Use of Rice Husk Ash and Domestic Plastic Wastes in Bituminous Concrete (BC)

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ABSTRACT

This paper presents the experimental results on the utilization of Rice Hush Ash (RHA) and Domestic Plastic Wastes as a replacement for mineral filler and Optimum binder content (OBC) in bituminous concrete mixes. Bituminous concrete mixes containing Rice Husk Ash and Domestic Plastic Wastes at different amounts and control specimens were prepared in accordance to Marshall Mix design, and their performance on stability, flow and bulk density were evaluated. Optimum binder content (OBC) and voids analysis were also conducted to compare performance of Rice Husk Ash and Domestic Plastic Wastes at different contents.

Results reveal that all Rice Husk Ash and Domestic Plastic Wastes mixes have satisfied the Public Works Department (PWD) specification and MORTH specification on wearing course in regard with Marshall Stability and Flow. This material is potentially to be used as partial or full substitution of mineral filler (stone dust) and Optimum binder content (OBC) in pavement construction. Modified bituminous mixes are expected to give higher life of surfacing depending upon degree of modification and type of additives used. The present study aims at developing bituminous mixes for the Bituminous Concrete (BC) Grade 1 incorporating the plastic wastes, waste tyre tubes and rice husk ash as partial replacement of the bitumen content.

In this study, the Stability-Flow analysis for the various BC Grade 1 mixtures with modified binders and with different percentage replacement of bitumen with plastic wastes, waste tyre tubes and rice husk ash are reported.

1. INTRODUCTION

The economy of any country depends indirectly or directly on good quality of roads and hence the quality of life as well. The term 'Road' refers to the structure constructed to facilitate the movement of men and materials from one place to another place. The network of roads in a country can be compared with that of arteries and veins in the human body, as arteries and veins are the carrier of blood, which convey it to the different parts of the body. So important are the roads which convey men, material and vital information to different parts of the country. In India, road transport carries approximately 60% of passenger traffic and 40% of freight transport.

The construction of highways involves huge amount of the investment and mainly sixty percent of the highway project cost is associated with the pavement construction. Pavement is a durable surfacing of a road, airstrip, or similar area and the primary function is to transmit loads to the sub-base and underlying soil sub-grade. Around ninety percent of the Indian Highways have a covered surface with bituminous layers which are constructed and maintained by using naturally available road aggregates and bitumen, a petroleum product, which being mixed at high temperatures to produce hot mix asphalt. Mix design for the different layers of the pavement can have a major impact on the performance, cost and sustainability of the bituminous surfaces.

1.1 Bituminous Concrete (BC) Mix

Bituminous Concrete is also called Asphaltic Concrete is the superior type of surfacing used for heavy traffic. Bituminous concrete is a dense or semi dense graded premix material consisting of well proportioned fine and course aggregates mixed together with tar or bitumen. The premix bituminous mixture is well compacted to obtain a high quality pavement wearing course. IRC has recommended 40 mm thick bituminous concrete surface course for highway pavements. This mix is generally prepared in a hot mix plant.

Bitumen of penetration grades 30/40 (VG-30), 60/70 (VG-20) or 80/100 (VG-10) are used mainly. In BC mix there is a wide scope of varying the gradation to obtain the good mix without affecting the durability of pavement. Achieving adequate compaction of bituminous mixes is crucial to the performance of flexible pavement. Normally Marshall Mix design method is adopted for mix design of Bituminous Concrete (BC). The bituminous concrete (BC) is always laid in a single layer over previously prepared Dense Bituminous Macadam base (DBM) Layer.

1.2 Material Specifications for Bituminous Concrete (BC) Mix

1.2.1 Bitumen

The bitumen for the BC is a paving bitumen of penetration Grade complying with Indian Standard Specifications for "Paving Bitumen" IS: 73-1961, and the grade range is from S 35 to S 90 or A 35 to A 90 (30/40 to 80/100) and of the penetration specified by MOSRT&H Specifications for Road and Bridge Works (Fifth Revision) Re-print April 2013 for Bituminous Concrete.

