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Research paper

Experimental Investigation on Bituminous Mixes with MoRTH Gradation and Superpave Gradation

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Abstract

The shape of aggregates particle has a significant influence on the performance of an asphalt pavement (Patrick, 2003). More percentage of flaky and elongated aggregates makes the mix to be harsh and leads in delay during the construction process. (Mathew, 2006). Hence it is felt that the study on the effect of the shape of aggregates on bituminous mixtures is relevant and essential. In bituminous mixtures, it is mandatory to maintain certain level of air voids to avoid the failure due to binder expansion during hot periods. The voids present in a compacted mix depend on the shape of the aggregates (Sridhar. et al), highly angular, flaky and elongated aggregates have more voids in comparison with rounded aggregates. In order to overcome the effect of shape of an aggregate, an investigation has been carried out to assess the performance of the bituminous mix under various properties. For finding the exact variation among the mixes, the volumetric analysis have been carried with fatigue and moisture sensitivity test. The result shows the superior performance in Superpave gradation when compared with MoRTH gradation. The optimum percentage of bitumen is 0.2% decrement corresponding to 4% of air-voids in Superpave graded mix.

Keywords: *flaky, elongated, stability, air-voids, voids in mineral aggregates, voids in filled with bitumen and fatigue.*

1. Introduction

The aggregate shape is one of the important properties considered in the design of asphalt mixes to avoid premature pavement failure and decrease in pavement performance. Especially in coarse aggregate, the size above 10mm has a strange correlation with the rut depth, because it has high angularity value and leads to more air voids.(NCHRP). The reduction of air voids within the materials is characterized by effective compaction. (Pandey et al). The performance of the mix is decided by the shape of the aggregate, so it is more significant in focusing the physical properties of coarse aggregate in bituminous mixes because it is more tendencies to break down during construction and subsequent traffic condition.

2. Need for the Study

It is found that limited studies have been reported about the influence of the shape of aggregates in bituminous mixes (Ajith Kumar, 2001). Generally, the aggregate shape is expressed in terms of flaky, elongated and combined aggregates or angularity number. In angularity number, the shapes such as cubical, flat, elongated and round are taken into account. Hence representing the various shapes of aggregates in terms of angularity number would be the more accurate approach. In India, the shape of aggregates is expressed only in terms of combined flakiness and elongation indices values specified in the MoSRTH specification for bituminous mixes. Only 30 % of flaky and elongated aggregates were applicable whereas, in foreign countries, only 10% of flaky and elongated aggregates for the traffic more than one million equivalent single axle loads are recommended (E Sleigh, 2002).

