Method of Test for
THE STABILITY AND FLOW OF
ASPHALTIC CONCRETE MIXTURES – MARSHALL METHOD
DOTD Designation: TR 305M/305-03

I. Scope

A. This method of test is designed to determine the physical characteristics, stability and flow of asphaltic concrete mixtures. This method is commonly known as the "Marshall Method."
B. Reference Documents
   1. DOTD TR 303 – Determination of Optimum Asphalt Cement Content for an Asphaltic Concrete Mixture
   2. DOTD TR 304 – Determination of Specific Gravity and Density Characteristics of Compressed Asphaltic Mixtures
   3. DOTD TR 203 – Sampling Asphaltic Mixtures
   4. Qualified Products List Manual, QPL 25 – Asphalt Mix Release Agents
   5. AASHTO M 92 – Standard Specification for Wire-Cloth Sieves for Testing Purposes

II. Apparatus

A. **Specimen mold assembly** – a mold with a diameter of 101.6 mm (4 in.) and a height of 76.2 mm (3 in.), base plates, and extension collars (Figure 1).
B. **Specimen mold holder** – mounted on the compaction pedestal so as to center the compaction mold over the center of the post. It shall hold the compaction mold, collar and base plate securely in position during compaction of the specimen.
C. **Compaction hammer** – a hand operated compaction hammer or an automatic compaction hammer. The hand operated compaction hammer (Figure 2) shall have a flat, circular tamping face of diameter 98.4 mm (3 ⅞ in.) and a sliding weight of 4.54±0.01 kg (10±0.02 lb). The sliding weight shall have a free fall of 457.2±1.6 mm (18±1/16 in.). The automatic compaction hammer (Figure 3) shall have a flat tamping face of 98.4 mm (3 ⅞ in.) diameter and a sliding weight of 4.54±0.01 kg (10±0.02 lb). The sliding weight shall automatically release itself for a free fall of 457.2±1.6 mm (18±1/16 in.). The automatic compaction hammer may be equipped with a programming counter which terminates the compaction at the completion of the required number of blows.
D. **Stability test mold** – the breaking head (Figure 4) shall consist of upper and lower cylindrical segments or test heads having an inside radius of curvature of 50.8 mm (2 in.) accurately machined. The lower segment shall be mounted on a base having two perpendicular guide rods or posts extending upward. Guide sleeves in the upper segment shall be in such a position as to direct the two segments together without appreciable binding or loose motion on the guide rods. Breaking heads of other design, but meeting the above-mentioned requirements, may be used with the approval of the Materials Engineer Administrator.
E. **Paper Disks** – a paper disk with a diameter of 101.6 mm (4 in.) for use as a bond breaker during compaction in the mold.
F. **Compression testing machine**
   1. **Loading jack** – the loading jack (Figure 5) shall consist of a screw jack mounted in a testing frame and shall produce a uniform vertical movement of 50.8 mm/min (2 in./min). A reversible ¼ HP electric motor with reversing switch mounted is attached to the jacking mechanism.

2. **Proving ring assembly** – the proving ring (Figure 5) shall be 44.48 kN (20,000 lb) capacity, sensitive to 88.9 N (20 lb), and be equipped with a micrometer dial. The micrometer dial shall be graduated in 0.0025 mm (0.0001 in.) markings. Upper and lower proving ring attachments are required for fastening the proving ring to the test frame and transmitting the load to the breaking head. There shall be a calibration chart to convert dial reading to stability load.

G. **Compaction pedestal** – the compaction pedestal shall consist of a wooden post capped with a steel plate. The post shall be of minimum dimensions 200 mm x 200 mm x 450 mm (8 in. x 8 in. x 8 in.) and shall be placed upon a solid concrete slab or other suitable rigid support. The cap for the post shall be a minimum dimension 300 mm x 300 mm x 250 mm (12 in. x 12 in. x 1 in.) and shall be firmly fastened to the post. The pedestal assembly shall be installed so that the post is plumb and the cap is level.

H. **Flow meter** – the flow meter shall consist of a guide sleeve and a gage. The activating pin of the gage shall slide inside the guide sleeve with a slight amount of frictional resistance. The guide sleeve shall slide freely over the guide rod of the breaking head. The flow meter gage shall be adjusted to zero when placed in position on the breaking head when each individual test specimen is inserted between the breaking head segments. Graduations of the flow meter gage shall be 0.1 mm (0.01 in.) divisions.

I. **Water bath** – the water bath shall be at least 140 mm (5 ½ in.) deep and shall be controlled so as to maintain the bath at 60±0.5°C (140±1°F). The tank shall have a perforated false bottom or be equipped with a rack for supporting the immersed specimens a minimum of 13 mm (½ in.) above the bottom of the bath. (Figure 6)

J. **Dial thermometer** – for determining the temperature of asphaltic mixture, with metal stem with a range of 10 to 260°C (40 to 50°F) sensitive to 3°C (5°F).