1.2.2 Coarse Aggregates

The coarse aggregates for the BC mix consists of crushed rock, crushed gravel or other hard material retained on IS 2.36 mm sieve. Aggregates should be clean, hard, and durable, of cubical shape, free from dust and soft or friable material, organic or other deleterious matter. Where the selected source of aggregates has poor affinity for bitumen, as a condition for the permission of that source, the bitumen shall be treated with an approved anti -stripping agent, as per the engineering's recommendations. Before approval of the source, the aggregates should be attested for stripping. The aggregates should satisfy the physical requirements as specified in Table 1.1 (Ref: MOSRT&H Specifications for Road and Bridge Works (Fifth Revision) for Bituminous Concrete).

1.2.3 Fine Aggregates

Fine aggregates for Bituminous Concrete consists of crushed or naturally occurring mineral material or a combination of the two, passing the 2.36mm Indian standard sieve and retained on the 75 micron Indian standard sieve. Aggregates should be clean, hard, durable, free from dust, dry and soft or friable matter, organic or other deleterious matter.

1.2.4 Fillers

Filler for the Bituminous Concrete consists of finely divided mineral matter such as rock dust, hydrated lime or cement, hydrated lime, fly ash or any other approved non plastic mineral matter and shall normally met by the material passing 75 micron sieve.

1.2.5 Additives

In the present study admixtures used were Rice husk Ash and Domestic Plastic Wastes (Glass Powder, Plastic Bottles Pieces, and Rubber Tyres)

2. METHODOLOGY

This stage is divided into three main sections as: Testing of Bitumen, Testing of Aggregates, Testing of Bituminous Concrete (BC) with additives and Testing of Bituminous Concrete (BC) without additives.

2.1 Testing of Bitumen: The sample of bitumen should be taken for Penetration Test, Viscosity Test and Softening Point Test. The penetration test is used to obtain consistency of bitumen at some specified temperature and designate grade of asphalt while softening point test is used to obtain temperature for bitumen melt, details of test is given in Table 2.1.

Table 2.1 Test results of Ingredient Bitumen Sample

TEST RESULTS FOR INGREDIENT BITUMEN		
Property	**Test Results**	**Specified Limits as per BIS : 73-1992**
Penetration at 25°C/100 gm /5 sec, mm	65	60-70
Softening Point, °C	51.7	40-55
Ductility, cm	75	> 75
Specific Gravity, at 27°C	1.01	>0.99
Viscosity at 60°C, Poise	1032	1000±200
135°C, cSt	265	>150

2.2 Testing of Aggregates: Sieve analysis test is used to determine the aggregate sizes from a sample taken from quarry. Through this sieve test, the proportion of coarse aggregates, fines aggregate and filler is determined and ensuring the aggregate is well blended within the gradation limit as specified in MORTH for Bituminous Concrete Grade. The sieve analysis test results should be determined or studied.

Table 2.2 Sieve Analysis Results

Sieve Size mm	Percentage Passing 20mm Aggregates	Percentage Passing 10mm Aggregates	Percentage Passing Fine Aggregates Sand	Percentage Passing 4.75mm down Crushed Stone and Dust	Percentage Passing Filler
19.00	83.00	100	100	100	100
13.20	21.00	100	100	100	100
9.50	2.00	69	100	100	100
4.75	2.00	5	100	100	100
2.36	1.00	2	87	94	100
1.18	1.00	1	84	61	100
0.600	1.00	1	75	38	100
0.300	1.00	1	39	25	100
0.150	1.00	1	17	17	98

0.075	1.00	1	2	4	86

Table 2.3 Combined Aggregate Gradations along with Filler for Bituminous Concrete

