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Experimental investigation of Bituminous Concrete Mix Using Rice Husk Ash as a Mineral Filler

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Abstract: ***The objective of this study is to assess the Marshall properties of Asphalt mix when traditional fillers are replaced by rice husk as mineral filler. Fillers when introduced in asphalt helps filling voids thus producing dense mix. In this study, rice husk ash as mineral filler was used at varying contents with varying bitumen contents. The prepared samples were tested for different Marshall Properties. It was observed significant improvement in Marshall Stability while volumetric properties were also within the range. Thus, rice husk ash can be incorporated in asphalt mix as mineral filler in those areas where such ashes are found abundantly, also solving disposal problems in turn the environmental problems as well.***

Keywords: bituminous concrete, mineral filler, rice husk ash, Marshall Test

1. Introduction

Asphalt roads are widely used everywhere. Asphalt is the mixture of mineral aggregates, bitumen and filler (optional) at correct proportion and correct mixing and compaction temperatures. Aphalt concrete are the highest standard that can be given to the pavement treatment. Asphalt technology is expensive as well. Asphalt technology is adopted by Department of Roads (DoR), Nepal and other government authorities of Nepal.

Asphalt mixes are of different types depending upon the aggregation gradation used such as dense graded asphalt mix, open graded asphalt mix and gap graded asphalt mix. Proper mix design is needed to prepare durable asphaltic pavements. Mineral filler when introduced in asphalt mix fills the voids in aggregates thus producing a dense asphaltic mix. Though, its use is optional. DoR identifies cement, stone dust and hydrated lime as fillers. These filler are expensive and are extensively used for secondary purposes as well. Thus, there is a need of cheap fillers which are readily available.

The mechanical properties of the asphalt mixtures are strongly dictated to the type and amount of the mineral filler. The introduction of filler into the asphalt mixture can greatly improve the mechanical properties of the mixtures and decrease the moisture susceptibility. Despite the mixed results attained from the static creep recovery tests, the deformation of the mixture can be significantly decreased by increasing the F/B ratio of the used filler [4].

1.1 Research objectives

The main research objective is to assess the Marshall properties of the asphalt mix when rice husk ash (RHA) is used as mineral filler. The optimum RHA content and its corresponding optimum binder content will also be found.

2. Rice husk ash as filler

Rice husk ash (RHA) is produced from the combustion of rice husks at higher temperatures. RHA is the by-product of industries that make the use of heat energy. Chemical composition of RHA shows predominant content of silica at about 90%, and alumina at around 11 % [1].

About 20% of a dried rice paddy is made up of the rice husks. The rate of rice husk ash is about 20% of the dried rice husk [4]. The annual paddy rice production of Nepal is about 5.34 million tons (Source: FAO, UN, 2018) which leads to production of 1.068 million tons of rice husks, and by burning this volume of rice husks; .21 million tons of RHA are produced. Those rice husk ash, if not disposed properly, would lead to environmental problems.

Table 1: Chemical composition of RHA [1]

Oxides	*Proportion*
CaO	1.58
SiO2	88.23
Al2O3	10.8
MgO	0.58
Fe2O3	-
K2O	4.23
TiO2	.07

3. Methodology

3.1 Sample preparation

Aggregates were collected from nearby crusher. Three types of aggregates were collected. The combined aggregate gradation conformed to the limit set by DoR

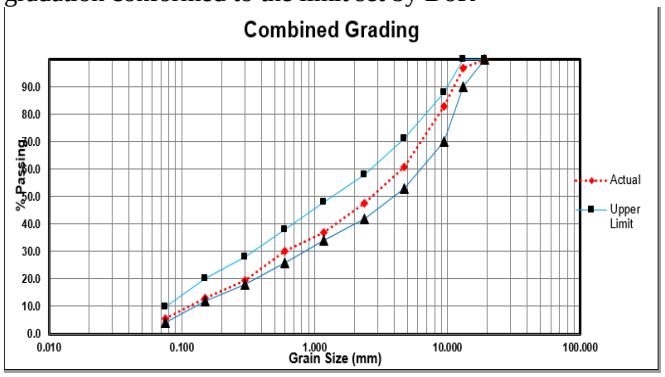

Figure 1: Combined aggregate gradation curve.

Aggregates used were tested for their conformance, as per the table 2.

Table 2: Physical tests of aggregate

Name of the test	*Result*	*DoR range*	*Standard Used*
LAA Test	29.07%	Max. 40%	IS 2386 Part 4
AIV Test	20.30%	Max. 30%	

Bitumen used was viscosity grade bitumen i.e. VG-30. Following tests were done.

Table 3: Standard tests on bitumen

Name of the test	*Standard used*	*Value*
Specific gravity	IS 1202	1.042 gm/cc
Penetration test.	IS 1203	59 mm
Ductility test	IS 1208	95 cm
Softening point	IS 1205	45.5 °C

3.2 Mix design

Marshall mix design was used as adopted by DoR as described in Asphalt Institute manual MS-2. Samples were prepared as described in the manual. Using 5% stone dust as filler, control mix was prepared at different bitumen contents (4.5% to 6.0%) with .5% increment. Rice husk ash were used at 2%, 3% and 4% at different bitumen contents.

