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Performance Improvement of Bituminous Mix using Sintered Fly ash Aggregate with LDPE and Polymer Modified Binders

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Abstract: With the development of the road industry and enhanced traffic, road construction materials have also been evolve and more unconventional ingredients have been included. The rationales were the scarcity of conventional natural materials and the jeopardized environment which have underpinned the tendency towards evaluation other materials resources to be incorporated in the road industry.

The inclusion of such materials entails several secondary and tertiary materials. Several waste by-products and materials have been investigated, assessed, evaluated for utilizations and practiced in the field. This study considers the use of SFA, RCA, and PMB40 in the construction of a bituminous concrete layer as a surface course or profiles corrective course. The study proposes to utilize the marginal aggregates of SFA and RCA. The study also determined all the physical properties of raw material used in this study as specified in MoRTH guidelines. The outcome of the study is to develop a high performance long life bituminous mixes using marginal materials. Effective utilization of marginal materials vis a conventional stone aggregates which is costly and depleting resource in road construction industry. Cost-effective utilization of non-conventional/ marginal aggregates and polymer modified binders in road construction industry, as these materials (like flyash, LDPE) are environmental hazards. The study also correlates well with the mission of the Government of India in development of several road schemes of NHAI and also in development in rural sector under the unique PMGSY scheme of GoI under application of innovative technology.

Keywords: Bituminous Mix, Sintered fly Aggregates, Polymer Modified Binders.

I. INTRODUCTION

India has about 58.98 lakh km of the road network, which is the second-largest in the world after the U.S.A. This comprises National Highway, Expressways, State highway, Major District Road, Other District Roads, and Village Roads. The construction and maintenance costs involve behind these roads are too huge. In currently so many countries of the world approach marginal aggregates and waste plastic material in flexible pavement construction. In India, it also developed some technologies to incorporate these marginal materials in pavement construction and slowly adding some guidelines such as the use of waste plastic in hot bituminous mixes, IRC SP 98. Swami et al. (2015) described in their study there are various types of soils and low grade materials available in the country which may be used to advantage in road construction.

In this study, the wearing surface of BC is designed by using marginal aggregates and polymer modified binders by the Marshall Method of bituminous mix design.

Sharma et al. (2012) reported that the rutting resistance, indirect tensile strength, and resilience modulus of bituminous concrete mix with polymer modified binder significantly improved. The optimum bitumen content finds out through the mix prepared with NA and PMB.

All the basic laboratory tests performed on these marginal aggregate and PMB before their use in mixes. It is found that the plastic coating required for enhancing the physical properties of marginal aggregates used in this study after conducting the physical test over them.

It is decided that the percentage of waste plastic required to coat the marginal aggregates. There are a total of six new modified BC mixes designed by replacing NA with RCA and SFA at different proportions. These six new modified BC mixes are compared with that BC mix which is designed with using conventional aggregates. All the physical and volumetric properties of BC mixes were compared at OBC. For their performance assessment, the curves and bar charts are drawn at the analysis stage.

II. LITERATURE REVIEW

This section presents the critical review of literature available on methodologies on performance improvement of bituminous concrete.

Shankar et al. (2019) investigated to characterize the mechanical properties of bituminous concrete mixes containing RCA or Reclaimed Aggregates (RA). They included all the major mechanical properties related to BC mixes such as the strength, rutting resistance, fatigue behavior, retained stability, and indirect tensile stresses. Goliya et al. (2017) studied the rutting behavior of polymer Modified bituminous mixes by using waste plastic. In their study, they use waste plastic as an additive in bituminous concrete to reduce the rutting defect in flexible pavement.

Asadi et al. (2017), study based on how to resolve the disposal problem of municipal solid waste. They developed a methodology for the replacement of conventional material with surroundings solid waste materials. Aravind et al. (2007) conducted a laboratory study on recycled mix design of different reclaimed asphalt pavement samples and subsequently develops an integrated mix design and structural design approaches for the hot recycled mix. Goel et al. (2004), study based on emerging road materials and innovative concepts that are recognized for future development. They observed the various waste products such as fly ash, blast furnace slag C&D waste, colliery spoil, spent oil shale, foundry sand, mill tailings, cement kiln dust used engine oil, marble dust, waste tyres, glass waste, china clay, and nonferrous slag. Rao et al. (2006) described that the Construction and Demolition (C&D) waste constitutes a major portion of total solid waste produced in the world, and most of it is disposed of in landfills.

