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Effect of Compaction Temperature on Optimum Binder Content of Bituminous Concrete

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Abstract: ***A laboratory experiment was conducted out to study the effect of compaction temperature on optimum binder content of Bituminous Concrete mix. Bituminous Concrete mix samples were prepared by Marshall Stability mix design. The experimental sample design included 1200g aggregates and stone dust with gradation of 25% of 20mm aggregates, 25% of 10mm aggregates and 50% of stone dust. The mixing temperature was kept at 160°C. Samples were compacted at different temperature as 80°C, 100°C, 120°C, 140°C & 160°C. The optimum binder content was calculated on the basis of 4% air voids, maximum bulk density and maximum stability.***

Based on this study, we found that on increasing the compaction temperature the Optimum Binder Content decreases. This is because on increasing the compaction temperature the viscosity of bitumen increases which results in increase of the workability of the mix. Due to the increased viscosity of bitumen, it lubricates the aggregates very well which provide less resistance to the compaction.

Keyword: Hot Mix Asphalt, Optimum Binder Content, Marshall Stability, Compaction Temperature.

I. INTRODUCTION

Roads are the dominant mode of transportation in India today. They carry almost 90 percent of the country's passenger traffic. India has a road network of over 56,03,293 km as on 31st March 2016, the second largest road network in the world. The length of national highways in India has increased from 70,934 km in 2010-11 to 1,01,011 in 2015-16.The density of India's highway network - at 0.66 km of highway per square kilometre of land – is similar to that of the United States (0.65) and much greater than China's (0.16) or Brazil's (0.20). Urban roads are the lifeline of the city and rural roads are the life line of the villagers as road connects them to the main city for the ease of their business.

Temperature is a key factor influencing percentage of bitumen in the mix, which affects its ability to coat and provide adequate coating for the aggregates in HMA paving mixes.

Saedi Houman [1] investigated the effect of compaction temperature from 85˚C to 160˚C on Marshall Properties of HMA and concluded that best temperature for laboratory compaction is 145˚C. It was also stated that Marshall Properties change drastically over 145˚C and below 115˚C. Ahmed Hassan Youness [2] conducted Marshall Stability test at different compaction temperature ranging from 70˚C to 140˚C, with an interval of 10˚C on bituminous mixture and suggested that from temperature range of 140°C to 110°C, there is variation up to 10% in the properties of HMA. At the same time below 110°C, mixture properties changes drastically.

The objectives of the present study are as follows:

1) To determine the job mix formula for bituminous concrete grade 1 using Marshall Stability test.
2) To determine the effect of laboratory compaction temperature on Optimum Binder content (OBC). This will lead to better control during laboratory compaction process.

II. METHODOLOGY AND EXPERIMENTAL WORK

A. Methodology

For the fulfilment of the demands of the above objectives we collected stone aggregates of size 20 mm, 10 mm & stone dust from a local crusher near Jagatpura and acquired VG-30 grade bitumen from local vendor.

Then the physical properties of aggregates and bitumen were determined by Indian Standards codes tests and the test values were compared from MoRTH (Ministry of Road Transportation and Highway) specifications. Sieve analysis of aggregates and stone dust was carried out. Proportioning of aggregates was done for Bituminous Concrete (BC), Grading I as prescribed in MoRTH. To determine the job mix formula and OBC (Optimum Binder Content) for Bituminous Concrete grade 1 Marshall Stability Test was carried out as per ASTM D6927-06 [3].

Further five Marshall specimens were prepared at different compaction temperatures of 80°C, 100°C, 120°C, 140°C & 160°C. Marshall Stability test was carried out for all the five specimens so as to obtain the results for our second objective. The variation in properties at different compaction temperatures were analysed and further conclusions were drawn.

B. Experimental Work

1) General: Stone aggregate of size 20mm, 10mm and stone dust used in this study were locally procured. Bitumen of VG-30 grade was collected from a local vendor. The physical properties of aggregates and bitumen are shown in Table I and 2.

