Study on the Influence of Shape of Coarse Aggregate and Waste Plastic on Strength of DBM MIX

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Abstract- Aggregate characteristics such as particle size, shape, and texture influence the performance and serviceability of hot mix asphalt pavement. The shape of aggregate particle has significant influence on performance of the Bitumen pavement. Plastic is non bio degradable and disposal of waste plastic is creates the serious hygienic problems in environment. To avoid the impact in environment the alternate use of waste plastic needed. The shape of aggregate is categorized by measuring particles largest diameter, smallest diameter and Intermediate diameter using Vernier Calipers. with these diameter the elongation ratio and flatness ratio is calculated with which the aggregate shape is determined. Later the Aggregate gradation required foe Dense Bituminous Mix is prepared as per MoRTH guidelines, DBM grading II is selected for this dissertation work. For convention DBM mix optimum bitumen content is determined using Marshall Stability Test. For obtained optimum bitumen content a new mix of DBM is prepared with different proportion and different shape of aggregates. For this dissertation work a proportion of 10%,15%, 20%,25%, 30% and 35% of cube and blade shape of aggregates is prepared and mix strength is determined using Marshall Stability Test.Later for obtained high strength mix a new mix of DBM is prepared with different proportion of waste plastic of 6%,8%,10%,12% and 14%. Also, other marshall properties such as flow value, bulk density VFB and VMA is analysed.

In DBM mix cube shape of aggregates with 20% has the higher strength than conventional mix,. Blade shape aggregate with 30% in the mix has the least strength. Coming to performance evaluation cube shape with 20% proportion with 12% of waste plastic has higher strength.

Key words: Hot mix asphalt, Dense bituminous macadam, Marshall stability test, aggregate shape.

I. INTRODUCTION

Road transport provides greater utility in transport over short and long hauls of lighter weight commodities and of lesser volumes, as also for passenger transport for shorthand medium hauls. Road as one of land transportation infra structure is very important in supporting the economic for both regional and national development. Bituminous concrete as one of road surface material is mainly influenced by the quality of aggregates since aggregate occupies 95% by weight in total mixture. Existence of blade shape aggregate in the bituminous mixes is undesirable and a dangerous phenomenon because, of their tendency to break under wheel load either during compaction in construction stage or in service life of the pavement .This interlocking property is obtained by existence of angular type aggregate.

The shape of aggregate particle has a significant influence on the performance of the bituminous pavement. Particle shape can be described as cubical, flat, elongated and round.

Dense Graded Bitumen Mixes for Pavements

These mixes possess continuous gradation of all primary aggregates. These particles are packed together. Here inter-particle surface friction is the reason behind their property of strength gain. Dense bituminous macadam is mainly used as binder course for roads having much higher number of heavy commercial vehicles. In DBM mix there is a wide scope of varying the gradation to obtain the good mix without affecting the durability of pavement. Achieving adequate compaction of bituminous mixes is crucial to the performance of flexible pavement.

Significance of Aggregate Shape on Bituminous Mixes

Aggregate shape properties are known to influence Bitumen pavement performance. Angularity and texture govern the frictional properties and dilation of the aggregate structure. Aggregate texture plays a major role in influencing the adhesive bond between the aggregate and the binder, while aggregate form influences the anisotropic response of Bitumen mixes Aggregate characteristics such as particle size, shape, and texture influence the performance and service ability of hot-mix asphalt pavement Flat and elongated particles tend to break during mixing, compaction, and under traffic. Therefore, aggregate shape is one of the important properties that must be considered in the mix design of asphalt pavements to avoid premature pavement failure.

Use of Plastic Waste in Flexible Pavements

Plastic is any synthetic or semi synthetic organic polymer. It is made from a wide range of organic polymers such as polyethylene, Polyvinyl Chloride (PVC) etc. that can be molded into the shape while soft and then set into a rigid and slightly elastic form. Plastics are durable and degrade very slowly, the chemical bonds that make plastic durable make it equally resistant to natural process of degradation (Chavan, 2013). The waste plastic is used as the stiffen binders for reducing the rutting, thermal cracking, stripping, cost of maintenance of pavement.

It improves the fatigue resistance, bituminous pavement durability and provides clean environment.

