Comparative Stability Analysis of Harder Grade Bitumen (VG-30 & VG-40) By Marshall Mix Design Method on DBM-I

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***Abstract*— Generally in India, the important highways are made up by Dense Bituminous Macadam (DBM) or Bitumen Concrete (BC). Bitumen mix design can be done by Marshall Mix Design Method; is a balancing method to adjust the proportions of various aggregate sizes and bitumen content. The present research focused on the use of harder grade bitumen VG-30 and VG-40 for better performance under heavy traffic load conditions. Marshall Mix Design Method for dense bituminous macadam (DBM-I) was adopted to find the optimum binder content.**

It was observed that the trend of stability value was increased with increasing bitumen content up to a maximum after which the stability decreases. Stability values were achieved highest for VG-40 grade bitumen than VG-30 grade bitumen at 4.50% of bitumen content. Further, as the OBC was 4.25% for VG-30 and VG-40 respectively, the Marshall Stability for VG-40 grade was also high as compared to VG-30 grade bitumen. It indicated that as the air voids percentage were 4.020% for VG-30 and 4.507% for VG-40 grade respectively.

***Index Terms*— Viscosity Grade (VG), Marshal Mix Design, Optimum Binder Content (OBC), Dense Bitumen Macadam (DBM).**

1. INTRODUCTION

In India rapid growth of urbanization is fueled by development of industrial and service sector which resulted in rapid growth of road vehicles in limited road space, to withstand the high stress with minimum maintenance [1]. India is the second fastest growing automobile in the world [2]. Most of the Indian highways are covered by bitumen called flexible pavement having less initial investment and maintenance [3]. The important highways in India are built by dense bituminous macadam (DBM) or bituminous concrete (BC).

The DBM is a base course layer of flexible pavement used in road construction under heavy traffic load conditions [4]. Dense Bituminous Macadam (DBM) is a binder course used for roads under heavy traffic load. At the present time, the dense bituminous macadam (DBM) is specified for use as a base course and binder course. Two gradation of the DBM are used. Grading I has a nominal maximum aggregate size (NMAS) of 37.5 mm and grading 2 has a NMAS of 25 mm. In the previous research studies, Patel M., Patel V., Patel D.K., Mishra C.B. (2014) [1] Used viscosity grade 30 paving mix with innovative warm mix additive in suitable doses and tested to determine key properties on Marshall Mix Design as per the provision of code practice. The test a result of VG 30 concrete mix with 5.5% optimum bitumen content was taken into consideration for mix design and it was found that it was seen that doses of 2% by weight of asphalt was also acceptable for road construction. Sarang G. (2014) [5] the research was carried out on Viscosity Graded (VG 30) bitumen and a chemical named Zycosoil was used as a stabilizing additive. Tomar R., Jain R.K. and Kostha MK (2013) [6] used bitumen 60/70 for Marshall Mix Design. It was observed that the blend of aggregates and bitumen. Bituminous mixes containing brick dust and silica fume as fillers were having Marshall Properties almost nearly same as those of conventional fillers such as cement and lime. Sangita et al. (2011) [7] studied the effect of waste polymer modifier (nitrile rubber and polythene). Various test results on 60/70 bitumen and aggregate satisfied the specified limits. It was observed that Marshall Stability and retained stability tests confirmed the optimum WPM content to be 8% the Waste Modified Polymer Binder (WPMB) mix containing 8% Waste Polymer Modifier (WPM) showed significant improvements in various properties of the bituminous concrete mixture. Shobhan and Zakaria (2001) [8] Used Crumb rubber modified bitumen, blended at specified temperatures. Marshall mix design was carried out by changing the modified bitumen content at constant optimum rubber content and subsequent tests have been performed to determine the different mix design characteristics and for conventional bitumen (60/70) also. This had resulted in much improved characteristics when compared with straight run bitumen and that too at reduced optimum modified binder content (5.67%). Sumit G. Dhundalwar, et al, (2017) [9] Compared the properties of the modified bitumen with ordinary bitumen. It was observed that the penetration and ductility values of the modified bitumen decreased with the increase in proportion of the plastic additive, up to 12% by weight.

The performance of bituminous pavement depends on the pavement design factors and the prevailing or actual factors including traffic load, climatic and drainage factors respectively. The pavement performance and life depends on the adequate sub-grade support properties of materials used and thickness of various pavement layers regarding traffic and climatic factors. The present study focused on the comparative performance evaluation of harder grade bitumen (VG-40) with convention bitumen grade (VG-30).