K. **Thermometer** – for water bath with a range of –1 to 82°C (30 to 180°F) sensitive to 0.5°(1°F).

L. **Miscellaneous equipment** - mixing spoon, scoop, containers with covers, gloves, container holders, goggles, rags, paper towels, specimen marker, lubricant.

M. **Specimen ejector** – a hydraulic jack and stand for removing specimens from the mold with minimum disturbance.

N. **Oven** – constant temperature forced air oven capable of maintaining a temperature range between 40±3°C and 200±3°C (100±5°F and 400±5°F).

O. **Sieves** – 37.5 mm (1 ½ in.) and 19.0 mm (¾ in.) conforming to AASHTO M 92.

P. **Mix release agent** – an approved product listed on QPL 25.

Q. **Asphaltic Concrete Plant Report** – DOTD Form No. 03-22-3085. (Figure 7)

III. Sample

A. **Sampling mixtures at the hot mix plant** – When sampling an asphaltic mixture, extreme care should be taken to obtain a truly representative sample of the material to be tested. Sample in accordance with DOTD S 203.

B. **Laboratory prepared samples** – for mix design purposes the mixture will be prepared as specified in DOTD TR 303, Method B.

IV. Health Precautions

Proper precautions are to be taken whenever hot materials or equipment must be handled. Use container holder or thermal gloves while handling hot containers. Wear eye protection while stirring and weighing heated materials due to possible shattering of particles. Dry contaminated materials under a vent to prevent exposure to fumes.

V. Preparation of Test Specimens

A. Place the specimen mold assembly in an oven set at the temperature determined in Step V.F. and preheat for a minimum of 30 minutes.
B. After sampling and before placing the mix in the preheated Marshall molds, coat the inside of the mold assembly and base plate with a light application of mix release agent.

Note 1: *Step V.B. should be completed within 10 minutes of sampling to avoid cooling of the mix.*

C. Remove the mold assembly from the oven and place a paper disk in the bottom of the mold.
D. Using the scoop, place adequate mix (approx. 1200 g) in the mold to produce a compacted specimen with a thickness 64±6 mm (2 ½ ± ¼ in.).
E. Using the scoop or other suitable device, rod the material in the mold 15 times around the outside of the mix and 10 times over the interior of the mix to secure a uniform placement. Smooth the surface of the mixture to a slightly rounded shape.
F. For mixtures with nonabsorptive aggregates, place the mold with material in the oven for 1 hr±5 minutes at the optimum compaction temperature. For mixtures with absorptive aggregates, place the mold with material in the oven for 2 hrs±5 minutes at the optimum compaction temperature. If the optimum compaction temperature of the mixture is not known, set the oven at 150°C (300°F).

Note 2: *If any aggregates in the mixture have a water absorption greater than 2%, it is considered an absorptive aggregate.*

G. Coat the base of the hammer with a light application of mix release agent.
H. Remove the mold with material from the oven and immediately compact the mixture with the specified blows of the compaction hammer. Take extreme care in counting the number of blows as most of the properties of the mixture are highly dependent on the degree of compaction applied.
I. Remove the base plate and collar and turn the mold with material over and reassemble the base plate and collar. Clean the base of the hammer by using a rag with mix release agent. Apply the same number blows to this side of the briquette.
J. After compaction, air cool the mold and its contents to approximately room temperature.
K. After the specimen has cooled, extract the specimen from the mold using the specimen ejector.
L. Clean the specimen with a clean rag or paper towel and mark the specimen with a sample ID number.
M. Measure the thickness of the specimen. Discard specimens that do not meet the thickness requirement of 64±6 mm (2 ½ ±¼ in.).

Note 3: *Testing of the briquette specimen may be done immediately or after several days.*

VI. Procedure

A. Determine the specific gravity of the briquette and the density characteristics in accordance with DOTD TR 304.
B. Place the briquette and testing mold in a water bath maintained at a temperature of 60±0.5°C (140±1°F) for a minimum time of 20 minutes, but not to exceed 30 minutes. The specimen shall not touch the side or the bottom of the water bath or the thermometer.
C. When more than one test specimen is to be broken, return the test mold to the water bath for a minimum of 5 minutes before testing the next specimen. Place each specimen a minimum of 25 mm (1 in.) apart in the water bath.
D. Clean the inside surface and guide rods of the testing mold prior to testing. Lubricate the guide rods so that the upper part of the test mold can move freely.

