SCIENCE VISION
Volume 2023, issue 2, pages 25–28
30 Jun 2023
https://doi.org/10.33493/scivis.23.02.01

RESEARCH ARTICLE

Effect of rock gradation in Stone Matrix Asphalt using Coir Fibre

Lalramdinsangi*, **Lalawmpuii, H. Laldintluanga**

Department of Civil Engineering, Mizoram University, Aizawl, 796004, India

Stone Matrix Asphalt (SMA) was introduced to counter heavy traffic and loading due to its better rut resistance. This study aims to determine the effect of rock gradation on SMA, water susceptibility, tensile strength, and retained tensile strength. The methods adopted for testing include the physical properties of rock and bitumen, the Marshall Stability Test, and the Water Sensitivity Test. Coir fibre is used in SMA to prevent draining as an alternative to cellulose fibre. The study shows that coir fibres satisfy the drain-down requirement for both 13 mm and 19 mm gradations, respectively. Laminate sedimentary rock aggregate used in SMA is susceptible to water. A larger size of gradation has achieved higher retained tensile strength, mainly due to the lesser degradation that develops in bituminous concrete

Received 15 May 2023
Accepted 28 June2023

*For correspondence:
lalramdinsangi8920@gmail.com

Contact us:
sciencevision@outlook.com

Keywords : Coir fibre, rock gradation, stability, stone matrix asphalt, water sensitivity

Introduction

The gradation of the particles determines the stone matrix asphalt. Gradation enhances material performance and the bonding capability of the mix. Material gradation must improve the hardness of the surface course.[1] It is critical to understand the Nominal Maximum Aggregate Size (NMAS) since it will affect performance and should be chosen depending on pavement requirements.[2] When compared to smaller sizes over the same volume of rock, larger aggregate sizes can withstand more repetitive impact stress, have stronger strength due to the individual thickness of the aggregate, and have less water absorption due to the reduced surface area. The existence of larger aggregate sizes aids in the attainment of greater density and strength.[3,4]

Stone Matrix Asphalt (SMA) is a feasible technique that can be employed in India, particularly for the high and growing traffic in India.[5] SMA mixtures are composed of interlocked coarse aggregate particles that transfer loads. The combinations with stone-to-stone contact had superior rutting properties.[6,7] Fibres increase the adherence of aggregate stone to aggregate stone and reduce the drain down of binders, resulting in a more durable product.[8] The addition of fibre to bituminous mixtures changes their properties by increasing their stability and flow value while decreasing the air voids.[9,10] The choice of filler, binder, and stabiliser had a major impact on the asphalt's ability to drain away.[11] Variations in fibre type and content can have a significant impact on how well SMA ruts.[12,13] Using coir as fibre offers a significant level of stability for a non-traditional fibre when taking into account all the features and parameters of the SMA mix. When fibre content is increased in stabilised mixtures, the stress-strain curves shape changes more gradually, and brittle-type failure does not appear to occur as in the case of control mixtures.[14,15] Coir fibre are affordable option for SMA construction and can be employed to efficiently increase SMA mix stability.[16]

Stone Matrix Asphalt (SMA) is a gap-graded combination that depends on stone-to-stone contact for strength and a thick mortar binder for durability. Since aggregates make up between 70% - 80% of the whole mix; they play a crucial role in giving SMA Mix strength. The right amount of coarse aggregate in the mix generates a skeleton-like structure that improves aggregate-to-aggregate

ISSN 0975-6175 (print) /2229-6026 (online) | CODEN SVCIC9

interaction and increases shear strength and rutting resistance, which is a key attribute for SMA. The drain down of binder in Stone Matrix Asphalt can result in the occurrence of fat spots on the surface. Therefore, fibres are added to prevent the drain down of the binder as well as to increase its tensile strength as asphalt pavement can easily crack under traffic load and low-temperature environment.

Materials and Methods

Aggregate samples were taken from Hlimen Quarry. Bitumen of VG-30 is used as per the specification of IRC SP 079. The selected stabilizer i.e., coir fibres were cut into small pieces of about 3 mm. Bitumen, coarse aggregate, and fine aggregate are the components of the bituminous mixes.

The physical properties of rock tests such as The Aggregate Impact Value (AIV), Los Angeles Abrasion Value (LAAV), Specific Gravity (SG), Water Absorption (WA), and bitumen and asphalt concrete test such as ductility, penetration, softening point, Marshall Stability Value and Water Sensitivity test were used to evaluate the influence of rock gradation on SMA, water susceptibility, and tensile strength and retained tensile strength. Preparations of SMA grade I & II for Marshall Stability and Tensile strength were done as per MoRT&H[17] and ASSHTO T 283[18].

Results

Effect of Gradation of SMA

The tests carried out for both grades show that the 19 mm grade shows better performance in terms of stability and retaining tensile strength. However, in 19 mm gradation, the gap produced is larger than in 13 mm gradation, and as a result, the drain-down of asphalt is slightly higher than that of 13 mm but is kept within the specification.

