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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled "**Experimental investigation of Bituminous concrete mix using rice husk ash as a mineral filler** " submitted by Shivu Khatri in partial fulfillment of the requirements for the degree of Master in Civil Engineering .

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ABSTRACT

Fillers when introduced in asphalt concrete helps filling voids thus producing a dense mix. Department of Roads, Nepal in its specification, 2073 identifies cement, stone dust and hydrated lime as fillers. These filler are expensive and are extensively used for secondary purposes. Thus, there is a need of filler which would fulfill the technical requirements as well as be economically cheaper than the existing ones.

In this thesis, rice husk ash as mineral filler was used at varying contents (2%, 3% and 4%) with varying bitumen contents (4.5% to 6%, with increment of .5%).Stone dust was used to produce control mix. The prepared samples were tested for different Marshall Properties. Moisture susceptibility of the samples were also tested as per Marshall Immersion Test.

Marshall Stability improved significantly, flow values were also within the range. Volumetric properties were also found to be satisfactory. The rice husk ash samples proved to be effective against moisture damage.

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 and in turn the environmental problems.

Key words: Bituminous concrete, mineral filler, rice husk ash, Marshall Test, Immersion Test

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LIST OF ABBREVIATIONS

ACV Aggregate Crushing Value

AIV Aggregate Impact Value

cum Cubic meter

DoR Department of Road

F/Y Fiscal year

Gm Theoritical Specific gravity/Unit weight

Gt Bulk Specific gravity/Unit weight of the mix

IRS Index of Retained Strength

LAA Los Angeles Abrasion

Min Minimum

MQ Marshall Quotient

OBC Optimum bitumen content

RHA Rice husk ash

PR Proving ring

SEM Scanning electron microscope

SSD saturated surface dry

Va air voids %

Vb % of bitumen

VFB Voids Filled with Bitumen

VG viscosity grade

VMA Voids in Mineral Aggregate

1.0 INTRODUCTION

1.1 Background

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. Asphalt concrete are the highest standard that can be given to the pavement treatment. Asphalt technology is expensive as well. Asphalt technology is adopted by DoR and other government authorities as well.

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. Mix design adopted by DoR is Marshall Mix design as described in asphalt institute manual MS-2.

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. (Diab & Enieb, 2018).

This study uses rice husk ash (RHA) as mineral filler.

1.2 Rice husk ash

RHA can be considered as an agro-industry waste. 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. (Source: Lung Hwang, Chao and Satish Chandra)The annual paddy rice production of Nepal is about 5.34 million tons (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. The huge amount of ash so produced leads to environmental issues if not disposed properly.

Chemical composition of RHA shows predominant content of silica at about 90%, and alumina at around 11 %.

Table 1. 1 Chemical composition of a RHA

S.N.	Oxides	Proportion (%)
1	CaO	1.58
2	SiO2	88.23
3	Al2O3	10.8
4	MgO	0.58
5	Fe2O3	-
6	K2O	4.23
7	TiO2	.07

(Al-Hdabi, 2016)

Figure 1. 1 SEM view of RHA, Source: (Al-Hdabi, 2016)

SEM view of the RHA shows the non-spherical and non-agglomerated regular-shaped particles.

1.3 Research Objective

i. To evaluate the performance of asphalt concrete mix using rice husk ash (RHA) as mineral filler.
ii. Finding the optimum mineral filler content.
iii. Finding optimum binder content (OBC) with rice husk ash as the filler.
iv. Finding moisture resistance of RHA mix.
v. Evaluation of financial cost.

1.4 Statement of problems

DoR identifies cement, stone dust and limestone only as fillers. Since these materials are expensive and are extensively use for secondary purposes as well, there is a need of more economic filler which would also satisfy filler characteristics. Nepal’s production of rice is impressive which in turn produces impressive amount of rice husks. These rice husks are used in factories as fuel which results heavy production of rice husk ash. This leads to disposal problems and hence environmental problems.

If these agro-industry wastes can be used in roads, it would minimize their disposal problems and minimize the use of other natural resources. Following photos shows haphazard disposal of rice husk ashes in the vicinity of Parasi area.

Figure 1. 2 Rice husk ashes haphazardly disposed in environment.

2.0 LITERATURE REVIEW

(Al-Hdabi, 2016) investigated the changes in mechanical properties of asphaltic mixtures using rice husk ash as filler. Three Marshall Specimens were prepared for each binder content, 4-6% with increment of .5% by mass of aggregate. The paper showed improvement in the pavement performance parameters. Marshall Stability was found to be approximately 65% increment than those in conventional hot asphalt mixes though slight increment in air voids were found but were within range. Water sensitivity was found to be better than that of Ordinary Portland cement filler. The paper also concluded that RHA filler asphalt mixes are more durable than Ordinary Portland cement filler asphalt mixes as per their moisture damage testing and long term aging results.

(Arabani & Amid Tahami, 2017) demonstrated that the rheological properties of bitumen was enhanced by adding rice husk ash as filler. Hot mix asphalt samples were made at optimum binder content which was found to be 5.6%. Five RHA contents were used i.e. 0-20% with increment of 5%, in terms of total binder mass. Marshall Stability were improved. Marshall Quotient, indicator of rutting resistance, was also impacted positively. Stiffness modulus was found to be better than that for conventional mixes. Furthermore, he added that the RHA mixes exhibited better fatigue life than the control mixes which was attributed to decrease in air voids and/or improvement in adhesion of binder and aggregates. 15% RHA sample showed highest fatigue resistance while 20% RHA sample showed highest rutting resistance.

(Bohara, 2017) compared the Marshall properties of cement, stone dust and rice husk ash fillers. The paper showed improvement in Marshall Properties with the use of filler. The paper also carried out the economic analysis when the above fillers are used. The paper concluded that fly ash as filler could be a better alternative to existing fillers with respect to performance and cost.

(Golalipour, Jamshidi, Niazi, Afsharikia & Khadem, 2012) investigated the impact of aggregate gradation variations on rutting characteristics of asphalt concrete mixtures. Marshall Tests were performed. The paper showed that Marshall Test can be a good indicator to evaluate the pavement rutting resistance. Furthermore, the paper concluded that the aggregate gradation has a critical role in rutting resistance due to the fact that aggregate structure is the main load carrying component of mixtures. The paper also showed that the gradation bands placed in the upper limit of asphalt mixture design gradation chart show the best performance against rutting while lower bands have the highest amount of permanent deformation.

(Kalkattawi, Fatani, & Zahran, 1995) investigated about the effect of filler on engineering properties of asphalt mixtures. The laboratory based study evaluated four fillers viz. kiln dust, volcanic tuft, iron slag and iron oxide, the results of whose were compared with stone dust filler .Marshall Stability test, Marshall loss of Stability test, dynamic shear test, Fatigue test etc. were performed. The paper concluded that filler type greatly impact the engineering properties of asphalt mix. Volcanic tuft and iron slag showed better results whereas kiln dust showed marginal results while iron oxide adversely impacted the desirable properties.

(Kumar, Mohan & Dash, 2018) concluded that rice straw ash as a filler have comparable Marshall Properties as those of conventional filler. Marshall Tests were carried out to find out the Marshall Stability and Flow values as well as volumetric analyses were done. Apart from satisfying Marshall Properties the filler would result in substantial asphalt road construction cost savings.

(Sargin, Saltan, Morova, Serin, & Terzi, 2013) studied about the use of rice husk ash as filler in hot mix asphalt. Control mixes were prepared using limestone as filler. After that, lime stone was partially replaced by rice husk ash at the rate of 25%, 50%, 75% and 100%. It was observed that 50% rice husk ash and 50% limestone of total filler rate had the best Marshall stability. The paper showed that the Marshall values increased up to a point and decreased from that point.

(S. Dobariya, May 2018) studied about the mechanical performance of asphalt mix using ceramic waste and rice husk ash as filler. Marshall Test and indirect tensile strength tests were carried out on the prepared samples. Rice husk ash was used at 2.5%, 3.5% and 4.5%. It was observed the improvement in stability value by adding rice husk ash as filler up to 2.5% and then decreased after 3.5% of the filler.

(Solaimanian, Harvey, Tahmoressi, & Tandon, 2003) discussed about the various test procedures to determine the moisture damage in asphalt mixes. Moisture sensitivity tests were categorized in two groups known as quantitative and qualitative tests. Furthermore, those tests were also categorized as tests done on loose samples and tests done on compacted samples. Marshall Immersion fell under the moisture sensitivity test done on compacted samples. Marshall Immersion test basically use conditioning phase as used in Immersion-Compression test, AASHTOT165-55, however Marshall Immersion test uses Marshall Stability as strength parameter rather than compressive strength. The paper concluded that "Mechanisms of moisture susceptibility/stripping may be different because of the different variables, but tests and their calibration must take into account materials, construction, traffic, and climate. The result will be that a given mix will have different risks depending on where and how it will be used, and these factors must be accounted for in test development, test evaluation and calibration, and test implementation."

The above literatures cited showed the better, if not, comparable results of Marshall values when rice husk ash is used as filler.

3.0 METHODOLOGY

The methodology of this research started with finding of the problem. Flow chart of the methodology used is shown in the following figure. The flow chart is self-explanatory.

Figure 3. 1 Flow chart of the methodology

3.1 Preparation of samples

3.1.1 Selection of aggregates

Aggregates were collected from Amuwa yard crusher located in Tinau River, Butwal. Three types of aggregates were used. Aggregate-A (19 mm down), Aggregate-B (10 mm down), Aggregate-C (4.75 mm down). Trials were done with different proportions of the aggregates to bring down the combined aggregate gradation within the limit set by specifications of DoR. Aggregates used conformed the gradation limits set by the DoR.

Figure 3. 2 Aggregates used (From the left Agg.-A, Agg.-B, Agg.-C)

Gradation curve for the aggregate used is shown in the following figure.

