

METHOD OF TEST FOR RESISTANCE TO STRIPPING OF ASPHALT CEMENT IN BITUMINOUS MIXTURE BY MARSHALL IMMERSION

1. SCOPE

1.1 This method covers a procedure for determining the resistance to stripping of bitumen-aggregate mixtures, compacted by the double plunger method, when immersed in water.

1.2 This method compares the Marshall stability values of air-cured specimens with the stability values of duplicate samples that have been cured in water, thus producing an index of percent retained stability.

2. RELEVANT DOCUMENTS

2.1 MTO Method LS-261

2.2 MTO Method LS-263

2.3 ASTM D 1074

2.4 ASTM D 1075

2.5 ASTM D 1559

3. DEFINITIONS

3.1 The index of percent retained stability is obtained by determining the Marshall stability values of a set of three specimens that have been immersed in water and expressing it as a percentage of the Marshall stability values of a duplicate set of air cured samples.

3.2 A numerical stripping rating is given to the specimens based on the degree of asphalt stripping from the surfaces of the coarse and fine aggregate particles when the specimens are broken open after curing in water.

4. APPARATUS

4.1 METAL CONTAINERS: Approximate 1000 g capacity, required for aggregates when heated in the oven.

4.2 WATER BATH: Capable of maintaining a temperature of $25 \pm 0.3^{\circ}\text{C}$ complete with perforated shelf located 50 mm above the bottom of the tank for holding specimens and supports. The shelf shall hold at least six specimens and supports.

4.3 WATER BATH: Of suitable capacity, capable of maintaining a temperature of $60 \pm 1.0^{\circ}\text{C}$.

4.4 AIR BATH: Capable of maintaining a temperature of $60 \pm 1.0^{\circ}\text{C}$ complete with a perforated shelf for holding specimens. The shelf shall hold at least six specimens.

- 4.5 COMPACTOR: A compression machine that is capable of providing an accurately controlled rate of vertical deformation.
- 4.6 MARSHALL MOLDS: Conforming to details as shown in Figure 4. Six required. Only one Marshall mold collar is required.
- 4.7 MOLD SUPPORTS: Steel bars, 75 mm in length and 25 mm by 25 mm square to provide temporary support for the molds. Two required.
- 4.8 TOP PLUNGER: A steel cylinder, 50 mm in diameter and 120 mm height. Two 25 mm thick x 100 mm diameter steel plates are welded to each end of the cylinder. (Figure 3)
- 4.9 BOTTOM PLUNGER: A steel circular plate, 100 mm in diameter and 33 mm in height. (Figure 3)
- 4.10 SUPPORT PLATES: Steel plates 100 mm in diameter and approximately 15 mm in height. Six required.
- 4.11 MIXER: A mixer using a 6 L capacity mixing pot with an "egg beater" or wire type of mix paddle. Hobart type mixer is suitable.
- 4.12 OVEN: Of suitable capacity and capable of maintaining a temperature between 93°C and 149°C. (Required to heat the Marshall molds and trough).
- 4.13 OVEN: Of suitable capacity and capable of maintaining a temperature range of 100 to 180°C $\pm$ 2.8°C. Required to dry the aggregates prior to batching, (105 to 110°C), as well as heating the aggregates prior to mixing with asphalt cement.
- 4.14 HOT PLATE: Capable of heating the asphalt cements to the specified mixing temperature $\pm$ 2.8°C.
- 4.15 THERMOMETERS/TEMPERATURE PROBE: Thermometers/probes suitable for measuring temperatures of aggregate, asphalt and bituminous mixtures in the range of 10 to 204°C with sensitivity of $\pm$ 2.8°C. Thermometers or probes are also required which are suitable for measuring water bath and air bath temperatures with a range from 20 to 70°C with sensitivity of $\pm$ 0.2°C.
- 4.16 METAL TROUGH: A round bottom trough approximately 750 mm in length and 125 mm wide at the top.
- 4.17 SPECIMEN SUPPORTS: Of galvanized sheet metal consisting of a bottom and three sides for support. They support the specimens in the water baths. Six required.
- 4.18 MAGNIFYING GLASS: Approximately 10x power.
- 4.19 BRIQUETTE EXTRUDER: 1-1/3 tonnes capacity lift jack or converted Marshall testing machine.
- 4.20 MAGNIFIER LAMP: Luxo
- 4.21 BALANCE: 5 kg capacity, sensitive to 0.1 g.
- 4.22 KETTLE: Sufficient capacity to hold approximately 1.0 L of asphalt cement.
- 4.23 METAL SCOOP: Flat bottomed- for batching aggregates.