Laboratory test procedure as described in the manual was used.

4. Results and Interpretations

Samples prepared were tested for Marshall Properties. Marshall Stability, Marshall Flow results are reported in KN and mm respectively.

4.1 Stability-Flow analysis

Marshall Stability is the peak resistance load obtained during a constant rate of deformation. Marshall Flow is a measure of the deformation (elastic plus plastic) of the specimen determined during the stability test [9].

It is clear from the figure 2, that stability value is maximum when 3% RHA filler was used. It shows improvement in stability values over traditional fillers i.e. stone dust as in the following curve. Maximum Stability value of 18 KN is observed for bitumen content of 5% for 3% RHA. Stability value increased when increasing the RHA content as it would siffen the binder thus increasing the stability value. After 3% of RHA, stability value decreased. If too much mineral filler is used, the filler can act as an asphalt binder extender, affecting the mixture as if it had a higher asphalt binder content. This net effect could actually cause the mixture to have a decrease in the Marshall Stability values [8].

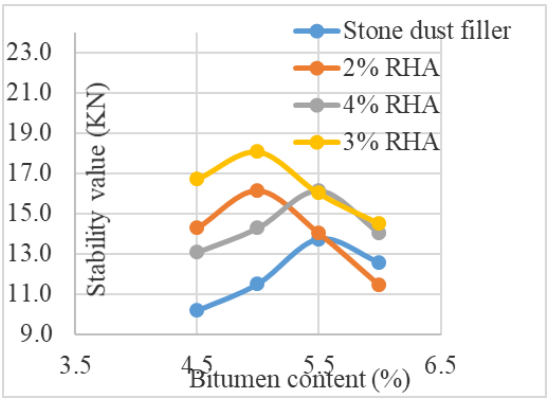

Figure 2: Stability vs. Bitumen content

Though flow values were greater than that for stone dust filler for RHAs, values were within the range specified by DoR, i.e. within 2-4 mm of flow values were observed. Results are shown in figure 3.

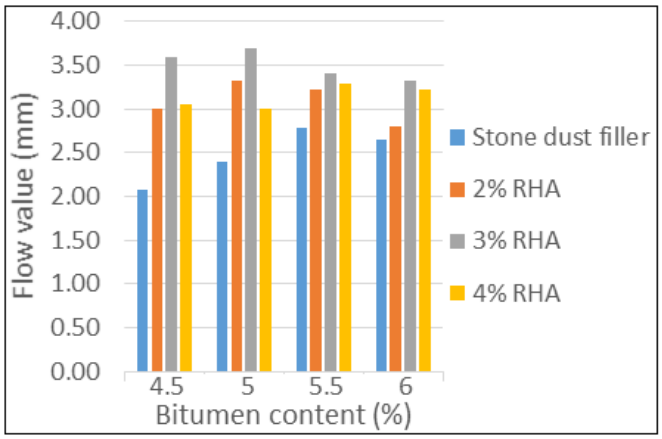

Figure 3: Flow values against bitumen content

4.2 Volumetric analysis

The volumetric properties of asphalt concrete mixtures strongly effect on the mechanical properties and durability of these mixtures and as a results their performance in the field.

Densities for RHAs are lesser than that for stone dust which is obvious since specific gravity of RHA is lesser than for the stone dust. Maximum density of 2.321 gm/cc is observed with RHA content of 2% at 6% bitumen. Maximum density of 2.318 gm/cc is observed with RHA content of 3% at 6.5% bitumen content. For a given bitumen content, air voids were greater than that for the stone dust. Though air voids, voids in mineral aggregate (VMA) requirements and voids filled with bitumen (VFB) satisfies DoR specifications.

The density decrease and air voids increase for the RHA mixtures in comparison with the control mixtures might be due to increase the stiffness of the binder when adding RHA particles [1].

