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Evaluation of Performance of Hot Asphalt Mix by Partially Replacing Stone Dust by Brick surkhi as a Filler Material

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Abstract

Filler material in asphalt concrete is one of the important constituents which provides additional stability by filling up the voids and providing denseness. However, researches show that asphalt concrete behaves differently with different fillers. This work takes a step to evaluate the performance of asphalt concrete with brick Surkhi used as partial replacement of conventional fillers. Aggregate and bitumen were collected and checked for their physical properties with reference to standard specification. The aggregate gradation was obtained by combining various size aggregate and fillers. The mix proportion were finalized. The Marshall test with stone dust was done at various bitumen content as a control mix. The Marshall test with varying brick surkhi content partially replacing stone dust as filler was done at various bitumen content. The test results showed that brick surkhi can be used as partial replacement of conventional fillers without much decrease in strength properties. Brick surkhi will be helpful in obtaining standard aggregate gradation and reduce use of stone dust.

Keywords

Brick Surkhi, Stone Dust, Marshall Stability, Marshall Flow value

1. Introduction

Bituminous roads are constructed with the mixture of bitumen, aggregates and mineral filler in suitable proportion to fulfil the requirement of strength and durability. Mix design aims at achieving these requirements through using different proportions and selecting the best one.The cost, durability and strength of asphalt mix depend on various factors such as gradation of aggregates, grade of bitumen and types and amount of filler material. The main function of filler is to fill voids in coarse aggregates which increase the density, stability and toughness of a bituminous paving mixture. Another function is the creation of a filler-asphalt mastic in which the particles of filler may be individually coated or present in mechanical and colloidal suspension. The mastic serves as a cementing agent in the mix. Conventionally stone dust is used as mineral filler in the bituminous mix. Non-conventional filler in the form of brick surkhi[1, 2] is being used to study its effect on the performance of bituminous mix by partially replacing stone dust by brick surkhi.

2. Materials and Method

2.1 Materials

2.1.1 Aggregate

Coarse aggregate confirming to the gradation requirement provided by Standard Specification for Road and Bridge Works, 2073 of Nepal were collected from Jagadamba crusher. All aggregates sources were Tikabhairav. Three sets of aggregate with different sizes were collected. To match gradation requirement[3], different trials and different sets of aggregates were used. In the procedure, to fulfill the requirement, 1st set of aggregate (Aggregate 1) was sieved through 16 mm sieve. The three sets of aggregate are represented as Aggregate 1, Aggregate 2 and Aggregate 3.

Aggregate 1 – 16mm down

Aggregate 2 – 10mm down

Aggregate 3 – 5mm down

The sieve analysis of above aggregates yielded following results:

Table 1: Sieve analysis of aggregates

Sieve size	Aggregate 1	Aggregate 2	Aggregate 3	Stone dust
19	100	100	100	100
13.2	55.52	100	100	100
9.5	11.7	98.77	100	100
4.75	2.44	44.67	85.96	100
2.36	2.02	9.11	73.27	99.96
1.18	1.82	3.49	61.89	99.46
0.6	1.76	2.29	44.39	99.16
0.3	1.71	1.65	18.93	92.78
0.15	1.63	1.32	5.61	62.02
0.075	1.07	0.76	2.23	37.74

The final gradation with varying surkhi content and standard gradation as given by Department of Roads(DoR) for asphalt concrete are shown in Table 2. The gradation changes in the lower sieve size with increase in surkhi content. The combined gradation for all percentages of brick surkhi used in this research were checked and found to be in limit with DoR gradation for Asphalt Concrete.

Table 2: Combined gradation change with surkhi content

	Surkhi Content					DoR Standard	
Siev size	0%	3%	5%	7%	9%	Low	Hig
19	100	100	100	100	100	100	100
13.2	91.1	91.1	91.1	91.1	91.1	90	100
9.5	81.9	81.9	81.9	81.9	81.9	70	88
4.75	59.6	59.6	59.6	59.7	59.6	53	71
2.36	45.1	45.1	45.1	45.1	45.1	42	58
1.18	39.9	39.9	39.9	39.9	39.9	34	48
0.6	34.1	34.2	34.2	34.2	34.3	26	38
0.3	25.1	24.8	24.6	24.4	24.2	18	28
0.15	14.8	14.1	13.6	13.2	12.7	12	20
0.075	8.6	7.6	6.8	6.1	5.4	4	10

The gradation requirement tests followed different other physical tests

Table 3: Physical Tests on Aggregate

Test	Limiting Value	Result	Standard
Los Angeles Abrasion Test	Maximum 30%	29%	IS 2386 Part IV
Aggregate Impact Test	Maximum 24%	16%	
Aggregate Crushing Value Test		21%	

2.1.2 Bitumen

Bitumen of viscosity grade VG10 was collected from GP Global Asphalt pvt.ltd. and was tested for its penetration value, specific gravity, ductility test, viscosity test and specific gravity[3]. The values were checked with the standard requirements from [3] and found satisfactory.