- 4.24 GLOVES: Heat resistance for handling hot equipment.
- 4.25 STOPWATCH OR TIMER
- 4.26 MARSHALL TESTING MACHINE: Meeting the requirements in ASTM D1559, Sections 3.7, 3.8. See Notes 2 and 3.

5. PREPARATION OF SPECIMENS

- 5.1 Prepare the aggregates using the procedure described in MTO Method LS-261, "Method of Preparation of Marshall Specimens Section 4. Test Procedure 4.1.1 and 4.1.2". Prepare 6 batches.
- 5.2 Place the aggregate in an oven maintained at a temperature not exceeding 28°C above the temperature that will yield a viscosity of $170 \pm 20 \text{ mm}^2/\text{s}$ for the asphalt used. Heating time shall be a minimum of 16 hours, normally overnight.
- 5.3 Preheat the mixing bowl in the same oven.
- 5.4 Preheat the metal trough, top and bottom plungers and the Marshall molds minus the base plates in the oven maintained at a temperature between 93 and 149°C.
- 5.5 Heat the asphalt on the hot plate to a temperature at which the viscosity is $170 \pm 20 \text{ mm}^2/\text{s}$ (Mixing temperature). The asphalt cement should not be held at the 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.
- 5.6 When the asphalt and aggregate have reached the desired temperatures, remove the container of aggregate from the oven and quickly place it in the mixing bowl. Dry mix the aggregate for 15 s.
- 5.7 After dry mixing, make a small depression in the center of the aggregate in the bowl and quickly add the required amount of asphalt (see Note 1) and mix for 45 seconds or until the aggregate is coated. Do not mix longer than 1-1/2 minutes. Report any mixing problems such as coating or balling of the mix.

Note 1: 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 %.

$$\begin{aligned}\text{Mass of A.C. required} &= \frac{1180 \times 5}{100 - 5} &= & 62.1 \text{ g} \\ \text{Total mix} &= 1180 \text{ g} + 62.10 \text{ g} &= & 1242.1 \text{ g}\end{aligned}$$

- 5.8 At the end of the wet mixing cycle, scrape as much mix as possible from the paddle.
- 5.9 While the mixing is in progress, remove the trough, mold, top and bottom plungers from the oven. Spread the mixture into the metal trough, using a back and forth motion. Place the bottom plunger on the lower platen of the compactor. Place the Marshall mold and collar over the lower plunger so that the mold is supported by the two steel bars. Using a metal trowel, transfer the mix

from the trough into the mold. Remove the mold collar. Form the mix into a slight mound at the top, but do not rod. Place the top plunger into the mold keeping it vertical until the initial load is applied.

Note 2: The temperature of the mixture immediately prior to compaction shall be within a range that will produce a viscosity of $280 \pm 30 \text{ mm}^2/\text{s}$ for the asphalt cement being used, otherwise the briquette shall be discarded. Refer to the temperature/viscosity chart for the asphalt cement in use. In no case shall the mixture be reheated.

5.12 Apply the initial load of 22,250 N, release the load and remove the two steel bars to allow full double plunger action. Apply a load of 166,800 N and hold for 2 minutes.

5.13 At the end of the 2 minute period release the load, remove the top plunger, transfer the briquette from the bottom plunger and place onto one of the support plates. Allow the briquette to cool to room temperature. Prepare the remaining five briquettes in the same manner. The plungers will not require additional heating if there is no delay.

6. TEST PROCEDURES

6.1 After cooling to room temperature extrude the test specimens using a mechanical extruder (1-1/3 tonnes capacity jack and frame), or a modified Marshall testing machine. Then place the specimens in the air bath maintained at $60^\circ\text{C} \pm 1^\circ\text{C}$ and leave for 16 to 18 h, usually overnight.

