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A Comparative Study on The Effect of Compaction on Strength and Physical Properties of Stone Matrix Asphalt Compacted by Marshall Compaction and SUPERPAVE Gyratory Compaction Methods.

KEYWORDS: Stone Matrix Asphalt (SMA), Gyratory Compactor, Marshall Method of compaction, Tensile Strength Ratio (TSR).

Yateen Lokesh	Dr. M. S. Amarnath	Dr. Manjesh. L
Assistant Professor, Department of Civil Engineering, Acharya Institute of Technology, Bangalore-107	Professor, Department of Civil Engineering, University Visveshwaraiah College of Engineering, Bangalore University, Bangalore.	Associate Professor, Department of Civil Engineering, University Visveshwaraiah College of Engineering, Bangalore University, Bangalore.

ABSTRACT *The last decade has witnessed a dramatic increase in vehicular traffic on roads in a developing country like India. This has raised additional traffic, augmented axle loads and increased tire pressure on pavements designed for earlier era. In this regard, besides considering increasing the pavement thickness due to the traffic loads, steps must also be taken to extend the pavement life by using different compaction methods such as gyratory laboratory compaction method to have durable mix and better simulate field conditions. Studies have been done to compare both laboratory compaction methods to verify different findings according to different conditions and climate. In this study Marshall Specimens were prepared for Stone Matrix Asphalt Mix (SMA) according to MORT&H – 2009 specifications with 80/100 neat bitumen by both Marshall Compaction and SUPERPAVE gyratory compaction methods and studied for changes in volumetric properties, and OBC obtained. The results obtained in this study shows that there is no substantial change in the OBC obtained from both the compaction methods. It was also seen that there was slight reduction in the percentage voids of the total mix when compacted by SUPERPAVE gyratory compactor when compared to the Marshall Compaction method due to better compaction and rearrangement of particles. There was also a slight increase in VMA during gyratory compaction as compared to the Marshall Compaction method. The percentage voids in the total mix was found to decrease with the increase in the binder percentage. But the voids filled by mineral aggregates and voids filled by bitumen was found to increase with the increase in binder content in both the cases. Tensile Strength Ratio (TSR) for Marshall Specimens prepared at OBC of 6.6% by both Marshall compaction and Gyratory compaction was compared and was found that TSR for gyratory compacted specimens was more than Marshall compacted specimens by 1.20% . The percentage drain down for the mix prepared at OBC was found to be just 0.15% which was within the limits with the maximum permissible limit of 0.3% according to MORT&H – 2009 specifications. It was also found that standard 50 gyrations in gyratory compactor for SMA Mix had to be increased to 75 gyrations for better compaction equivalent to 50 blows on either side in Marshall Compaction and to attain similar volumetric properties as that of Marshall compacted specimens.*

Introduction
The last decade has witnessed a dramatic increase in vehicular traffic on roads in a developing country like India. This has raised additional traffic, augmented axle loads and increased tire pressure on pavements designed for earlier era. In this regard, besides considering increasing the pavement thickness due to the traffic loads, steps must also be taken to extend the pavement life by using different compaction methods such as gyratory laboratory compaction method to have durable mix and better simulate field conditions. In this study Marshall Specimens were prepared for Stone Matrix Asphalt Mix (SMA) according to MORT&H – 2009 specifications with 80/100 neat bitumen by both Marshall Compaction and SUPERPAVE gyratory compaction methods and studied for changes in volumetric properties, and OBC's obtained.

Objectives of the Present Study
The main objective of this study was to carry out Marshall Mix design for SMA Mix according to MORT&H – 2009 gradation and specifications and prepare Marshall Specimens using Marshall Compaction method and SUPERPAVE gyratory compaction method and to compare the OBC obtained from the two methods. The next objective was to compare the Tensile Strength Ratio (TSR) and volumetric properties like percentage voids (Vv), (Vb), voids filled by mineral aggregates (VMA), voids filled by bitumen (VFB) of the specimens compacted using both Marshall and SUPERPAVE gyratory compaction technique and also to carry out Drain down test on the Marshall Mix prepared to the obtained OBC.

Methodology
The aggregate obtained from the quarry was sieved to separate the aggregate into different sizes for later use. Aggregate blend satisfying the mid gradation limits as in Table.1 were used after checking its suitability as per the specifications as mentioned in Table.2. This series also involves basic tests on 80/100 penetration grade bitumen for its suitability for the study as per the MORT&H specifications and the results of the same is mentioned in Table.3.

