Experimental Study of Flexible Pavement Containing Sandstone Waste as Fine Aggregate

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Abstract- Continuous development of road networks require a large quantity of natural resources, which is a critical challenge in civil engineering. Because of the large-scale road building, there is a high demand for aggregate, resulting in a lot of blasting, quarrying, crushing, and so on. On the other side, industrial byproducts and locally accessible materials pose environmental and landfill issues, but they may be used in road building. The marshall mix characteristics of hot mix asphalt incorporating sandstone waste as a substitute for fine aggregate was examined in this experimental investigation. In this experimental work, sandstone waste in different percentages including 0%, 25%, 50%, 75% and 100% were used. Several tests were conducted on flexible pavement including los angeles abrasion, aggregate impact value, aggregate crushing test, Shape test and Marshall stability test. Raising the percentage replacement from 0% to 25%, marshall stability increases than reduced on increasing sandstone waste. Maximum strength was observed when fine aggregate was substituted with sandstone waste at 25%. It was also observed that at up to 50% replacement of fine aggregate with sandstone waste fulfilled the whole requirement of the DBM layer of pavement according to MORTH Specification and can be used in the pavement as an alternative to fine aggregate. It reduces the cost of material and decrease environmental problem. It can also be used on the pavement where the traffic load is less.

Keywords– Sandstone waste, Fine Aggregate Marshall Mix.

1. INTRODUCTION

India has one of the world's largest road networks and one of the world's fastest expanding economies (PRS India legislative research 2018). In 2016-17, around 6604 km of national roads were built. As part of its infrastructure reforms, the Government of India intends to build over 84,000 km of national highways across the country (Government of India 2018). The design of the pavement and the design of the mix are two significant concerns in flexible pavements. Solid waste management is currently one of the most serious issues confronting governments all over the world. The problem is caused by urbanisation, industrialization, bad urban planning, and a lack of suitable assets, all of which contribute to a massive amount of solid waste. This issue has resulted in serious ecological, social, and monetary insolvencies in developing countries such as India. Residential, mechanical and other wastes are creating ecological pollution and have become long-term concerns for humankind.

The use of sandstone waste as a partial replacement for fine aggregate in road construction was investigated in this study. The sandstone waste was utilised as a partial substitute up to 100% fine aggregate in the dense bitumen macadam layer of the flexible pavement**.**

2. LITERATURE SURVEY

A systematic survey of literature available in public domain was carried out related to the topic.

Ergun et al. (2011) reported that mortar made with 5% replacement of marble mud waste or 10% replacement of diatomite (amorphous silica pozzolanic material) had high strength compared to the control mix.

Hamza et al. (2013) observed that using granite stone dust in concrete blocks enhanced the characteristics of the concrete blocks by up to 10% replacement. Hebhoub et al. (2007) enhanced the results by replacing around 75% of the sand with marble stone slurry. Kumar et al. (2016) discovered good long-term outcomes with natural coarse aggregate replacing quartz sandstone up to 40%.

Using incineration slag in place of sandstone and varying water-cement ratios and aggregate sizes, Wu et al. (2016) examined the effect on the permeability coefficient of concrete blocks made with the different mixes. The permeability coefficient was within the general specifications for permeable road surfaces.

Yilmaz and Tugcrul (2012) used sandstone aggregate instead of coarse aggregate. The results showed that subarkose-arkose, sublitharenite-litharenite, and arkose aggregates (various grades of sandstone) with clay cement reduced concrete strength by 40-50 percent when compared to subarkose, quartz sandstone, and arkose aggregates with carbonate cement because these aggregates resulted in a weaker aggregate-cement bond than others. High-strength concrete may be made from five distinct aggregate types: gabbro, basalt, quartzite, limestone, and sandstone. Gabbro concrete had the greater compressive strength, whereas sandstone had the least.

(Ibrahim et al. 2009) investigated the use of crushed stone, a black, fine-grained volcanic rock, as a replacement for limestone aggregates. Three replacement mixes were created: one with 100% coarse and fine basalt aggregate, another with coarse limestone aggregate totally replaced with coarse basalt aggregate, and a third with 100% fine LS replaced with basalt fines. Marshall stability, indirect tensile strength, Young's modulus, rutting, fatigue, and compound creep were used to analyze the results. Water sensitivity tests revealed that mixtures including basalt as fine aggregate failed and were declared inappropriate for further testing. The increased Marshall strength suggested that the basalt aggregates were properly interlocked and hardened. Consequently, the best performance was obtained from samples containing coarse basalt aggregates and fine limestone aggregates, according to the results.

Santosh et al. (2013) replaced fine aggregate with sandstone in concrete pavers and observed the maximum strength at 50% replacement of fine aggregate.