6.2 At the end of the 16 to 18 h period remove the briquettes from the air bath, place on a flat, non-absorbent surface and allow them to cool to room temperature.

6.3 Determine the Bulk Relative Densities of the briquettes using MTO Method LS-262. Group the six briquettes into two sets of three so that the average B.R.D. of each set is essentially the same.

6.4 Place one set of briquettes in the $25^\circ\text{C} \pm 0.3^\circ\text{C}$ water bath for one hour. Remove and quickly dry with a damp towel, then test for Marshall stability and flow. The time from removal from the water bath to completion of the stability test shall not exceed 30 seconds. After testing, break open the briquettes and allow them to sit overnight.

6.5 Place the other set in the vacuum cell(s) containing distilled water at $25 \pm 1^\circ\text{C}$. Place the top on the vacuum cell(s) conforming to details as shown in Figures 1, 2 and reduce the pressure to $30 \pm 1 \text{ mm Hg}$ for a period of one 1 h. Agitate the cell(s) periodically to release the air. At the end of the specified time release the pressure slowly. Remove the briquettes, place them in the metal holders and immerse them in the $60^\circ\text{C} \pm 1^\circ\text{C}$ water bath containing distilled water. Keep the briquettes in the bath for 24 h.

6.6 After 24 hours remove and place in the $25^\circ\text{C} \pm 0.3^\circ\text{C}$ water bath for one hour. Remove and quickly dry with a damp towel, then test for Marshall stability and flow. The time from removal from the water bath to completion of the stability test shall not exceed 30 seconds. After testing, break open the briquettes and allow them to sit overnight.

6.7 AIR CURED SPECIMENS: Using the illuminating-magnifying glass, examine the coating of the coarse aggregate (Ret. 4.75 mm, Pass 4.75 mm/Ret. 600 µm and the Pass 600 µm) of the broken faces of the specimens (briquettes). Assign a coating rating (heavy, medium or light, etc.) based on the following criteria:

Coating Rating	Description Of Film
Heavy	Thick shiny black film. Most of coarse aggregate particle surfaces covered with adhering fine aggregate visible.
Medium	Thinner film than above, opaque. Most of coarse aggregate particle surfaces are covered with adhering fine aggregate.
Light	Thin film. Still opaque. Coarse aggregate particle has very little fine aggregate adhering to surface due to thin film. Usually pass 300 µm material is visible.
Heavy Stain	Dark brown translucent film. Some fine aggregate adhering to surface.
Medium Stain	Medium-dark brown translucent film. Little or no fine aggregate adhering to surface.
Light Stain	Light brown translucent film. No fine aggregate adhering to surface.

6.8 WATER CURED SPECIMENS: Using the illuminating-magnifying glass, examine the broken faces of the specimens (briquettes) for percentage of stripping for both coarse and fine aggregates.

6.9 Assign a stripping rating for each set of water-cured briquettes, using the following formula:

$$R = P_L + C + F$$

where:

P_L = 3 when no stripping is evident

P_L = 4 when some stripping is evident

C = coarse aggregate stripping factor

F = fine aggregate stripping factor

C	% STRIPPING
0	less than 10 %
1	10 % to 30 %
2	31 % to 60 %
3	greater than 60 %

F	% STRIPPING
0	less than 10 %
1	10 % to 30 %
2	greater than 30 %

7. CALCULATIONS

$$7.1 \quad \% \text{ Retained Stability} = \frac{\text{Marshall Stability (water samples)}}{\text{Marshall Stability (air samples)}} \times 100$$

8. REPORT

The report, (See Figure 5), shall include the following;

- 8.1 Percent retained stability.
- 8.2 All Flow values.
- 8.3 Coating rating.
- 8.4 Stripping rating factor and estimated % stripping. Note any swelling.

9. GENERAL NOTES

- 9.1 The Marshall flow values should be recorded because they may be used in further review of this test method.
- 9.2 If stripping in a salt solution is to be studied use a 0.5 percent solution (by mass) of NaCl in distilled water.
- 9.3 Perforated circular shelves with legs, placed one on top of the other, will allow several briquettes to be placed in the vacuum cell at one time.
- 9.4 When briquettes are in the vacuum cell gently shake the cell two or three times at intervals to help dislodge the air bubbles from the briquettes.
- 9.5 When determining stability and flow values, either the Marshall, Pine or the Rainhart testing apparatus may be used.
- 9.6 The asphalt content is normally set at the same percentage as designated in the approved mix design.
- 9.7 The fixed upper platen on the compression machine must be used.
- 9.8 If the retained stability is less than 70 %, repeat the complete test, with an additive (if no additive is used) or an increased dosage of additive (if an additive is used already).