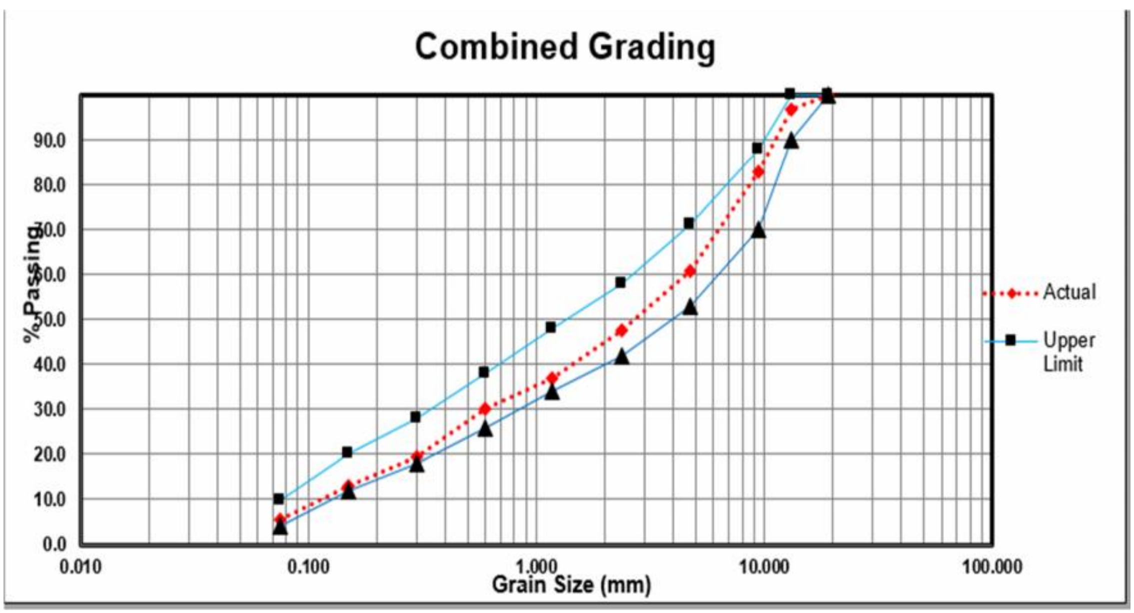

Figure 3. 3 Combined grading curve

Table 3.1 Physical tests of the aggregates

Name of the test	Result	DoR range	Standard Used
LAA Test	29.07%	Max. 40%	IS 2386 Part 4.
ACV Test	21.53%	Max. 30%	
AIV Test	20.30%	Max. 30%	

3.1.2 Asphalt cement selection

Viscosity grade bitumen (VG-30) was used. Physical properties of the bitumen from the lab tests are summarized as below.

Table 3.2 Standard tests of the bitumen

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

3.1.3 Filler selection

Two types of fillers were used. Stone dust filler was used to only produce the control mix. Another filler used was the rice husk ash (RHA). RHA was used as 0%, 2%, 3%, and 4%. RHA used in the mix was collected from the MK rice mill located in Parasi, Nawal-Parasi district. The RHA was produced as a by-product of combustion of rice husks at rice husk boilers. Rice husk was used as a source of heat energy. RHA which was obtained from the mill was little bit larger in size. So, it was sieved down through 75 micron to be used as filler.

Figure 3. 4 Rice husk ash

3.1.4 Mixing proportion

Mix proportion used was according to the following table.

Samples were prepared as described in the asphalt institute manual MS-2.Total number of samples prepared were 60, with 3 sets of each bitumen content and each filler ratio.

Table 3. 3 Mix proportion

Bitumen %	19 mm agg.	10mm agg.	4.75 mm down	Filler
	Stone dust filler (Control mix)			
(4.5%-6.5%)	20%	35%	40%	5%
	Rice husk ash 2%			
(4.0%-6.0%)	20%	35%	43%	2%
	Rice husk ash 3%			
(4.5%-6.5%)	20%	35%	42%	3%
	Rice husk ash 4%			
(4.5%-6.5%)	20%	35%	41%	4%

3.1.5 Mix design

Stability and the durability are the two primary characteristics determined in mix design. The goal is to find an economical blend and gradation of aggregates and asphalt binder that give a mixture that has:

- Enough asphalt binder
- Enough workability
- Enough mixture stability
- Sufficient voids
- Sufficient voids
- The proper selection of aggregates to provide skid resistance in high-speed traffic applications.

(The Asphalt Institute)

Figure 3. 5 Marshall Specimens being prepared and final specimen**.**

3.2 Marshall test

Marshall Test was carried out to study the volumetric analysis and stability-flow analysis of asphalt mix. Marshall Method is the most widely used method because it is simple to use, readily available in our country, less expensive and its proven record.

The Marshall tests presented here is carried out in the laboratory of Trade Improvement Road Project (TRIP) Butwal-Belhiya road project, DoR. The Marshall method used here is based upon the Asphalt Institute manual MS2 as adopted by DoR.

Figure 3. 6 Marshall Stability Apparatus

Figure 3. 7 Marshall Equipments (From top left Marshall Hammer, Jack to extract sample from the mold, Water bath, Sample molds.)

3.2.1 Laboratory Procedure

Samples were made using different filler contents for different proportion of filler. Control mix was made using stone dust as filler.

i) Sample preparation:

Control sample was prepared using stone dust as filler at 5% proportion. Bitumen content was varied from 4.5% to 6.5% with an increment of .5%. For each bitumen content 3 sets of specimen were prepared.

Test samples were prepared using rice husk ash as filler at different percent of bitumen content, 4.5% to 6.5% with an increment of .5%, at different proportion of rice husk ash.

ii) Marshall Specimens preparation and Marshall Test was conducted as per asphalt institute manual MS2.

- All the aggregates were heated at 160 degree Celsius prior to mixing with the heated bitumen.
- Mixture was placed in the mold and were given 75 blows at each face using filter paper at each face.
- The prepared specimen were let cool in the room temperature.
- The specimen were extracted from the mold using the jack after 24 hour.
- Samples were weighed for volumetric analysis.
- Samples were put in the water bath for about 30 to 40 minutes at 60 degree Celsius.
- Samples were placed in the Marshall apparatus for stability, flow readings.

3.3 Marshall Immersion test

The test procedure for Marshall Immersion test is similar to that of Immersion-Compression test as described in ASTM D1075and AASHTO T 165-86 (1990),"Effect of Water on Cohesion of Compacted Bituminous Mixtures" except for the fact that Marshall Stability is used as strength parameter rather than compressive strength as in Immersion-compression test while the conditioning of the samples are same. This test is based upon the standard CRD-C 652-95 "Standard Test Method for Measurement of Reduction in

Marshall Stability of Bituminous Mixtures Caused by Immersion in Water." in conjunction with AASHTO T 165-86 (1990).

This test measures the loss in cohesion due to moisture damage.

The Marshall Immersion Test was conducted in Central laboratory of DoR.

3.3.1 Laboratory procedure

Prepare six Marshall Test specimens (4 in. in diameter and 2.5 in. ± 0.125 in. in height) as described in Asphalt Institute manual MS-2. Marshall Tests are done as described above.

- Perform volumetric analysis to find out the bulk specific gravity of the prepared samples.
- Sort out the specimens in two groups such that bulk specific gravity of Group 1 (unconditioned samples) is essentially same as that for Group 2 (conditioned samples).
- Store the group 1 samples in air bath maintained at 25 °C for not less than 4 hours and test for Marshall Stability.
- Store the group 2 samples in water bath maintained at 60 °C for 24 hours. Transfer the samples to another water bath maintained at 25 °C for 2 hours to bring down to the test temperature. Test for Marshall Stability of the samples.

Stability-flow analysis:

- Marshall Stability: Marshall Stability is the peak resistance load obtained during a constant rate of deformation.
- Marshall Flow: Marshall Flow is a measure of the deformation (elastic plus plastic) of the specimen determined during the stability test.
- Marshall Stability is controlled by the angle of internal friction of the aggregate and the viscosity at 60 C of the asphalt binder.
- Marshall Flow is a function of the asphalt binder stiffness and the asphalt binder content of the mixture.

(The Asphalt Institute)

Volumetric analysis:

Volumetric properties, i.e. density and voids, affect the pavement performance characteristics and durability of the asphalt mixtures.

The parameters of volumetric analysis are:

- Air voids.
- Voids in mineral aggregate (VMA).
- Voids filled with binder (VFB).

The results of the laboratory experiment are expressed in the following terms:

- Marshall Stability-KN.
- Marshall Flow-mm.
- Voids in Mineral Aggregate-%.
- Voids Filled with Bitumen-%.
- Air voids-%.
- Density-gm/cc.
- Index of Retained Strength-%.

Figure 3. 8 Marshall Equipments for Marshall Immersion test.

4.0 RESULTS AND INTERPRETATION

4.1 Stability -Flow Analysis

Marshall Stability is the peak resistance load obtained during a constant rate of deformation. (Asphalt Institute manual MS-2).

Marshall Flow is a measure of the deformation (elastic plus plastic) of the specimen determined during the stability test. (Asphalt Institute manual MS-2). Quantitatively, Marshall Flow is the deformation of the specimen at Marshall Stability.

Maximum stability of 18 KN is observed at 3% RHA content with bitumen content of only 5%. Stability value increased up to 3% RHA and decreased afterwards. Massive increment in stability value is observed when ordinary stone dust filler is replaced with RHA as filler. The graphs of stability vs bitumen content showed a typical Marshall curve. Stability values satisfied the specifications of DoR.

Flow values were found to be greater than that for the control mix. Even though, the values were within the range set by specifications of DoR, i.e. 2-4 mm. Marshall Stiffness (Marshall Quotient) were also within the range as specified by DoR.

Marshall Test summary and Marshall curves i.e. Stability vs bitumen content and flow vs bitumen content are shown in the following graphs.

Table 4. 1 Stability-Flow analysis

S. N.	DESCRIPTION	UNIT	BITUMEN CONTENT (%)						Remarks
			4.0	4.5	5.0	5.5	6.0	6.5	
	Rice Husk Ash			0%					
1	MARSHALL STABILITY	KN		10.2	11.5	13.7	12.6	11.1	
2	FLOW VALUE	mm		2.08	2.40	2.78	2.65	2.82	
	Rice Husk Ash			2%					
1	MARSHALL STABILITY	KN	13.0	14.3	16.1	14.0	11.4		
2	FLOW VALUE	mm	2.78	3.00	3.32	3.22	2.80		

S. N.	DESCRIPTION	UNIT	BITUMEN CONTENT (%)					Remarks
			4.5	5.0	5.5	6.0	6.5	
	Rice Husk Ash		3%					
1	MARSHALL STABILITY	KN	16.7	18.0	16.0	14.5	12.0	
2	FLOW VALUE	mm	3.60	3.70	3.40	3.32	3.28	
	Rice Husk Ash		4%					
1	MARSHALL STABILITY	KN	13.0	14.3	16.1	14.0	12.1	
2	FLOW VALUE	mm	3.05	3.00	3.28	3.22	3.30	

Figure 4. 1 Stability vs bitumen content

Figure 4. 2 Flow vs bitumen content

4.2 Volumetric Analysis

Volumetric properties, i.e. density and voids, affects the pavement performance characteristics and durability of the asphalt mixtures.

Densities of RHA modified mix are lesser than that for the control mix, it may be due to lighter RHA particles i.e. lesser specific gravities of the RHA than that for the stone dust filler. Densities were increased with increase in bitumen content as shown in the graph of density vs bitumen content. Maximum density is observed for RHA content of 2%. Densities started decreasing after 3% of RHA as filler. Maximum density of 2.335 gm/cc is observed with RHA content of 2% at 6% bitumen content. Maximum density of 2.318 gm/cc is observed with RHA content of 3% at 6.5% bitumen content.

Air voids were maximum for that of 4% RHA and minimum for that of the control mix.

Density vs bitumen content, air voids vs bitumen content, VMA vs bitumen content and VFB vs bitumen content are shown in the following graphs.

Table 4. 2 Density void analysis.