Quarry waste was used as aggregate in granular sub-base courses (Teja et al. 2013). The physical qualities of recycled scrap aggregate were evaluated. They had satisfied the MoRT&H requirements for strength, hardness, and durability. An experimental analysis revealed that all of the mixtures met the minimal code values.

Ameri (2012) conducted an experimental study of stone matrix-asphalt mixes containing steel slag. According to the Marshall Stability results, it was found that mixtures containing steel slag have shown encouraging results compared to those containing stone.

3. MATERIAL AND RESEARCH METHODOLOGY

3.1. Introduction

The current study is focused on utilizing locally available sandstone quarry and polishing waste as a fine aggregate in flexible pavement. Limited studies are available in this.

The methodology for this work consists of various steps (also shown in Fig. 1):

1. Procurement of raw materials
2. Evaluation of physical properties
3. Preparation of marshall mix
4. Testing of samples

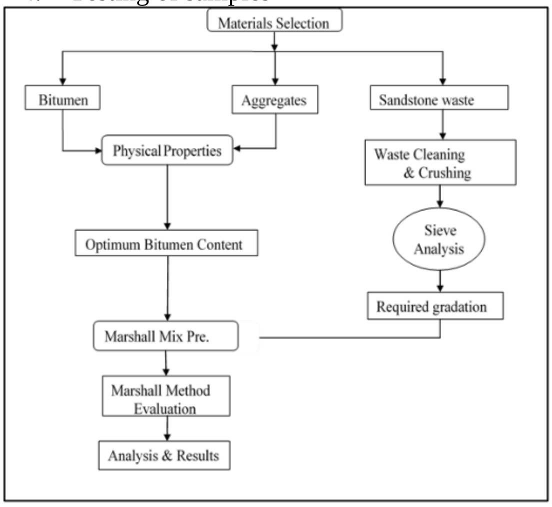

Fig. 1. Work plan

3.2. Materials

In this study fine aggregates, coarse aggregates, bitumen and sandstone waste were used to produce bituminous mixes. The suitability of these materials wcheckedheck in the laboratory by performing various tests. The used raw materials and their characterization in the laboratory are as follows**:**

3.2.1. Aggregate

The fine aggregate (of size 4.75 mm) and coarse aggregate (of size 10 & 20 mm) were used for this study. According to BIS: 2386 (part-1) - 1963, sieve analysis was performed to determine the particle size distribution of aggregates. Fine aggregates were obtained from a nearby crusher with fractions passing 4.75 mm and retained on a 0.075 mm IS sieve. The aggregate's fineness modulus was also measured. The fineness modulus of fine aggregate typically varies from 2 to 3.2. The fineness modulus of fine aggregate was reported to be 2.65 as shown in Table 1. Fine aggregate belongs to zone-II as per BIS: 383 (2016).

Table 1. Sieve analysis for aggregate

Sieve size (mm)	**Cumulative % passing**		
	Fine Aggregate	**10 mm**	**20 mm**
40			100
20			41.28
10	100	97.85	4.16
4.75	98.80	30.30	0.41
2.36	96.80	6.17	0
1.18	91.35	0	0
0.600	40.10	0	0
0.300	7.10	0	0
0.150	0.80	0	0
Fineness Modulus	265.05/100 = **2.65**	565.67/100 = **5.65**	754/100 = **7.54**

Coarse aggregates were obtained from a local source which consists stone chips varying from 4.75 mm to 20 mm size. Before using aggregates in the pavement, its physical properties must be evaluated. The sieve analysis, los angels, impact, specific gravity, and water absorptions tests were performed to evaluate the properties of coarse aggregate as shown in Table 2. The sieve analysis test was performed the same as discussed above for fine aggregate.

Table 2. Physical Properties of aggregates

Sr. No.	Properties	Results	Limitation as per IS code	Test Method
1	Log angeles abrasion value	22.58%	35%	IS 2386 Part 4
2	Impact value	23.64%	27%	IS 2386 Part 4
3	Specific gravity	2.77	-	IS 2386 Part 3
4	Water absorption	0.36	2%	IS 2386 Part 3
5	Flakiness & elongation index	22.46%	35%	IS 2386 Part 1

3.2.2. Binder

Bitumen is also known as Asphalt. Bitumen is produced from the distillation of crude oil. Bitumen was used in the marshall mix as a binder content.VG- grade 30 was used as a binder content for marshall mix design for flexible pavement. Before using bitumen in the pavement, its physical properties must be evaluated. The physical characteristics of bitumen were evaluated using ductility, softening point, and specific gravity tests as shown in Table 3.