3. Literature Review

Flat and elongated aggregates are generally, considered undesirable in bituminous mixes because it has more tendencies to break down during construction and subsequent traffic operations. The aggregate shape is one of the important properties which is considered in the design of asphalt mixes to avoid premature pavement failure and decrease in pavement performance. Several circumstances arise in the transportation sector, that the pavement will withstand the maximum effort by means of mix design. It can sustain the tremendous effort attain by the researcher to develop a sophisticated pavement design for the current generation. This literature review helps to focus the present and future scope in the pavement design and deals with the review of literature related to the shape of aggregates and its influence on the properties of bituminous mixtures. Abu Zakir Morshed et al [2014] experimented that the Marshall Stability is found to be 14% increases in flakiness index, whereas the 34% for the elongation index. Elongated particles caused more instability than the flaky particle in Marshall Method. Using repeated load test, permanent deformation furnishes increases in terms of increases of flaky and elongated aggregates. Bambang et al [2005] studied the influence of asphalt mixture which relates the properties of asphalt mixture such as Optimum binder, workability and resilient modulus, with increase and decrease of various properties in volumetric analysis corresponding to the shape of aggregates. Behroooz [2008] found out that, the effect of coarse aggregate angularity on the mechanical performance mainly based on the permanent deformation, creep and fatigue resistance. The aggregate mixture leads to an increase in the fatigue resistance of HMA mixture. Bose et.al [2003] has discussed, that the volumetric analysis results shows 0.7% of variation in the optimum binder content. Among both method, Superpave mix gives decrease in binder content compared to Marshall Mix and also it gives more percentage of fatigue life with high percentage of resistance during rutting. Boyapati [2005] has studied that Superpave mix design is suitable for all weather condition for newly laying road construction. If the existing road is severely damaged by ravelling, potholes, cracks and ruts depth, then it is categorized by severity levels which is surveyed through PCI (Pavement Condition Index). Deepesh Kumar Singh Lodhi. et al [2016] Flakiness index should be kept below 25% for better strength and durability, increasing in flakiness with decreasing in, flow value gives poor interlocking. Ganapati Naidu. [2013] investigated the parameters used in Marshall Method are satisfied with the replacement of 20% of the cubical, blade, rod and disk aggregates which attains the minimum requirement of 9kN stability in the DBM mixes. Israa F. Jasim [2012] found that the pavement structure transferred more load to the top surface, Hence it has to be designed that, it should bear the vehicle loads. In both Marshall and Superpave mix design, the aggregates are equally assigned, but increase in stability value is arrived in Superpave mixes. Isaac et al [2006] studied the most suitable percentage of flaky and elongated aggregates in the bituminous concrete mix by Rothfutch graphical method. The result describes that, optimum bitumen content increases by 10% - 13.5% for combined index, 35% - 50% for flaky and 30% - 70% for elongated aggregates are reported. Jacobs, [1995] reported that repeated traffic loadings, resulted in fatigue failure, early it will initiate cracks and lead to the propagation of potholes. Jack E. Stephens [1974] investigated the shape of aggregate are detrimental to mixing, compaction, and stability. Voids decrease with increasing asphalt; higher voids always occurring only greater than 30% use of flat aggregates. Reduction in, stability occurs only above 6% of asphalt content, but in case of 50% regular (25% flat & 25% rod) is maintained throughout the mix. Janoo et al [1998] examined the effect due to changes in shape; angularity and roundness of the aggregates are good enough for the design mix. Joshi et al [2013] found optimum compaction level to avoid unacceptable distortion and displacement when it is open for traffic flow. Adequate voids should be present before traffic is opened, thus leads to adjust the effects of bleeding and loss of stability. Khan [2008] has investigated that the percentage of accumulated strains in Superpave is less at 25°C and 40°C. This shows the amount of water penetration is low in the design mix. MoSRTH [2013] In India, MoRTH specification for road and bridge works specifies the maximum percentage between Flakiness and Elongation Indices, the value should not be more than 30% of design mix. Pandey et al [2001] investigate that the shapes of aggregates influence the strength and durability of the pavement, the material compaction includes the interlocking of the aggregates framework and it helps in the reduction of air voids within the materials. The compaction technique which is used in this study is Hugo hammer which gives closer to the field compaction. Hugo hammer has a rotating base varies from 100 to 150mm diameter with indents 3mm to the 6mm depth at an angle measuring 30° each provide the shearing action to the mix, this shearing action will help the re-orientation of aggregates and simulate the field condition. Reddy et al [2009] found that, the percentage of standard axle load of 8.3 tonnes of commercial vehicles moving on the highways exceeding the legal limit 10.2 tonnes, this may leads the existing road may deteriorate as early as possible during seasonal variation. Sakthibalan et al [2009] found that flakiness index up to 32% for DBM and 33% for SDBC can be permitted without compromising the specification requirements. The angularity number increases with increase in the proportion of flaky aggregates. Sarika et.al [2015] carried out that, Superpave gives optimum binder content for Hot Mix Asphalt (HMA) corresponding to 4% Air Voids. The variation level between Marshall and Superpave is found to be 0.25%. In coarser gradation, Superpave trial gives satisfactory results compared to Marshall trial grade. Sridhar et.al [2007] investigated that Hugo hammer gives better results with an indentation on the face will simulate the field condition than the Marshall hammer. Hugo Hammer with rotating base with coarser gradation in the bituminous mix gives good compaction simulating with field condition. Suren Muhammad Salih. et al [2013] Elongated particles caused more stability than a flaky particle in terms of Marshall Stability, with reduced Marshall Stability only in higher mixing temperature. Youness Ahmed et.al [2014] studied that Cubical shape of aggregates gives the increased values in stiffness modulus which is higher than the disk and blade shape. Veeraragavan et al [2009] found that, bituminous pavements causes premature cracking on the surface due to traffic loading. This causes is coomon to all the type of bituminous pavements and these may reduce by choosing the material in effective manner.