S.N.	DESCRIPTION	UNIT	BITUMEN CONTENT (%)				
			4.5	5.0	5.5	6.0	6.5
	Rice Husk Ash		0%				
1	Theoritical density of the mix (Gt)	gm/cm3	2.489	2.471	2.453	2.436	2.419
2	Bulk density of the mix (Gm)	gm/cm3	2.297	2.331	2.357	2.358	2.366
3	% of air voids (Va)	%	7.70	5.70	3.90	3.20	2.20
4	% of bitumen (Vb)	%	9.92	11.19	12.44	13.58	14.76
5	Voids in mineral aggregate (VMA)	%	17.62	16.89	16.34	16.78	16.96
6	Voids filled with bitumen (VFB)	%	56.30	66.25	76.13	80.93	87.03

S.N.	DESCRIPTION	UNIT	BITUMEN CONTENT (%)				
			4.0	4.5	5.0	5.5	6.0
	Rice Husk Ash		2%				
1	Theoritical density of the mix (Gt)	gm/cm3	2.498	2.480	2.462	2.444	2.427
2	Bulk density of the mix (Gm)	gm/cm3	2.23	2.263	2.291	2.299	2.335
3	% of air voids (Va)	%	10.60	8.70	6.90	5.90	3.80
4	% of bitumen (Vb)	%	8.57	9.77	11.00	12.13	13.44
5	Voids in mineral aggregate (VMA)	%	19.17	18.47	17.90	18.03	17.24
6	Voids filled with bitumen (VFB)	%	44.71	52.91	61.44	67.28	77.96

S. N.	DESCRIPTION	UNIT	BITUMEN CONTENT (%)				
			4.5	5.0	5.5	6.0	6.5
	Rice Husk Ash		3%				
1	Theoretical density of the mix (Gt)	gm/cm3	2.475	2.457	2.440	2.422	2.406
2	Bulk density of the mix (Gm)	gm/cm3	2.222	2.232	2.258	2.298	2.318
3	% of air voids (Va)	%	10.20	9.20	7.40	5.10	3.60
4	% of bitumen (Vb)	%	9.60	10.71	11.92	13.23	14.46
5	Voids in mineral aggregate (VMA)	%	19.80	19.91	19.32	18.33	18.06
6	Voids filled with bitumen (VFB)	%	48.47	53.79	61.70	72.18	80.07

S. N.	DESCRIPTION	UNIT	BITUMEN CONTENT (%)				
			4.5	5.0	5.5	6.0	6.5
	Rice Husk Ash		4%				
1	Theoretical density of the mix (Gt)	gm/cm3	2.470	2.453	2.435	2.418	2.401
2	Bulk density of the mix (Gm)	gm/cm3	2.208	2.225	2.256	2.283	2.288
3	% of air voids (Va)	%	10.60	9.30	7.40	5.60	3.80
4	% of bitumen (Vb)	%	9.54	10.68	11.91	13.14	14.27
5	Voids in mineral aggregate (VMA)	%	20.14	19.98	19.31	18.74	18.97
6	Voids filled with bitumen (VFB)	%	47.36	53.45	61.67	70.12	75.23

Figure 4. 3 Density vs bitumen content

Figure 4. 4 Air voids vs bitumen content

Figure 4. 5 VMA vs bitumen content

Figure 4. 6 VFB vs bitumen content

4.3 Optimum binder content

Optimum binder content was calculated taking the average binder content of maximum stability, 4% air voids, and maximum density. 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. (Bohara, 2017)

Table 4. 3 Optimum binder content

		Rice Husk Ash (RHA)			
S.N.	Marshall parameters	0%	2%	3%	4%
1	Bitumen at max. Stability	5.50%	5.00%	5.00%	5.50%
2	Bitumen at max. Density	6.50%	6.00%	6.50%	6.50%
3	Bitumen at 4% air Voids	5.45%	5.95%	6.35%	6.45%
4	Optimum bitumen content (Average of 1,2 and 3)	**5.82%**	**5.65%**	**5.95%**	**6.15%**

The relationship of RHA filler content and Optimum binder content is shown in the following graph. From the graph, the optimum binder content for 3% RHA is calculated to be 5.95. At this OBC, air voids are found to be 5.15% which exceeds the limit used i.e. (3%-5%). Thus, OBC for 3% RHA is adjusted as 6.05%. Marshall Parameters for different filler contents are tabulated below:

Figure 4. 7OBC vs RHA

Table 4. 4 Marshall Properties at optimum binder content.

S.N.	Marshall parameters at O.B.C.	Unit	Rice Husk Ash (RHA)			
			0%	2%	3%	4%
	Optimum binder content taken		5.82%	5.65%	6.05%	6.15%
1	Stability	KN	13.00	13.90	14.20	13.50
2	Density	gm/cc	2.358	2.305	2.300	2.290
3	Air Voids	%	3.50%	4.90%	4.90%	5.00%
4	VMA	%	16.60%	17.50%	18.40%	18.70%
5	VFB	%	79.00%	72.00%	73.00%	72%
6	Flow value	mm	2.75	3.25	3.30	3.25
7	Marshall quotient		4.73	4.28	4.30	4.15

4.4 Moisture susceptibility test

Moisture susceptibility test was conducted as described above.

Test results are summarized in table below:

Table 4. 5 Moisture susceptibility test result.

Specimen no.	Bitumen %	Marshall Stability (KN)	Remarks
D1	6.05	17.1	Dry samples
D2	6.05	19.5	
W1	6.05	15.8	Wet samples
W2	6.05	18.1	

Average Marshall Stability of dry samples (S1) =18.3 KN

Average Marshall Stability of wet samples (S2) =16.95 KN

Index of Retained Strength (IRS) =S2/S1 *100% = **92.62%.**

Retained Marshall Stability is calculated in terms of Index of Retained Strength (IRS) as the numerical ratio of average Marshall Stability of wet samples to average Marshall Stability of dry samples. From the above results IRS of rice husk ash is found to be 92.62% which surpasses the limit generally used i.e. 70%.

It implies that RHA mixes are not greatly influenced by moisture.

4.5 Financial Analysis

Cost of the rice husk ash is not certain in Nepalese markets, since it is not sold commercially. Rice husk used in this research was obtained from a local rice mill in Nawal-Parasi district. Rice husk ash are the by-product of combustion of rice husks. The ash can be obtained from local rice mills, Paper industries, noodle industries and industries that use rice husk as a source of heat energy. The ashes were haphazardly thrown in the environment by the industries since it can be of little to no use.

Cost of rice husk ash is taken as average of three industries Nawal-Parasi district viz. local rice mill industry in Bardaghat, Paper mill in Parasi and Noodles factory in Parasi district.

Table 4. 6 Rice husk ash price.

S.No.	Industry/Factory	Cost in NRs. (per ton)	
		Season	Off-season
1	Local rice mill	1000	500
2	Paper mill	1800	1100
3	Noodles factory	1700	1250

Average rate used for RHA is NRs. 1225 per ton.

Norms used for rate analysis is Norms for rate analysis of road and bridge works 2075, Department of Roads, Nepal. Nawal-Parasi district rate 2076/077 is used for equipment hire rates, labor rates and material rates.

Proportion used is as below:

Rates are taken from Nawal-Parasi district rate for F/Y 076/077.

Table 4. 7 Proportion for rate analysis.

S.No.	Item	Bitumen (OBC) %	Aggregate %			Filler %
			(20-10) mm	(10-5) mm	5 mm down	
1	Stone dust filler	5.82	20	35	40	5
2	2% RHA	5.65	20	35	43	2
3	3% RHA	6.05	20	35	42	3
4	4% RHA	6.15	20	35	41	4

Table 4. 8 Cost analysis

	Unit	Rate	Quantity			
			Stone dust filler	2% RHA	3% RHA	4% RHA
Density of the compacted mix(gm/cc)			2.358	2.305	2.300	2.290
Labor						
Unskilled labor	md	550	5	5	5	5
Skilled labor	md	800	15	15	15	15
Material						
Bitumen (VG-30)	kg	73	12363.90	11772.08	12530.72	12670.51
Aggregates 20-10 mm	Cum	1875	28.37	27.78	27.62	27.47
Aggregates 10-5 mm	Cum	1350	49.65	48.62	48.33	48.07
Aggregates 5 mm and below	Cum	1350	56.75	59.73	57.99	56.31
Stone dust filler	ton	1500	10.64			
Rice husk ash filler	ton	1225		4.17	6.21	8.24
Equipment						
Pneumatic roller	hr	1000	6.00	6.00	6.00	6.00
Paver finisher	hr	1400	6.00	6.00	6.00	6.00
Batch mix HMP	hr	500	6.00	6.00	6.00	6.00
Generator	hr	150	6.00	6.00	6.00	6.00
smooth wheeled roller	hr	500	12.00	12.00	12.00	12.00
Cost			12,088.15	11,537.92	12,112.22	12,214.86

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Cost analysis used above does not include transportation costs, royalty and collection rates of materials.

4.6 Limitations

- Study was limited to VG-30 grade bitumen only, other grades were not studied.
- Effect of aggregate gradation was not taken into consideration.

4.7 Discussion and Conclusion

This research investigates the use of rice husk ash as filler in asphalt mix and evaluates the Marshall parameters of the prepared samples. RHA as mineral filler was used at varying contents (2%, 3% and 4%) with varying bitumen contents (4.5% to 6%, with increment of .5%). Stone dust was used to produce control mix. The prepared samples were tested for different Marshall Properties. Moisture susceptibility of the samples were also tested as per Marshall Immersion Test. The Marshall parameters fall well within the range specified by DoR.

Following conclusions can be drawn:

Conclusions

i. Stability value improves significantly due to 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 6.05%.

ii. 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.

iii. 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.

iv. RHA mixes are not greatly influenced by moisture as shown in Marshall Immersion Test.

v. Mixes using RHA fillers cost lesser than that for existing filler materials which substantially reduce the costs.