In the Marshall Stability Test, results have shown that the larger size of aggregate has a higher result as compared to the smaller size of aggregate, as shown in Table 1. This could be justified by the stone-to-stone contact of the coarse aggregate, wherein as the coarse aggregate volume grows, stone-to-stone contact is developed. This stone-to-stone skeleton structure increases the internal strength and therefore the load resistance is more.

Meanwhile, the Indirect Tensile test has given a lower value with a larger particle size that may be due to weak bonding between the binder and the aggregates when the tensile load is applied.

Influence of water in SMA using water sensitivity analysis

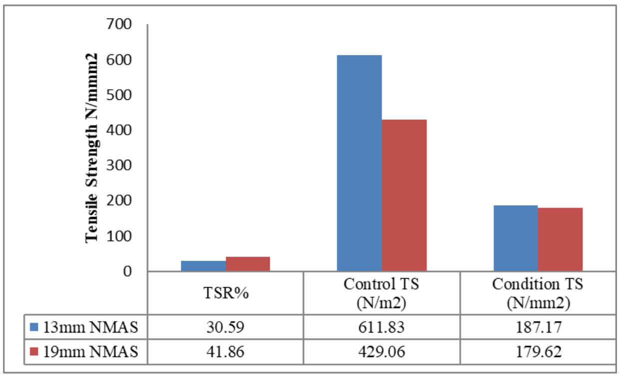

Figure 1: Indirect Tensile Test

There is a significant reduction in tensile strength for both grades after the SMA sample undergoes the freeze-thaw cycle. The reduction in strength is mainly due to the high-water absorption of aggregate as well as the presence of small sequences in rock aggregate. The retained tensile strength values in 19 mm and 13 mm are 41.86% and 30.59%, respectively. The larger gradation has achieved higher retention strength as the aggregate degrades less when wheel load is applied, as shown in Figure 1.

Table 1: Marshall Stability Test on SMA

SMA 13 mm	% binder	Gb	Gt	Vv	Vb	VMA	VFB	Stability in Kg	Flow mm
S1	6.50	2.33	2.43	3.90	14.87	18.77	79.23	737	4
S2	6.50	2.33	2.43	4.03	14.85	18.88	78.65	642	5
S3	6.50	2.34	2.43	3.66	14.91	18.56	80.30	655	6
Average	**6.50**	**2.33**	**2.43**	**3.86**	**14.87**	**18.74**	**79.40**	**678**	**5**
SMA 19 mm	**% binder**	**Gb**	**Gt**	**Vv**	**Vb**	**VMA**	**VFB**	**Stability in Kg**	**Flow mm**
S1	6.50	2.26	2.43	6.72	14.43	21.16	68.22	874	6
S2	6.50	2.32	2.43	4.43	14.79	19.22	76.95	969	5
S3	6.50	2.17	2.43	10.82	13.80	24.62	56.04	683	6
Average	**6.50**	**2.25**	**2.43**	**7.32**	**14.34**	**21.66**	**67.07**	**842**	**5.67**

The SMA is susceptible to water as the retained tensile strength value is less than the prescribed value of 85% as per IRC SP-079[19] due to the presence of highly degradable of rock used.

Discussion

A larger gradation of aggregates produces more stability due to the development of stone-to-stone contact, which increases the internal strength of the SMA mixture. Both SMA gradations satisfied the drain-down requirements and indicate that coir fibre can be used as an alternative to cellulose fibre to prevent drain-down.

A bituminous concrete with a finer gradation (13 mm NMAS) provides better tensile strength over a coarser gradation (19 mm NMAS), as the bituminous mix can be packed more densely due to the finer aggregate particles. Meanwhile, a larger size of gradation (i.e., 19 mm max. nominal size) has achieved higher retained tensile strength compared to a 13 mm gradation, mainly due to the less degradation that develops in a bituminous structure.

The reduction of tensile strength after an SMA sample undergoes the freeze and thaw cycle (weathering action) both in 19 mm and 13 mm gradations is mainly due to the high-water absorption of aggregate as well as the presence of a small sequence of rock layers.

The performance of laminate sedimentary aggregate cannot achieve the minimum retained tensile strength value, mainly due to the low resistivity of weathering action. This indicates that the laminated sandstone aggregate used in the SMA is susceptible to water and not recommended for SMA.

Acknowledgment

We thank the Department of Civil Engineering, Mizoram University for allowing us to perform laboratory work.

References

1. Devulapalli, L., Sarang, G., Kothandaraman, S. (2022). Characteristics of aggregate gradation, drain down and stabilizing agents in stone matrix asphalt mixtures: A state of art review. *Journal of Traffic & Transportation Engineering (English Edition)*, **9(2)**, 167-179. https://doi.org/10.1016/j.jtte.2021.10.007

2. Chiranjeevi, G. (2018). Analysis of Stone Matrix Asphalt (SMA) with Interactive Properties of Gradation. International *Journal for Modern Trends in Science and Technology*, **4(4)**,83-87. http://www.ijmtst.com/volume4/issue4/15.IJMTST040432.pdf

3. Sarang, G., Lekha, B. M., Geethu, J. S., Ravi Shankar, A. U. (2015). Laboratory performance of stone matrix asphalt mixtures with two aggregate gradations. *Journal of Modern Transportation*, **23(2)**, 130-136. https://doi.org/http://dx.doi.org/10.1007/s40534-015-0071-5