3.1. Background of MoRTH

In India, the maximum percentage of flaky and elongated aggregates can be used in the bituminous mix is 30%. Flakiness index should be kept below 25% for better strength and durability (Lodhi et al). Increased flaky aggregates resulted in a decrease in flow and lead in poor interlocking (Samuel et al). Apart from flaky and elongated aggregates, cubical aggregates give increased in stiffness modulus. (Youness et al). An equal amount of flaky and elongated aggregates in the mixes gives better mix properties than other combinations. (Krishnamurthy et al).

3.2. Background of Superpave

All kind of failures can be reduced by using Superpave mix design. It will optimize the asphalt mixtures, with proper selection of materials and compaction techniques. (Asphalt Institute). Superpave is used to optimize the various materials to suit the environmental condition. During, 1987 Strategic Highway Research Program (SHRP) introduced a product to achieve the maximum results in a different process. The four basic steps to be followed for preparation of molds is selection of aggregates, traffic volume, asphalt content and climatic condition. This can reduce fatigue cracking and produce better results even in low temperatures.

3.3. Background of Superpave

Aggregate is a collective term of the mineral materials extracted from open quarry. Aggregate size are obtained by crushing it using mechanical devices and it is used based on their desired properties. Particularly size of aggregates is derived on the BIS (Bureau of Indian Standards). Coarse aggregates are the prime material used in pavement construction. It has a tendency to bear load stresses occurring during traffic condition. Aggregates are used in the construction of flexible pavement layers, in granular sub-base and base course. Normally these layers are specified as Water Bound Macadam (WBM), Wet Mix Macadam (WMM), etc.

The aggregate used in pavement layers are subject to heavy moving loads. These aggregates have to withstand the high magnitude of load stresses and wear and tear. Due to the continue moving load the top surface is easily getting polished or smooth under severe traffic condition. It reduces the friction between the tyre and the surface. To overcome all these effects, aggregates are so selected and it should bear the sufficient strength or resistance to crushing. For all kind of pavement layers, the specific gravity of the aggregates should be more; hence it has more strength compared with less specific gravity.

3.4. Objectives and Scope

In the present study, two types of the mix were considered for the design. The specimen was prepared as per MoSRTH Specification and Superpave gradation with different percentage of flaky and elongated aggregates in the design mix.

To evaluate the effect of Superpave graded bituminous Mixes under the following properties,

- Stability
- Flow

- Air Voids (V_a)
- Voids in Mineral Aggregates (VMA)
- Voids Filled with Bitumen (VFB)
- Optimum Binder Content(OBC)
- Indirect tension
- Moisture Sensitivity
- Fatigue

To identify the maximum permissible percentage of Flaky, Elongated and Combined Aggregates for obtaining better performance in Superpave graded bitumen mixes.

4. Data Collection

In this study, the behavior of Bituminous Concrete was studied with aggregates varying from 0% to 100% of flaky, elongated and combined aggregates. To quantify the effect of combined aggregates the percentage of flaky and elongated aggregates are equally varied. The relationship between conventional and modified mix is correlated with the test results. The Preparation of specimen for both Bituminous Concrete and Superpave graded mix is taken from MoRTH specification and Asphalt Series No. 2.

