaction temperature. This has been the guide for Marshall mix design criteria and the relationship continues to be valid for laboratory purposes within Superpave. In Ontario the mixing and compaction temperature are the temperatures where the asphalt cement has viscosities of 0.17 and 0.28 Pa.s respectively.

The Brookfield Viscometer, a rotational device (ASTM D 4402), is used to determine the mixing, compaction, and pumping temperatures in the Superpave system. Viscosity measurements at 135° C and 165° C are plotted on a Loglog viscosity vs. log temperature chart shown below and the mixing and compaction temperature interpolated.

The procedure for establishing the mixing and compaction temperatures for the laboratory is valid for refinery produced asphalt cements and may not be valid for some polymer modified asphalt cements. The supplier of these asphalt cements must be consulted for their mixing and compaction temperature recommendations.



The relationship between temperature and viscosity in this example shows the idealized laboratory mixing and compaction ranges. The asphalt cement is a "super lubricant" at the mixing temperature and a "super glue" somewhere around the compaction temperature range.

Figure 4: Sample Temperature Viscosity Chart

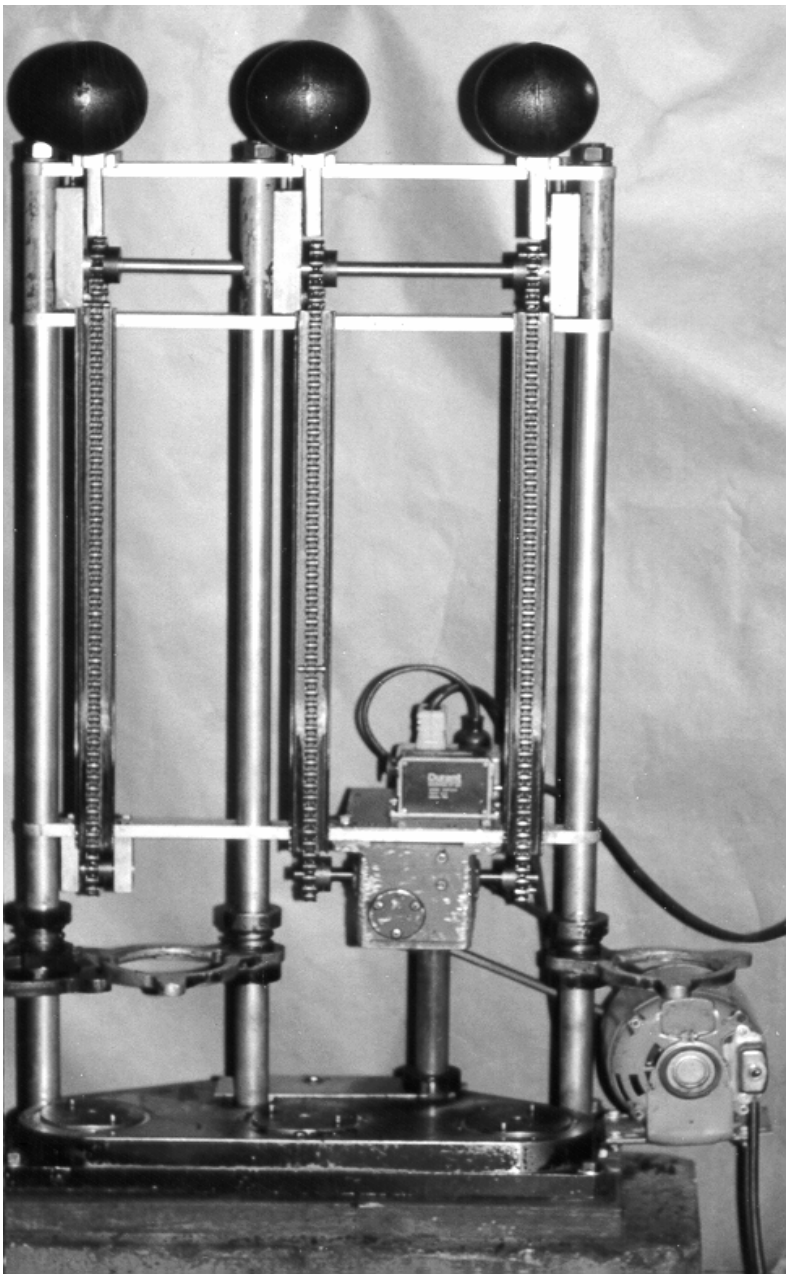


Figure 5

Mechanical Compactor

Figure 6

Mechanical Asphalt Mixer