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Evaluating the Performance of Superpave Graded Bituminous Mix

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Abstract

Background/Objectives: In all over India, the bituminous mixes are designed based on the fulfillness of laboratory standards. The existing method is not focusing on field condition, they simulate only time based requirements. **Methods:** To improvise the quality and performance of bituminous mix, the product of SHRP asphalt research program has developed a new system called Superpave (Superior Performance Pavements). Superpave design mix will optimize the asphalt mixtures resistance in deformation, fatigue, cracking and rutting. The Superpave system was created to make the best technology to suit the environmental condition with the better performance compared to Marshall Methods. **Findings:** In Superpave design only 10% of flat and elongated aggregates are acceptable. The main objectives of this study to develop, the performance based design mix for Indian condition using Superpave graded bituminous mix. This study is mainly focusing on the Superpave graded bituminous mixes. The various factors such as, Stability, Flow, Voids in Mineral Aggregates (VMA), Voids in Filled Bitumen (VFB) and Air Voids (Va) are compared with Marshall hammer and Hugo Compactor. **Applications/ Improvements:** In this Study it suggest that, the using of Hugo Hammer gives improving in strength and Increasing effects in Volumetric Analysis.

Keywords: Marshall Hammer and Hugo Compactor, Superpave, VMA, VFB, Va,

1. Introduction

The optimum binder content for volumetric studies between Superpave and Marshall Method were found to be 4.4 and 5.1 percentage. The Superpave mix proves lower results compared with Marshall Method. The lowest value 0.7% of binder content of Superpave is arrived in stability test. Superpave gives 60% higher fatigue life and 25% higher resistance to rutting. Hence it has been concluding that the Superpave mix gives betterment results which can be used for hot climate and in heavy traffic condition[1]. Superpave mix shows excellent results in accumulated strains. The percentage of accumulated strains for Superpave gives 0.14 at 25°C, 0.145 at 40°C, and 0.404 at 25°C. For Marshall Mix gives 1.673 at 25°C, 2.965 at 40°C, and 3.694 at 25°C. It helps to be resistant to the effect of water penetratio[2]. The OBC for Marshall and Superpave for 4% Air Voids shows equal results (6.6% and 6.5%), So there is slight variation of 0.1%. When TSR shows the 91.92% for Marshall and 93.12% for Superpave, these results gives gradual variation between the mix[3]. In Hot Mix Asphalt (HMA) the OBC corresponding to 4% Air Voids Superpave gives 5.25% and Marshall gives 5.5%, the variation between the two mixes is 0.25%. The Superpave Lower grade trail gives better results compared to Marshall Lower grade. The lower gradation trial gives better results, due to coarser gradation selection[4].

The asphalt binder content is determined from the Superpave is superior to Marshall mixes, But, it is not fully applied to all common places in Thailand. It is suggested that, recommendation is made with adjustment in Superpave mix[4]. In flexible pavement, the design mix for pavement surfaces should meet the MORTH specification and gives a good riding comfort, also it must meets the various general requirements such as frictional characteristics, permeability, tire and pavement wear, segregation,

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raveling, appearance, light reflectance, and noise[5]. The Shape and Size of aggregates and binder are characterized to the rutting characteristics of a dense graded surface of HMA mixture with the nominal maximum size. The 12.5 mm size has a strangest correlation with the rut depth, whereas the coarse aggregate will have more angularity value and it has more voids[6]. The mix design is purely depends on the properties of aggregates and proportions of various aggregate sizes and bitumen content.

1.2 Need for the Study

The Superpave design mix gives an Improving wheel-tracking resistance and Stability in high temperature of bituminous pavements and it helps to increase the life of the pavement. It gives the improving the spalling resistance, resistance abrasion, resistance against reflection cracks and the toughness in the low temperature.

1.3 Objectives

- To evaluate the effect of shape of aggregate on Superpave graded bitumen Mixes on the following properties. 1. Optimum bitumen content. 2. Voids in Mineral aggregates. 3. Voids in Filled Bitumen. 4. Air voids. 5. Stability 6. Flow.
- To identify the maximum permissible percentage of Flaky, Elongated and Combine Flaky and Elongated Aggregates for obtaining better performance in Superpave graded bitumen mixes.