4.1. Bituminous Concrete (BC)

The gradation of Bituminous Concrete arrives from the MoRTH Specification, Grading II and physical properties of Bituminous Concrete are tabulated in the table. 1. It consists of construction in a single layer of bituminous concrete has a thickness of 30mm / 40mm / 50mm on a previously prepared bituminous bound surface. As per combined gradation of coarse and fine aggregates and filler, fall within the limits.

The aggregates and bitumen (VG 30) grade used in this study were tested under Ministry of Shipping, Road Transport, and Highways Specifications are tabulated in Table 1. and Table 2.

Table 1: Physical Properties of aggregates

Specified Test	Specification Requirements		
	Standard	Test Result	Code
Aggregate Crushing Value	30 %	15.48	IS: 2386
Aggregate Impact value	30 %	16.72	IS: 2386
Specific Gravity - Coarse	-	2.77	IS: 2386
Specific Gravity - Fine	-	2.67	IS: 2386
Water absorption	2 %	0.18	IS: 2386
Los Angeles Abrasion	30 %	13.45	IS: 2386

Table 2: Physical Properties of VG 30 grade Bitumen

Specified Test	Specification Requirements		
	Standard	Test Result	Code
Penetration (mm) @ 25° C	59	50 to 70	IS 1203: 1978
Flash Point, @ °C	230°	220	IS 1209: 1978
Ductility @ 25°C	65	40	IS 1206: 1978
Specific Gravity @ 25°C	1.01	0.97 to 1.02	IS 1202: 1978
Softening Point, @ °C	49°	47	IS 1205: 1978
Absolute Viscosity at 25°C	2200	2400	IS 1206: 1978

4.2. BC mix and Superpave Graded Mix

The optimum binder content for the mix design is calculated by the average value of maximum density, maximum stability and air-voids(4%). Sometimes Marshall Stability values, Flow value and percentage Voids Filled with Bitumen at the average value of bitumen content are checked with the Marshall mix design specifications. The volumetric properties are calculated at the design for each trials asphalt binder content. For all kind of bituminous pavements the optimum binder content is determined by 4% air voids. The consolidated result is tabulated in table 3.

Table 3: Test Results of BC mix and Superpave Graded Mix

.S.no	Test Specification	A	B	C	D
1	Optimum Binder Content (OBC), %	4.90	5.30	5.16	5.10
2	Stability, kN	18.00	18.10	19.10	19.5
3	Flow, mm	3.12	3.50	3.58	3.61
4	Air voids, (Va %)	4.58	5.3	5.78	5.34
5	Voids in Mineral Aggregates (VMA, %)	15.40	17.00	17.30	16.5
6	Voids Filled with Bitumen (VFB, %)	70.52	67.82	66.38	68.2
7	Tensile Strength Ratio (TSR, %)	92.03	91.45	92.75	93.23

A. BC with non-flaky and non-elongated aggregates with Marshall Hammer
B. Superpave Graded with non-flaky and non-elongated aggregates with Marshall Hammer
C. BC with non-flaky and non-elongated aggregates with Hugo Hammer
D. Superpave Graded with non-flaky and non-elongated aggregates with Hugo Hammer