Table 3. Physical characteristics of bitumen

S. No.	Properties	Result	IS Code	Specifications as per IS 73 (2007)
1	Ductility value	40.45	IS:1208	Min 40 cm
2	Softening point value	53	IS :1205	> 47 °C
3	Specific gravity	1.01	IS:12 02	0.99 (min)

3.2.3. Sandstone

Sandstone (as shown in Fig 2) is a clastic sedimentary rock comprised primarily of silicate granules the size of sand. Physical properties of sandstone dust as shown in Table 4**.**

Fig. 2. Sandstone dust

Table 4. Physical properties of Sandstone

Properties	Value
Specific Gravity	2.7
Water Absorption	0.32%

3.3. Mix design and testing details

Marshall Mix design is a widely used laboratory method for measuring the strength and flow characteristics of bituminous pavement mixes. Marshall properties like stability, flow value, unit weight and air voids were evaluated to determine the optimum binder content (OBC). The mixes were prepared according to the Marshall procedure specified in ASTM D1559. Coarse aggregate, fine aggregate and fillers were mixed according to adopted gradation as given in Table 3.8. Sieve analysis was performed to determine the gradation (as shown in Fig 3).

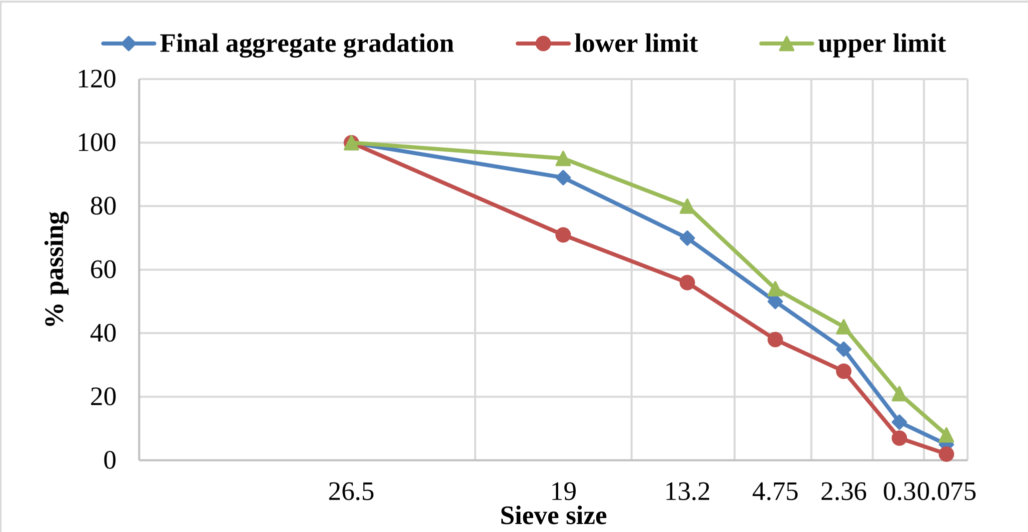

Fig. 3. Final gradation graph for mix design

Table 5. Analysis of Marshall Test Results for Different mixes for DBM layer

Mix	OBC (%)	Max. Stability (KN)	Density (gm/cc)	Flow (mm)	Air voids (%)	VFB	Marshall Quotient (KN/mm)
M_0	4.97	14.59	2.36	3.50	3.60	73	4.168
M_{25}	4.79	18	2.355	3.76	3.55	70	4.78
M_{50}	4.87	12.88	2.356	3.85	3.98	71.27	3.345
M_{75}	5.0	8.9	2.350	3.8	4.2	72	2.34
M_{100}	5.04	8.7	2.35	5.9	4.78	64.15	1.47
MoRTH Limitation	-	Min 9	-	2-4	3-5	65-75	2-5

Optimum Binder Content was determined by taking average value of following three binder content obtained from graph i.e.

- Binder content correspond to maximum stability
- Binder content correspond to maximum unit weight
- Binder content corresponding to the 4% percentage air voids.

4. RESULT AND DISCUSSION

This section presents the results of the tests carried out in the laboratory to investigate the various properties such as density, strength, impact resistance, flow value and marshall tests of the sandstone waste mix concrete.

This section deals with the effect of sandstone waste on fine aggregate in flexible pavement. Marshall test results for various mixes are shown in Table 5 and Figs. 4-8.

Theoretically, as the replacement % rises stability rises up to a certain point and then gradually droped. As a result, the mix becomes weak to plastic deformation. Simultaneously the stability values fall.

When the percentage replacement is increased from 0% to 100%, the fraction of air voids initially drops and then rises. As the particles are arranged properly, air gaps decrease in replacement from 0% to 25%, and sandstone dust fills the vacant spaces in the mix.

When percentage replacement of sandstone dust increases initially flow value is increases than decrease. This can be happened due to improper filling of voids.

VFB reduces initially when replacement % increases 0 to 25% and subsequently increases when the percentage replacement increases from 25% to 50% because VFB inversely corealted with VMA.