Objective

- To determine the basic properties of aggregate, bitumen.
- To categorized the coarse aggregate into different shapes (cube and blade shape).
- To determine the particle index value of the cube and blade shape coarse aggregate.
- To determine the optimum percentage replacement of shape of coarse aggregate in DBM mix by Marshall Stability test method.
- To determine the optimum percentage waste plastic for optimum percentage replacement of shape of coarse aggregate DBM mix by Marshall Stability test method.
- To determine the rutting potential of DBM mix with optimum percentage replacement of shape of coarse aggregate and optimum percentage replacement of waste plastic.

II. MATERIALS USED

Aggregate Properties

Table 2.1 Physical Characteristics of Grade 2 Aggregates- Test Results

SI No	Aggregate tests	Method	Results	Standard results as per MORTH-500
1	Aggregate Impact Test	IS : 2386(Part IV)-1963	21.38%	Max 27%
2	Specific Gravity	IS : 2386(Part III)-1963	2.6	2.5-2.7
3	Flakiness index Elongation index Combined index	IS : 2386(Part I)-1963	13.86% 11.62% 25.48%	Max 30%
4	Abrasion test	IS : 2386(Part IV)-1963	24.81%	Max 35%
5	Water Absorption	IS : 2386(Part III)-1963	0.23%	Max 2%
6	Crushing strength	IS : 2386(Part IV)-1963	28.57%	Max 30%

Binder

Table 2.2 Test Results for 60/70 Penetration grade Bitumen

SI No	Test Method	Method	Results	Standard results MoRTH-500 (IS:73)
1	Specific gravity test	IS:1203	1.02	1.02
2	Penetration test	IS:1203	67mm	Min 45 mm
3	Ductility test	IS:1208	90mm	Min 40 mm
4	Softening point test	IS:1205	54°c	45°c-55°c

Mineral Filler

Table 2.3 Test Results for Mineral Filler(Stone dust) Total weight = 1000gms

SL No	IS sieve size (mm)	Weight retained (gms)	Percentage weight retained (gms)	Cumulative percentage weight retained (gms)	Cumulative percentage weight passed (gms)	Cumulative percent passing by weight of total aggregate (gms)
1	0.6	0	0	0	100	100
2	0.3	10	1	1	99	95-100
3	0.075	60	6	7	93	85-100

Waste Plastic

Plastic mainly consist of polystyrene, poly propylene, ploy vinyl chloride, HDPE and LDPE. In this study mainly LDPE like carry bags are used to study increase road life compare to normally prepared road.

III. METHODOLOGY

- Selection and collection of Materials
- Test on aggregate & bitumen
- Gradation and Blending of aggregate for DBM
- Classification of shape of coarse aggregate(cube and blade shape)
- Particle index value test for cube and blade shape coarse aggregate
- Marshal stability test for determine optimum percentage replacement of shape of coarse aggregate in DBM mix(10%,15%.20%25%,30%,35%)
- Marshal stability test for to determine the optimum percentage of waste plastic for optimum percentage replacement of shape of coarse aggregate in DBM mix(6%,8%,10%,12%,14%,16%)
- Rutting potential of DBM mix with optimum percentage replacement of shape of coarse aggregate and optimum percentage replacement of waste plastic
- Result and discussion

IV. EXPERIMENTAL PROGRAMME

For Dense Bituminous mixtures determining of stability by conducting Marshall Test was first done with varying percentages 4.5%, 5.0%, 5.5% for getting accuracy value varying percentage 4.6%, 4.7%, 4.8%, 4.9% of bitumen (60/70) as a binder and stone dust as filler material for normal mix. Once Optimum Binder Content is determined, the maximum stability of the mix is determined by replacing the different shape of aggregates in the mix say Blade and Cube shape from varying proportion of 10%, 15%, 20% ,25%, 30%, and 35% into the mix. Replacing the waste plastic to the bitumen from varying proportion 6%, 8%, 10%, 12% and 14% to obtained high stability DBM mix.

Aggregate Gradation

Table 3.1 Aggregates Blending Results

Material A:19mm-12.5mm:44% Material B:12.5mm-2.36mm:15% Material C:4.75mm-0.075mm:39% Material D:0.075mm-PAN:2%				
MoRTH Specification				
Sieve size(mm)	Upper limit	Lower limit	Middle limit	Trial mix
37.5	100	100	100	100
26.5	100	90	95	100
19	95	71	83	87
13.2	80	56	68	63
4.75	54	38	46	45
2.36	42	28	35	36
0.3	21	7	14	14
0.075	8	2	6	4