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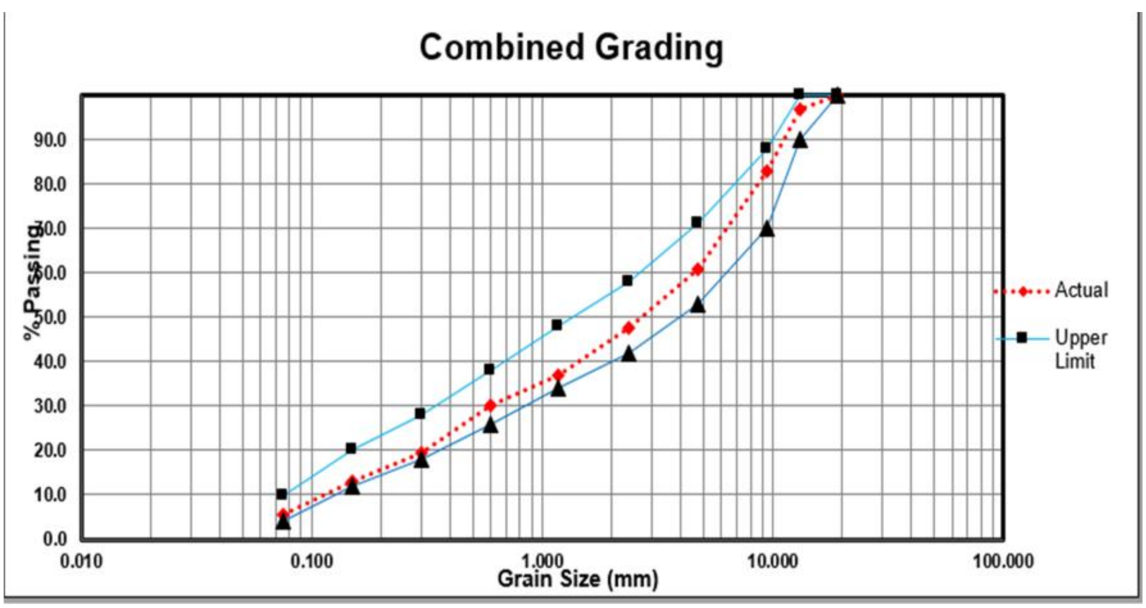
6.0 APPENDIXES

APPENDIX 1: Combined Aggregate Grading

SEIVE SIZE (mm)	INDIVIDUAL GRADING			COMBINATION			ALL-IN AGG	SPEC. LIMIT	
	Percent passing (%)			10-16mm	5-10mm	DUST (0-5)			
	CA-19mm	CA-10mm	Fine agg (5 mm down)	20.0 %	35.0 %	42.0 %		Lower	Upper
19.0	100.00	100.00	100.00	20.00	35.00	45.00	100.00	100	100
13.2	83.25	100.00	100.00	16.65	35.00	45.00	96.65	90	100
9.5	18.70	97.15	100.00	3.74	34.00	45.00	82.74	70	88
4.75	22.31	36.21	97.20	4.46	12.67	43.74	60.88	53	71
2.36	21.80	26.10	75.78	4.36	9.14	34.10	47.60	42	58
1.180	15.14	22.30	58.25	3.03	7.81	26.21	37.05	34	48
0.600	12.17	29.81	38.28	2.43	10.43	17.23	30.09	26	38
0.300	9.18	10.14	31.00	1.84	3.55	13.95	19.34	18	28
0.150	8.15	14.20	14.16	1.63	4.97	6.37	12.97	12	20
0.075	5.80	7.10	4.55	1.16	2.49	2.05	5.69	4	10



APPENDIX 2: Sieve Analysis of Rice Husk Ash Filler

Seive Size (mm)	Retained	Retained %	Cumulative Retained	Cumulative Retained %	Cumulative pass %
0.600	0.1	0.2	0.2	99.8	99.8
0.300	5.12	10.24	10.4	89.6	89.6
0.075	35.75	71.5	81.9	18.1	18.1
Pan	9.03	18.06	100.0	0.0	0.0

APPENDIX 3: Aggregate Tests

LOS ANGELES ABRASION TEST

Gradation used is Grade-B.

Total weight of sample taken= 5000 gms.

CALCULATION

Original weight of the Test Sample (W1) = 5000.00 gms
Final weight of the test sample passing 1.7 mm sieve (W2) =1453.50 gms
Percentage of loss : (W1-W2)/W1 * 100
Los Angeles Abrasion Value = 29.07%

Aggregate Impact Value TEST

Weight of sample passing 12.5 mm and retained on 10 mm sieve taken (W1)= 400 gms

Weight passing 2.36 mm sieve (W2)= 83.68 gms
AIV value=   W2/W1 *100   20.92%

Aggregate Crushing Value TEST

Weight of sample passing 12.5 mm and retained on 10 mm sieve taken (W1)= 600 gms

Weight passing 2.36 mm sieve (W2) = 129.2 gms
ACV value=   W2/W1 *100   21.53%

APPENDIX 4: Bitumen Tests

SOFTENING POINT OF BITUMEN

(RING & BALL)

ASTM-D-36

Material Description :- Jal Bitumen VG 30

Temperature when ball no.1 touches Bottom Plate		T 1	48	°C
Temperature when ball no.2 touches Bottom Plate		T 2	49	°C

SOFTENING POINT = (T1+T2)/2 =   48.5   °C

REPORTED SOFTENING POINT =   48.5   °C

DUCTILITY TEST

Material Description :- Jal Bitumen VG 30

Temperature of Water Bath 25 ◦c

Determination no.	1	2	3
Ductility value in cm	96	96	93
Average ductility value		95	

Reported ductility value= 95 cm.

PENETRATION OF BITUMEN

Material Description :- Jal Bitumen VG 30

Temperature of Water Bath 25 ◦c [SDT=25◦c]

Determination no.	1	2	3
Penetration (1/10mm)	55	62	60
Average Penetration		59.00	

Reported Penetration (1/10) = 59.00.

APPENDIX 5: Specific gravity tests

All weights are in grams.

Aggregate (19-10 mm)

Sample weight = 2000

Weight of Saturated Surface Dry (SSD) sample in water (A) = 1305.6

Weight of Saturated Surface Dry (SSD) sample in air (B) = 2038

Weight of oven dried sample (C) = 1968

Specific gravity= C/(B-A) = 2.687

Aggregate (10-5 mm)

Sample weight = 1000

Weight of Saturated Surface Dry (SSD) sample (A) in air =1008.3

Weight of gas jar, sample and water (B) =2209.0

Weight of gas jar, and water (C) =1580.7

Weight of oven dried sample (D) = 995.8

Specific gravity= D/A-(B-C) =2.621

Fine Aggregate (0-5 mm)

Sample weight = 500

Weight of Saturated Surface Dry (SSD) sample (A) in air = 508.9

Weight of pycnometer, sample and water (B) =1780.3

Weight of pycnometer, and water (C) = 1456.9

Weight of oven dried sample (D) = 498.5

Specific gravity= D/A-(B-C) =2.686

Rice husk ash filler

Sample weight = 50

Weight of pycnometer (m1) =318.4

Weight of pycnometer, and sample (m2) =368.4

Weight of pycnometer, sample and water (m3) =1482.1

Weight of pycnometer, and water (m4) =1455.7

Specific gravity = (m2-m1)/ [(m4-m1)-(m3-m2)] = 2.12

Bitumen

	Determination No.	1	2	Unit
	Temperature	25	25	**°C**
A	Wt. of Pycnometer	42.33	24.8	gms
B	Wt. of Pycnometer+sample	62.97	35.05	gms
C=(B-A)	Wt. of Sample	20.6	10.3	gms
D	Wt. of Pycnometer+sample+water	90.4	49.9	gms
E	Wt. of Pycnometer+water	89.55	49.5	gms
C\(C+E-D)	Specific Gravity	1.043	1.040	
	Average Specific Gravity	1.042		

APPENDIX 6: District Rates

Item	Unit	Rate (NRs.)
Labor		
Unskilled labor	md	550
Skilled labor	md	800
Material		
Bitumen (VG-30)	kg	73
Aggregates 20-10 mm	Cum	1875
Aggregates 10-5 mm	Cum	1350
Aggregates 5 mm and below	Cum	1350
Stone dust filler	ton	1500
Rice husk ash filler	ton	1225
Equipment		
Pneumatic roller	hr	1000
Paver finisher	hr	1400
Batch mix HMP	hr	500
Generator	hr	150
smooth wheeled roller	hr	500

APPENDIX 7: Experimental data for stone dust filler

MARSHALL TEST RESULTS

Flow Guage 1 Div=(mm) 0.01

Proving ring factor 41.69 N

Bitumen Content (%)	Sample No.	Thickness (mm)	Marshall Stability				Flow (Div)	Mean Flow (Div)	Mean Flow (mm)	Remarks
			PR Reading	Correction Factor	Corrected Load (N)	Mean Stability (KN)				
4.5	1	65.73	250	0.93	9692.9	10.2	225.00	208.33	2.08	
	2	65.08	290	0.96	11606.5		200.00			
	3	68.20	250	0.89	9276.0		200.00			
5.0	1	64.43	300	0.93	11631.5	11.5	190.00	240.00	2.40	
	2	64.00	290	0.96	11606.5		260.00			
	3	67.70	305	0.89	11316.8		270.00			
5.5	1	61.73	360	1.00	15008.4	13.7	280.00	278.33	2.78	
	2	63.73	330	1.00	13757.7		270.00			
	3	64.83	310	0.96	12406.9		285.00			
6.0	1	63.53	295	1.09	13405.4	12.6	245.00	265.00	2.65	
	2	63.73	290	1.00	12090.1		300.00			
	3	64.67	305	0.96	12206.8		250.00			
6.5	1	65.21	280	0.96	11206.3	11.1	240.00	281.67	2.82	
	2	67.20	310	0.86	11114.6		295.00			
	3	61.60	255	1.04	11056.2		310.00			

DENSITY TESTS

BITUMEN Content (%)	Specimen No.	Wt. of Dry Specimen in Air (gm)	Wt. of SSD Specimen in air (gm)	Wt. of Specimen in Water (gm)	Volume of Specimen (ml)	Density of Specimen (gm/ml)	Mean Density (gm/ml)	Thickness (mm)	Remarks
4.5	1	1202.6	1204.4	684.3	520.1	2.312	2.297	65.73	
	2	1200.1	1202.6	685.4	517.2	2.320		65.08	
	3	1202.6	1206.0	673.4	532.6	2.258		68.20	
5.0	1	1201.7	1208.0	693.9	514.1	2.337	2.331	64.43	
	2	1195.7	1203.3	692.0	511.3	2.339		64.00	
	3	1196.5	1199.5	683.3	516.2	2.318		67.70	
5.50	1	1201.5	1206.5	698.3	508.2	2.364	2.357	61.73	
	2	1205.8	1210.0	699.1	510.9	2.360		63.73	
	3	1211.1	1215.0	698.7	516.3	2.346		64.83	
6.0	1	1205.3	1212.2	701.2	511.0	2.359	2.358	63.53	
	2	1212.3	1216.9	705.7	511.2	2.371		63.73	
	3	1197.8	1213.3	702.3	511.0	2.344		64.67	
6.5	1	1201.3	1201.8	698.3	503.5	2.386	2.366	65.21	
	2	1202.7	1203.1	685.2	517.9	2.322		67.20	
	3	1196.8	1198.4	697.4	501.0	2.389		61.60	

MAXIMUM THEORETICAL DENSITIES

A. COMBINED AGGREGATE

S.N	COMPONENT	MATERIALS	DENSITY (a)	COMPONENT FRACTION (b)	COMPONENT VALUE (a) x (b)	REMARKS
1	19-10 mm	AGGREGATE - 1	2.687	0.200	0.537	
2	5-10 mm	AGGREGATE - 2	2.621	0.350	0.917	
3	(0-0.075)mm	Rice Husk Ash	2.120	0.000	0.000	
4	(0-5)mm	STONE DUST	2.686	0.450	1.209	

DENSITY OF COMBINED AGGREGATE (TOTAL) $g_a =$ 2.663

B. DENSITY OF BITUMEN, $g_{b=}$ 1.042 gm/cc Jal Bitumen (VG 30)

C. THEORETICAL DENSITY OF A.C. MIXES

S.N.	BITUMEN CONTENT (%)	BITUMEN CONTENT FRACTION	TOTAL AGGREGATE FRACTION	VOLUME OF BITUMEN	VOLUME OF AGGREGATE	TOTAL VOLUME	MAXIMUM DENSITY (gm/cc)
	P	p = P/100	(1-p)	$v_a = p/g_b$	$v_b = (1-p)/g_a$	$V = v_a + v_b$	g = 1/ V
1	4.5	0.045	0.955	0.0432	0.3586	0.4018	2.489
2	5.0	0.050	0.950	0.0480	0.3567	0.4047	2.471
3	5.5	0.055	0.945	0.0528	0.3548	0.4076	2.453
4	6.0	0.060	0.940	0.0576	0.3529	0.4105	2.436
5	6.5	0.065	0.935	0.0624	0.3510	0.4134	2.419