10. PRECAUTIONS

- 10.1 Handle all hot equipment with heat resistant gloves.
- 10.2 When in an air bath, water bath or vacuum cell, each briquette must be placed on one of its flat surfaces. The briquettes must not touch each other.
- 10.3 Always place the briquettes in the metal holders before immersing in the 60°C bath as the briquettes are too fragile to remove from the water bath without support.

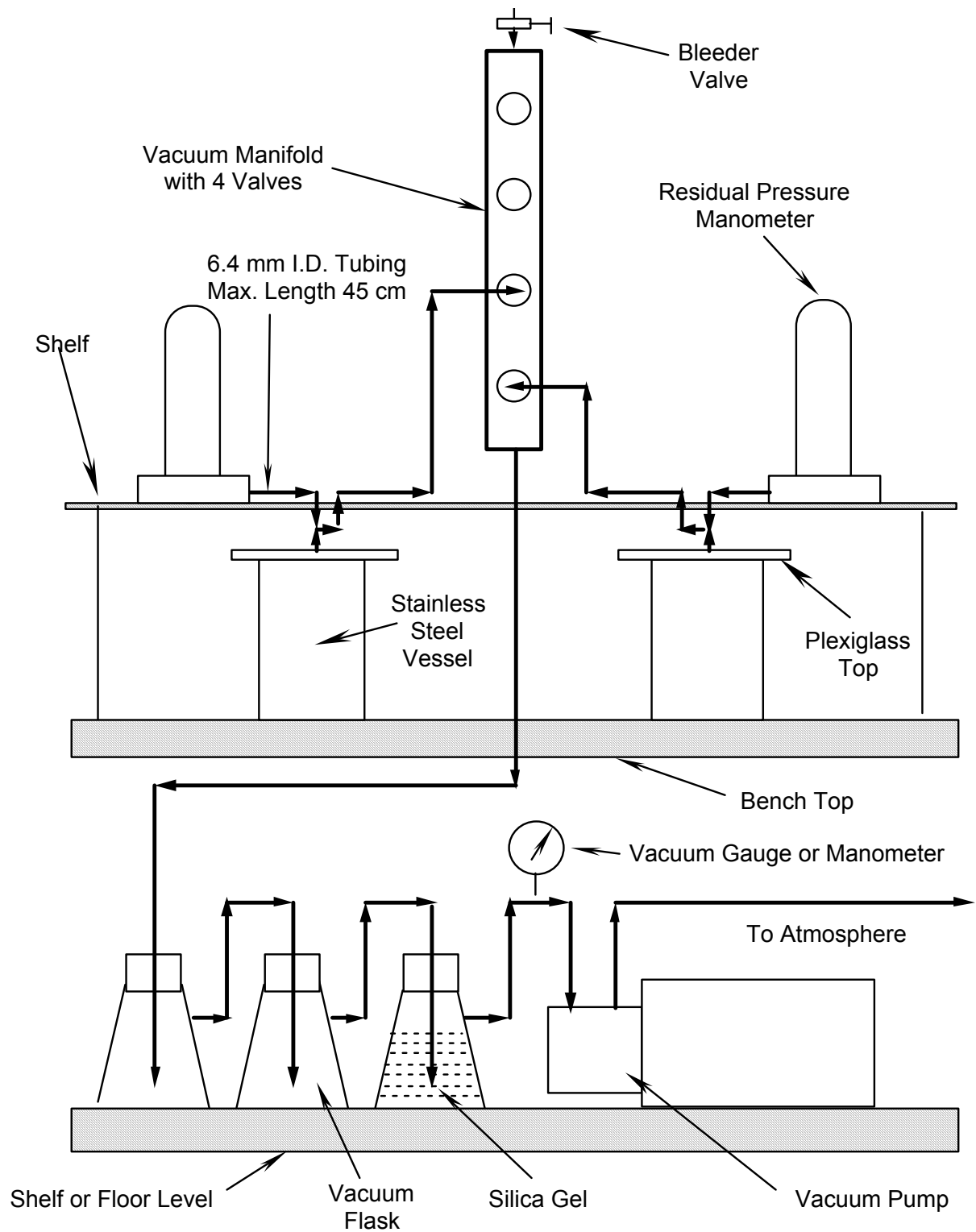
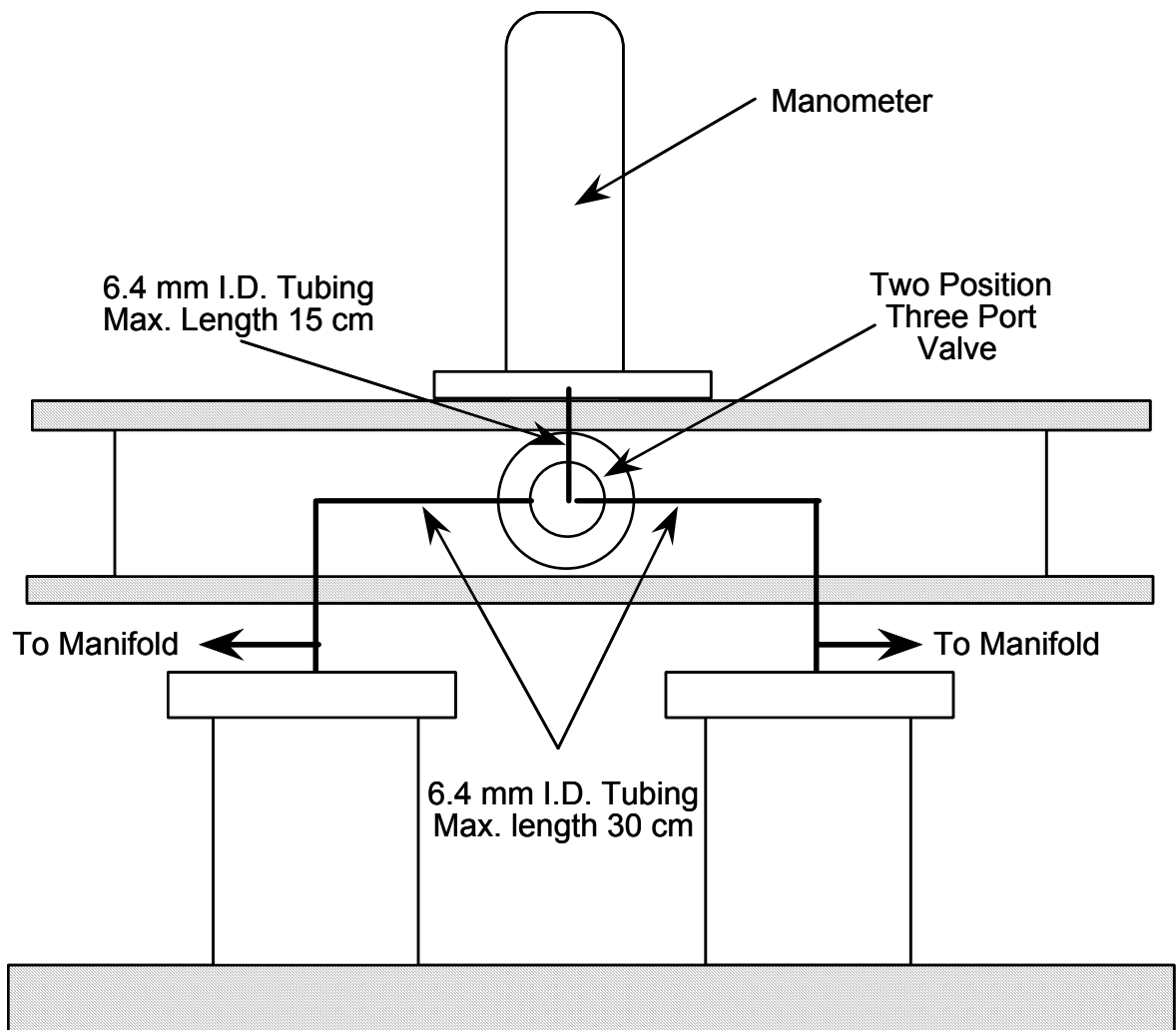


Figure 1

Vacuum Saturation System



MRD equipment using one manometer for two vessels

Note: Tubing between the manometer and the vessels must be kept as short as possible to enable accurate pressure readings.