Table 4: Physical Tests on Bitumen

S.N	Characteristics	Method of Test	Value/ IS73.2006
i	Penetration at 25°C, 100 g, 5 s, 0.1 mm, Min	IS 1203	93/80-100
ii	Absolute viscosity at 60 °C, Poises,Min	IS 1206 part 2	
iii	Softening point (R & B) °C, min	IS 1205	
iv	Ductility at 25 °C, cm, min	IS 1208	>100/75
v	Specific gravity	IS 1202	1.024

2.1.3 Filler

Brick surkhi was collected from the Bhaktapur Ceramics Pvt.Ltd., Bhaktapur. Sieve analysis of collected Brick surkhi yielded following results:

Table 5: Sieve Analysis of Surkhi

Sieve size (mm)	Percentage passing
0.3	83.36
0.15	38.96
0.075	1.36

Specific gravity of filler materials summed up in

Table 6: Specific Gravity of Fillers

Material	Specific gravity (G)
Brick surkhi	2.52
Stone dust	2.6

2.2 Mix Proportion

All together 5 sets of Marshall test with VG10 grade bitumen were prepared to study about the variation in the properties of the specimen with the varying proportion of Brick Surkhi. The control mix was prepared as per the gradation specified in selection of aggregates. Then stone dust was partially replaced by brick surkhi at different percentages as follows:

Table 7: Mix Proportion

Brick surkhi	Aggregate 1	Aggregate 2	Aggregate 3	Stone dust
0%	20%	30%	30%	20%
3%	20%	30%	30%	17%
5%	20%	30%	30%	15%
7%	20%	30%	30%	13%
9%	20%	30%	30%	11%

For each combination of aggregates and filler, 1 set (15 samples) each was made varying the bitumen content as 4.5, 5,5.5,6,6.5.

2.3 Marshall Test

Marshall tests were performed with respect to [4, 5] , standard test method for Marshall stability and flow of bituminous mixtures. The results of the experiments were expressed in terms of following terms:
a. Marshall stability–kN
b. Flow value– in mm
c. Percentage of air voids – percentage
d. Voids in Mineral Aggregate (VMA) – percentage
e. Voids Filled with Bitumen (VFB) – percentage
f. Unit weight of specimen (G) – gm/cm^3

The minimum requirement of these parameters for the mix design were as provided in the specification [3].