TABLE I
TEST RESULTS OF AGGREGATES

Properties	Test Method	Obtained Values	IS Specifications
Grain Size Analysis	IS 2386 Part 1 [4]	3	Maximum 5% passing 0.075mm
Flakiness and Elongation Index	IS 2386 Part 1 [4]	32.87	Maximum 35% Combined
Impact Value	IS 2386 Part 4 [5]	22.17	Maximum 24%
Abrasion Value	IS 2386 Part 4 [5]	27.7	Maximum 30%
Water Absorption	IS 2386 Part 3 [6]	0.51	Maximum 2%
Specific Gravity	IS 2386 Part 3 [6]	2.61 (20mm)	2.5-3
		2.61 (10mm)	
		2.52 (Stone Dust)	

TABLE 2
TEST RESULTS OF BITUMEN

Test	Test Method	Test Results	Specifications as per IS 73 (2007) [11]
Ductility	IS – 1208 [7]	100cm	Minimum 40cm
Specific Gravity	IS – 1202 [8]	1.01	Minimum 0.99
Softening Point	IS – 1205 [9]	52.4˚C	>47˚C
Viscosity	IS – 1206 [10]	385cST	Minimum 350cST

2) Gradation Considered for Bituminous Mix: For Bituminous Concrete, Gradation 1 was selected. The required grading for these mixes according to MoRTH is given in Table 3. The graphical representation is shown in Figure 1.

TABLE 3
COMPOSITION OF BITUMINOUS CONCRETE LAYER, GRADING 1 (MORTH-2013)

Sieve Size (mm)	20mm (25%)	10mm (25%)	Stone Dust (50%)	Achieved Gradation	Desired Gradation
26.5	25	25	50	100	100
19	23	21	50	94	90-100
13.2	6	15	50	71	59-79
9.5	1	6	50	57	52-72
4.75	0	0	40	40	35-55
2.36	0	0	32	32	28-44
1.18	0	0	25	25	20-34
0.600	0	0	18	18	15-27
0.3	0	0	10	10	10-20
0.15	0	0	8	8	5-13
0.075	0.00	0.00	3	3	2-8

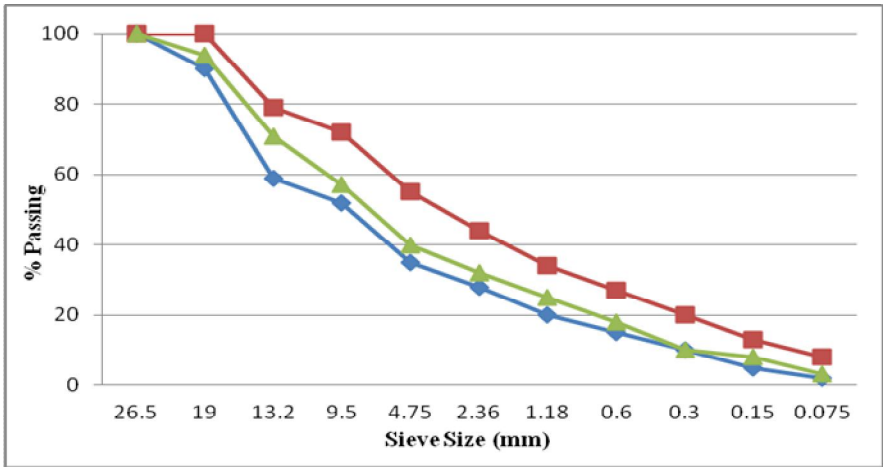

FIG. 1 GRADATION OF AGGREGATES

III. ANALYSIS OF RESULTS

The Marshall Test Results of Bituminous Concrete at 160°C mixing temperature for different compaction temperatures (80°C, 100°C, 120°C, 140°C and 160°C) are presented in tabular form. The bitumen content corresponding to maximum stability, maximum bulk density and 4% air voids was obtained and average of three bitumen content was taken as OBC.