Figure 2

Vacuum Saturation System - Alternative Set up

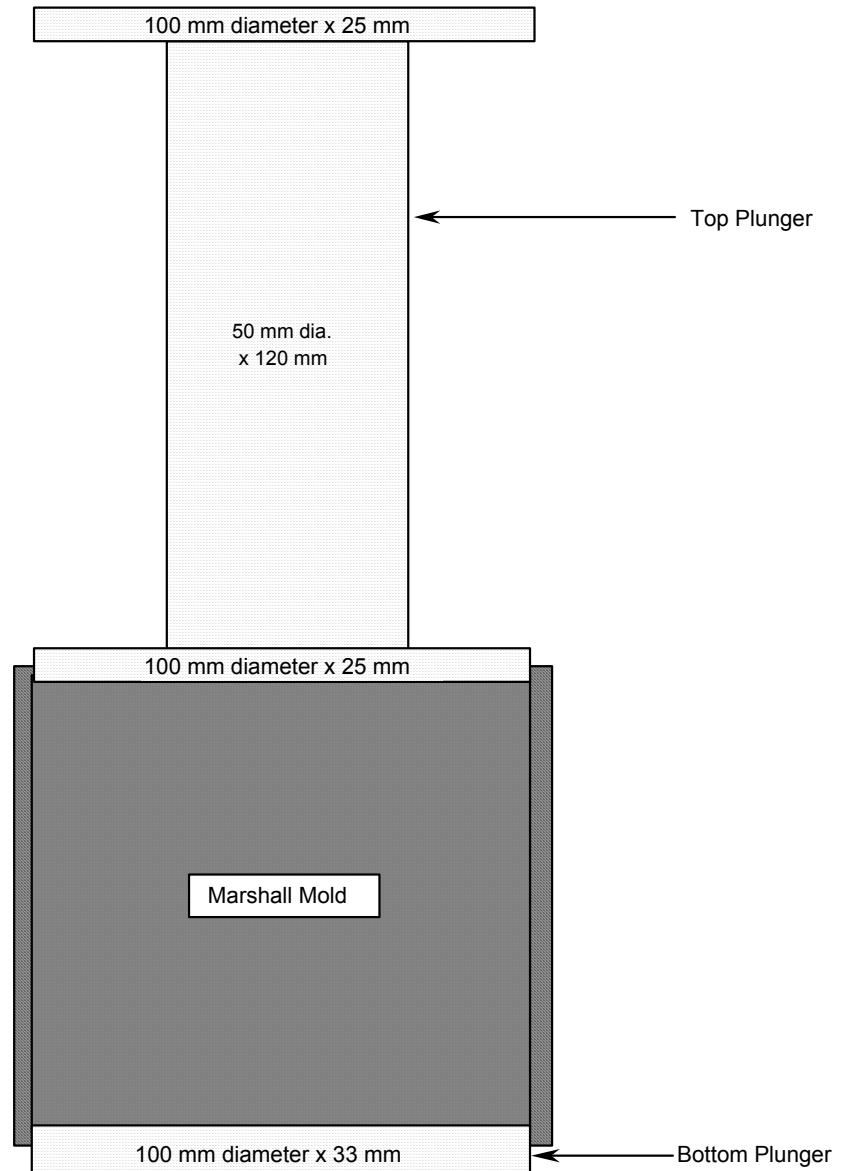


Figure 3
Double Plunger Apparatus

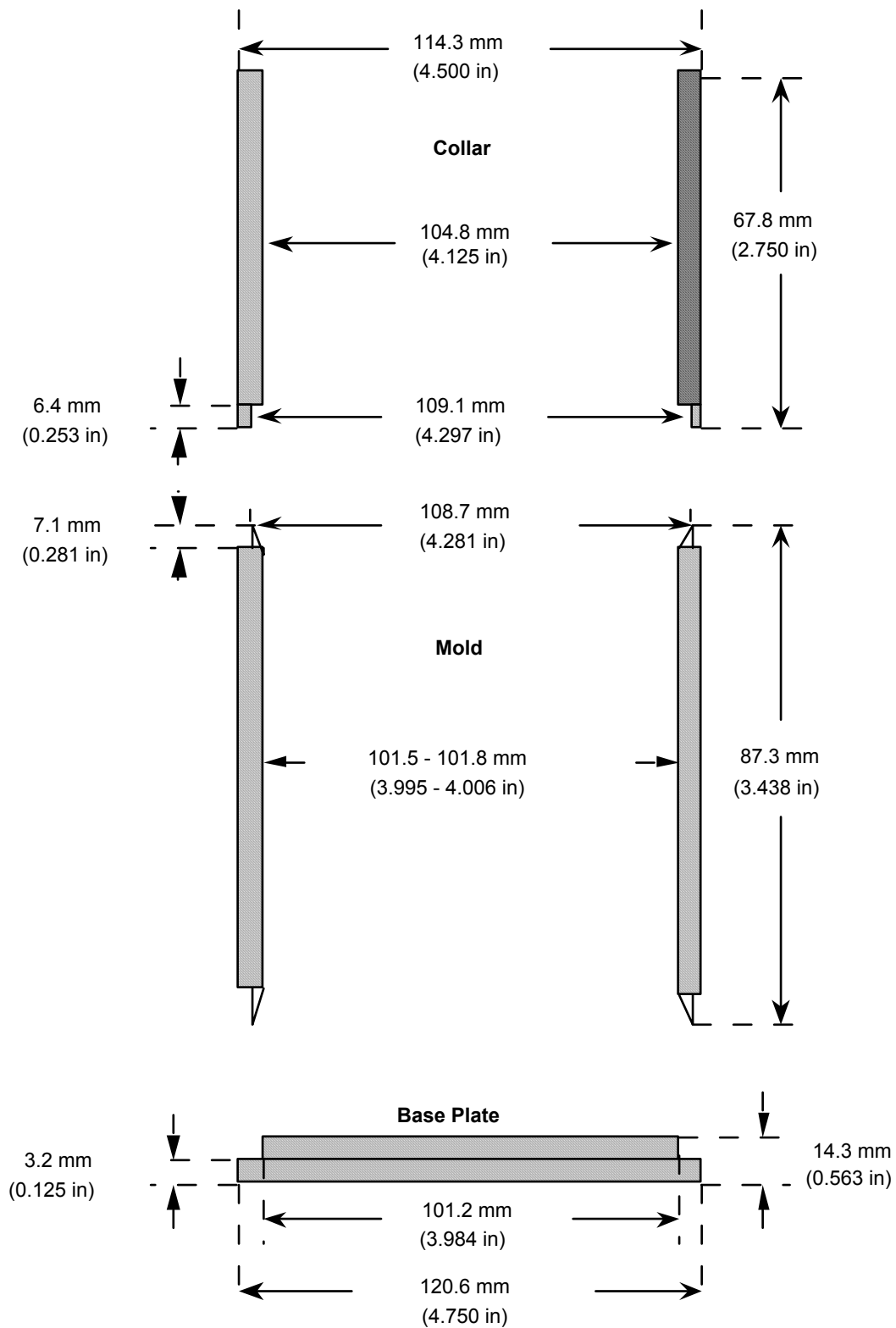


Figure 4

Dimensions for 4" Compaction Mold

Marshall Immersion Data Sheet

Pressure (mm Hg)	Brigette #	BRD	Stability (C) (Corr'd)	Flow (.25mm)	Coating Rating*		Estimated		Stripping Rating (R)	% Retained Stability
					Ret. 4.75 /ret600	Pass 4.75 /ret600	C/A	% Stripping F/A		
30	Air									
	Average									
	Water									
	Average									

*Coating rating

H
M
L
HS
MS
LS

-Heavy
-Medium
-Light
-Heavy Stain
-Medium Stain
-Light Stain

Pressure (mm Hg)

30

Yes

No

Swelling

Contract :

Mix Type:

Antistripping Additive :

% Antistripping Additive :

Figure 5

MTO Marshall Immersion Form