2. OBJECTIVES OF PRESENT STUDY

- To study the physical properties of aggregates and harder grade bitumen (VG-30 and VG-40) for Dense Bituminous Macadam (DBM) Grade-I as per MoRTH specifications.
- To evaluate the engineering properties including Marshall Stability, Marshall Flow, Marshall Quotient, Density, Voids in Mix and Voids Filled with Bitumen.
- Determine the Optimum Binder Content (OBC) for the Marshall Mix with bitumen viscosity grade VG-30 and VG-40.
- To study and analysis the effect of superior grade bitumen on pavement performance.

3. MATERIALS AND METHODS

Materials

Coarse Aggregate:

The course aggregate was collected from IRCON crusher source; near Kolayat, Bikaner District. Physical properties of coarse aggregate were tested as per MoRTH guidelines, given in Table 1.

Table 1: Physical Properties for Coarse Aggregate

S. No.	Description of Test	Test Results	Acceptable Limits as per MoRTH Table- 500-7
1.	Aggregate Impact Value	22.22%	27 % Maximum
2.	Los Angeles Abrasion Value	22.50%	30 to 35 % Maximum
3.	Crushing Value	23.38%	45 % Maximum
4.	Combined Flakiness and Elongation indices	30.27%	35 % Maximum
5.	Water Absorption	1.47%	2 % Maximum

Fine Aggregate:

The fine aggregate was collected from IRCON crusher source; near Kolayat, Bikaner District. Physical properties of fine aggregate were tested as per IS: 383. The physical properties of fine aggregates are given in Table 2.

Table 2: Physical Properties for Fine Aggregate

S. No.	Description of Test	Test Results	Acceptable Limits as per IS:383
1.	Grain Size Analysis	Separate Analysis is done	27 % Maximum
2.	Water Absorption	1.55	2 (Max.)
3.	Specific Gravity	2.67	NIL

Filler:

Stone dust is used as filler for the present study. The source was IRCON crusher near Kolayat, Bikaner District. In the present study the filler materials was free from organic. Impurities and had a plasticity index less than 4.

Bitumen:

Bitumen grade VG-30 and VG-40 is used as binder content for the present study. The source of bitumen was Indian Oil Corporation limited, Mathura refinery. Physical properties of bitumen grade VG-30 and VG-40 are given as below in Table 3.

Table 3: Physical Properties of Bitumen Grade VG-30 & VG-40 as Per IS: 73

S.No	Description of Test	VG-30	Limit (Min.)	VG-40	Limit (Min.)
1.	Penetration (mm)	47	45	40	35
2.	Softening Point (°C)	49.85	47	56.50	50
3.	Ductility (cm)	>25	25	>40	40
4.	Absolute Viscosity at 60°C (Poise)	2415	2400-3600	3309	3200-4800

5.	Specific Gravity	1.023		1.031	

Mix Design of DBM

The mix proportion was carried out as per the MoRTH specification. The aggregate gradation is given in Table 4.

Table 4: Batch Mix as per JMF

S.No	Material	Material JMF	Weight Percentage of all Materials in one batch mix	Quantity of all materials as per JMF in Kg
1	40mm	19%	18.193%	181.925
2	20mm	18%	17.235%	172.350
3	10mm	19%	18.193%	181.925
4	Dust	40.00%	38.300%	383.000
5	Filler	4.00%	3.830%	38.300
6	Bitumen		4.250%	42.500
		100.00%	100%	**1000.000**

4. RESULTS AND DISCUSSIONS

Determination of Marshall Stability and Flow Value for VG-30 and VG-40

Table 5: Marshall Properties of Bituminous Concrete Mix Prepared Using VG-30

S.No	Bitumen %	Gb	Gt	Vv %	Vb %	VMA %	VFB %	Marshal Stability kn
1.	4.00	2.396	2.519	4.874	9.369	14.243	65.78	21.59
2.	**4.25**	**2.408**	**2.509**	**4.020**	10.00	14.025	71.33	**21.08**
3.	4.50	2.401	2.500	3.966	10.561	14.527	72.70	24.25
4.	4.75	2.392	2.490	3.931	11.107	15.038	73.86	26.04
5.	5.00	2.386	2.481	3.833	11.661	15.494	75.26	22.42

Table 5 showed the test results of different binder content i.e. 4.25%, 4.50%, 4.75% and 5.00 % for VG-30 grade bitumen.

Table 6: Marshall Properties of Bituminous Concrete Mix Prepared Using VG-40

S.No	Bitumen %	Gb	Gt	Vv %	Vb %	VMA %	VFB %	Marshal Stability kn
1.	4.00	2.377	2.520	5.681	9.221	14.903	61.879	23.45
2.	**4.25**	**2.397**	**2.510**	**4.507**	**9.880**	**14.388**	**68.673**	**24.26**
3.	4.50	2.403	2.500	3.885	10.488	14.373	72.968	27.58
4.	4.75	2.393	2.490	3.898	11.025	14.922	73.880	26.64
5.	5.00	2.380	2.480	4.037	11.542	15.578	74.088	25.62

Further Table 6 showed the test results of different binder content i.e. 4.25%, 4.50%, 4.75% and 5.00 % for VG-40 grade bitumen.