E. Remove the testing mold from water bath, then remove the specimen and place it in the testing position with the upper part of the testing mold placed on the specimen.
F. Transfer the complete assembly and specimen to the platform of the Marshall testing machine. Place the flow meter on one of the guide rods and set to zero. Exercise extreme care to ensure that the movable inner rod of the flow meter makes contact with the guide rod when in the testing position.
G. Apply a load to the specimen by means of a constant rate of movement of the testing machine of 50.8 mm/min (2 in./min) until the maximum load is reached and the load decreases as indicated by the load dial.
H. During the application of the load, hold the flow meter firmly against the top of the upper part of the testing mold. When the maximum load is reached on the load dial, instantly remove the flow meter.
I. Record the maximum dial reading of the load dial on the appropriate form.
J. Record the maximum dial reading of the flow meter, using the proper units, on the appropriate form.
K. Determine and record the stability value from the load calibration chart for the testing machine.
L. Since excessive cooling of the specimen causes an increase in stability and a decrease in flow value, extreme rapidity of testing is necessary. The time that elapses between the removal of the specimen from the water bath and the failure of the specimen shall not be more than 30 seconds.

VII. Calculations

Stability values vary directly with the thickness of the specimen; therefore, make the necessary correction for the thickness. Flow values need no corrections. Correct the stability values as follows:

1. Compute the difference (C) in the weights of the briquette to the nearest 0.1 g using the following formula:

$$\text{Difference} = A - B$$

where:

A = wt. of briquette in air, g
B = wt. of briquette in water, g

example:

A = 1209.3
B = 704.0

$$\text{Difference} = 1209.3 - 704.0$$

$$\text{Difference} = 511.5\text{g}$$

Note 4: *The difference in the weights corresponds to the volume of the briquette.*

2. From the Stability Correction Table, record the thickness and the correction factor corresponding to the volume obtained above.

Note 5: *The volume – thickness relationship is based on a specimen diameter of 101.5 mm (4 in.).*

example:

thickness – 62 mm ($2\,^{7}/_{16}$ in.)
correction factor = 0.96

3. Divide the original stability value by the correction factor to determine the corrected stability value.

$$\text{Corr. Stability} = \frac{\text{Stability from Chart}}{\text{Correction Factor}}$$

example:

original stability = 1831 lbs.
correction factor = 0.96

$$\text{Corrected Stability} = \frac{1831}{0.96}$$

$$\text{Corrected Stability} = 1907\ \text{kN}$$

Note 6: *The measured stability of a specimen divided by the factor for the thickness of the specimen equals the corrected stability for a 64 mm (2 ½ in.) specimen.*

VIII. Report

A. Report the Corrected Stability to the nearest 0.01 kN (1 lb).

B. Report the Flow Value, representing each 1/100th of an inch (0.1 mm), to the whole number.

IX. Normal Test Reporting Time

Normal test reporting time (including preparation of specimens) is 6 hours.

STABILITY CORRECTION TABLE

Volume of Specimen in Cubic Centimeters	Approximate Thickness of Specimen Inches	mm	Correction Factor
457-470	2 ¼	58	0.84
471-482	2 5/16	59	0.88
483-495	2 ⅜	60	0.92
496-508	2 7/16	62	0.96
509-522	2 ½	64	1.00
523-535	2 9/16	65	1.04
536-546	2 5/8	67	1.08
547-559	2 11/16	68	1.12
560-573	2 ¾	70	1.16

TABLE OF EQUIVALENTS
(for Figures 1 and 4)

Metric Equivalents Customary	U.S. Customary Units, in.	Metric Equivalents mm	U.S. Customary Units, in.	Metric Equivalents mm	U.S. Customary Units, in.	Metric Equivalents mm	U.S. Customary Units, in.
0.13	0.005	17.5	11/16	58.7	2 5/16	104.8	4 ⅛
0.8	1/32	19.0	¾	63.5	2 ½	108.7	4 9/32
1.6	1/16	22.2	⅞	69.8	2 ¾	109.1	4 19/64
30	⅛	23.8	15/16	73.0	2 ⅞	114.3	4 ½
4.8	3/16	25.4	1	76.2	3	117.5	4 ⅝
6.4	¼	28.6	1 ⅛	82.6	3 ¼	120.6	4 ¾
7.1	9/32	31.8	1 ¼	87.3	3 7/16	128.6	5 1/16
9.5	⅜	34.9	1 ⅜	98.4	3 ⅞	130.2	5 ⅛
12.6	0.496	38.1	1 ½	101.2	3 63/64	146.0	5 ¾
12.67	0.499	41.3	1 ⅝	101.35	3.990	152.4	6
12.7	½	44.4	1 ¾	101.47	3.995	158.8	6 ¼
14.3	9/16	50.8	2	101.6	4	193.7	7 ⅝
15.9	⅝	57.2	2 ¼	101.73	4.005	685.8	27