1.4 Superpave

In recent generation a new method is used to optimize the various materials to suit the environmental condition is Superpave (**Su**perior **Per**forming Asphalt **Pave**ments). Superpave was first developed by SHRP (**S**trategic **H**ighway **R**esearch **P**rogram) between the years 1987 to 1993. The product is developed to achieve the maximum results in different process, considering the asphalt binder, aggregate selection, traffic and climatic condition; theses are four basic steps to be followed for preparation of moulds. This can produce the better results in low temperature and thermal fatigue cracking etc.

The basic Steps involved in the Superpave mix design are

- Selection of Material.
- Selection of design aggregates structure.
- Selection of Binder content according to climatic condition.
- Evaluating the performance of mixture for moisture sensitivity.

Superpave mix design is also suitable for existing road condition. If the existing road is severely damaged by cracks, potholes and ruts. Then it is categorized by severity levels, and it is surveyed by Pavement Condition Index through field data[7]. The damaged existing road is excavated and a new surface is laid. Superpave gives sufficient pavement thickness and improving the spalling resistance, resistance abrasion, resistance against reflection cracks and the toughness in the low temperature.

1.5 Superpave Mix Design

The highlight of the Superpave mix is changing the compaction technique in Laboratory test methods. The usage of Gyratory Compactors (SGC) in Laboratory, gives the betterment results compared with field condition. SGC shares some traits with existing gyratory compactors, but it has completely new operational characteristics. The SGC will give appropriate information about the compactability of the mixture during compaction. The SGC is used in laboratory test, so that there is no change in the mix and it gives satisfactory results in low air void contents under traffic action. Superpave contains new requirements selection for gradation and aggregates used in design mix.

1.6 Control Points

The gradation limits has a basic Control points which may function on different ranges, whereas as the gradation line should pass through it. These Control points are correlated in different size, first it has chosen as nominal maximum size, and secondary it has chosen an intermediate size of 2.36 mm and the smallest size of 0.075 mm are placed. The formation of new gradation will occur with these any Control points based on the nominal maximum aggregate size of the design mixture and it is controlled by the base line formed for 12.5 mm gradation.

1.7 Restricted Zone

Within the maximum density line, the restricted zone is strictly maintaining the intermediate size between 2.36 mm and 0.3 mm size, with these ranges the new gradation line ought to pass below the restricted zone. Before arrive the gradation, the aggregate are mandatorily tested and it has to be evaluated for forming design aggregates structures. If these aggregates structures lies between the controls points, hence it has to meets to form Superpave requirements. The gradation limits for 12.5 mm Sieve Size of various controls points are shown in Figure 1.

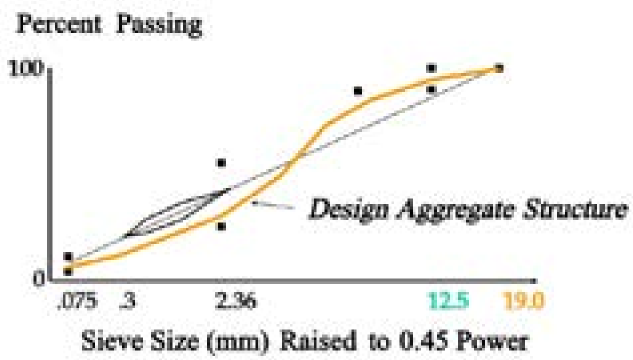

Figure 1. The 12.5 mm Sieve size raised to 0.45 power.

1.7.1 Maximum Size

Normally the density line will plot a straight line which may pass between maximum size and Nominal maximum size. The size one which is larger than nominal maximum size is said to be Maximum size.

1.7.2 Nominal Maximum Size

Even though the size is differentiated, the one sieve size larger is manage to retain more than 10% of first sieve is accepted as Nominal Maximum Size.