4. Laldintluanga, H., Ramhmachhuani, R., Ralte, Z. (2023). Rock Aggregate Size Influence on Physical Degradation of Laminate Sedimentary Rocks in Flexible Pavement. *Journal of Geosciences Research*, **8(2)**, 127-132. https://www.gondwanags.org.in/jgsr-vol-8-no-2-july-2023/

5. Talati, A., Talati, V., Mehta, J., Dr. (2014). Study of Stone Matrix Asphalt For The Flexible Pavement. International *Journal of Engineering Development and Research*, **2(1)**, 789-792. https://www.ijedr.org/papers/IJEDR1401143.pdf

6. Krzysztof, B. (2016). 'Stone Matrix Asphalt – Theory and Practice'. Boca Raton London New York, CRC Press, 43.

7. Qui, Y. F., Lum, K. M. (2006). Design and Performance of Stone Mastic Asphalt" Methodology and design. *Journal of Transportation Engineering*, **132(12)**, 956-963. https://doi.org/10.1061/(ASCE)0733-947X(2006)132:12(956)

8. Razahi, M. M., Chopra, A. (2020). A Review of Using Sisal Fiber and Coir Fiber as Additives in Stone Matrix Asphalt. *International Research Journal of Engineering and Technology*, **7(2)**,1692-1697. https://www.researchgate.net/publication/343230947_A_Review_of_Using_Sisal_Fiber_and_Coir_Fiber_As_Additives_In_Stone_Matrix_Asphalt

9. Venkatesh V, U. M., Prasad S, S. G. (2018). A Review on Stone Matrix Asphalt by Using Stabilizing Additives. *International Journal of Technical Innovation in Modern Engineering & Science*, **4(8)**, 162-166. https://www.ijtimes.com/IJTIMES/index.php/ijtimes/article/view/737/690

10. Vale, A. D., Casagrande, M. D. T., Soares, J. B. (2013). Behaviour of Natural Fiber in Stone Matrix Asphalt Mixtures Using Two Design Methods. *Journal of Materials in Civil Engineering*,

26(3), 1-44. https://doi.org/http://dx.doi.org/10.1061/(ASCE)MT.1943-5533.0000815

11. Kadali, R. B., Chowdary, V. (2013). Performance evaluation of stone matrix asphalt (SMA) using low cost fibres. *Journal of Indian Roads Congress*, **74 (2),** 159-174. https://www.researchgate.net/publication/274709862_Performance_evaluation_of_stone_matrix_asphalt_SMA_using_low_cost_fibres

12. Behbahani, H., Nowbakht, S., Fazaeli, H., & Rahmani, J. (2009). Effects of Fiber Type and Content on the Rutting Performance of Stone Matrix Asphalt. *Journal of Applied Sciences*, **9(10)**, 1980-1984. https://doi.org/10.3923/jas.2009.1980.1984

13. Satyavathi, M., Rao, B. S., & Rao, G. V. (2016). Experimental Study of Stone Matrix Asphalt with Coir Fiber and Pineapple Fiber. *International Journal of Engineering Sciences & Research Technology*, **5(11)**, 378-385. https://doi.org/10.5281/zenodo.167081

14. Shekar, P. C., Rajath, B. H., Vishwas, J. S. (2018). Experimental Investigation of Stone Mastic Asphalt by Varying Mix Design. *International Research Journal of Engineering and Technology*, **5 (5)**, 300-305. https://www.irjet.net/archives/V5/i5/IRJET-V5I559.pdf

15. Bindu, C. S., Beena, K. S. (2015). Shear Strength Characteristics of Coir Fibre Stabilised Stone Matrix Asphalt Mixtures. *International Journal of Sustainable Construction Engineering &Technology*, **6(2)**, 26-36. https://1library.net/document/ydvnogly-shear-strength-characteristics-fibre-stabilised-matrix-asphalt-mixtures.html

16. Baby, B., Baby, B. T., Xavier, J. P., Hafis, M., Vipinan, D. (2017). Effect Of Coir Fiber on Stone Matrix Asphalt (SMA) With Marble Waste as Filler. *International Research Journal of Engineering and Technology*, **5(2)**, 1899-1902. https://www.irjet.net/archives/V5/i2/IRJET-V5I2400.pdf

17. Ministry of Road Transport and Highways, Specifications for Road and Bridge Works, Fifth Revision, Indian Roads Congress, New Delhi, 2001. mort.250.2013.pdf (resource.org)

18. American Association of Highway and Transportation Officials, Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage, AASHTO T 283. AASHTO T 283- (antpedia.com)

19. Tentative Specification for Stone Matrix Asphalt, Indian Roads Congress, New Delhi, IRC SP 079. IRC SP 079: Tentative Specifications for Stone Matrix Asphalt : Indian Roads Congress : Free Download, Borrow, and Streaming : Internet Archive characteristics of mudrocks of the Siwalik Group, Central Nepal. *International Journal of Engineering Research and Applications*, **11 (1)**, 59-73.