12.MARSHALL STABILITY TEST.
(ASTM – D – 1559 & MS-2)

INTRODUCTION:

Bruce Marshall, a former Bituminous Engineer with the Mississippi State Highway Department, formulated the concepts of the Marshall method of designing paving mixtures. The U.S.Army Crops of Engineers, through extensive research and correlation studies, improved and added certain features to Marshall's test procedure, and ultimately developed mix design criteria.

The original Marshall method is applicable only to hot-mix asphalt paving mixtures containing aggregates with maximum sizes of 25mm or less.

This method covers the measurement of the resistance to plastic flow of cylindrical specimens of bituminous paving mixture loaded on the lateral surface by means of the Marshall apparatus.

Object:

To determine the stability, flow, voids, voids in mineral aggregates, voids filled with asphalt and density of the asphalt mixture by Marshall stability test.

Apparatus:

a) Specimen Mould Assembly – Mould cylinders 101.6mm(4 in.) in diameter by 75mm(3 in.) in height, base plates, and extension collars.

b) Specimen Extractor – Steel disk with a diameter 100mm, and 12.7mm thick for extracting the compacting specimen from the specimen mould with the use of the mould collar. A suitable bar is required to transfer the load from the proving ring adapter to the extension collar while extracting the specimen.

c) Compaction Hammer – The compaction hammer shall have a flat, circular tamping face and a 4.5kg(10 lb) sliding weight with a free fall of 457mm (18 in.). Two compaction hammers are recommended.

d) Compaction Pedestal – The compaction pedestal shall consist of 200X200X460mm(8X8X18 in.) wooden post capped with a 305X305X25mm(12X12X1 in.) steel plate. The pedestal should be installed on concrete slab so that the post is plumb and the cap is level. Mould holder provided consisting of spring tension device designed to hold compaction mould centered in place on compaction pedestal.

e) Breaking Head – It consists of upper and lower cylindrical segments or test heads having an inside radius of curvature of 50 mm. The lower segment is mounted on a base having two vertical guide rods, which facilitate insertion in the holes of upper test head.

Bitumen Extractor.

Marshall Stability Appratus

f) Loading Machine – The loading machine is provided with a gear system to lift the base in upward direction./ on the upper end of the machine, a calibrated proving ring of 5 tonne capacity is fixed. In between the base and the proving ring, the specimen contained in test head is placed. The loading machine produces a movement at the rate of 50mm per minute. Machine is capable of reversing its movement downward also.

g) Flow meter – One dial gauge fixed to the guide rods of a testing machine can serve the purpose. Least count of 0.25mm(0.01 in.) is adequate.

h) Oven or hot plates

i) Mixing apparatus.

j) Thermostatically control water bath.

k) Thermometers of range 0 – 360^{0}C with 1^{0}C sensitivity.

Procedure:

In the Marshall method each compacted test specimen is subjected to the following tests and analysis in the order listed below:

i) Bulk density determination

ii) Stability and flow test

iii) Density and voids analysis

At least three samples are prepared for each binder content.

Preparation of test specimens:

The coarse aggregates, fine aggregates and the filler material should be proportioned and mixed in such a way that final mix after blending has the gradation with in the specified range.

The aggregates and filler are mixed together in the desired proportion as per the design requirements and fulfilling the specified gradation. The required quantity of the mix is taken so as to produce a compacted bituminous mix specimen of thickness 63.5mm, approximately.

Preparation of Mixtures: Weigh into separate pans for each test specimen the amount of each size fraction required to produce a batch that will result in a compacted specimen 63.5 +/- 1.27mm(2.5 +/-0.05 in.) in height. This will normally be about 1200gm(2.7 lb.). It is generally to prepare a trial specimen prior to preparing the aggregate batches. If the trial specimen height falls outside the limits, the amount of aggregate used for the specimen may be adjusted using:

$$\text{Adjusted mass of aggregate} = \frac{63.5\ (\text{mass of aggregate used})}{\text{Specimen height (mm) obtained}}$$

Take the sample as mentioned above, and heated to a temperature of 175^0 to 190^0C. The compaction mould assembly and hammer are cleaned and kept pre-heated to a temperature of 100^0C to 145^0C. The bitumen is heated to temperature of 121^0 to 138^0C and the required quantity of first trial percentage of bitumen (say, 3.5% by weight of mineral aggregates) is added to the heated aggregate and thoroughly mixed using a mechanical mixer or by hand mixing with trowel. The mixing temperature may be 153^0 to 160^0C. The mix is placed in a mould and compacted by hammer, with 75 blows on either side (for light compaction it is 50 blows). The compaction temperature may be 138^0 to 149^0C. The compacted specimen should have a thickness of 63.5 +/- 3.0mm. Three specimens should be prepared at each trial bitumen content, which may be varied at 0.5 percent increments up to about 7.5 or 8.0 percent.

Marshall Stability and Flow values: The specimens to be tested are kept immersed under water in a thermostatically controlled water bath maintained at 60^0 +/- 1^0C for 30 to 40 minutes. The specimen are taken out one by one, placed in the Marshall test head and the Marshall Stability value (maximum load carried in kg. before failure) and the flow value (the deformation the specimen undergoes during loading up to the maximum load in 0.25mm units) are noted. The corrected Marshall stability value of each specimen is determined by applying the appropriate correction factor.