In restricted zone the formation of group will be assigned and strictly maintained the gradation not to pass over it. If a gradation is passing in restriction zone, then is called as humped gradation. In Superpave gradation the aggregates lies between these sizes are justified and said as hummed gradation. While Superpave originally recommended that gradations pass below the restricted zone, it is not a requirement. But in case of several highways agencies are successfully chosen the grade which is passing the restricted zone. The agencies has more experience to overcome the situation and gives a satisfactory results even it is passed in restricted zone. Before using such gradations, it is recommended that experience or testing be evaluated to determine if the particular aggregate structure performs satisfactorily (adequate VMA, non-tender mix behaviour, etc). Promptly before choosing gradation, it is to identify the basic feature which is specified or maintained in the 0.45-power chart. Asphalt institute arrive 0.45-power chart to fulfill the gradation of Superpave gradation mix.

1.8 Asphalt Institute Superpave Gradation for 12.5 mm

$$\textbf{Passing}\ (\textbf{P}\ \%) = \left[\frac{(100-F)\,(d^n - 0.075^n)}{(D^n - 0.075^{n})}\right] + F \qquad (1)$$

Where,

P = % Passing sieve size‘d’ (mm).

D = Max aggregate size (12.5mm).

F = % Filler (5%).

n = 0.45.

The gradation of 12.5 mm sieve is shown Table 1. And clearly explains the percentage passing in Superpave 12.5 mm, which is derived from the Asphalt Institute Superpave gradation for 12.5 mm in Equation (1). The values 0.45 power table is prepared in the form of graph is plotted with respect to percentage passing and sieve size.

Table 1. Superpave gradation for 12.5 mm

Size (d) mm	D	Passing (P %)	Cumulative % Retained	% Retained	12.5 mm	
					Min	Max
19		-	-	-	100	
12.5	12.5	100	0	0	90	100
9.5	12.5	87.736	12.26	12.26		90
4.75	12.5	62.737	37.26	25		
2.36	12.5	44.29	55.71	18.45	28	58
1.18	12.5	32	68	12.29	25.6	32
0.6	12.5	24	76	8	19.1	23
0.3	12.5	16	84	8	15.5	16
0.075	12.5	5	95	11	2	10
Pan				5		

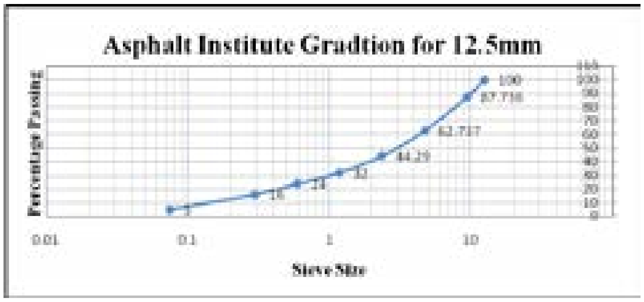

Figure 2. The 12.5 mm sieve size raised to 0.45 power.

In Figure 2 Shows, the 0.45 power chart of 12.5 sizes is derived from the Asphalt Institute. In case, a trial blend shows the curve which is closer to the maximum % passing of the nominal size and lay below the restricted zone, then it is said to be a fine blend.

2. Hugo Compactor

Hugo hammer is the one which gives equivalent value derived from the field compaction. The base of the Hugo Hammer is 100/150 mm diameter and it has a rotating base which is shown in Figure 3. The Hugo Hammer has indents at the bottom base side with 30º angle faced hammering over the surface. Indents depth is measured as 3 mm/6 mm as shown in Figure 4 with an angle 30º. This will provide a shearing action to the mix. The specimen is prepared with Marshall Method and is compacted with Hugo Hammer. According to IS Specification binders are classified according to their physical properties and their performance.

Figure 3. Hugo hammer.

Figure 4. Hugo compactor showing indents.

2.1 Materials

2.1.1 Binder

Bitumen is available in a variety of types and grades. Bitumen is normally used 5 to 6 % of the total mixtures. The properties of binders are often improvised by adding modifies or other ingredients to balance the flow, oxidation and elasticity etc. Bituminous binder used in this study is VG30 grade bitumen obtained from Hindustan Petro Chemical Limited (HPCL) Chennai. The viscosity grade properties are derived in Table 2.