APPENDIX 8: Experimental data for 2% RHA

MARSHALL TEST RESULTS
(75 Blows Compaction)

Flow Guage 1 Div = (mm) 0.01
Proving ring factor 41.69 N

Bitumen Content (%)	Sample No.	Sample Thickness (mm)	Marshall Stability				Flow (Div)	Mean Flow (Div)	Mean Flow (mm)	Remarks
			PR Reading	Correction Factor	Corrected Load (N)	Mean Stability (KN)				
4.0	1	68.50	375	0.83	12976.0	13.0	290.00	278.33	2.78	
	2	70.30	425	0.86	15237.7		265.00			
	3	70.80	305	0.86	10935.3		280.00			
4.5	1	67.40	410	0.86	14699.9	14.3	320.00	300.00	3.00	
	2	66.36	480	0.93	18610.4		295.00			
	3	70.73	265	0.86	9501.2		285.00			
5.0	1	65.63	385	0.89	14285.1	16.1	390.00	331.67	3.32	
	2	66.66	560	0.93	21712.2		305.00			
	3	66.03	320	0.93	12406.9		300.00			
5.5	1	64.09	345	0.93	13376.2	14.0	355.00	321.67	3.22	
	2	66.03	325	0.93	12600.8		250.00			
	3	66.33	415	0.93	16090.3		360.00			
6.0	1	70.73	195	0.86	6991.4	11.4	390.00	280.00	2.80	
	2	66.76	350	0.89	12986.4		220.00			
	3	67.80	385	0.89	14285.1		230.00			

DENSITY TESTS OF MARSHAL TEST SPECIMENS

BITUMEN Content (%)	Specimen No.	Wt. of Dry Specimen in Air (gm)	Wt. of SSD Specimen in air (gm)	Wt. of Specimen in Water (gm)	Volume of Specimen (ml)	Density of Specimen (gm/ml)	Mean Density (gm/ml)	Thickness (mm)	Remarks
4.0	1	1189.8	1193.5	664.3	529.2	2.248	2.232	68.50	
	2	1195.5	1196.1	657.9	538.2	2.221		70.30	
	3	1200.6	1198.8	659.9	538.9	2.228		70.80	
4.5	1	1203.7	1203.9	676.2	527.7	2.281	2.263	67.40	
	2	1196.4	1196.7	669.2	527.5	2.268		66.36	
	3	1215.4	1217.0	674.6	542.4	2.241		70.73	
5.00	1	1199.7	1203.9	681.2	522.7	2.295	2.291	65.63	
	2	1201.2	1200.2	684.8	515.4	2.331		66.66	
	3	1210.6	1226.3	687.9	538.4	2.249		66.03	
5.5	1	1206.6	1204.9	685.3	519.6	2.322	2.299	64.09	
	2	1206.5	1208.5	684.7	523.8	2.303		66.03	
	3	1208.7	1220.4	688.1	532.3	2.271		66.33	
6.0	1	1204.7	1205.3	690.2	515.1	2.339	2.335	70.73	
	2	1202.1	1202.8	691.4	511.4	2.351		66.76	
	3	1214.5	1215.4	691.2	524.2	2.317		67.80	

MAXIMUM THEORETICAL DENSITIES

A. COMBINED AGGREGATE

S.N	COMPONENT	MATERIALS	DENSITY (a)	COMPONENT FRACTION (b)	COMPONENT VALUE (a) x (b)	REMARKS
1	19-10 mm	AGGREGATE - 1	2.687	0.200	0.537	
2	5-10 mm	AGGREGATE - 2	2.621	0.350	0.917	
3	(0-0.075)mm	Rice Husk Ash	2.120	0.020	0.042	
4	(0-5)mm	STONE DUST	2.686	0.430	1.155	

DENSITY OF COMBINED AGGREGATE(TOTAL) g_a 2.652

B. DENSITY OF BITUMEN, g_b = 1.042 gm/cc Jal Bitumen (VG 30)

C. THEORETICAL DENSITY OF A.C. MIXES

S. N.	BITUMEN CONTENT (%)	BITUMEN CONTENT FRACTION	TOTAL AGGREGATE FRACTION	VOLUME OF BITUMEN	VOLUME OF AGGREGATE	TOTAL VOLUME	MAXIMUM DENSITY (gm/cc)
	P	p = P/100	(1-p)	$v_a = p/g_b$	$v_b = (1-p)/g_a$	$V = v_a + v_b$	$g = 1/V$
1	4.0	0.040	0.960	0.0384	0.3620	0.4004	2.498
2	4.5	0.045	0.955	0.0432	0.3601	0.4033	2.480
3	5.0	0.050	0.950	0.0480	0.3582	0.4062	2.462
4	5.5	0.055	0.945	0.0528	0.3563	0.4091	2.444
5	6.0	0.060	0.940	0.0576	0.3544	0.4120	2.427

APPENDIX 9: Experimental data for 3% RHA

MARSHALL TEST RESULTS

Flow Guage 1 Div=(mm) 0.01
Proving ring factor 41.69 N

Bitumen Content (%)	Sample No.	Sample Thickness (mm)	Marshall Stability				Flow (Div)	Mean Flow (Div)	Mean Flow (mm)	Remarks
			PR Reading	Correction Factor	Corrected Load (N)	Mean Stability (KN)				
4.5	1	66.60	465	0.93	18028.8	16.7	350.00	360.00	3.60	
	2	66.30	465	0.93	18028.8		360.00			
	3	69.90	405	0.83	14014.1		370.00			
5.0	1	67.70	510	0.86	18285.2	18.0	370.00	370.00	3.70	
	2	67.60	510	0.86	18285.2		340.00			
	3	71.20	490	0.86	17568.2		400.00			
5.5	1	66.20	415	0.93	16090.3	16.0	320.00	340.00	3.40	
	2	69.00	425	0.83	14706.1		290.00			
	3	67.40	480	0.86	17209.6		410.00			
6.0	1	66.80	470	0.86	16851.1	14.5	345.00	331.67	3.32	
	2	67.00	375	0.86	13445.0		340.00			
	3	65.70	355	0.89	13172.0		310.00			
6.5	1	64.20	290	0.93	11243.8	12.0	455.00	328.33	3.28	
	2	66.60	305	0.93	11825.4		270.00			
	3	67.40	360	0.86	12907.2		260.00			

DENSITY TESTS OF MARSHAL TEST SPECIMENS

BITUMEN Content (%)	Specimen No.	Wt. of Dry Specimen in Air (gm)	Wt. of SSD Specimen in air (gm)	Wt. of Specimen in Water (gm)	Volume of Specimen (ml)	Density of Specimen (gm/ml)	Mean Density (gm/ml)	Thickness (mm)	Remarks
4.5	1	1207.5	1208.9	667.5	541.4	2.230	2.222	66.60	
	2	1207.1	1207.3	669.6	537.7	2.245		66.30	
	3	1210.6	1213.7	661.1	552.6	2.191		69.90	
5.0	1	1208.4	1208.9	671.4	537.5	2.248	2.232	67.70	
	2	1210.8	1211.2	673.2	538.0	2.251		67.60	
	3	1205.3	1206.3	657.7	548.6	2.197		71.20	
5.50	1	1214.9	1215.0	681.3	533.7	2.276	2.258	66.20	
	2	1212.5	1213.9	671.0	542.9	2.233		69.00	
	3	1193.0	1193.3	666.7	526.6	2.265		67.40	
6.0	1	1215.0	1215.7	688.2	527.5	2.303	2.298	66.80	
	2	1203.0	1203.7	686.1	517.6	2.324		67.00	
	3	1230.0	1236.6	693.9	542.7	2.266		65.70	
6.5	1	1200.9	1201.4	690.3	511.1	2.350	2.318	64.20	
	2	1215.6	1216.6	689.4	527.2	2.306		66.60	
	3	1211.6	1212.1	685.2	526.9	2.299		67.40	

MAXIMUM THEORETICAL DENSITIES

A. COMBINED AGGREGATE

S.N	COMPONENT	MATERIALS	DENSITY (a)	COMPONENT FRACTION (b)	COMPONENT VALUE (a) x (b)	REMARKS
1	19-10 mm	AGGREGATE - 1	2.687	0.200	0.537	
2	5-10 mm	AGGREGATE - 2	2.621	0.350	0.917	
3	(0-0.075)mm	Rice Husk Ash	2.120	0.030	0.064	
4	(0-5)mm	STONE DUST	2.686	0.420	1.128	

DENSITY OF COMBINED AGGREGATE(TOTAL) g_a 2.646

B. DENSITY OF BITUMEN, g_b= 1.042 gm/cc Jal Bitumen (VG 30)

C. THEORETICAL DENSITY OF A.C. MIXES

S. No.	BITUMEN CONTENT (%)	BITUMEN CONTENT FRACTION	TOTAL AGGREGATE FRACTION	VOLUME OF BITUMEN	VOLUME OF AGGREGATE	TOTAL VOLUME	MAXIMUM DENSITY (gm/cc)
	P	p = P/100	(1-p)	$v_a = p/g_b$	$v_b = (1-p)/g_a$	$V = v_a + v_b$	g = 1/ V
1	4.5	0.045	0.955	0.0432	0.3609	0.4041	2.475
2	5.0	0.050	0.950	0.0480	0.3590	0.4070	2.457
3	5.5	0.055	0.945	0.0528	0.3571	0.4099	2.440
4	6.0	0.060	0.940	0.0576	0.3552	0.4128	2.422
5	6.5	0.065	0.935	0.0624	0.3533	0.4157	2.406

APPENDIX 10: Experimental data for 4% RHA

MARSHALL TEST RESULTS

Flow Guage 1 Div=(mm) 0.01

Proving ring factor= 41.69 N

Bitumen Content (%)	Sample No.	Sample Thickness (mm)	Marshall Stability				Flow (Div)	Mean Flow (Div)	Mean Flow (mm)	Remarks
			PR Reading	Correction Factor	Corrected Load (N)	Mean Stability (KN)				
4.5	1	68.50	375	0.83	12976.0	13.0	290.00	305.00	3.05	
	2	70.30	425	0.86	15237.7		305.00			
	3	70.80	305	0.86	10935.3		320.00			
5.0	1	67.40	410	0.86	14699.9	14.3	380.00	300.00	3.00	
	2	66.36	480	0.93	18610.4		295.00			
	3	70.73	265	0.86	9501.2		225.00			
5.5	1	65.63	385	0.89	14285.1	16.1	425.00	328.33	3.28	
	2	66.66	560	0.93	21712.2		250.00			
	3	66.03	320	0.93	12406.9		310.00			
6.0	1	64.09	345	0.93	13376.2	14.0	355.00	321.67	3.22	
	2	66.03	325	0.93	12600.8		250.00			
	3	66.33	415	0.93	16090.3		360.00			
6.5	1	69.82	355	0.86	12728.0	12.1	360.00	330.00	3.30	
	2	65.21	285	0.89	10574.7		320.00			
	3	66.52	335	0.93	12988.5		310.00			