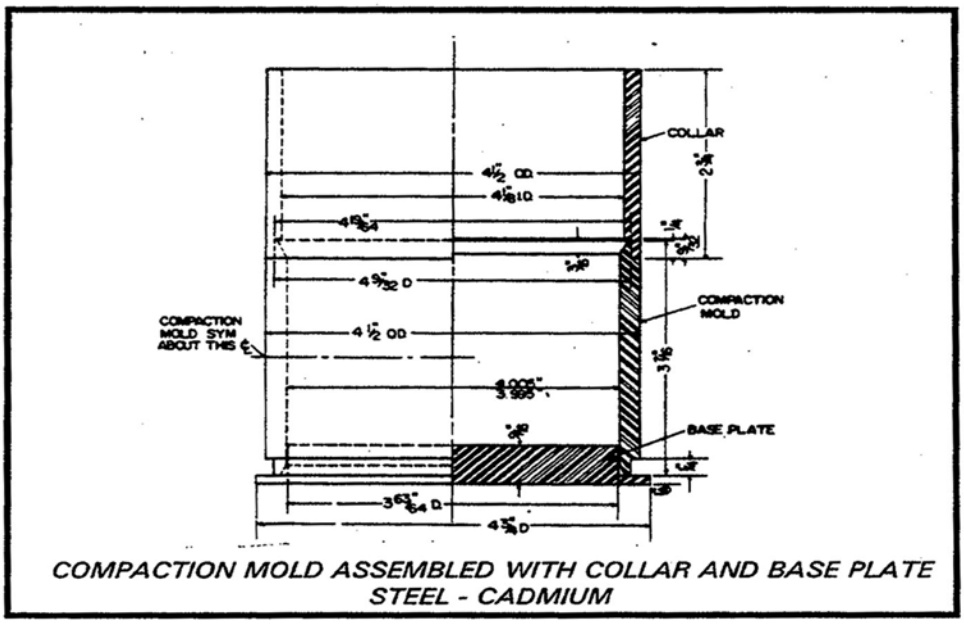

Figure 1
Compaction Mold

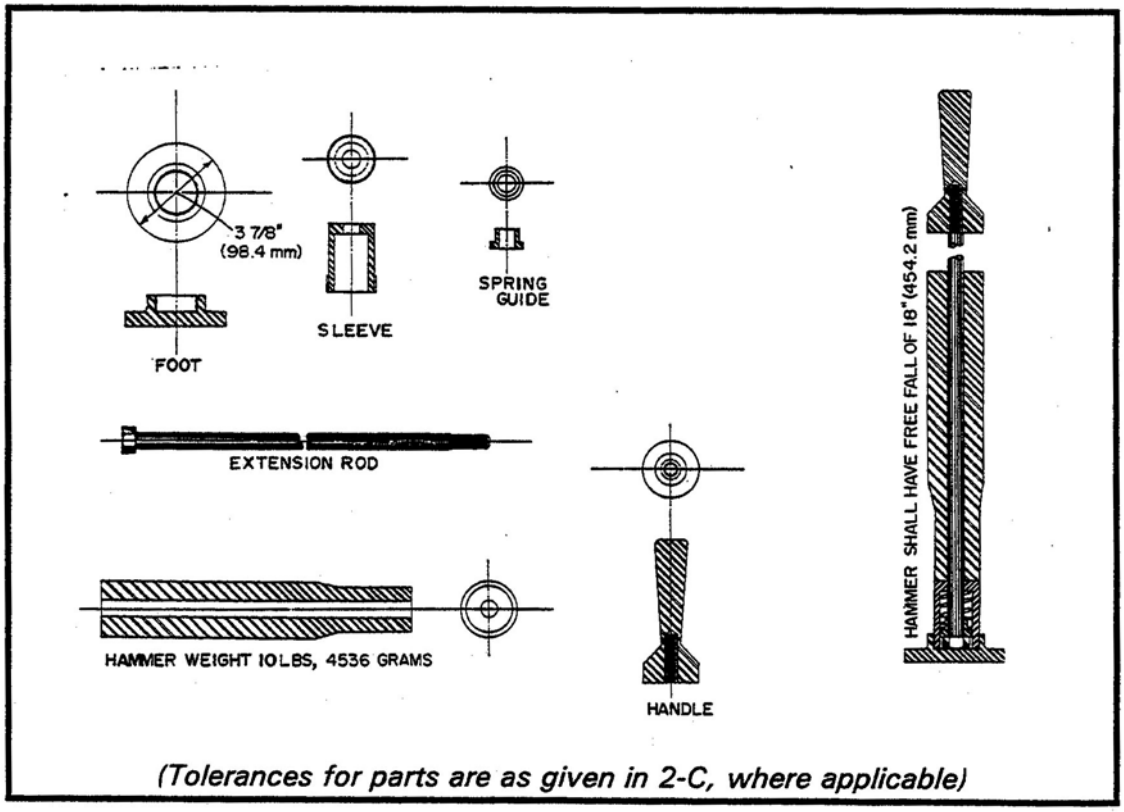

Figure 2
Compaction Hammer (Hand)