MORTH SPECIFIED GRADATION FOR BITUMENOUS CONCRETE		
Grading	1	2
Thickness	50 mm	30-40 mm
Nominal Aggregate Size	19 mm	30 – 40 mm
Sieve, mm	-	-
45	0	0
37.5	0	0
26.5	100	0
19	90-100	100
13.2	59-79	90-100
9.5	52-72	70-88
4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	34-48
0.6	15-27	26-38
0.3	10-20	18-28
0.15	5-13	12-20
0.075	2-8	4-10
Bitumen Content, %	Min. 5.20	Min. 5.40

Table 2.4 Percentage of Aggregate and Filler by Weight, Blended to Obtain the recommended Gradation

Aggregate Type	**Percentage By Weight of Aggregates**
10mm Nominal size Crushed Course Stone Aggregates	38.00
Fine Aggregates (Sand)	10.00
4.75 mm Down Crushed Stone and Dust	50.00
Filler	2.00
TOTAL	100

Table 2.5 Physical Requirements of Coarse Aggregates for BC MIX

Aggregate Type	**Test**	**Testing Method**	**Value Obtained**	**Specifications**

			%	
20 mm	Aggregate Impact Value	IS:2386(Part 4)	12	Max 27
	Combined Flakiness and Elongation Index(Total)	IS:2386(Part 1)	30	Max 35
	Soundness with Magnesium Sulphate (5 Cycles)	IS:2386(Part V)	4.50	
10 mm	Aggregate Impact Value	IS:2386(Part 4)	13	Max 27
	Combined Flakiness and Elongation Index(Total)	IS:2386(Part 1)	32	Max 35
	Soundness with Magnesium Sulphate (5 Cycles)	IS:2386(Part V)	4.90	

Table 2.6 Specific Gravity and Water Absorption Characteristics of Material

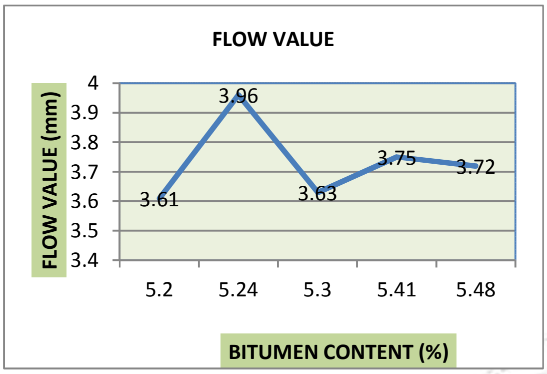
Aggregate Type	**Specific Gravity**	**Water Absorption %**
20 mm Nominal Size Course Stone Aggregates	2.63	1.50
10mm Nominal size Crushed Course Stone Aggregates	2.66	1.90
Fine Aggregates (Sand)	2.43	NA
4.75 mm Down Crushed Stone and Dust	2.54	NA
Filler	3.06	NA
Bitumen (VG-10 or 80/100 Penetration Grade)	1.03	NA

2.3 Testing of Bituminous Concrete Grade Mix Design Without any Additives: To calculate the optimum binder content (OBC), Marshall Samples were prepared by varying percentage of 60/70 binder without any admixture of any modifier. Stability-Flow analysis and Volumetric analysis was carried out for the prepared Marshall Core samples with varying bitumen content from 5.2% to 5.5%. The test values obtained are plotted graphically.

Table 2.7 Marshall Properties of Specimens without Admixture

Bitumen Content (%)	**Unit weight (gm/cc)**	**Stability (KN)**	**Flow Value (mm)**	**Air Void VTA (%)**	**Voids in mineral aggregates VMA (%)**	**Voids Filled with Bitumen VFB (%)**

5.20	2.32	16.31	3.61	4.43	16.21	63.15
5.24	2.30	17.51	3.96	4.55	15.10	69.40
5.30	2.292	16.90	3.63	4.51	16.52	72.69
5.41	2.30	18.15	3.75	4.56	16.73	72.73
5.48	2.29	17.70	3.72	4.27	16.63	74.34