DENSITY TESTS OF MARSHAL TEST SPECIMENS

BITUMEN Content (%)	Specimen No.	Wt. of Dry Specimen in Air (gm)	Wt. of SSD Specimen in air (gm)	Wt. of Specimen in Water (gm)	Volume of Specimen (ml)	Density of Specimen (gm/ml)	Mean Density (gm/ml)	Thickness (mm)	Remarks
4.5	1	1212.9	1190.5	654.3	536.2	2.262	2.208	68.50	
	2	1205.1	1196.1	647.9	548.2	2.198		70.30	
	3	1209.3	1198.8	639.9	558.9	2.164		70.80	
5.0	1	1211.4	1204.9	676.2	528.7	2.291	2.225	67.40	
	2	981.7	983.6	537.0	446.6	2.198		66.36	
	3	1201.0	1213.9	664.6	549.3	2.186		70.73	
5.50	1	1205.9	1203.9	674.6	529.3	2.278	2.256	65.63	
	2	1201.9	1200.2	669.0	531.2	2.263		66.66	
	3	1207.2	1226.3	684.1	542.2	2.226		66.03	
6.0	1	1203.9	1204.9	680.2	524.7	2.294	2.283	64.09	
	2	1203.9	1205.5	670.8	534.7	2.252		66.03	
	3	1202.8	1217.4	694.9	522.5	2.302		66.33	
6.5	1	1211.3	1212.2	681.4	530.8	2.282	2.310	69.82	
	2	1201.6	1203.8	685.8	518.0	2.320		65.21	
	3	1203.9	1208.2	691.2	517.0	2.329		66.52	

MAXIMUM THEORETICAL DENSITIES

A. COMBINED AGGREGATE

S.N	COMPONENT	MATERIALS	DENSITY (a)	COMPONENT FRACTION (b)	COMPONENT VALUE (a) x (b)	REMARKS
1	16 mm	AGGREGATE - 1	2.687	0.200	0.537	
2	5-10 mm	AGGREGATE - 2	2.621	0.350	0.917	
3	(0-0.075)mm	Rice Husk Ash	2.120	0.040	0.085	
4	(0-5)mm	STONE DUST	2.686	0.410	1.101	

DENSITY OF COMBINED AGGREGATE(TOTAL) g_a 2.641

B. DENSITY OF BITUMEN, $gb_{=}$ 1.042 gm/cc Jal Bitumen (VG 30)

C. THEORETICAL DENSITY OF A.C. MIXES

S. No.	BITUMEN CONTENT (%)	BITUMEN CONTENT FRACTION	TOTAL AGGREGATE FRACTION	VOLUME OF BITUMEN	VOLUME OF AGGREGATE	TOTAL VOLUME	MAXIMUM DENSITY (gm/cc)
	P	p = P/100	(1-p)	$v_a = p/g_b$	$v_b = (1-p)/g_a$	$V = v_a + v_b$	g = 1/ V
1	4.5	0.045	0.955	0.0432	0.3616	0.4048	2.470
2	5.0	0.050	0.950	0.0480	0.3597	0.4077	2.453
3	5.5	0.055	0.945	0.0528	0.3578	0.4106	2.435
4	6.0	0.060	0.940	0.0576	0.3560	0.4136	2.418
5	6.5	0.065	0.935	0.0624	0.3541	0.4165	2.401

APPENDIX 11: Mixing Proportion

Mix Proportion for stone dust filler

Bitumen %	Aggregate-1	Aggregate-2	Rice Husk Ash	Stone Dust	Bitumen	Total Weight
4.5	233.49	408.61	0.00	525.36	52.54	1220
5	232.38	406.67	0.00	522.86	58.10	1220
5.5	231.28	404.74	0.00	520.38	63.60	1220
6	230.19	402.83	0.00	517.92	69.06	1220
6.5	229.11	400.94	0.00	515.49	74.46	1220

Mix Proportion for 2% RHA filler

Bitumen %	Aggregate-1	Aggregate-2	Rice Husk Ash	Stone Dust	Bitumen	Total Weight
4	234.62	410.58	23.46	504.42	46.92	1220
4.5	233.49	408.61	23.35	502.01	52.54	1220
5	232.38	406.67	23.24	499.62	58.10	1220
5.5	231.28	404.74	23.13	497.25	63.60	1220
6	230.19	402.83	23.02	494.91	69.06	1220

Mix Proportion for 3% RHA filler

Bitumen %	Aggregate-1	Aggregate-2	Rice Husk Ash	Stone Dust	Bitumen	Total Weight
4.5	233.49	408.61	35.02	490.33	52.54	1220
5	232.38	406.67	34.86	488.00	58.10	1220
5.5	231.28	404.74	34.69	485.69	63.60	1220
6	230.19	402.83	34.53	483.40	69.06	1220
6.5	229.11	400.94	34.37	481.13	74.46	1220

Mix Proportion for 4% RHA filler

Bitumen %	Aggregate-1	Aggregate-2	Rice Husk Ash	Stone Dust	Bitumen	Total Weight
4.5	233.49	408.61	46.70	478.66	52.54	1220
5	232.38	406.67	46.48	476.38	58.10	1220
5.5	231.28	404.74	46.26	474.12	63.60	1220
6	230.19	402.83	46.04	471.89	69.06	1220
6.5	229.11	400.94	45.82	469.67	74.46	1220

APPENDIX 12: Laboratory Recommendation

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled "**Experimental investigation of Bituminous concrete mix using rice husk ash as a mineral filler** " submitted by Shivu Khatri in partial fulfillment of the requirements for the degree of Master in Civil Engineering .

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ABSTRACT

Fillers when introduced in asphalt concrete helps filling voids thus producing a dense mix. Department of Roads, Nepal in its specification, 2073 identifies cement, stone dust and hydrated lime as fillers. These filler are expensive and are extensively used for secondary purposes. Thus, there is a need of filler which would fulfill the technical requirements as well as be economically cheaper than the existing ones.

In this thesis, rice husk ash as mineral filler was used at varying contents (2%, 3% and 4%) with varying bitumen contents (4.5% to 6%, with increment of .5%).Stone dust was used to produce control mix. The prepared samples were tested for different Marshall Properties. Moisture susceptibility of the samples were also tested as per Marshall Immersion Test.

Marshall Stability improved significantly, flow values were also within the range. Volumetric properties were also found to be satisfactory. The rice husk ash samples proved to be effective against moisture damage.

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 and in turn the environmental problems.

Key words: Bituminous concrete, mineral filler, rice husk ash, Marshall Test, Immersion Test

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Shivu Khatri

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LIST OF ABBREVIATIONS

ACV Aggregate Crushing Value

AIV Aggregate Impact Value

cum Cubic meter

DoR Department of Road

F/Y Fiscal year

Gm Theoritical Specific gravity/Unit weight

Gt Bulk Specific gravity/Unit weight of the mix

IRS Index of Retained Strength

LAA Los Angeles Abrasion

Min Minimum

MQ Marshall Quotient

OBC Optimum bitumen content

RHA Rice husk ash

PR Proving ring

SEM Scanning electron microscope

SSD saturated surface dry

Va air voids %

Vb % of bitumen

VFB Voids Filled with Bitumen

VG viscosity grade

VMA Voids in Mineral Aggregate

1.0 INTRODUCTION

1.1 Background

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. Asphalt concrete are the highest standard that can be given to the pavement treatment. Asphalt technology is expensive as well. Asphalt technology is adopted by DoR and other government authorities as well.

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. Mix design adopted by DoR is Marshall Mix design as described in asphalt institute manual MS-2.

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. (Diab & Enieb, 2018).

This study uses rice husk ash (RHA) as mineral filler.

1.2 Rice husk ash

RHA can be considered as an agro-industry waste. 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. (Source: Lung Hwang, Chao and Satish Chandra)The annual paddy rice production of Nepal is about 5.34 million tons (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. The huge amount of ash so produced leads to environmental issues if not disposed properly.

Chemical composition of RHA shows predominant content of silica at about 90%, and alumina at around 11 %.

Table 1. 1 Chemical composition of a RHA

S.N.	Oxides	Proportion (%)
1	CaO	1.58
2	SiO2	88.23
3	Al2O3	10.8
4	MgO	0.58
5	Fe2O3	-
6	K2O	4.23
7	TiO2	.07

(Al-Hdabi, 2016)

Figure 1. 1 SEM view of RHA, Source: (Al-Hdabi, 2016)

SEM view of the RHA shows the non-spherical and non-agglomerated regular-shaped particles.

1.3 Research Objective

i. To evaluate the performance of asphalt concrete mix using rice husk ash (RHA) as mineral filler.

ii. Finding the optimum mineral filler content.

iii. Finding optimum binder content (OBC) with rice husk ash as the filler.

iv. Finding moisture resistance of RHA mix.

v. Evaluation of financial cost.

1.4 Statement of problems

DoR identifies cement, stone dust and limestone only as fillers. Since these materials are expensive and are extensively use for secondary purposes as well, there is a need of more economic filler which would also satisfy filler characteristics. Nepal’s production of rice is impressive which in turn produces impressive amount of rice husks. These rice husks are used in factories as fuel which results heavy production of rice husk ash. This leads to disposal problems and hence environmental problems.

If these agro-industry wastes can be used in roads, it would minimize their disposal problems and minimize the use of other natural resources. Following photos shows haphazard disposal of rice husk ashes in the vicinity of Parasi area.

Figure 1. 2 Rice husk ashes haphazardly disposed in environment.

2.0 LITERATURE REVIEW

(Al-Hdabi, 2016) investigated the changes in mechanical properties of asphaltic mixtures using rice husk ash as filler. Three Marshall Specimens were prepared for each binder content, 4-6% with increment of .5% by mass of aggregate. The paper showed improvement in the pavement performance parameters. Marshall Stability was found to be approximately 65% increment than those in conventional hot asphalt mixes though slight increment in air voids were found but were within range. Water sensitivity was found to be better than that of Ordinary Portland cement filler. The paper also concluded that RHA filler asphalt mixes are more durable than Ordinary Portland cement filler asphalt mixes as per their moisture damage testing and long term aging results.

(Arabani & Amid Tahami, 2017) demonstrated that the rheological properties of bitumen was enhanced by adding rice husk ash as filler. Hot mix asphalt samples were made at optimum binder content which was found to be 5.6%. Five RHA contents were used i.e. 0-20% with increment of 5%, in terms of total binder mass. Marshall Stability were improved. Marshall Quotient, indicator of rutting resistance, was also impacted positively. Stiffness modulus was found to be better than that for conventional mixes. Furthermore, he added that the RHA mixes exhibited better fatigue life than the control mixes which was attributed to decrease in air voids and/or improvement in adhesion of binder and aggregates. 15% RHA sample showed highest fatigue resistance while 20% RHA sample showed highest rutting resistance.

(Bohara, 2017) compared the Marshall properties of cement, stone dust and rice husk ash fillers. The paper showed improvement in Marshall Properties with the use of filler. The paper also carried out the economic analysis when the above fillers are used. The paper concluded that fly ash as filler could be a better alternative to existing fillers with respect to performance and cost.