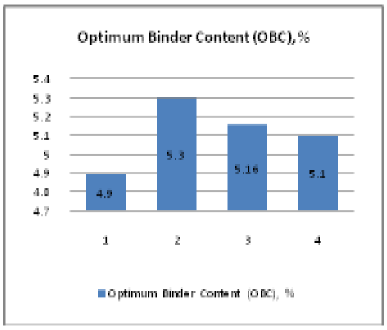

Figure 1: OBC of different mixes

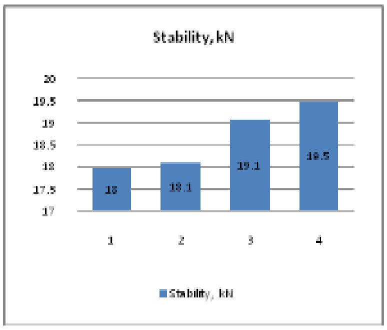

Figure 2: Stability of different mixes

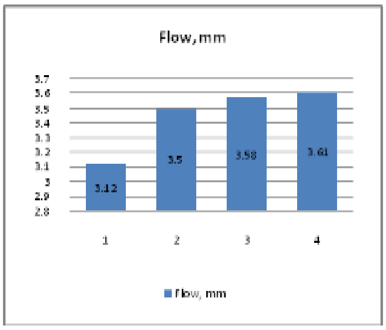

Figure 3: Flow of different mixes

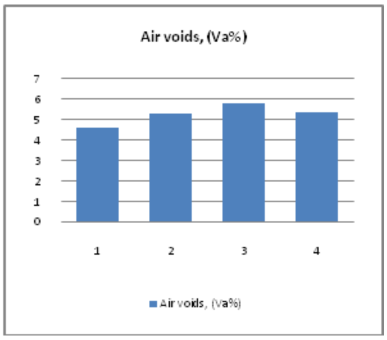

Figure 4: Air voids of different mixes

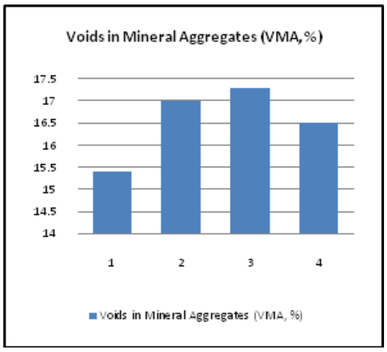

Figure 5: Voids in Mineral aggregates of different mixes

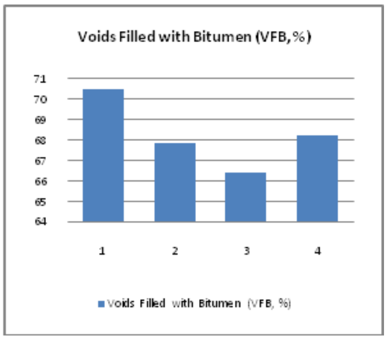

Figure 6: Voids Filled with Bitumen of different mixes

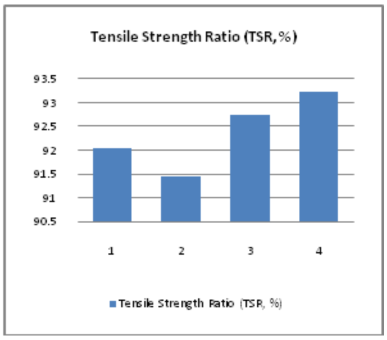

Figure 7: Tensile Strength Ratio of different mixes

5. Result Background

This research work investigates the possibility of implementing, the Superior Performance asphalt. Pavement (SUPERPAVE) gradation. The laboratory results of the study, using both the Marshall and Superpave mix design procedures were evaluated and compared in Figure 1 to Figure 7. The volumetric analysis is derived from figures and shows the variation of results depends on the different gradation of aggregates.

6. Conclusion

The main conclusion is as follows:

The results obtained from the present investigation shows the superiority of Superpave graded mixes over the conventional mixes. Thus it is recommended for highways, where the traffic volume is substantially high. Superpave gradation can be used in various places with modification in temperature level during the construction and compaction of layers. The grading requires the shifting up of flaky and elongated particle in upper and lower level because of locally available aggregates. The VG 30 grade is capable of withstanding the variation in high temperature, therefore it is recommended to use the same binder content for both Marshall gradation and Superpave gradation which is used in India. The binder content determined from the Superpave graded mix design produce lower than Marshall Mix. For Aging, superior quality bitumen binders or polymer modification would be required to satisfy the gradation derived from Superpave. The results are correlated with SPSS software for interpolating the data for plotting the graph. The study findings cannot be applied directly to all types of binders in the Indian road network, but the alteration of aggregate size and polymers can be recommended with Superpave specification based on the climatic condition, it also confirms that the Superpave graded mix design can be adopted to replace the Marshall gradation. The results of fatigue test show, satisfactory performance and give the better experimental results towards the Superpave Gradation.

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