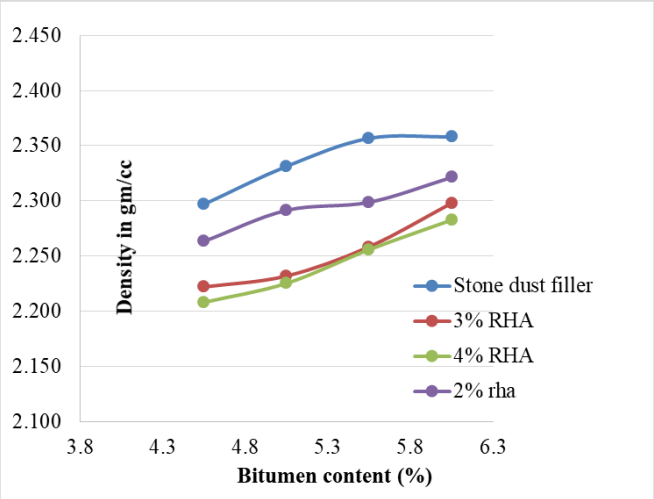

Figure 3: Density vs. bitumen content

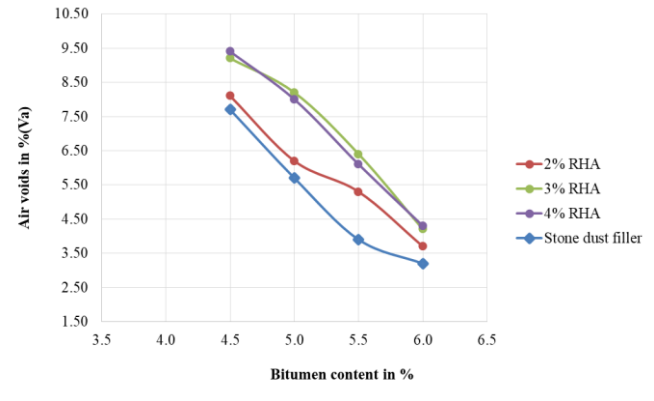

Figure 4: Air voids vs. bitumen content

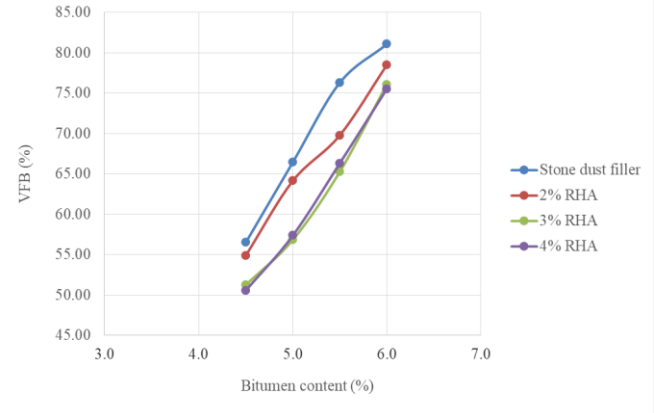

Figure 5: Voids filled with bitumen vs. bitumen content

4.3 Optimum binder content

Enough binder content is required so that all the aggregate particles get coated with enough binder which would make the asphalt mix durable. The most common method in determining the optimum asphalt binder content is to first determine the asphalt binder content that has the desired amount of mixture air voids. Optimum binder content was calculated taking the average binder content of maximum stability, 4% air voids, and maximum density.

Table 4: Optimum binder content

Marshall parameters	*Rice Husk Ash*			
	0%	2%	3%	4%
Bitumen at max Stability	5.50%	5.00%	5.00%	5.50%
Bitumen at max. Density	6.00%	6.00%	6.50%	6.00%
Bitumen at 4% air Voids	5.45%	5.85%	5.95%	6.00%
Optimum bitumen content (Average of 1,2 and 3)	5.65%	5.62%	5.82%	5.83%

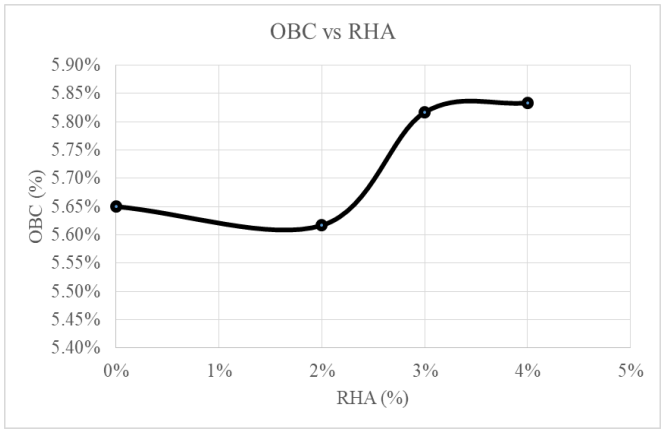

Figure 5: optimum binder content vs. Rice husk ash %

Optimum binder content increased with the increase in RHA filler content. This may be attributed to the increased viscosity of mix and resistance to the movement for filling up the voids [7].

5. Conclusions

Introduction of rice husk ash as a mineral filler in the asphalt mix impacted the mix positively. Stability values for RHA were significant, while flow values were within the range. Air voids, VMA and VFB requirements were also within the range set by DoR. Use of the RHA could result in savings of economy and can prove to be a potential solution for rice husk ash disposal in areas where such ashes are produced tremendously. Following conclusions can be drawn from the study.

- Stability value improves significantly with the introduction of rice husk ash as filler.
- Stability value of 3% RHA is found to be the best though its optimum bitumen content is 5.82%.
- Though the density decreases and air voids increase than that for the stone dust as filler, density values and air voids were satisfactory for the RHA as well.
- Optimum Binder content increased while increasing the filler content which may be due to increased resistance to flow of the binder due to the RHA filler.

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Author Profile

Shivu Khatri received the bachelor degree in civil engineering from Tribhuwan University, Institute of Engineering, Pulchowk Campus, Nepal in 2015. He is currently serving as a Highway Engineer in Ministry of Physical Infrastructure and Transport, Department of Roads since September, 2016.