The Indian Road Congress also launched the provision as IRC: 121 - 2017 for use of demolished concrete in the construction field. Although the present study also majorly focuses on the utilization of demolished waste from building and demolished concrete roads

III. PROPOSED METHODOLOGY

In this study, development of methodology for the assessment of characteristics of BC based on a literature review of marginal aggregates and modified binder used as a pavement construction material. The proposed methodology is follows:

1) *Procurement of Material and Characterisation:* The raw material that required for the study was procured. The procured mainly three types of raw material i.e. aggregates, fillers, and binders and then Characterized them Natural Aggregates of 19 mm nominal size, Recycled Aggregates also of 19 mm nominal size and SFA of range 4.75 mm to 16 mm. and PMB40 as the binder for mixes.
2) *Assessment of Physical propErties of raw Material:* Assessment of physical properties of procured materials (NA, RCA, SFA, filler, and binders, etc). All the laboratory tests which are mentioned in MoRTH (2013) for these raw materials were done.
3) *Gradation of Aggregates:* based on the nominal size of aggregates, we have selected the Grading-I for the BC mix design according to MoRTH (2013) guidelines. Then matching the obtained grading of Natural Aggregates with a range of Grading-I.
4) *Mix Design by using NA and PMB40:* After the grading of aggregates, we have selected the proportions of aggregates and prepare the mix of BC with the trial value of bitumen with 4.8%. For each sample of the trial value of bitumen three specimens were prepared. The compaction of the specimens through the Marshall hammers and kept in a water bath at 60°C maintained temperature for 30 minutes.
5) *Determine the OBC:* We have prepared similarly other specimens with 5.2%, 5.6%, 6%, and 6.4% of bitumen. Then all specimens who are prepared at different bitumen content put into the Marshall Machine one after the other. Then note the readings of Marshall Stability value and flow values shown on the screen of the digital Marshall Machine. By drawing the graph between the stability value and bitumen content we have found the optimum bitumen content.
6) *Plastic Coating of Marginal Aggregates:* By assessment of the physical properties of marginal aggregates we have decided that to improve the physical properties of these aggregates we have to coat them with waste plastic. Thus we have coated them with plastic of 5%, 10%, and 15% weight of marginal aggregates**.**
7) *Optimum Dosages of Plastic:* After the plastic coating aggregates again find out their physical properties and select the dosage of plastic at which they satisfy the minimum requirement of BC mixes and does not affect the flow value of BC mix.
8) *Proportioning of Aggregate for Modified BC:* We have decided the replacement of natural aggregates with marginal aggregates for modified BC mixes at 5%, 10%, and 15%. Thus we have made a total of six new proportions of modified BC mixes, three of them with RCA and other three of with the SFA.

9) *Design of Modified BC mixes at OBC of Natural Mix:* Then we have again prepared specimens for Marshall tests according to the existing design of the Natural mix. We have only replaced the proportion of natural aggregates with plastic-coated marginal aggregates.
10) *Marshall Test of Modified BC Mixes:* The specimen of modified BC kept in the Marshall Test machine and observed the Marshall Stability Value and flow values of modified BC mixes.
11) *Analysis and Results:* The results obtained through the natural BC mix and all six modified BC mixes have to tabulate and compare with each other at OBC. By drawing the bar graph of each mix the analysis of results will be done.

IV. ANALYSIS AND RESULTS

This section presents the test results obtained after performing tests on all the seven types of BC mix through the Marshall Testing Machine. First of all, we have performed the basic test on the PMB40. As based on the previous literature review we select the modified binder in this study. We can observe from Table 5.1 all the basic properties of PMB40 are under the safe limit. The limits of these properties in MoRTH incorporate from the IRC SP: 53 guidelines on the use of modified bitumen in road construction. According to the IRC SP: 53 its is suggested that the use of PMB40 over the 40℃ temperature more beneficial. The test results of PMB40 are tabulated in Table 5.1.