The following tests are determined first, to find out the density, voids, VMA and VFB.

Tests:

The specific gravity and apparent specific gravity values of the different aggregates, filler and bitumen used are determined first.

i) Bulk specific gravity of aggregate 'Gsb' is given by:

$$Gsb = \frac{P1 + P2 + \ldots\ldots + Pn}{P1/G1 + P2/G2 + \ldots\ldots + Pn/Gn}$$

Where, Gsb = Bulk specific gravity for the total aggregate.
P1, P2, Pn = Individual percentages by weight of aggregate.
G1, G2, Gn = Individual bulk specific gravities of aggregate.

ii) Effective specific gravity of aggregate 'Gse' is given by:

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

Where, Gse = Effective specific gravity of aggregate, constant for all at 5% bitumen content.
Gmm = Maximum specific gravity of paving mixture (no air voids), determine by Vacuum pump test (ASTM – D – 2041).
Pb = Bitumen content, percent by total weight of mixture.
Gb = Specific gravity of Bitumen.

iii) Maximum specific gravity of mixture 'Gmm' is given by:

$$Gmm = \frac{100}{Ps/Gse + Pb/Gb}$$

Where, Gmm = Maximum specific gravity of paving mixture (no air voids)
Ps = Aggregate content, percent by total weight of mixture
Pb = Bitumen content, percent by total weight of mixture
Gse = Effective specific gravity of aggregate
Gb = Specific gravity of bitumen

iv) Bitumen absorption 'Pba' is given by:

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

Where, Pba = Absorbed bitumen, percent by weight of aggregate
Gse = Effective specific gravity of aggregate
Gsb = Bulk specific gravity of aggregate
Gb = Specific gravity of bitumen

v) Effective bitumen content of a paving mixture 'Pbe' is given by:

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

vi) Voids in mineral aggregate in compacted paving mixture 'VMA' is given by:

$$VMA = 100 - \frac{Gmb\ Ps}{Gsb}$$

Where, VMA = Voids in mineral aggregate, percent of bulk volume
Gsb = Bulk specific gravity of total aggregate
Gmb = Bulk specific gravity of compacted mixture
Ps = Aggregate content, percent by total weight of mixture

vii) Air voids in compacted mixture 'Va' is given by:

$$Va = 100 \text{ X} \frac{Gmm - Gmb}{Gmm}$$

Where, Va = Air voids in compacted mixture, percent of total volume
Gmm = Maximum specific gravity of paving mixture
Gmb = Bulk specific gravity of compacted mixture

viii) Voids filled with bitumen in compacted mixture 'VFB' is given by:

$$VFB = \frac{100(VMA - Va)}{VMA}$$

Where, VFB = Voids filled with bitumen, percent of VMA
VMA = Voids in mineral aggregate, percent of bulk volume
Va = Air voids in compacted mixture, percent of total volume

Determination of Optimum Bitumen Content:

Six graphs are plotted with values of bitumen content against the values of:

a) Density 'Gmb' g/cc.
b) Marshall Stability, S kg.
c) Voids in total mix, Va %.
d) Flow value, F (0.25mm units).
e) Voids filled with bitumen, VFB %.
f) Voids in mineral aggregate, VMA %.

Let the bitumen contents corresponding to maximum density be B1, corresponding to maximum stability be B2 and that corresponding to the specified voids content Va (4.0% in the case of dense AC mix) be B3. Then the Optimum Bitumen Content is given by:

$$\text{Optimum Bitumen Content (OBC)} = (B1 + B2 + B3)/3$$

The values of flow and VFB are found from the graphs, corresponding to bitume content OBC. All the design values of Marshall stability, flow, voids and VFB ar checked at the Optimum Bitumen Content, with the specified design requirements of th mix.

Design Requirements of the mix:

i) Marshall Stability value, kg	=	820 kg.(min.)
ii) Flow value, 0.25mm units	=	8 – 16
iii) Voids in total mix, Va %	=	3 – 5 %
iv) Voids in mineral agg.(VMA), %	=	10 – 12 %(min.)
v) Voids filled with bitumen(VFB) %	=	65 – 75 %

The highest possible Marshall stability values in the mix should be aimed at consisten with the other four requirements mentioned above. In case the mix designed does no fulfill any one or more of the design requirements, the gradation of the aggregates o filler content or bitumen content or combination of these are altered and the design test are repeated till all the requirements are simultaneously fulfilled.

Job Mix Formula:

The proportions in which the different aggregates, filler and bitumen are to be mixed are specified by weight or by volume for implementation during construction.

Caution: Mixes with high Marshall stability values and very low Flow values are not desirable as the pavements of such mixes may be brittle and are likely to crack unde heavy traffic.