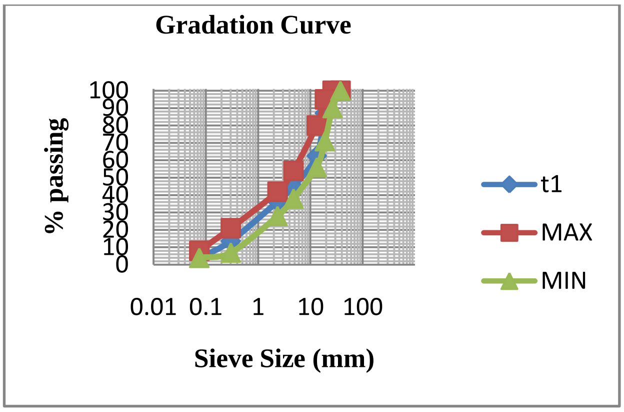

Fig 3.1: Gradation curve for Blending of Aggregates

Aggregate gradation is one of the most basic laboratory test done which aims to determine the percentages of different size of aggregates to be used in the mix. After the basic tests, the aggregates are further used in the determination of the proper blend to give a good mix consisting of different size of aggregates. The different size of aggregates used to obtain proper blend are 19mm down size, 12.5mm down size, 4.75mm down size and stone dust. A known amount of aggregates were taken for sieve analysis. The aggregate gradation is done by using Job Mix Formula Method to find the individual percentages of different sized aggregates to be used confirming to the upper and lower limits specified as per MoRTH table 500-10 grading-2. The gradation of aggregates for DBM-grade2 mix as shown in Table 3.1.

Quantification of Aggregate

Coarse aggregates are classified in to different shapes using zingg's diagram classification of coarse aggregates. Aggregates passing 19mm and retained on 12.5 mm IS sieve is collected from sieve analysis. The collected samples is cleaned thoroughly and its largest diameter (d_l), smallest diameter (d_s) and intermediate diameter (d_i) is measured using Vernier Calipers. The elongation ratio and flatness ratio is calculated using the formula,

$$\text{Elongation ratio} = d_i/d_l$$

$$\text{Flatness ratio} = d_s/d_i$$

With these ratios the aggregates are classified in to Blade shape, Cubical shape as shown in table 4.2

Table 3.2 Aggregate shape classification using zingg's classification

Aggregate shape	Elongation ratio	Flatness ratio
Blade	< 2/3	< 2/3
Cubical	> 2/3	> 2/3

Table 3.3 Quantification of Aggregates

Longest diameter (dl) cm	Shortest diameter (ds) cm	Intermediate diameter (di) cm	Elongation ratio	Flatness ratio	Shape
1.6	1.4	1.5	0.937	0.9333	CUBE
1.4	1.2	1.3	0.928	0.923	CUBE
1.5	0.3	0.9	0.6	0.333	BLADE
1.1	0.2	0.65	0.591	0.378	BLADE

Particle Index Value Test

This test is used to determine the combined effect of particle shape and surface texture of aggregates. The experiment is carried as explained in chapter-3. Aggregates of different shapes are tested individually in this experiment and result is tabulated Table-3.4 gives the experimental results.

Table 3.4: Particle Index of Coarse Aggregates

SL NO	SHAPE	M_{10}	M_{50}	V_{10}	V_{50}	P.I
1	Cube	4373	4518	46.82	45.06	15.3
2	Blade	4856	4996	40.95	39.23	9.4

Marshall Stability Test for Different Shape And Proportion Of Coarse Aggregates

The Marshall specimens are prepared with different shape of aggregates (Blade and cube) with different proportions (10%, 15%, 20%, 25%, 30%, 35%) in the mix. The blending of the mix remains same as of the conventional mix but the optimum bitumen content of 4.7% is maintained. For every shape and proportion of aggregates three samples is prepared and average stability value is considered. In this dissertation work it is observed that cube shape of aggregates with 20% replacement in the mix has highest strength and blade shape with 30% replacement has minimum strength. Following tables (3.5, 3.6) gives the average Marshall stability values for different shape and proportion of aggregates.