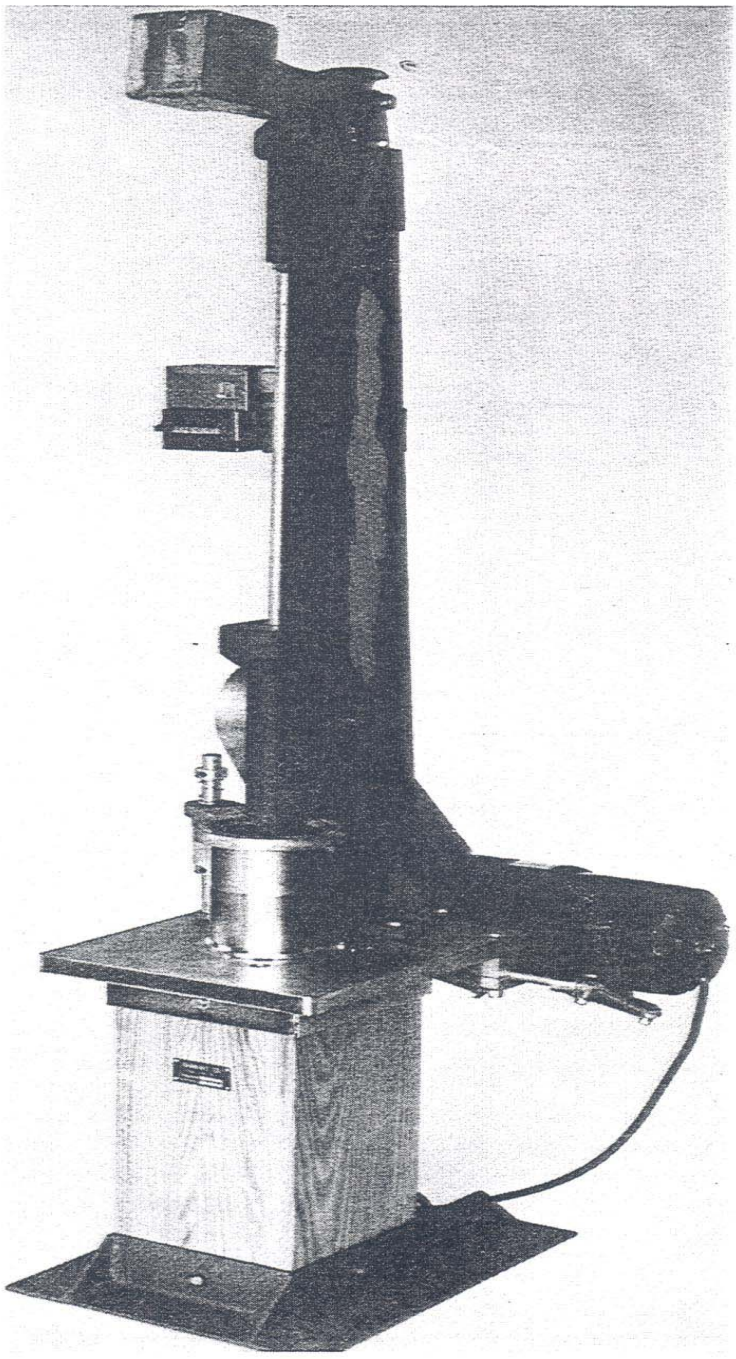

Figure 3
Automatic
Compaction Hammer

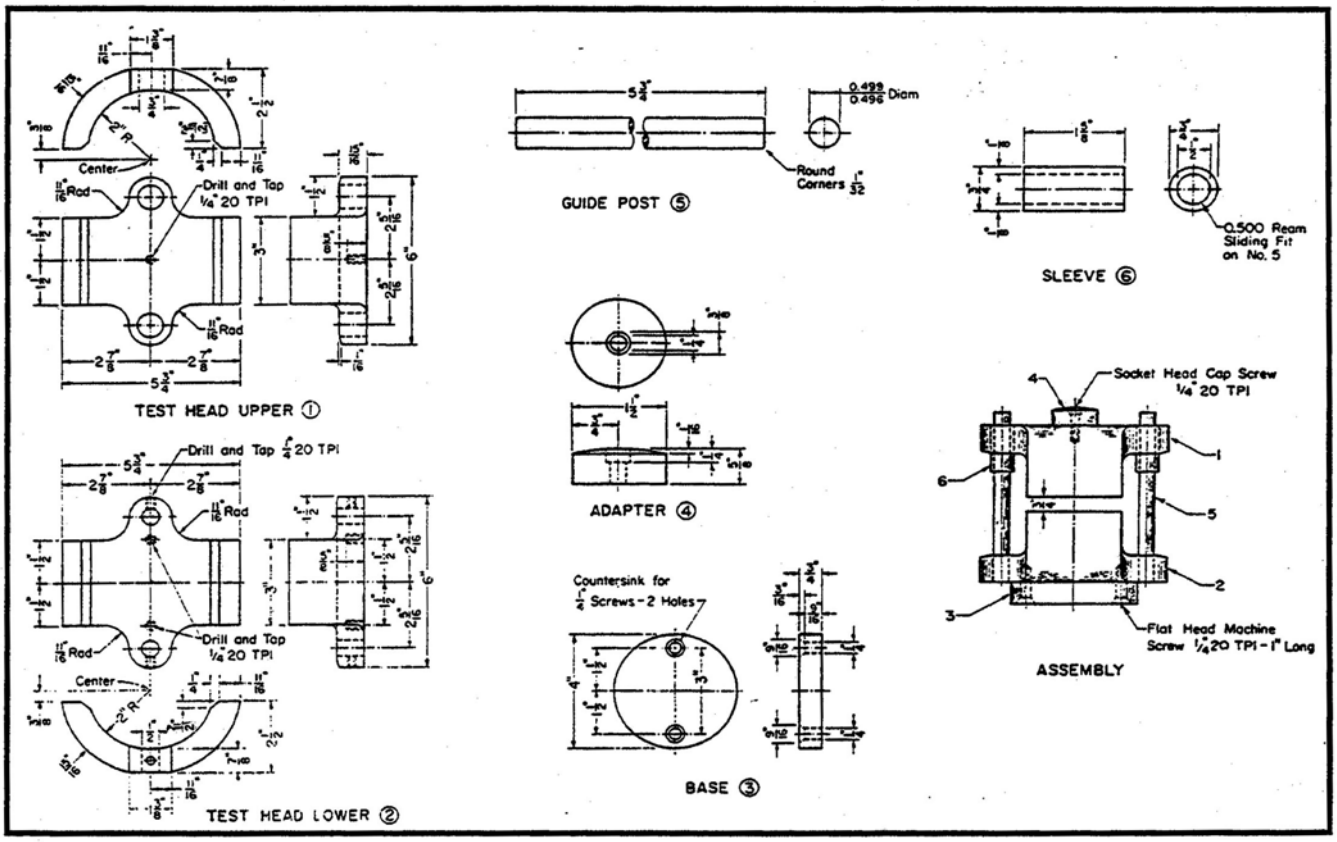

Figure 4
Breaking Head

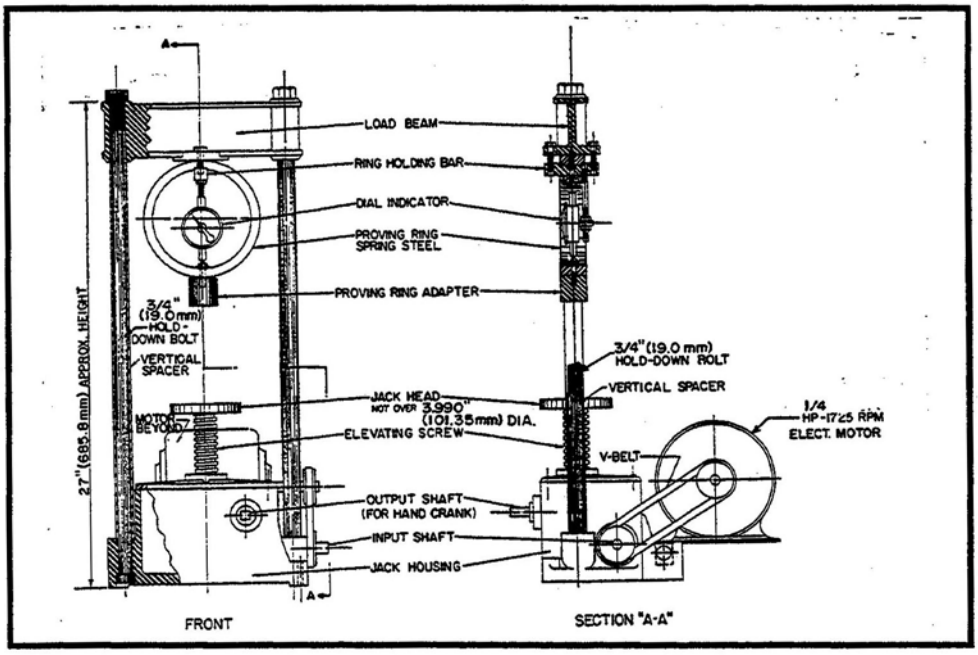

Figure 5
Compression Testing Machine

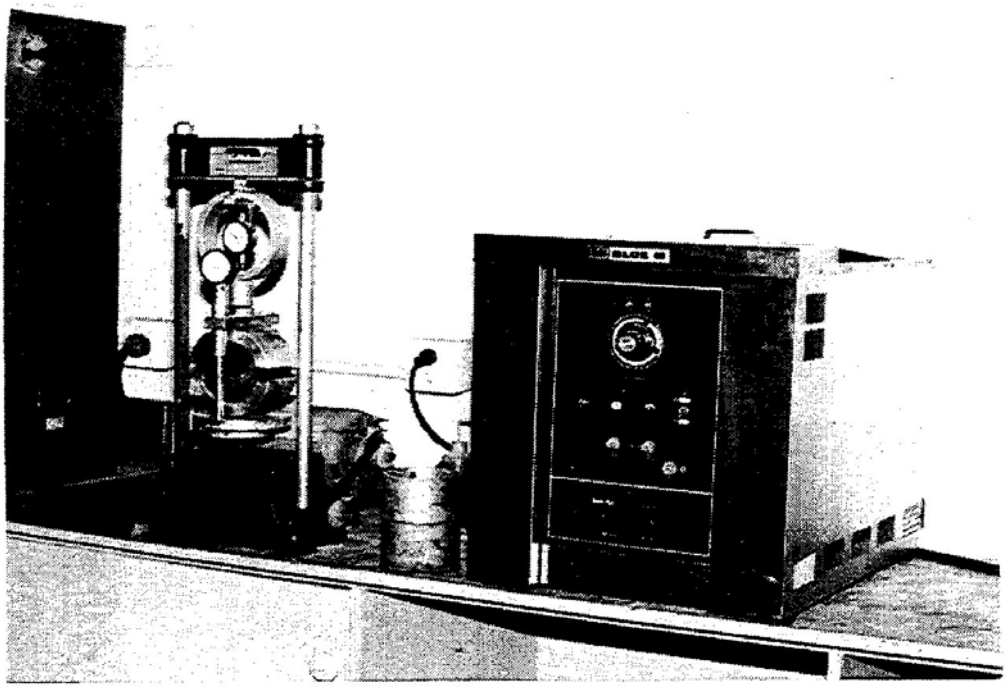

Figure 6
Hot Water Bath, Compression Testing Machine
And Flow Meter with Specimen in place ready to use

MATT MENU SELECTION -- 04

2000 Specifications

DOTD 03-22-3085
Rev. 06/02

ASPHALTIC CONCRETE PLANT REPORT - (2000 Specifications)

English/Metric E (M / E) Spec Year 2000 <Entry Fields located on MATT Menu