Correction Factors

Volume of Specimen in cc	Approximate Thickness of Specimen in mm	Correction Factors
457 - 470	57.1	1.19
471 - 482	58.7	1.14
483 - 495	60.3	1.09
496 - 508	61.9	1.04
509 - 522	63.5	1.00
523 - 535	65.1	0.96
536 - 546	66.7	0.93
547 - 559	68.3	0.89
560 - 573	69.9	0.86

Swell test:

Apparatus:

a) Moulds with internal diameter 101.6mm(4 in.) and length 127mm(5 in.)

b) Perforated, 98.4mm diameter x 3.2mm thick with adjustable stem, for swell measurement.

c) Dial gauge, mounted on tripod, with reading accuracy to 0.025mm.

d) Aluminum pans, 190mm diameter x 64mm deep.

Procedure:

Allow compacted swell test specimen to stand at room temperature for at least one hour. Place the mould and specimen in 190mm diameter x 64mm deep aluminum pan. Place the perforated disk on specimen, position the tripod with dial gauge on mould, and set the adjustable stem to give a reading of 2.54mm on the dial gauge. Introduce 500ml of water into the mould on top of the specimen and the measure distance from the top of the mould to the water surface with the graduated scale. After 24 hours, read the dial gauge to the nearest 0.025mm and record the change as swell. Also, measure the distance from the top of the mould to the water surface with the graduated scale and record the change as permeability or the amount of water in ml that percolates into and/or through the test specimen.

Note:

i) Water Sensitivity: The loss of stability on immersion in water at 60^0C. The allowable limit is minimum 75% retained strength.

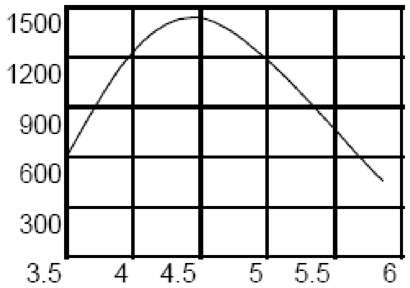
ii) Marshall Quotient (Stiffness): is the ratio of stability and flow.

Allowable limit for base course = 350

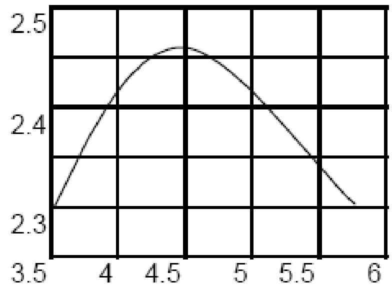
for wearing surfaces = 400.

Marshall Curves:

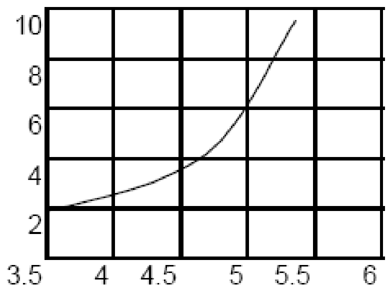
Bitumen(%) 'vs' Stability(kg)



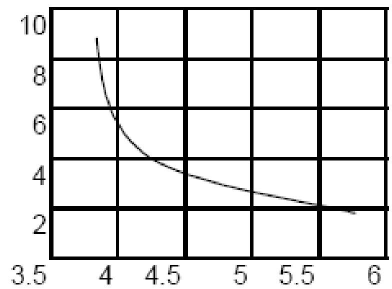
Bitumen(%) 'vs' Density (g/cc)



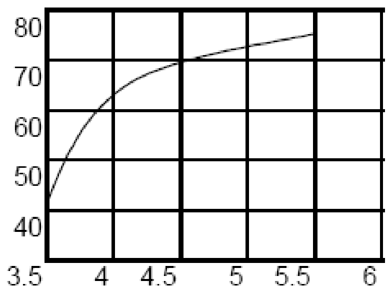
Bitumen(%) 'vs' Flow(mm)



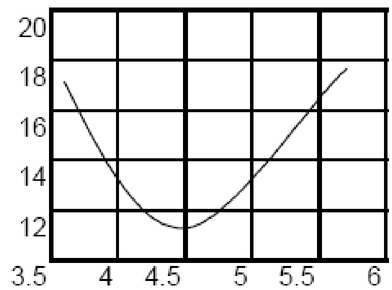
Bitumen (%) 'vs' Voids(%)



Bitumen(%) 'vs' VFB(%)



Bitumen(%) 'vs' VMA(%)



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FORM D27

Punjab State Road Sector Project
PWD B&R Branch, Govt. of Punjab
Punjab Roads & Bridges Development Board

MARSHALL TEST

LOCATION: ______________________ DATE TESTED: ____________________
DATE SAMPLED: ______________________ TESTED BY: ____________________

DENSITY DETERMINATION	JMF density:					
SAMPLE NO.	1	2	3	4	5	6
1. Wt. in Air, g						
2. Wt.in air SSD, g						
3. Wt. in Water, g						
4. Volume, cc						
5. Density, g/cc						
6. Air Voids in Mix, %						
7. VMA, %						
8. Stability						
10. Flow, mm						

Remarks: ____

Approved /Not Approved:

Contractor's Representative

Materials Engineer Consultant

Resident Engineer Consultant