Table 2. Physical properties of bitumen

Test	Results	Specifications	Specifications
Penetration (mm) @ 25º C	59	50 to 70	IS 1203: 1978
Flash Point, °C	230°	220	IS 1209: 1978
Ductility at 25°C	65	40	IS 1206(part 2): 1978
Specific Gravity at 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(part 2): 1978

2.1.2 Aggregate

Aggregates are the most influence factor to be considered in bituminous mix; hence it has the great extent of transferring the load to the sub-grades. About 95% by weight is taken by aggregate, while the structure formation plays a vital role in terms of gradation. The aggregate were collected from Tambaram quarry, Chennai, India. All the size of the aggregates are collected and washed and dried. These aggregates were used for preparing the trail bends to meet the aggregates gradation. The aggregate property is shown in Table 3.

Table 3. Physical properties of aggregates

Test	Test Results	Specifi - cations	Speci - fications
Aggregate Crushing Value	30% Max	15.48	IS: 2386
Aggregate Impact value	30% Max	16.72	IS: 2386
Specific Gravity - Coarse	-	2.77	IS: 2386
Specific Gravity - Fine	-	2.67	IS: 2386
Water absorption	2% Max	0.18	IS: 2386
Los Angeles Abrasion	30% Max	13.45	IS: 2386

2.1.3 Observations

The both Marshall Mix and Superpave design is analyzed with MoRTH Specification. The various factors such as, Stability, Air Voids (Va), Voids in Mineral Aggregates (VMA), Voids in Filled Bitumen (VFB) and Flow values are calculated for each specimen. The mean Value of both Marshall and Superpave specimens are prepared using different binder content are tabulated in Table 4 and Table 5.

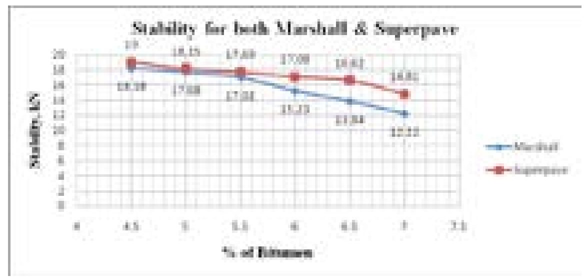

Figure 5. Stability values as per MoRTH specification.

2.1.4 Graphs

The specimens are tested in Marshall Stability testing equipment and values are interpolated. The results are tabulated and graphs are plotted with bitumen content on the 'X' axis and 1. Density 2. Marshall Stability. 3. Flow

Table 4. Mean values for Marshall method

No of Sample	Bitumen Content	Bulk Density	Stability	Flow	Va	VMA	VFB
3	4.5	2.39	18.18	2.95	4.21	14.4	70.87
3	5	2.33	17.68	3.21	5.82	16.82	65.81
3	5.5	2.32	17.02	3.47	5.73	17.7	67.61
3	6	2.37	15.23	3.63	2.75	16.06	83.02
3	6.5	2.34	13.84	4.51	2.78	17.04	83.69
3	7	2.29	12.22	4.98	4.9	19.78	75.2

Table 5. Mean values for Superpave method

No of Sample	Bitumen Content	Bulk Density	Stability	Flow	Va	VMA	VFB
3	4.5	2.33	19	2.91	6.88	16.39	60.7
3	5	2.31	18.15	3.23	5.12	17.75	61.29
3	5.5	2.32	17.69	4.23	4.2	17.64	67.89
3	6	2.34	17.08	4.26	3.78	17.29	76.06
3	6.5	2.36	16.62	5.36	2.79	17.04	83.89
3	7	2.35	14.81	6.18	2.44	17.67	86.28

Value. 4. Air Voids (Va). 5. VFB and 6. VMA on 'Y' axis plotted. For calculating the optimum binder content only Individual value of 1. Maximum density. 2. Maximum Stability. 3. Mid range of recommended flow value. 4. Mid range of recommended voids content are determined.

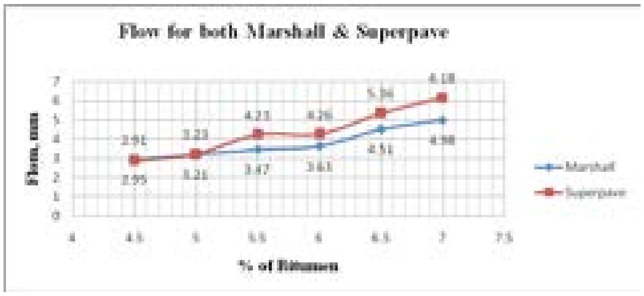

Figure 6. Flow values as per MoRTH specification.