Table 3.5: Marshall Properties of DBM mix with cube shape aggregates

MARSHALL TEST RESULTS	CUBE 10%	CUBE 15%	CUBE 20%	CUBE 25%	CUBE 30%	CUBE 35%
STABILITY (kN)	15.92	16.26	16.60	16.37	16.10	16.28
FLOW (mm)	2.4	2.46	2.5	1.95	1.9	1.7
AIR VOIDS (%)	3.1	3.28	3.3	3.43	3.5	3.58
DENSITY (gm/cc)	2.423	2.422	2.420	2.423	2.425	2.424
VFB (%)	77.73	76.71	76.60	75.87	75.48	75.05
VMA (%)	13.92	14.08	14.09	14.21	14.28	14.35

Table 3.6: Marshall Properties of DBM mix with blade shape aggregates

MARSHALL TEST RESULTS	BLADE 10%	BLADE 15%	BLADE 20%	BLADE 25%	BLADE 30%	BLADE 35%
STABILITY (kN)	11.01	10.77	10.49	10.34	10.22	10.33
FLOW (mm)	1.7	1.55	1.3	1.45	1.5	1.64
AIR VOIDS (%)	3.36	3.35	3.51	3.52	3.55	3.6
DENSITY (gm/cc)	2.422	2.422	2.421	2.424	2.427	2.431
VFB (%)	76.26	75.54	75.43	75.37	75.21	74.94
VMA (%)	14.15	14.27	14.28	14.29	14.32	14.36

Here the Marshall Stability test conducted on DBM Mixture with replacing different shape of aggregates of varying Percent from 10%, 15%, 20%, 25%, 30% and 35%. The stability value obtained 16.60kN for the cube shape 20% replacement and minimum stability is recorded for blade shape 30% replacement. Comparing to the conventional DBM mix the DBM mix with containing 10%, 15%, 20%, 25%, 30% and 35% cube shape aggregates possesses more strength along with that blade shape of aggregates with any proportion in the mix yields less strength to that of the conventional mix.

Marshall Stability test for cube 20% aggregate and different proportion of waste plastic.

The Marshall specimens are prepared with cube 20% shape of aggregates with different proportions (6%, 8%, 10%, 12%, 14%) of waste plastic are replaced for OBC bitumen content the mix. The blending of the mix remains same as of the conventional mix but the optimum bitumen content of 4.7% is maintained. For every shape and proportion of waste plastic mix three samples is prepared and average stability value is considered. In this dissertation work it is observed that cube shape 20% with waste plastic 12% replacing of bitumen has highest strength . Following tables (3.7) gives the average

Marshall stability values for Cube 20% aggregate and Different Proportion of Waste Plastic.

Table 3.7: Marshall Properties of DBM mix with cube 20% aggregate and different proportion of waste plastic.

MARSHALL TEST RESULTS	**WASTE PLASTIC CONTENT BY WEIGHT OF BITUMEN**				
	WP 6%	**W.P 8%**	**W.P 10%**	**W.P 12%**	**W.P 14%**
STABILITY (kN)	14.6	15.9	16.8	20.3	18.2
FLOW (mm)	2.32	2.9	3.1	3.8	5.1
AIR VOIDS (%)	3.12	3.00	2.91	2.6	3.3
DENSITY (gm/cc)	2.425	2.48	2.53	2.59	2.41
VFB (%)	67.60	74.17	78.76	83.24	81.90
VMA (%)	9.57	11.61	13.65	15.51	18.22

Here the Marshall Stability test conducted on DBM Mixture with replacing 20% cube shape coarse aggregate with different different proportion of waste plastic(6%, 8%, 10%, 12%, 14%).The maximum stability value obtained 16.8kN for the cube shape 20% replacement and waste plastic 12% replacement for bitumen.