Proj.No. 178-02-0020 Plant H914 Mix Code 05

Proj.No. Seq. No. 043 Lot Number 424

Proj.No. Purp Code 3 No. Gradations

Proj.No. TSR, % Ten.Str.Control

Proj.No. Lot Size 2000 Act.Lot Tons (Mg)

Start Date Weather:

End Date Temp:High °F(°C) Low °F (°C)

PLANT TEST PROPERTIES (AASHTO T 166, T 209 & T 245 / DOTD TR's 304, 305 & 327)			1	2	3	4	AVERAGE
Wt (Mass) in Air	A		1209.3				
Wt (Mass) in Water	B		704.0				
Difference		A - B	505.3				
SSD Wt (Mass)	C		1210.2				
Bulk Sp Gr of Mix (G_{mb})	D	A / (C - B)	2.389				
Density	E	D x 62.4	149.1				
Theo Max Sp Gr (G_{mm})	F		2.490				
% Gmm	G	100 x D / F	95.9				
% Voids, V_a	H	100 - G	4.1				
% VMA	J	100 - (D x Ps) / Gsb	13.8				
% VFA	K	100 X (J - H) / J	70				
Dial Reading Marshall Test (AASHTO T245)			172				
Stability	From Chart		1831				
Thickness			2 7/16				
Correction Factor			0.96				
Corrected Stability			1907				
Flow 1/100			8				
Sample Taken Tons/Mg Accum.							
Temp of Mix °F			317°				

DISCHARGE TEMPERATURE JMF Limits:	TONS ACC.	ACT. TEMP.
1		
2		
3		
4		
5		

% MOISTURE CONTENT (AGGR)

% MOISTURE CONTENT (MIX)