Table.1 Typical Grading Requirements for SMA as Per MORT&H - 2009

Sieve Size IS (mm)	Percentage passing (mid limits)
26.5	100
19	100
13.2	95
9.5	62.5
4.75	24
2.36	20
1.18	17
0.600	15
0.300	15
0.075	10

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Table.2 Results of test on Aggregate

Sl. No	Tests	Result	Requirements as per MORT&H - 2009
1	Aggregate crushing value (%)	24.71	25% maximum
2	Aggregate impact value (%)	11.6	18% maximum
3	Aggregate Specific Gravity 1. Coarse aggregates 2. Fine aggregates	 2.683 2.750	 2.58 minimum
4	Water absorption (%)	0.52	2% maximum
5	Los Angeles Abrasion Value (%)	18.4	30% maximum
6	Flakiness and Elongation index (combined) (%)	28.5	30% maximum (combined)

Table.3 Physical properties of neat bitumen 80/100

Sl. No	Characteristics	Test results
1	Penetration at 25^0 C,0.1 mm, 100gm, 5sec	90.33
2	Softening point (R&B), (^{0}C), min	44.5
3	Specific Gravity	1.01
4	Flash & Fire point,^{0}C	230, 255
5	Separation difference in Softening Point R&B, ^{0} C, max	2
6	Ductility @ 27^{0}C, cm	97

The second series involved the mix design. A total of 24 specimens (12 for Marshall and 12 for SUPERPAVE Gyratory compaction) were prepared to find and compare the optimum binder content (OBC) from both the compaction methods taking four different binder percentages 5.5, 6, 6.5, and 7. The OBC was obtained by taking average of the binder percentage for 4% air voids and maximum bulk density. The specimens were prepared by giving 50 blows on either side during Marshall Compaction and 75 gyrations were used to prepare specimens in SUPERPAVE gyratory compactor instead of 50 gyrations for better compaction. The specimens from both the methods were compared for percentage voids (Vv), (Vb), voids filled by mineral aggregates (VMA), voids filled by bitumen (VFB). Indirect tensile strength (ITS) test was also conducted on the specimens prepared from both the methods to the obtained OBC to compare the Tensile Strength Ratio (TSR). This series also involved Drain down test to find the percentage drain of bitumen from the standard Marshall Mix according to the specifications to the obtained OBC.