Table 5.1Physical Properties of Bitumen used in BC

Properties	Test Method	PMB-40 Results	MoRT&H specification (2013)
Penetration (100 gram,5second at 25ºC) (1/10th of mm)	IS 1203	37	30 to50
Softening Point ºC (Ring and Ball Apparatus), Minimum	IS 1205	72	60
Ductility at 27 ºC (5cm/ minute pull),cm	IS 1208	65	+50
Specific Gravity	IS 1202	-	1.01
Viscosity at 150 ºC, Poise	IS 1206 (Part 2)	6.5	5-9
Flashpoint, ºC, minimum	IS 1209	237	220
Fire point, ºC, minimum	IS 1209	252	247

After conducting the test on bitumen we have conducted the test on aggregates used in the construction of BC mixes. Table 5.2 shows the results obtained through the basic laboratory test on aggregates.

Table 5. 2 Physical Properties of Aggregates used in BC

Properties	Test Method	Natural Aggregate	Recycled Concrete Aggregate	Sintered Fly ash Aggregate	MoRTH specification (2013)
Aggregate Impact Value	IS:2386 (IV)	11.93%	19.23%	37.45%|	Max 24%
Los Angeles Abrasion Value	IS: 2386(IV)	16.95%	24.53%	42.53%	Max 30%
Water Absorption Value	IS:2386 (III)	0.86%	4.21%	13.12%	Max 2%
Specific Gravity	IS:2386 (III)	2.78 for 20 mm,	2.68	1.72	2.5-3.0

Table 5.3 presents after the plastic coating of SFA the water absorption and specific gravity are not satisfying the requirement of aggregates used in BC. But these properties are improved as compared to the fresh SFA

Table 5.3 Properties of Plastic Coated Sintered Fly ash Aggregates

Properties	0% waste plastic	5% waste plastic	10 % waste plastic	15% waste plastic
Aggregate Impact value	37.45%	34.52%	29.41%	27.63%
Los Angeles Abrasion Value	42.53%	39.21%	34.31%	32.21%
Water Absorption Value	13.12%	9.13%	5.13%	4.95%
Specific Gravity	1.12	1.43	1.57	1.51
Optimum Dosage of Plastic	10% weight of total marginal aggregates			

Table 5.4 shows that the properties of the BC mix which was prepared with the Natural aggregates and PMB40. We have named this BC mix to as N mix. We have tabulated all the results of the properties of BC mixes at different trial bitumen content. We have calculated the average values of three specimens of each trial bitumen content for all the properties of BC mixes presented in Table 5.4

Table 5.4 Properties of N Mix using NA.

S. no.	Property Tested	Bitumen Content by weight of Aggregate				
		4.8%	5.2%	5.6%	6.0%	6.4%
1	Marshall Stability (KN)	13.12	14.23	13.45	12.34	12.02
2	Flow value (mm)	3.13	3.41	3.73	3.94	4.12
3	Bulk density (g/cc)	2.46	2.53	2.52	2.51	2.49
4	Volume of void, Vv (%)	3.90	4.21	4.33	4.41	4.62
5	Void in Mineral Aggregate, VMA (%)	14.37	13.34	14.56	16.45	17.09
6	Void filled with Bitumen, VFB (%)	71.0	74.51	76.23	77.67	78.13
7	Marshall Quotient (KN/mm)	4.23	4.17	3.60	3.13	2.92

A. Analysis of Natural BC mix

The mean values of different parameters of mix calculated and tabulated in **Table 5.4**. Graphs are plotted between the percentage of bitumen content and the following parameters.

1) Marshall Stability Value (KN)
2) Marshall Flow Value (mm)
3) Unit Weight (g/cc3).
4) Voids Filled With Bitumen (%)
5) Void Mineral Aggregate (%)

Figure 5.1 shows that the relation between the Marshall Stability Value and the bitumen content of BC mixes.