All specimens were capable for least stability suggested for low volume traffic. Flow value represent the flexibility and plasticity of the mix design. MoRT&H 2013 recommends flow value of 2-4 mm to give suitable strength and brittleness to mix.

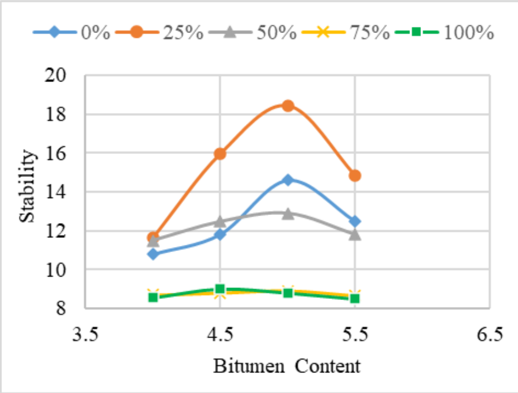

Fig 4. Stability values of mixes with varying binder content

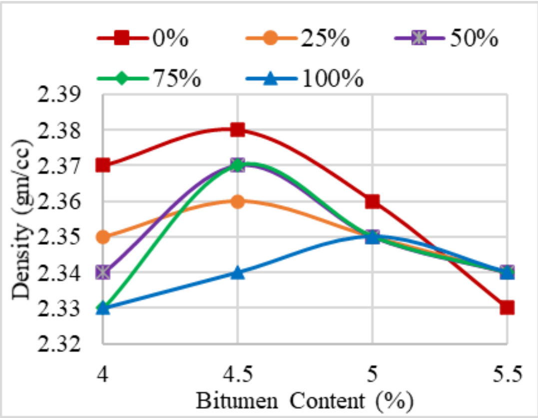

Fig 5. Density values of mixes with varying binder content

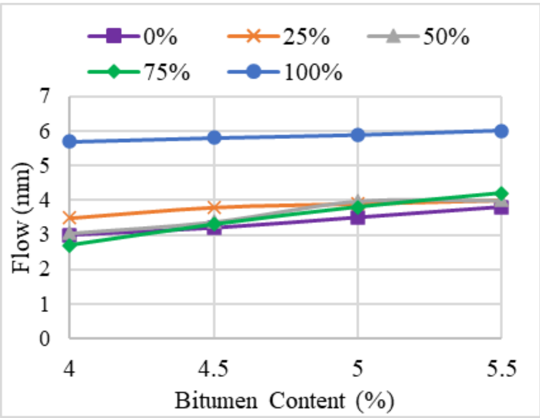

Fig 6. Flow values of mixes with varying binder content

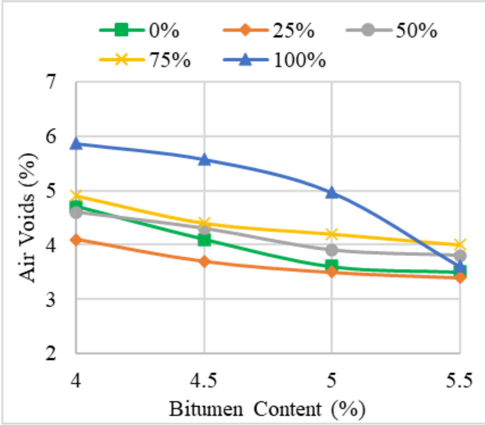

Fig 7. Air void of mixes with varying binder content

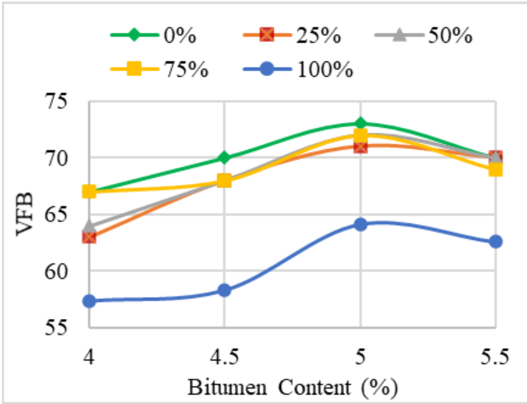

Fig 8. VFB values of mixes with varying binder content

5. CONCLUSION

Experiments are being carried out to investigate the use of sandstone waste as a substitute for fine aggregate in flexible pavement up to 100 %. According to the results of the study, the following conclusions have been reached:

Maximum strength was attained by substituting fine aggregate with sandstone waste at 25%. With up to 50% replacement of fine aggregate with sandstone, waste fulfilled the whole requirement of DBM layer of pavement according to MORTH Specification and can be used in the pavement as an alternativtoof fine aggregate. It has been found that replacing fine aggregate with sandstone waste increases the strength of the pavement. It reduces the cost of materials and decreases the environmental problem. It can be used on the pavement where the traffic load is less. All specimens were capable of the least stability suggested for low-volume traffic.

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