Results showed that the optimum binder content was 4.25% for VG-30 and VG-40 grade bitumen because at this percentage the bitumen concrete mix full fills all the mix requirements as per MoRTH (5th revision) specifications.

Determination of Marshall Stability and Flow Value for VG-30 and VG-40

Figure 1 showed the graphically representation of Air Voids Percent and between bitumen grade.

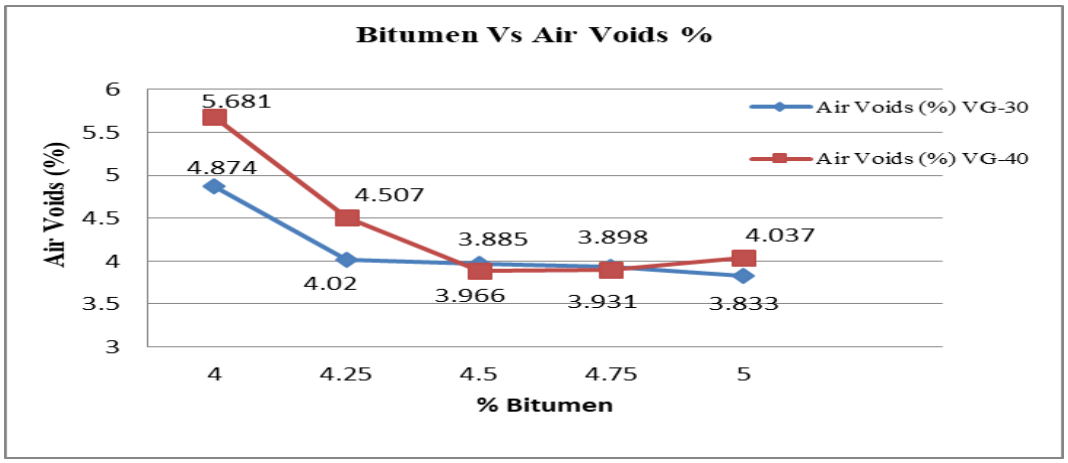

Figure 1: The Graph between of Air Voids Percentage and Bitumen Content (%)

It was found that the percent of air voids (Va) steadily decreased with increasing bitumen content and at bitumen content 4.5 to 4.75, flow value of VG-30 and VG-40 were approximately same and then after slightly increased flow value with increasing bitumen content.

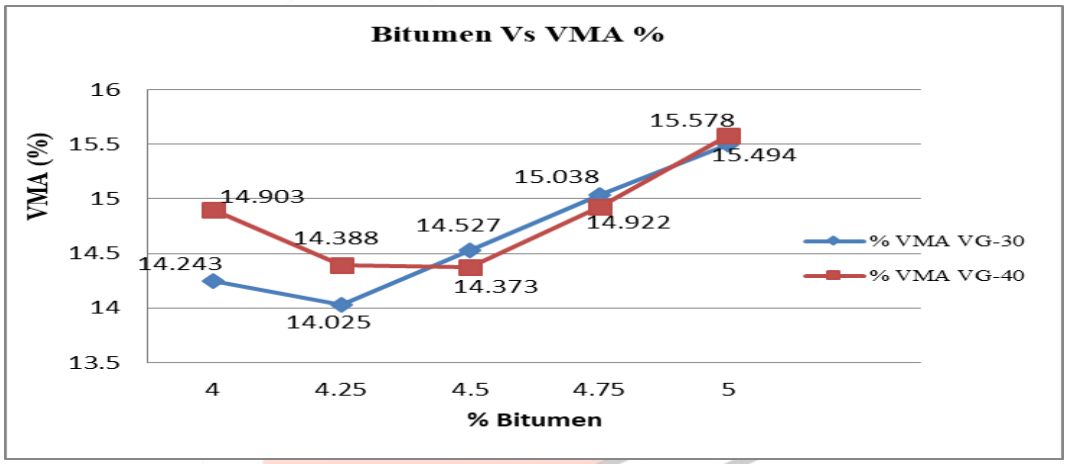

Figure 2: The Graph between VMA and Bitumen Content (%)

Figure 2 showed that the percent voids in mineral aggregate (VMA) generally decreased to a minimum value of then increases with increasing bitumen content of VG-30 and VG-40.