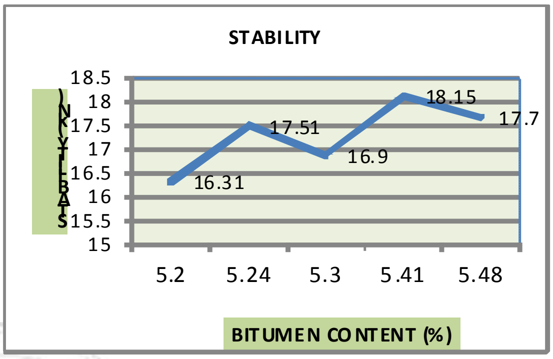
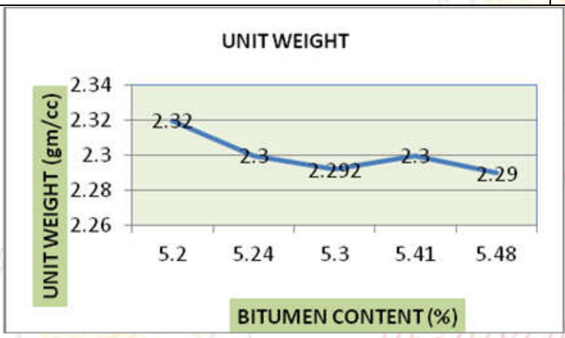


Fig 2.1 Variation of Stability Value to the Variation in Bitumen Content

Fig 2.2 Variation of Flow Value to the Variation in Bitumen Content



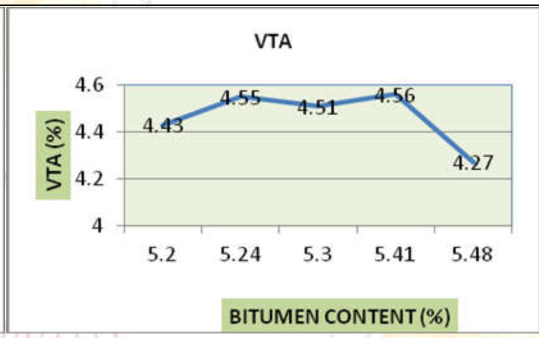
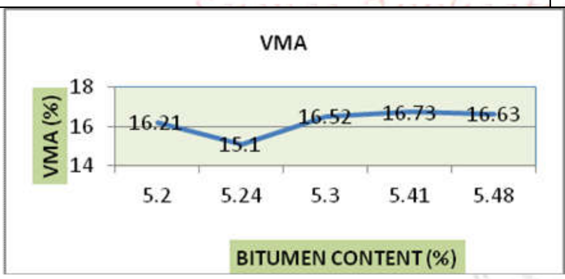


Fig 2.3 Variation of Unit Weight to the Variation in Bitumen Content

Fig 2.4 Variation of VTA to the Variation in Bitumen Content



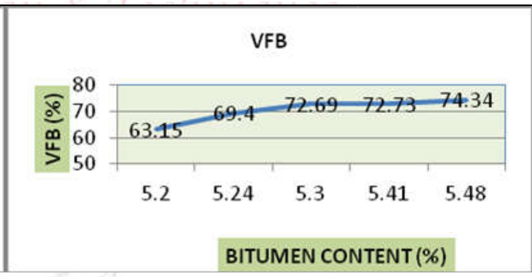


Fig 2.5 Variation of VMA to the Variation in Bitumen Content

Fig 2.6 Variation of Marshal Stability Value to the Variation in Bitumen Content

2.4 Testing of Bituminous Concrete Grade Mix Design with Additives:

The waste plastic bottles may be used in the bituminous mixes of Bituminous Concrete (BC) Grade and stability flow characteristics of the mix will be carried out using Marshall Method of bituminous mix design. The optimum binder content (OBC) of mix should also be replaced with some percentage of plastic content to determine the Stability and Flow characteristics of the modified mix.