(Golalipour, Jamshidi, Niazi, Afsharikia & Khadem, 2012) investigated the impact of aggregate gradation variations on rutting characteristics of asphalt concrete mixtures. Marshall Tests were performed. The paper showed that Marshall Test can be a good indicator to evaluate the pavement rutting resistance. Furthermore, the paper concluded that the aggregate gradation has a critical role in rutting resistance due to the fact that aggregate structure is the main load carrying component of mixtures. The paper also showed that the gradation bands placed in the upper limit of asphalt mixture design gradation chart show the best performance against rutting while lower bands have the highest amount of permanent deformation.

(Kalkattawi, Fatani, & Zahran, 1995) investigated about the effect of filler on engineering properties of asphalt mixtures. The laboratory based study evaluated four fillers viz. kiln dust, volcanic tuft, iron slag and iron oxide, the results of whose were compared with stone dust filler .Marshall Stability test, Marshall loss of Stability test, dynamic shear test, Fatigue test etc. were performed. The paper concluded that filler type greatly impact the engineering properties of asphalt mix. Volcanic tuft and iron slag showed better results whereas kiln dust showed marginal results while iron oxide adversely impacted the desirable properties.

(Kumar, Mohan & Dash, 2018) concluded that rice straw ash as a filler have comparable Marshall Properties as those of conventional filler. Marshall Tests were carried out to find out the Marshall Stability and Flow values as well as volumetric analyses were done. Apart from satisfying Marshall Properties the filler would result in substantial asphalt road construction cost savings.

(Sargin, Saltan, Morova, Serin, & Terzi, 2013) studied about the use of rice husk ash as filler in hot mix asphalt. Control mixes were prepared using limestone as filler. After that, lime stone was partially replaced by rice husk ash at the rate of 25%, 50%, 75% and 100%. It was observed that 50% rice husk ash and 50% limestone of total filler rate had the best Marshall stability. The paper showed that the Marshall values increased up to a point and decreased from that point.

(S. Dobariya, May 2018) studied about the mechanical performance of asphalt mix using ceramic waste and rice husk ash as filler. Marshall Test and indirect tensile strength tests were carried out on the prepared samples. Rice husk ash was used at 2.5%, 3.5% and 4.5%. It was observed the improvement in stability value by adding rice husk ash as filler up to 2.5% and then decreased after 3.5% of the filler.

(Solaimanian, Harvey, Tahmoressi, & Tandon, 2003) discussed about the various test procedures to determine the moisture damage in asphalt mixes. Moisture sensitivity tests were categorized in two groups known as quantitative and qualitative tests. Furthermore, those tests were also categorized as tests done on loose samples and tests done on compacted samples. Marshall Immersion fell under the moisture sensitivity test done on compacted samples. Marshall Immersion test basically use conditioning phase as used in Immersion-Compression test, AASHTOT165-55, however Marshall Immersion test uses Marshall Stability as strength parameter rather than compressive strength. The paper concluded that "Mechanisms of moisture susceptibility/stripping may be different because of the different variables, but tests and their calibration must take into account materials, construction, traffic, and climate. The result will be that a given mix will have different risks depending on where and how it will be used, and these factors must be accounted for in test development, test evaluation and calibration, and test implementation."

The above literatures cited showed the better, if not, comparable results of Marshall values when rice husk ash is used as filler.

3.0 METHODOLOGY

The methodology of this research started with finding of the problem. Flow chart of the methodology used is shown in the following figure. The flow chart is self-explanatory.

Figure 3. 1 Flow chart of the methodology

3.1 Preparation of samples

3.1.1 Selection of aggregates

Aggregates were collected from Amuwa yard crusher located in Tinau River, Butwal. Three types of aggregates were used. Aggregate-A (19 mm down), Aggregate-B (10 mm down), Aggregate-C (4.75 mm down). Trials were done with different proportions of the aggregates to bring down the combined aggregate gradation within the limit set by specifications of DoR. Aggregates used conformed the gradation limits set by the DoR.

Figure 3. 2 Aggregates used (From the left Agg.-A, Agg.-B, Agg.-C)

Gradation curve for the aggregate used is shown in the following figure.

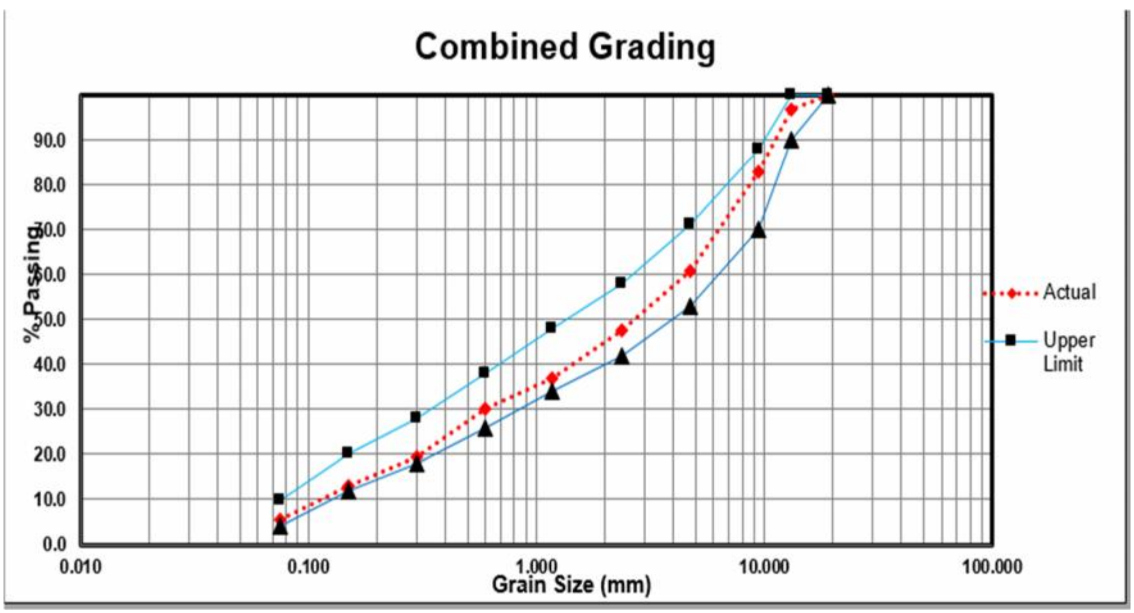

Figure 3. 3 Combined grading curve

Table 3.1 Physical tests of the aggregates

Name of the test	Result	DoR range	Standard Used
LAA Test	29.07%	Max. 40%	IS 2386 Part 4.
ACV Test	21.53%	Max. 30%	
AIV Test	20.30%	Max. 30%	

3.1.2 Asphalt cement selection

Viscosity grade bitumen (VG-30) was used. Physical properties of the bitumen from the lab tests are summarized as below.

Table 3.2 Standard tests of the bitumen

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

3.1.3 Filler selection

Two types of fillers were used. Stone dust filler was used to only produce the control mix. Another filler used was the rice husk ash (RHA). RHA was used as 0%, 2%, 3%, and 4%. RHA used in the mix was collected from the MK rice mill located in Parasi, Nawal-Parasi district. The RHA was produced as a by-product of combustion of rice husks at rice husk boilers. Rice husk was used as a source of heat energy. RHA which was obtained from the mill was little bit larger in size. So, it was sieved down through 75 micron to be used as filler.

Figure 3. 4 Rice husk ash

3.1.4 Mixing proportion

Mix proportion used was according to the following table.

Samples were prepared as described in the asphalt institute manual MS-2.Total number of samples prepared were 60, with 3 sets of each bitumen content and each filler ratio.

Table 3. 3 Mix proportion

Bitumen %	19 mm agg.	10mm agg.	4.75 mm down	Filler
	Stone dust filler (Control mix)			
(4.5%-6.5%)	20%	35%	40%	5%
	Rice husk ash 2%			
(4.0%-6.0%)	20%	35%	43%	2%
	Rice husk ash 3%			
(4.5%-6.5%)	20%	35%	42%	3%
	Rice husk ash 4%			
(4.5%-6.5%)	20%	35%	41%	4%

3.1.5 Mix design

Stability and the durability are the two primary characteristics determined in mix design. The goal is to find an economical blend and gradation of aggregates and asphalt binder that give a mixture that has:

- Enough asphalt binder
- Enough workability
- Enough mixture stability
- Sufficient voids
- Sufficient voids
- The proper selection of aggregates to provide skid resistance in high-speed traffic applications.

(The Asphalt Institute)

Figure 3. 5 Marshall Specimens being prepared and final specimen**.**

3.2 Marshall test

Marshall Test was carried out to study the volumetric analysis and stability-flow analysis of asphalt mix. Marshall Method is the most widely used method because it is simple to use, readily available in our country, less expensive and its proven record.

The Marshall tests presented here is carried out in the laboratory of Trade Improvement Road Project (TRIP) Butwal-Belhiya road project, DoR. The Marshall method used here is based upon the Asphalt Institute manual MS2 as adopted by DoR.

Figure 3. 6 Marshall Stability Apparatus

Figure 3. 7 Marshall Equipments (From top left Marshall Hammer, Jack to extract sample from the mold, Water bath, Sample molds.)

3.2.1 Laboratory Procedure

Samples were made using different filler contents for different proportion of filler. Control mix was made using stone dust as filler.

i) Sample preparation:

Control sample was prepared using stone dust as filler at 5% proportion.

Bitumen content was varied from 4.5% to 6.5% with an increment of .5%.

For each bitumen content 3 sets of specimen were prepared.

Test samples were prepared using rice husk ash as filler at different percent of bitumen content, 4.5% to 6.5% with an increment of .5%, at different proportion of rice husk ash.

ii) Marshall Specimens preparation and Marshall Test was conducted as per asphalt institute manual MS2.

- All the aggregates were heated at 160 degree Celsius prior to mixing with the heated bitumen.
- Mixture was placed in the mold and were given 75 blows at each face using filter paper at each face.
- The prepared specimen were let cool in the room temperature.
- The specimen were extracted from the mold using the jack after 24 hour.
- Samples were weighed for volumetric analysis.
- Samples were put in the water bath for about 30 to 40 minutes at 60 degree Celsius.
- Samples were placed in the Marshall apparatus for stability, flow readings.

3.3 Marshall Immersion test

The test procedure for Marshall Immersion test is similar to that of Immersion-Compression test as described in ASTM D1075and AASHTO T 165-86 (1990),"Effect of Water on Cohesion of Compacted Bituminous Mixtures" except for the fact that Marshall Stability is used as strength parameter rather than compressive strength as in Immersion-compression test while the conditioning of the samples are same. This test is based upon the standard CRD-C 652-95 "Standard Test Method for Measurement of Reduction in

Marshall Stability of Bituminous Mixtures Caused by Immersion in Water." in conjunction with AASHTO T 165-86 (1990).

This test measures the loss in cohesion due to moisture damage.

The Marshall Immersion Test was conducted in Central laboratory of DoR.