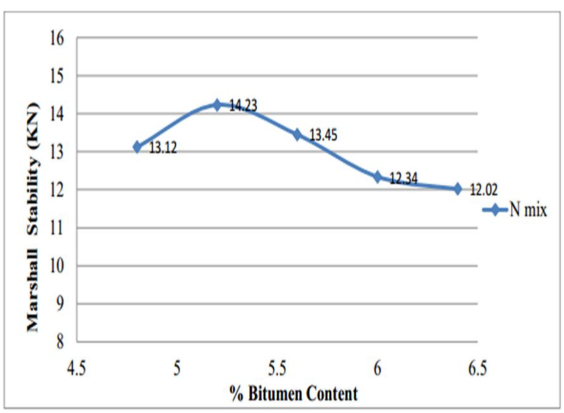

Figure 5.1 Marshall Stability vs. Bitumen Content

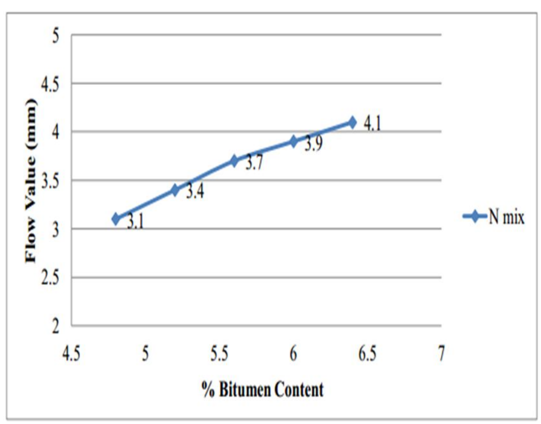

Figure 5.2 Marshall Flow Value vs. Bitumen

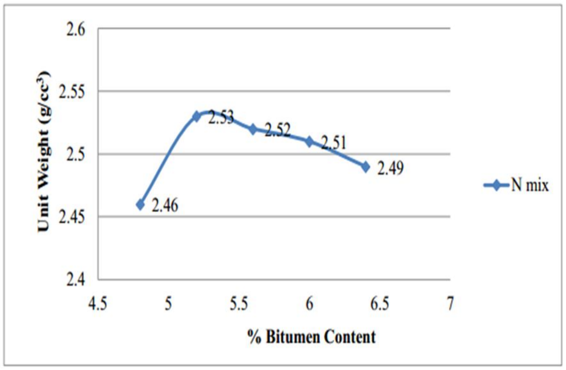

Figure 5.3 Unit Weight vs. Bitumen Content

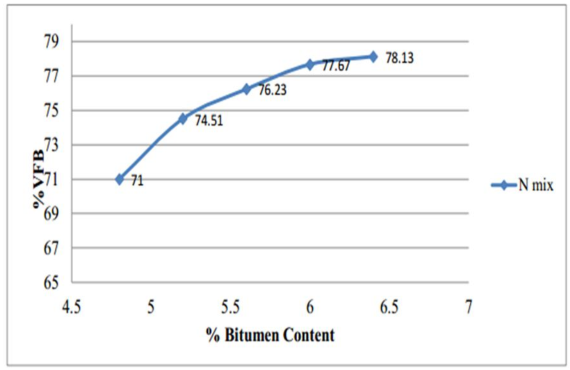

Figure 5.4 VFB vs. Bitumen Content

B. Results

1) *Optimum Bitumen Content of Natural BC Mix:* After the tabulation and plotting of curves between different parameters of BC mix and bitumen content, we have decided the OBC for N mix. As we know that the value of bitumen content at which the sample has a maximum Marshall Stability Value and minimum Marshall Flow Value will gives the Optimum Bitumen Content. Here we can observed from Figure 5.1 and Figure 5.2 the Optimum Bitumen Content is 5.2% for N mix. We can also observed from Figures – 5.3, 5.4 and 5.5 that on the increment of bitumen percentage the voids present in the mix decrease.

V. CONCLUSIONS

The following conclusions have been drawn based from the study:

A. It is observed that the Marshall Stability value increases with bitumen content up to 5.2% and thereafter decreases. We observe that the Marshall Flow Value decreases upon addition of plastic-coated marginal aggregates i.e the resistance to deformations under heavy wheel loads increases.

B. It is also concluded that the values of the parameters like VMA, VA, VFB are within the required specifications in 5% replacement of NA with SFA and on 10% replacement in the case of RCA

C. The PMB show improved properties for pavement constructions over the conventional bitumen. This also can reduce the amount ofplastics waste present in surroundings which otherwise is considered to be a threat to the hygiene of the environment

D. The plastic coating also reduces the void spaces present in the BC mixes. It causes to prevents the water absorption and oxidation of bitumen by entrapped air. The road can withstand heavy traffic and show better service life.

E. The plastic coating SFA reduces the effective bitumen content up to some extent.

F. This study will have a positive impact on the environment as it will reduce the volume of plastic waste, fly ash, and demolished concrete waste thus the solve the problem of incineration and land filling. It will not only add value to marginal aggregates and waste plastic but will develop a technology, which is eco-friendly.

G. This small investigation not only utilizes beneficially, the waste demolished material, fly ash non-degradable waste plastics but also provides us an improved pavement with better strength and longer life period.

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