Bituminous mix design for Bituminous Concrete (BC) Grade by Marshal Method will be carried out by replacing the optimum binder content with varying percentages of rice husk ash to determine the Stability-Flow characteristics of the modified mix should also be known.

2.4.1 Results of BC Grade 1 Mix Design with Plastic Waste:

The waste plastic bottles were used in the bituminous mixes of BC Grade 1 and stability flow characteristics of the mix was carried out using Marshall Method of bituminous mix design. The optimum binder content (OBC) of 5.20%, 5.24% and 5.30% was replaced with 10%, 14% and 18% of plastic content to determine the Stability and Flow characteristics of the modified mix. The outputs are shown by graphically and also in Table 2.8

Table 2.8 Test Outputs for Stability and Flow by Varying Plastic Content

Replacement of OBC with plastic%	Height of sample (mm)	Corrected stability (KN)	Flow (mm)
10	100	13.36	3.32
14	101	12.80	3.26
18	100	11.86	3.25

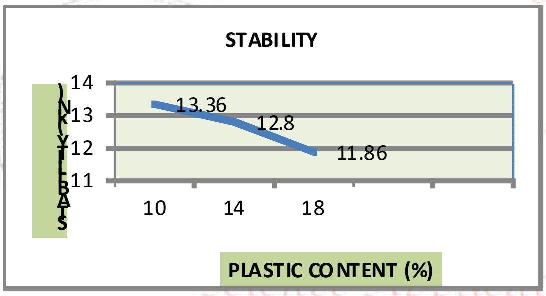


Fig 2.7 Variation of Stability Value to the Variation in Plastic Waste Content

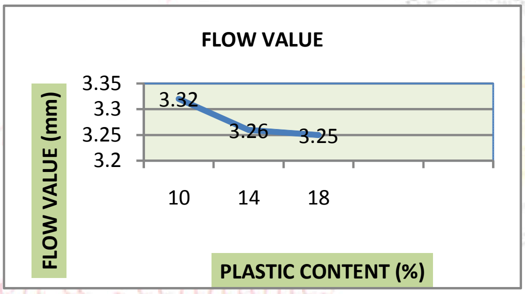


Fig 2.8 Variation of Flow Value to the Variation in Plastic Waste Content

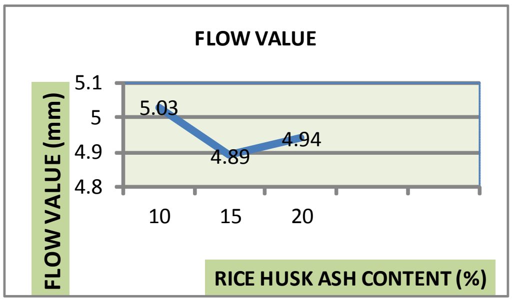
2.4.2 Results of BC Grade 1 Mix Design with Rice Husk Ash:

Marshal method of bituminous mix design for BC grade 1 was carried out by replacing the optimum binder content with varying percentages of 10%, 15% and 20% rice husk ash to determine the Stability-Flow characteristics of the modified mix. The outputs are as shown in table 2.9.

Table 2.9 Test Outputs for Stability and Flow by Varying Rice Husk Content

Replacement of OBC with Rice husk%	Height of sample (mm)	Corrected stability (kN)	Flow (mm)
10	100	14.25	5.03

15	99	15.34	4.89
20	100	16.86	4.94



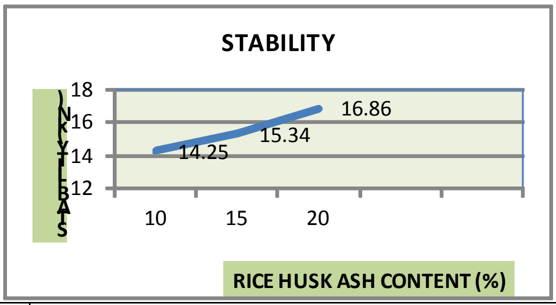


Fig2.9 Variation of Stability Value to the Variation in Rice Husk Ash Content	Fig 2.10 Variation of Flow Value to the Variation in Rice Husk Ash Content