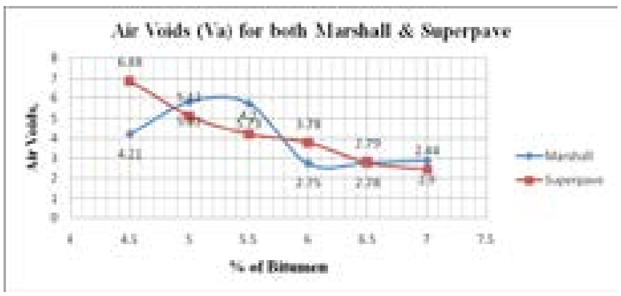

Figure 7. Air voids values as per MoRTH specification.

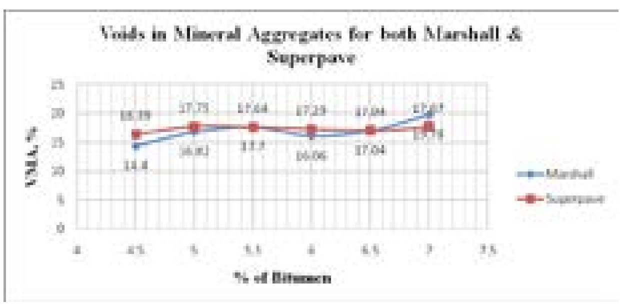

Figure 8. VMA values as per MoRTH specification.

2.2 Results and Discussion

A comparison of results between Marshall and Superpave is differentiated in Figure 4. to Figure 9. In Table 6. it shows that, the Superpave gradation gives better performance compared to Marshall Method. For Both Marshall Method and Superpave Gradation mix, Optimum Bitumen is derived from Air voids 4%. Optimum Bitumen content is determined form 6 trials batches varying from 4% to 7% percentage increasing of 0.5% difference. The corresponding Value with respect to 4% Air voids for Marshall Mix is 5.7%. Whereas the Superpave corresponding to 4% Air Voids is 5.5%. Therefore, the result shows the variation of 0.2% decreased value compared to Marshall Mix.

3. Conclusion

This research is to find out the effect of gradation between Marshall and Superpave bituminous mix. This trial mix is focusing on stability, flow values an optimum binder content. A comparison is carried out by using locally available material in Tambaram Quarry.

- All the Specimen are prepared only in the Tambaram quarry.
- Local aggregates are also suitable in Superpave graded bituminous mix.
- Local aggregates are recommended for Indian condition with proper design standards.
- Superpave showed better results compared to Marshall method.
- Choice of bitumen is the major one to be considered in this Superpave mix design. Ensure that a proper bitumen is so selected for the design mix. Viscosity Grade (VG30) is Suitable for Southern region.

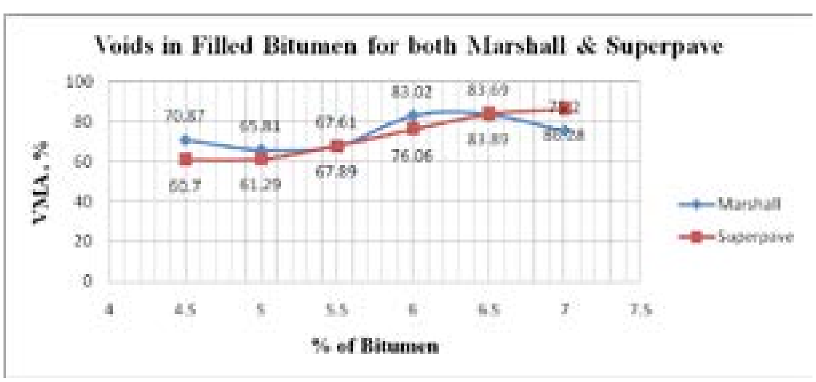

Figure 9. VFB values as per MoRTH specification.

4. Acknowledgements

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