	TEST 1	TEST 2
% AC Met/Sc		
% Anti-Strip		
% Lime		

PERCENT PAY

Stability

Gradation

Anti - Strip

ASPHALT CONTENT	AM Check			PM Check		
	Asphalt	Aggr	RAP	Asphalt	Aggr	RAP
2nd Meter Reading						
1st Meter Reading						
Difference						
Corr.lbs of AC/Aggr						
% AC						

ANTI STRIP CONTENT	AM Check		PM Check	
	Asphalt	Anti Strip	Asphalt	Anti Strip
2nd Meter Reading				
1st Meter Reading				
Gallons				
Corr. Gal. at 60 °F				
Pounds Used				
% Anti Strip				

THEORETICAL MAXIMUM SPECIFIC GRAVITY, Gmm "RICE" (AASHTO T 209 or DOTD TR 327)

		Gmm1		Gmm2	
		Sample a	Sample b	Sample a	Sample b
Wt of Mix	A				
Wt of Pyc. & Water	D				
Wt of Pyc. Water & Mix	E				
Difference	A + D - E				
Gmm	A/(A + D - E)	Gmm 1a	Gmm 1b	Gmm 2a	Gmm 2b

Gmm1 = (Gmm1a + Gmm1b) / 2 = Gmm2 = (Gmm2a + Gmm2b) / 2 =

Theo. Max. Sp. Gr Gmm = (Gmm1 + Gmm2) / 2 =

Ps (from JMF)

Gsb (from JMF)

$$Gse = \frac{100 - Pb}{\frac{100}{Gmm} - \frac{Pb}{Gb}} =$$

(Pb is % A.C., Gb = 1.03)

$$Pba = \frac{(100 \times Gb)(Gse - Gsb)}{Gsb \times Gse} =$$

$$Pbe = Pb - \frac{Pba \times Ps}{100} =$$

*** Note: Report Once per Lot ***

MATERIAL		SOURCE	COLD FEED, %	COLD FEED + RAP, %	MIX, %
Bin No. 1					
Bin No. 2					
Bin No. 3					
Bin No. 4					
Bin No. 5					
Bin No. 6					
RAP Aggr.					
RAP AC					
Asphalt	Grade				
			100 %		100 %

% AC BY EXTRACTION (DOTD TR 323)			TEST 1	TEST 2
Wt. (Mass) of Mix, Trays & Pan	M_T			
Wt. (Mass) of Trays & Pan	M_P			
Total Wt. (Mass) of Mix	M_S			
Correction Factor for Mix, %	CF			
Moisture Correction, % (TR 319)	MC	$M_T - M_P$		
Wt. (Mass) Loss, %	M_L			
AC Content, %	AC	(M_L - CF) or (M_L - CF - MC)		
Dry Total Wt. (Mass) of Aggr.	M			
Dry Wt. (Mass) After Wash, (TR 309)	X			
Decantation Loss	Y	M - X		
Accumulated Total	Z			
% Difference		(M - Z / M) (100)		
Sample Taken - Tons/Mg Accum				

Technician:

Inspector:

District Lab:

Approved By:

GRADATION OF EXTRACTED AGGREGATE (AASHTO T 30 or DOTD TR 309) - % CRUSHED (DOTD TR 306)

SIEVE	TEST NO. 1 WEIGHT (Mass)	%	% COARSER	% PASSING	DEV 1	TEST NO. 2 WEIGHT (Mass)	%	% COARSER	% PASSING	DEV 2
2 in. (50 mm)										
1 1/2 in. (37.5 mm)										
1 in. (25.0 mm)										
3/4 in. (19.0 mm)										
1/2 in. (12.5 mm)										
3/8 in. (9.5 mm)										
No. 4 (4.75 mm)										
No. 8 (2.36 mm)										
No. 16 (1.18 mm)										
No. 30 (600 µm)										
No. 50 (300 µm)										
No. 100 (150 µm)										
No. 200 (75 µm)				•					•	

Passing 200 (75 µm)		WT CRUSHED		WT CRUSHED
Decant. Loss	Y	WT + 4 (4.75 mm)		WT + 4 (4.75 mm)
Accum. Total	Z	% CRUSHED		% CRUSHED

AVERAGES			
Sieves	Average	Avg. Dev.	JMF Limits
2 in. (50 mm)			
1 1/2 in. (37.5 mm)			
1 in. (25.0 mm)			
3/4 in. (19.0 mm)			
1/2 in. (12.5 mm)			
3/8 in. (9.5 mm)			
No. 4 (4.75 mm)			
No. 8 (2.36 mm)			
No. 16 (1.18 mm)			
No. 30 (600 µm)			
No. 50 (300 µm)			
No. 100 (150 µm)			
No. 200 (75 µm)			
% AC			
% AC(Met/Sc)		% AC- JMF	
% Crushed		Min.	

Figure 7
Asphaltic Concrete Plant Report