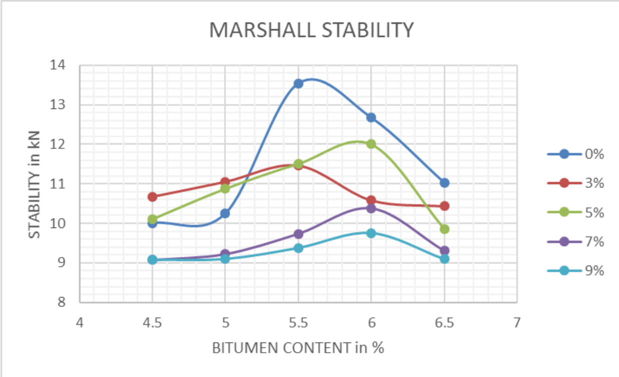

Figure 1: Marshall stability vs bitumen content vs surkhi content

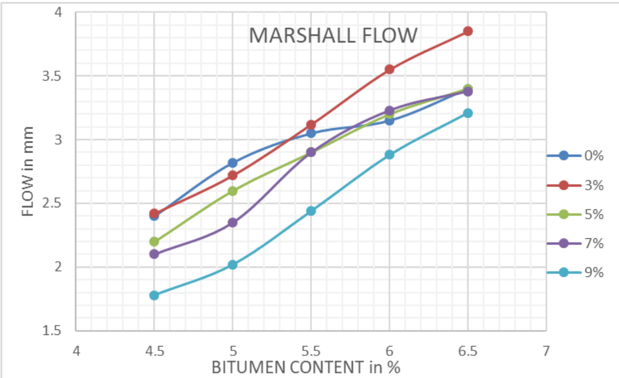

Figure 2: Marshall Flow value vs bitumen content vs surkhi content

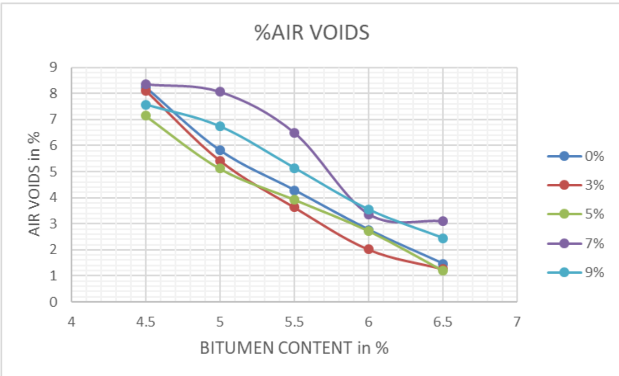

Figure 3: Percentage Air voids vs bitumen content vs surkhi content

3. Results and Conclusion

3.1 Graphical Analysis

In Figure 1, the variation of Marshall Stability Value with varying Bitumen content is shown and different line represent different surkhi content. The stability for mix with stone dust only is slightly more than the mix replacing stone dust with surkhi.

In Figure 2, the variation of Marshall Flow Value with varying Bitumen content is shown. The flow value is decreasing with increase in surkhi content.

In Figure 3, the variation of percentage air voids with varying Bitumen content is shown.

In Figure 4, the variation of unit weight with varying Bitumen content is shown.

In Figure 5, the variation of VFB with varying Bitumen content is shown.