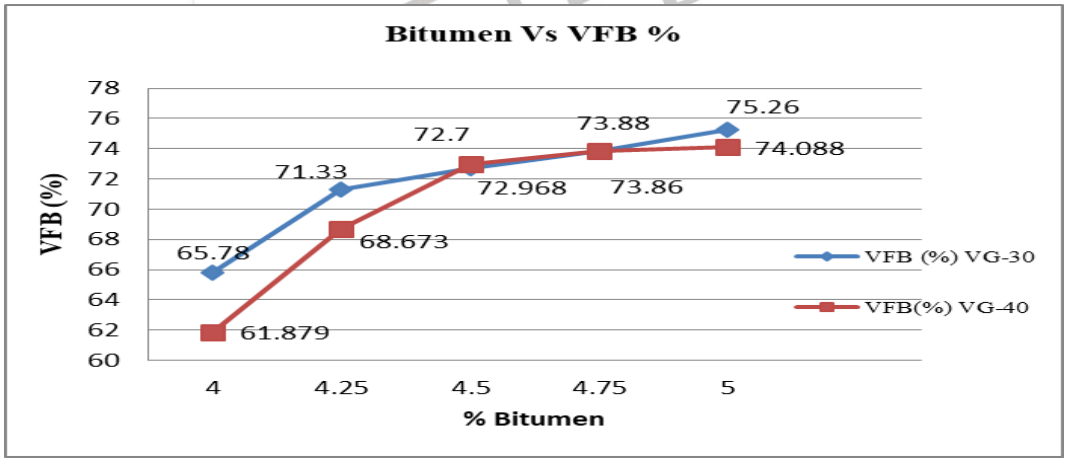

Figure 3: The Graph between VFB and Bitumen Content (%)

Figure 3 showed that the percent voids filled with bitumen (VFB) steadily increased with Increasing bitumen content, because the VMA were being filled with bitumen grade VG-30 and VG-40.

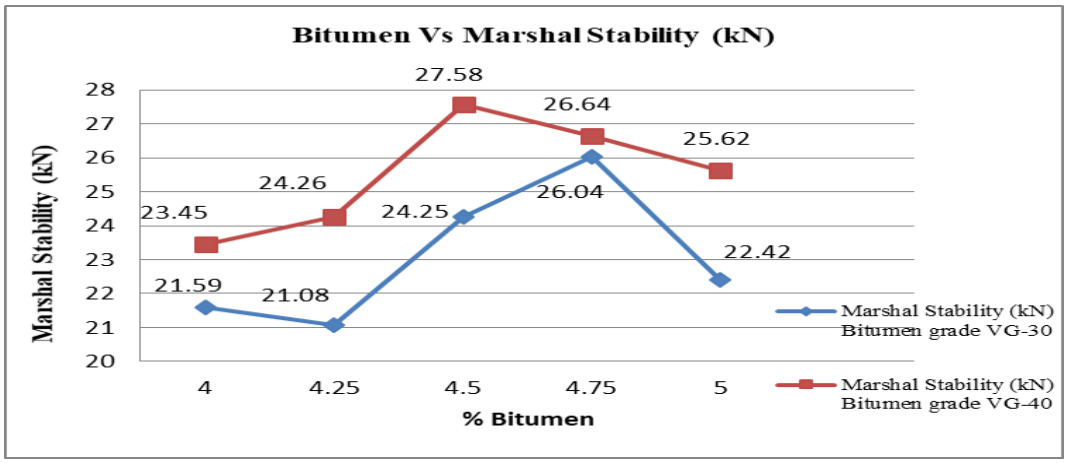

Figure 4: The Graph between Marshal Stability and Bitumen Content (%)

Figure 4 showed the Graph between Marshal Stability values (kN) and Bitumen Grade (VG-30 & VG-40).

It was observed that the trend of stability value was increased with increasing bitumen content up to a maximum after which the stability decreases. Stability values were achieved highest for VG-40 grade bitumen than VG-30 grade bitumen at 4.50% of bitumen content. Further, as the OBC was 4.25% for VG-30 and VG-40 respectively, the Marshall Stability for VG-40 grade was also high as compared to VG-30 grade bitumen.

5. CONCLUSION

- Table 1 and 2 showed that the aggregates were satisfying the requirements as per MoRTH (Vth Revision).
- Table 3 showed that the bitumen grades VG-30 & VG-40 were satisfying the test results as per IS 73: 2006 and IRC: SP -53: 2010.
- The graphs showed the volumetric and mechanical properties of Marshall specimens, obtained at varying binder contents for VG-30 & VG-40 indicated that the optimum binder content (OBC) of 4.25% (by weight of aggregates) satisfying the criteria's referred in MoRTH specifications.
- It was observed that the Marshall Stability values was increased with increasing bitumen content and were achieved higher value for VG-40 grade bitumen than VG- 30 grade bitumen, at VG-30 grade bitumen at 4.50% of bitumen content. This showed that the Marshall stability was increased by approx. 5% with VG-40 binder grade than VG-30 grade.

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