3. DISCUSSIONS OF RESULTS

3.1 Effect of Plastic Waste on the Stability & Flow Analysis of BC Grade 1 Mix: Table 2.8 and Figs. 2.7 and 2.8 show the variation of stability and flow of BC mix with percentage replacement of OBC with plastic content. It is observed from the data obtained that on replacing OBC with 10%, 14% and 18% waste plastic. The stability value decreased by 13.36% with 10% plastic waste, 12.80% with 14% plastic waste and 11.86% with 18% plastic waste. However, all the three mixes have higher stability value than the minimum specified stability value as per MS2 and MORTH specifications. But the flow criteria of 2 to 5 mm for BC grade 1 *[MS2 and MORTH]* was satisfied only for the mix with 10% plastic waste.

3.2 Effect of Rice Husk Ash on the Stability & Flow Analysis of BC Grade 1 Mix: The Optimum binder content calculated for the BC grade 1 was replaced with the 10%, 15% and 20% Rice Husk ash. Table 2.9 and Figs. 2.9 and 2.10 shows the variation of stability and flow of BC mix with percentage replacement of OBC by varying percentages of rice husk ash as stated above. With this replacement, the stability value increased by 14.25% with 10% Rice Husk ash, however, the stability value increased by 15.34% with 15% rice husk ash and by 16.86% with 20% rice husk ash replacement. However, all the three mixes have higher stability value than the minimum specified stability value as per MS2 and MORTH specifications. But the flow criteria of 2 to 5 mm for BC grade 1 *[MS2 and MORTH]* was satisfied for the mix with 15% Rice Husk ash and 20% Rice Husk ash. Fig. 2.9 and Fig 2.10 shows the comparison of the stability values for the selected replacement levels of the different percentage materials used. It is observed that replacement of OBC by 20% of Rice Husk Ash has the highest stability value.

4. CONCLUSION AND FUTURE SCOPE

4.1 Conclusions

The major conclusions drawn from the study carried out on stability value and flow analysis of BC (GRADE 1) by using different additives are as under:

1. The flow criteria for BC grade 1 is satisfied only if the Bitumen is replaced by 10% plastic waste, although the stability values lie within the specific range for all replacement levels.
2. It is observed from the data obtained that on replacing OBC with 10%, 14% and 18% waste plastic, the stability value decreased. The stability value decreased by 13.36% with 10% plastic waste, 12.80% with 14% plastic waste and 11.86% with 18% plastic waste.
3. The flow criteria of 2 to 5 mm for BC grade 1 *[MS2 and MORTH]* was satisfied only from the mix with 10% plastic waste.
4. The stability value increased by 14.25% with 10% Rice Husk ash, however, the stability value also further increased by 15.34% with 15% rice husk ash and by 16.86% with 20% rice husk ash replacement.
5. Although the stability value increased for 10% replacement of OBC by rice husk ash and reduced for 15% and 20% replacement levels, but the 10% replacement level only does not satisfy the flow criteria. It indicates that 15 to 20% replacement level of rice husk ash is suited for creating a stable and flow able BC mix of grade 1. Higher limit of rice husk ash replacement needs further investigations.
6. Of the three materials used, replacement of OBC by 10% discarded Rice Husk has the highest stability value.

4.2 Scope for Future Work

A trial section of a pavement, with Bituminous Concrete (BC) Grade layer, can be prepared and investigated by using the optimum percentage replacement values of various additives obtained in the work. This trial section can be evaluated for the performance characteristics both in terms of structural evaluation as well as functional evaluation of the pavement. We can also use the other type of natural and artificial additives for further study.

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