In Figure 6, the variation of Optimum Bitumen

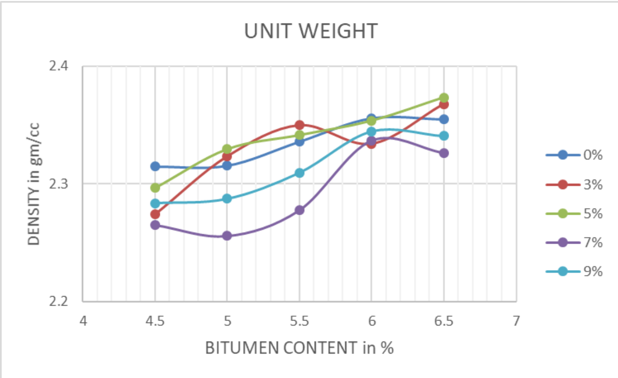

Figure 4: Unit weight vs bitumen content vs surkhi content

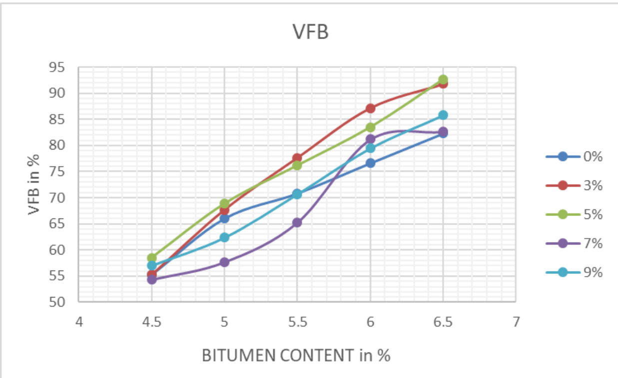

Figure 5: Voids Filled with Bitumen(VFB) vs bitumen content vs surkhi content

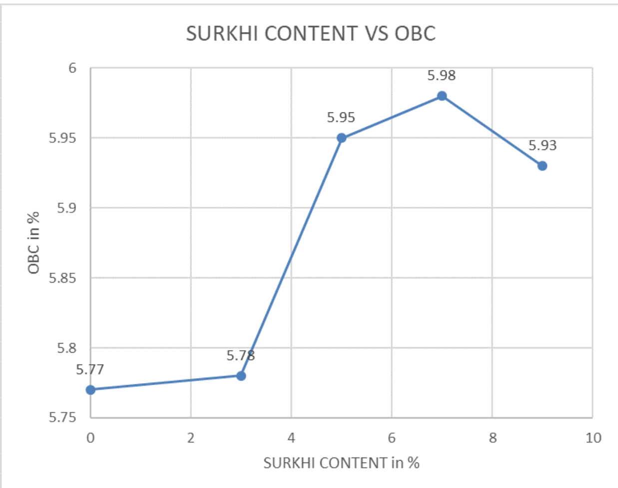

Figure 6: Optimum Bitumen Content(OBC) vs surkhi content

Content with varying Surkhi content is shown. The OBC value iniatially increases with increase in amount of surkhi used as replacement of stone dust and then decreases.

In Figure 7, the variation of Stability values at OBC

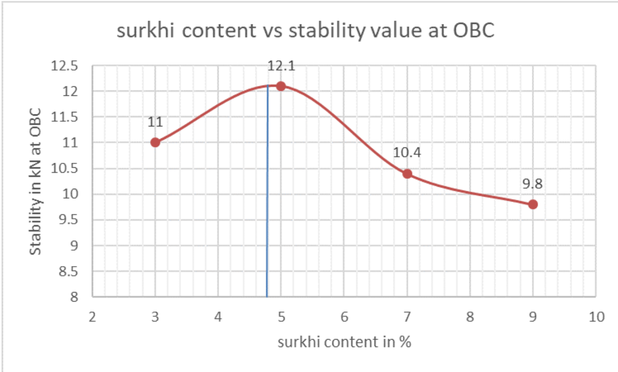

Figure 7: Stability Value at OBC vs surkhi content

with varying surkhi content is shown. The Stability value at OBC increases with increasing surkhi content initially and then decreases. From the graph.the maximum stability is at surkhi content of 4.8.

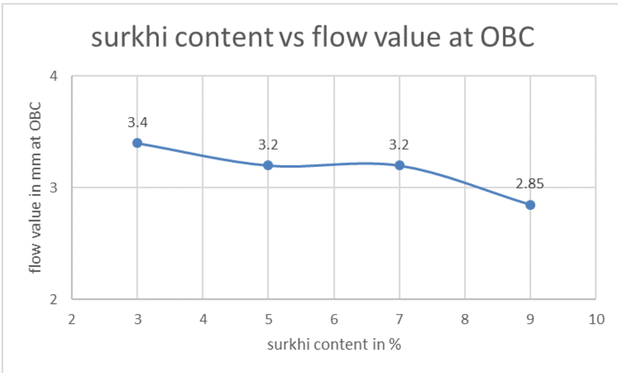

Figure 8: Flow value at OBC vs surkhi content

In Figure 8, the variation of flow values at OBC with varying surkhi content is shown. The flow value at OBC decrease with increasing surkhi content.

Table 8: Mix Properties at Optimum Bitumen Content

Surkhi %	0	3	5	7	9	DOR limit
OBC %	5.77	5.78	5.95	5.98	5.93	
Density gm/cc	2.33	2.34	2.35	2.33	2.34	
%Air Voids	3.5	2.9	3	3.4	3.6	3 to 5
Marshall Stability kN	13.1	11	12.1	10.4	9.8	Min. 9.0
Marshall Flow mm	3.1	3.4	3.2	3.2	2.85	2 to 4
Marshall Quotient	4.23	3.24	3.78	3.25	3.44	2 to 5

3.2 Discussion and Conclusion

This study discusses the results of partially replacing the conventional stone dust filler with brick surkhi, to evaluate the possibility of using surkhi as a filler and following conclusions were made:

- Comparing properties of mix with surkhi as filler with control mix, surkhi can be used to partially replace stone dust filler without highly compromising the mix properties.
- Marshall Stability value of mix with surkhi was slightly less as compared with that of mix with stone dust as filler but easily satisfied minimum requirements of asphalt concrete mix. As the surkhi content increased Marshall stability value initially increased and then decreased.
- The optimum filler surkhi content with respect to stability value is found to be 4.8 percent.
- The flow values decreased with increasing filler surkhi content but all mixes satisfied the limits specified in SSRBW.
- Marshall Quotient for mix with surkhi was slightly less than that of mix with stone dust as filler but satisfied minimum requirements of asphalt concrete mix.
- Optimum Bitumen Content has been found increasing initially as we increase the surkhi content as filler and then decreases.

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