A. Experimental Work to show effect of compaction temperature on Optimum Binder Content

Marshall Stability Test Results

1) *OBC at 80°C Compaction Temperature:* Optimum Binder Content was determined at 80°C compaction temperature. The average of 3 major properties of Marshall Specimen was taken into consideration. The results of OBC are shown in Table – 4.

TABLE 4
CALCULATION OF OBC AT 80°C COMPACTION TEMPERATURE

Maximum Bulk Density	6%
Maximum Stability	5.5%
Bitumen Content corresponding to 4% Air Voids	5.75%
Average Bitumen Content	5.75%
Bitumen Content corresponding to total mix	5.43%

2) *OBC at 100°C Compaction Temperature:* Compaction Temperature was increased to 100°C and Marshall Stability test results were determined. It was observed that there is slight change of 1.3% in OBC on increasing compaction temperature to 100°C. The Marshall Stability test results are shown in Table - 5.

TABLE 5
CALCULATION OF OBC AT 100°C COMPACTION TEMPERATURE

Maximum Bulk Density	6%
Maximum Stability	5.5%
Bitumen Content corresponding to 4% Air Voids	5.67%
Average Bitumen Content	5.72%
Bitumen Content corresponding to total mix	5.36%

3) *OBC at 120°C Compaction Temperature:* At 120°C compaction temperature, OBC again decreases down to 1.12%. The calculation of OBC is shown in Table – 6.

TABLE 6
CALCULATION OF OBC AT 120°C COMPACTION TEMPERATURE

Maximum Bulk Density	6%
Maximum Stability	5.5%
Bitumen Content corresponding to 4% Air Voids	5.33%
Average Bitumen Content	5.61%
Bitumen Content corresponding to total mix	5.3%

4) *OBC at 140°C Compaction Temperature:* The viscosity kept on reducing on increasing the compaction temperature. At 140°C compaction temperature, following results were obtained:

TABLE 7
CALCULATION OF OBC AT 140°C COMPACTION TEMPERATURE

Maximum Bulk Density	6%
Maximum Stability	5.5%
Bitumen Content corresponding to 4% Air Voids	5.25%
Average Bitumen Content	5.58%
Bitumen Content corresponding to total mix	5.28%

5) *OBC at 160°C Compaction Temperature:* On further increasing compaction temperature to 160°C, OBC kept on reducing. The results of OBC is shown in Table – 7.

TABLE 7
CALCULATION OF OBC AT 160°C COMPACTION TEMPERATURE

Maximum Bulk Density	6%
Maximum Stability	5.5%
Bitumen Content corresponding to 4% Air Voids	5.125%
Average Bitumen Content	5.54%
Bitumen Content corresponding to total mix	5.2%

IV. CONCLUSION

On the basis of above study, we have concluded that on increasing the compaction temperature the OBC decreases. The variation of OBC at different compaction Temperature is shown in Figure – 2.

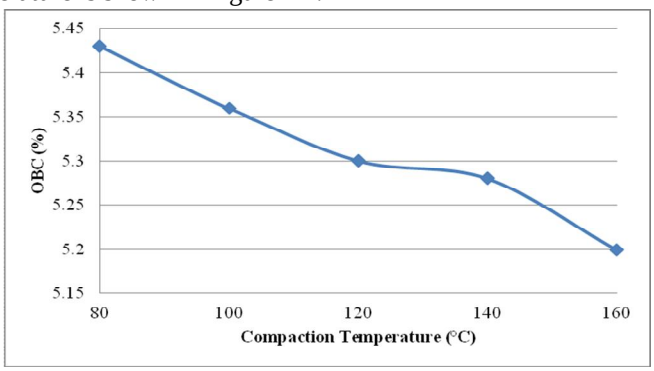

FIG. 1 GRAPH OBC VS COMPACTION TEMPERATURE

This is because on increasing the compaction temperature the viscosity of bitumen increases which results in increase of the workability of the mix. Due to the increased viscosity of bitumen, it lubricates the aggregates very well which provide less resistance to the compaction.