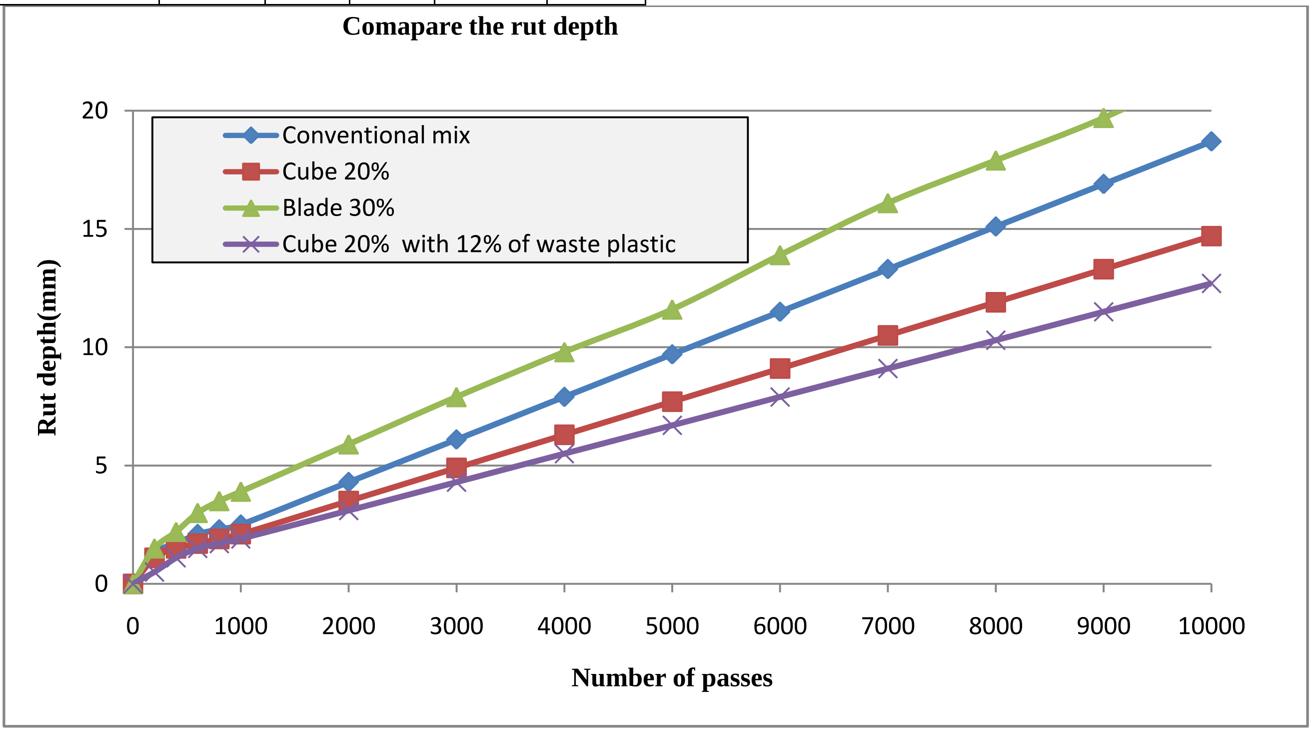

Fig.3.2: Compare the rut depth

Immersion Wheel Tracking

The rutting test was done for DBM conventional mix, cube shape aggregate 20% replacement for coarse aggregate, blade shape aggregate 30% replacement and plastic 12% replacement with 20% cube shape aggregate replacement..From rutting study it is observed that DBM with plastic 12% replacement with 20% cube shape aggregate replacement shows less rutting depth compared to other mix. Blade 30% replacement shows more rutting depth than convention mix. From this study it is also clear that DBM mix of plastic 12% replacement with 20% cube shape aggregate replacement shows less affinity towards deformation and good strength here recommended for the road construction.

V. CONCLUSION

The following conclusions are derived from the results of the present study considering Marshall Properties of DMA mixes.

1. Aggregate and bitumen used this study satisfies the requirements of MORTH specification.
2. The coarse aggregate are successfully classified into cube and blade shape based on Zingg diagram.
3. The stability of the Marshall mix with different aggregate shape and proportion shows the good results against the minimum Marshall strength of 9KN.

4. In Marshall stability test Cube shape aggregates having 20% proportion in DBM mix possess higher stability of 16.60 KN and the cube aggregate proportion of 30% replacement shows lower stability 16.10KN.
5. Blade shape of aggregates in the mix has the least strength compared cube shape of aggregates strength in the mix. Blade shape with 30% proportion in the Marshall mix have less strength of 10.22KN and blade shape with 10% proportion in the Marshall mix have more strength of 11.01KN compare to other blade proportion.
6. The optimum percentage replacement of shape of coarse aggregate in DBM mix by Marshall Stability test method is cube shape of aggregate of 20% proportion.
7. The Optimum Plastic Content to replacement of bitumen in DBM mix with 20% proportion of cube shape aggregate replacement to coarse aggregate, the maximum stability is obtained at 12% of waste plastic is 20.3 KN.
8. DMA mix with 20% cube shape coarse aggregate replacement and 12% waste plastic replacement to bitumen shows less deformation compared to control mix. It indicates that rutting characteristic of coarse aggregate and waste plastic used sample is more resistance to wearing.

VI. FUTURE SCOPES

1. DBM mix with different types of plastic with different filler.
2. DBM mix with different grade and different classification of aggregate.
3. Wheel tracking test can be done with different shape of aggregate with different wheel pressure and different slab thickness.

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