Results and Discussions

Figure1. Bulk Density Vs Percentage Binder

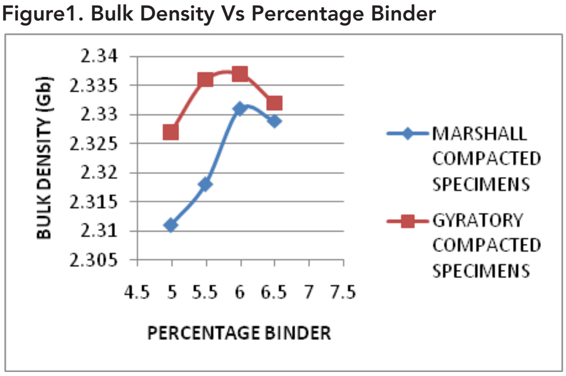


Figure2. Voids in total Mix Vs Percentage Binder

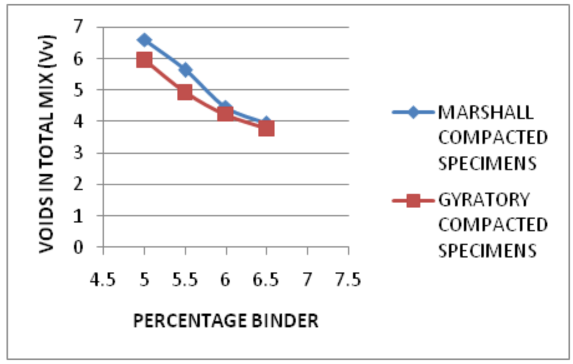


Figure3. Volume of Bitumen Vs Percentage Binder

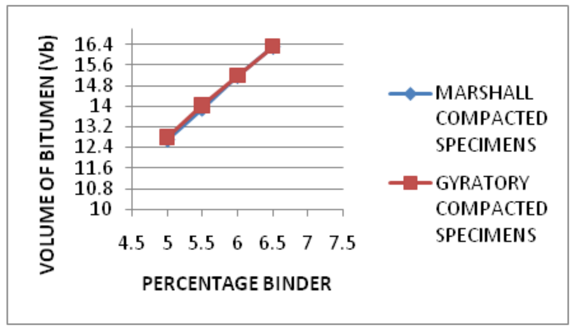


Figure4. Voids in Mineral Aggregates Vs Percentage Binder

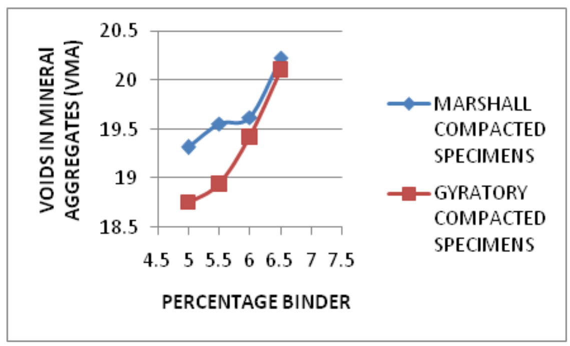
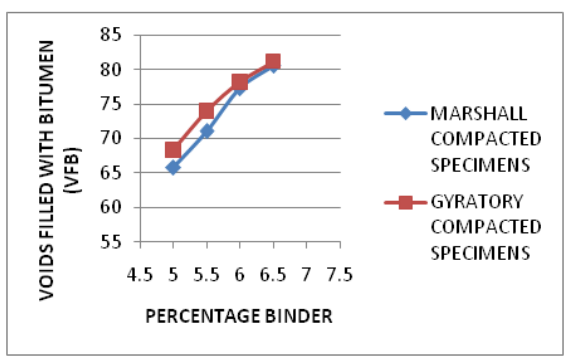


Figure5. Voids Filled with Bitumen Vs Percentage Binder



From the above results the OBC found by Marshall Compaction is 6.50% and that by SUPERPAVE gyratory compaction is 6.60% respectively. Similarly the TSR were 91.92% and 93.12% respectively as shown below. The percentage drain down was also found to be 0.15% satisfying the permissible limit of maximum 0.3% according to the specifications.

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Table 4. TSR for gyratory compacted specimens

GYRATORY COMPACTION				
SAMPLE	CONDITIONED		UNCONDITIONED	
	DIVSIONS	St (N/mm2)	DIVSIONS	St (N/mm2)
1	14	3.90	15.4	4.21
2	14.2	3.96	15.2	4.24
TSR 93.12%				

Table5. TSR for Marshall compacted specimens

MARSHALL COMPACTION				
SAMPLE	CONDITIONED		UNCONDITIONED	
	DIVSIONS	St (N/mm2)	DIVSIONS	St (N/mm2)
1	13.8	3.85	15	4.18
2	14	3.9	15.2	4.24
TSR 91.92%				

- The results obtained in this study shows that there is no substantial change in the OBC obtained for 4% air voids from both the compaction methods (i.e. 6.6% for Marshall compacted specimens and 6.5% for gyratory compacted specimens) and varied only by 0.1%. This shows that numbers of gyrations taken are reasonable in comparing with 50 blows in Marshall.
- It was also seen that there was slight reduction in the percentage voids of the total mix when compacted by SUPERPAVE gyratory compactor than compared to the Marshall Compaction method due to better compaction and rearrangement of particles as projected in Figure2.
- There was also a slight increase in VMA during gyratory compaction as compared to the Marshall Compaction method with a minimum permissible value 17% in both the cases according to the specifications as seen in Figure4 while voids filled with bitumen was found to increase with the increase in binder content in both the case as seen in Figure5.
- Tensile Strength Ratio (TSR) for Marshall Specimens prepared to the obtained OBC of 6.6% by both Marshall compaction and Gyratory compaction was compared and was found that TSR for gyratory compacted specimens was more than Marshall compacted specimens by 1.20% respectively and the same has been projected in Table4 and Table5 respectively.
- The percentage drain down for the mix prepared to the obtained OBC was found to be just 0.15% which was within the limits with the maximum permissible limit of 0.3% according to MORT&H – 2009 specifications.
- The numbers of Marshall Blows were not equivalent to the number of gyrations.
- It was also found that standard 50 gyrations in gyratory compactor for SMA Mix had to be increased to 75 gyrations for better compaction equivalent to 50 blows on either side in Marshall Compaction and to attain similar volumetric properties as that of Marshall compacted specimens.
- In all it can be said that SUPERPAVE gyratory compactor can be used to produce realistic specimens which compared favorably to in-service mixtures after traffic compaction. This method of compaction can also be used to simulate the increasing loads and tire pressures of vehicles operating on the pavement. Prior to this compaction technique, it was not possible to achieve a realistic field density in laboratory specimens.
- But the main drawback is that the number of gyrations required equivalent to the number of Marshall Blows has to be found out for every mix because it varies from place to place depending on the aggregate properties. Numbers of trials have to be carried out to find the optimum number of gyrations to compact the specimens of a particular mix to arrive at similar properties as when compacted by Marshall Method.

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