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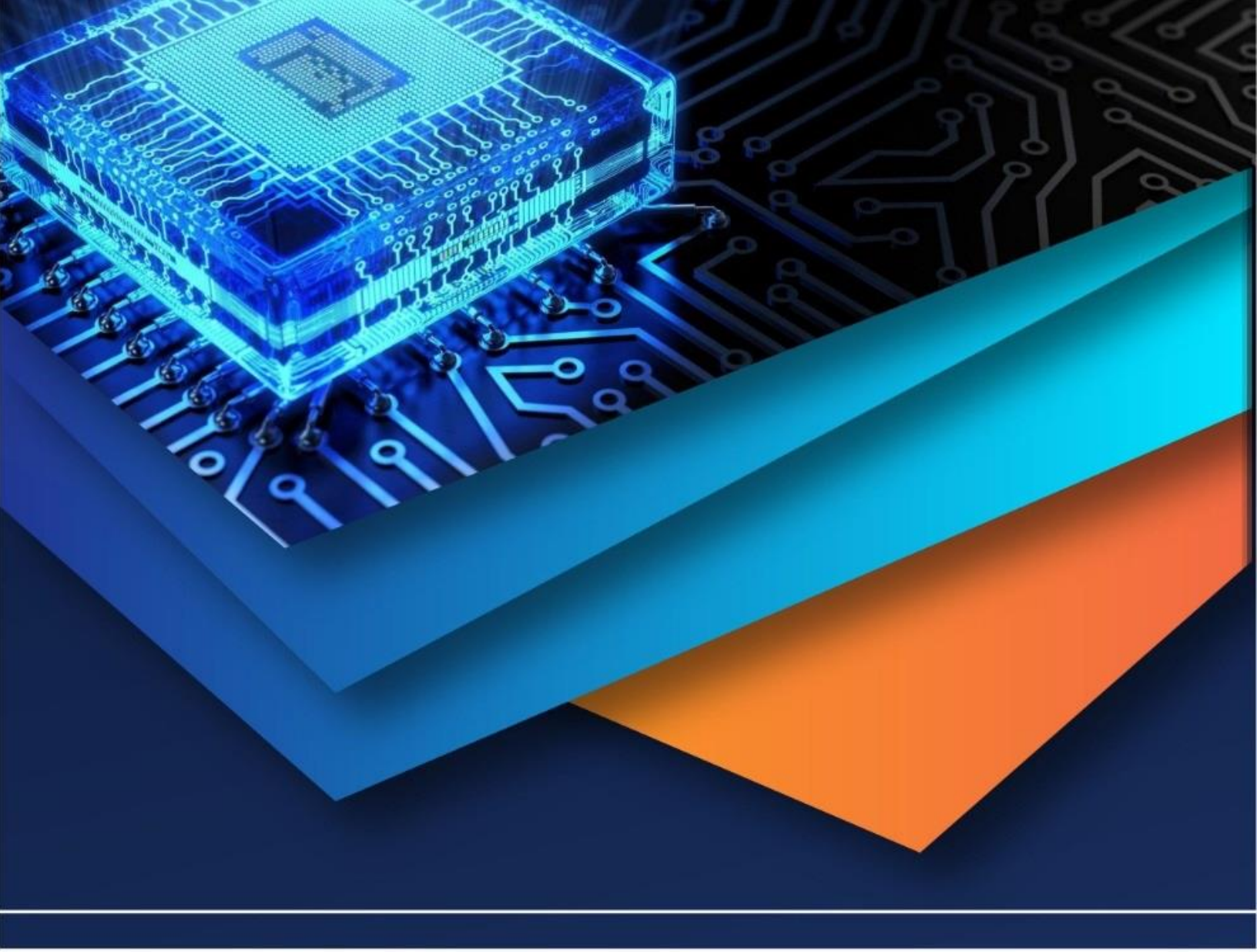

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