3.3.1 Laboratory procedure

Prepare six Marshall Test specimens (4 in. in diameter and 2.5 in. ± 0.125 in. in height) as described in Asphalt Institute manual MS-2. Marshall Tests are done as described above.

- Perform volumetric analysis to find out the bulk specific gravity of the prepared samples.
- Sort out the specimens in two groups such that bulk specific gravity of Group 1 (unconditioned samples) is essentially same as that for Group 2 (conditioned samples).
- Store the group 1 samples in air bath maintained at 25 °C for not less than 4 hours and test for Marshall Stability.
- Store the group 2 samples in water bath maintained at 60 °C for 24 hours. Transfer the samples to another water bath maintained at 25 °C for 2 hours to bring down to the test temperature. Test for Marshall Stability of the samples.

Stability-flow analysis:

- Marshall Stability: Marshall Stability is the peak resistance load obtained during a constant rate of deformation.
- Marshall Flow: Marshall Flow is a measure of the deformation (elastic plus plastic) of the specimen determined during the stability test.
- Marshall Stability is controlled by the angle of internal friction of the aggregate and the viscosity at 60 C of the asphalt binder.
- Marshall Flow is a function of the asphalt binder stiffness and the asphalt binder content of the mixture.

(The Asphalt Institute)

Volumetric analysis:

Volumetric properties, i.e. density and voids, affect the pavement performance characteristics and durability of the asphalt mixtures.

The parameters of volumetric analysis are:

- Air voids.
- Voids in mineral aggregate (VMA).
- Voids filled with binder (VFB).

The results of the laboratory experiment are expressed in the following terms:

- Marshall Stability-KN.
- Marshall Flow-mm.
- Voids in Mineral Aggregate-%.
- Voids Filled with Bitumen-%.
- Air voids-%.
- Density-gm/cc.
- Index of Retained Strength-%.

Figure 3. 8 Marshall Equipments for Marshall Immersion test.

4.0 RESULTS AND INTERPRETATION

4.1 Stability -Flow Analysis

Marshall Stability is the peak resistance load obtained during a constant rate of deformation. (Asphalt Institute manual MS-2).

Marshall Flow is a measure of the deformation (elastic plus plastic) of the specimen determined during the stability test. (Asphalt Institute manual MS-2). Quantitatively, Marshall Flow is the deformation of the specimen at Marshall Stability.

Maximum stability of 18 KN is observed at 3% RHA content with bitumen content of only 5%. Stability value increased up to 3% RHA and decreased afterwards. Massive increment in stability value is observed when ordinary stone dust filler is replaced with RHA as filler. The graphs of stability vs bitumen content showed a typical Marshall curve. Stability values satisfied the specifications of DoR.

Flow values were found to be greater than that for the control mix. Even though, the values were within the range set by specifications of DoR, i.e. 2-4 mm. Marshall Stiffness (Marshall Quotient) were also within the range as specified by DoR.

Marshall Test summary and Marshall curves i.e. Stability vs bitumen content and flow vs bitumen content are shown in the following graphs.

Table 4. 1 Stability-Flow analysis

S. N.	DESCRIPTION	UNIT	BITUMEN CONTENT (%)						Remarks
			4.0	4.5	5.0	5.5	6.0	6.5	
	Rice Husk Ash			0%					
1	MARSHALL STABILITY	KN		10.2	11.5	13.7	12.6	11.1	
2	FLOW VALUE	mm		2.08	2.40	2.78	2.65	2.82	
	Rice Husk Ash			2%					
1	MARSHALL STABILITY	KN	13.0	14.3	16.1	14.0	11.4		
2	FLOW VALUE	mm	2.78	3.00	3.32	3.22	2.80		

S. N.	DESCRIPTION	UNIT	BITUMEN CONTENT (%)					Remarks
			4.5	5.0	5.5	6.0	6.5	
	Rice Husk Ash		3%					
1	MARSHALL STABILITY	KN	16.7	18.0	16.0	14.5	12.0	
2	FLOW VALUE	mm	3.60	3.70	3.40	3.32	3.28	
	Rice Husk Ash		4%					
1	MARSHALL STABILITY	KN	13.0	14.3	16.1	14.0	12.1	
2	FLOW VALUE	mm	3.05	3.00	3.28	3.22	3.30	

Figure 4. 1 Stability vs bitumen content

Figure 4. 2 Flow vs bitumen content

4.2 Volumetric Analysis

Volumetric properties, i.e. density and voids, affects the pavement performance characteristics and durability of the asphalt mixtures.

Densities of RHA modified mix are lesser than that for the control mix, it may be due to lighter RHA particles i.e. lesser specific gravities of the RHA than that for the stone dust filler. Densities were increased with increase in bitumen content as shown in the graph of density vs bitumen content. Maximum density is observed for RHA content of 2%. Densities started decreasing after 3% of RHA as filler. Maximum density of 2.335 gm/cc is observed with RHA content of 2% at 6% bitumen content. Maximum density of 2.318 gm/cc is observed with RHA content of 3% at 6.5% bitumen content.

Air voids were maximum for that of 4% RHA and minimum for that of the control mix.

Density vs bitumen content, air voids vs bitumen content, VMA vs bitumen content and VFB vs bitumen content are shown in the following graphs.

Table 4. 2 Density void analysis.

S.N.	DESCRIPTION	UNIT	BITUMEN CONTENT (%)				
			4.5	5.0	5.5	6.0	6.5
	Rice Husk Ash		0%				
1	Theoritical density of the mix (Gt)	gm/cm3	2.489	2.471	2.453	2.436	2.419
2	Bulk density of the mix (Gm)	gm/cm3	2.297	2.331	2.357	2.358	2.366
3	% of air voids (Va)	%	7.70	5.70	3.90	3.20	2.20
4	% of bitumen (Vb)	%	9.92	11.19	12.44	13.58	14.76
5	Voids in mineral aggregate (VMA)	%	17.62	16.89	16.34	16.78	16.96
6	Voids filled with bitumen (VFB)	%	56.30	66.25	76.13	80.93	87.03

S.N.	DESCRIPTION	UNIT	BITUMEN CONTENT (%)				
			4.0	4.5	5.0	5.5	6.0
	Rice Husk Ash		2%				
1	Theoritical density of the mix (Gt)	gm/cm3	2.498	2.480	2.462	2.444	2.427
2	Bulk density of the mix (Gm)	gm/cm3	2.23	2.263	2.291	2.299	2.335
3	% of air voids (Va)	%	10.60	8.70	6.90	5.90	3.80
4	% of bitumen (Vb)	%	8.57	9.77	11.00	12.13	13.44
5	Voids in mineral aggregate (VMA)	%	19.17	18.47	17.90	18.03	17.24
6	Voids filled with bitumen (VFB)	%	44.71	52.91	61.44	67.28	77.96

S. N.	DESCRIPTION	UNIT	BITUMEN CONTENT (%)				
			4.5	5.0	5.5	6.0	6.5
	Rice Husk Ash		3%				
1	Theoretical density of the mix (Gt)	gm/cm3	2.475	2.457	2.440	2.422	2.406
2	Bulk density of the mix (Gm)	gm/cm3	2.222	2.232	2.258	2.298	2.318
3	% of air voids (Va)	%	10.20	9.20	7.40	5.10	3.60
4	% of bitumen (Vb)	%	9.60	10.71	11.92	13.23	14.46
5	Voids in mineral aggregate (VMA)	%	19.80	19.91	19.32	18.33	18.06
6	Voids filled with bitumen (VFB)	%	48.47	53.79	61.70	72.18	80.07

S. N.	DESCRIPTION	UNIT	BITUMEN CONTENT (%)				
			4.5	5.0	5.5	6.0	6.5
	Rice Husk Ash		4%				
1	Theoretical density of the mix (Gt)	gm/cm3	2.470	2.453	2.435	2.418	2.401
2	Bulk density of the mix (Gm)	gm/cm3	2.208	2.225	2.256	2.283	2.288
3	% of air voids (Va)	%	10.60	9.30	7.40	5.60	3.80
4	% of bitumen (Vb)	%	9.54	10.68	11.91	13.14	14.27
5	Voids in mineral aggregate (VMA)	%	20.14	19.98	19.31	18.74	18.97
6	Voids filled with bitumen (VFB)	%	47.36	53.45	61.67	70.12	75.23

Figure 4. 3 Density vs bitumen content

Figure 4. 4 Air voids vs bitumen content

Figure 4. 5 VMA vs bitumen content

Figure 4. 6 VFB vs bitumen content

4.3 Optimum binder content

Optimum binder content was calculated taking the average binder content of maximum stability, 4% air voids, and maximum density. 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. (Bohara, 2017)

Table 4. 3 Optimum binder content

		Rice Husk Ash (RHA)			
S.N.	Marshall parameters	0%	2%	3%	4%
1	Bitumen at max. Stability	5.50%	5.00%	5.00%	5.50%
2	Bitumen at max. Density	6.50%	6.00%	6.50%	6.50%
3	Bitumen at 4% air Voids	5.45%	5.95%	6.35%	6.45%
4	Optimum bitumen content (Average of 1,2 and 3)	**5.82%**	**5.65%**	**5.95%**	**6.15%**

The relationship of RHA filler content and Optimum binder content is shown in the following graph. From the graph, the optimum binder content for 3% RHA is calculated to be 5.95. At this OBC, air voids are found to be 5.15% which exceeds the limit used i.e. (3%-5%). Thus, OBC for 3% RHA is adjusted as 6.05%. Marshall Parameters for different filler contents are tabulated below:

Figure 4. 7OBC vs RHA

Table 4. 4 Marshall Properties at optimum binder content.

S.N.	Marshall parameters at O.B.C.	Unit	Rice Husk Ash (RHA)			
			0%	2%	3%	4%
	Optimum binder content taken		5.82%	5.65%	6.05%	6.15%
1	Stability	KN	13.00	13.90	14.20	13.50
2	Density	gm/cc	2.358	2.305	2.300	2.290
3	Air Voids	%	3.50%	4.90%	4.90%	5.00%
4	VMA	%	16.60%	17.50%	18.40%	18.70%
5	VFB	%	79.00%	72.00%	73.00%	72%
6	Flow value	mm	2.75	3.25	3.30	3.25
7	Marshall quotient		4.73	4.28	4.30	4.15

4.4 Moisture susceptibility test

Moisture susceptibility test was conducted as described above.

Test results are summarized in table below:

Table 4. 5 Moisture susceptibility test result.

Specimen no.	Bitumen %	Marshall Stability (KN)	Remarks
D1	6.05	17.1	Dry samples
D2	6.05	19.5	
W1	6.05	15.8	Wet samples
W2	6.05	18.1	

Average Marshall Stability of dry samples (S1) =18.3 KN

Average Marshall Stability of wet samples (S2) =16.95 KN

Index of Retained Strength (IRS) =S2/S1 *100% = **92.62%.**

Retained Marshall Stability is calculated in terms of Index of Retained Strength (IRS) as the numerical ratio of average Marshall Stability of wet samples to average Marshall Stability of dry samples. From the above results IRS of rice husk ash is found to be 92.62% which surpasses the limit generally used i.e. 70%.

It implies that RHA mixes are not greatly influenced by moisture.

4.5 Financial Analysis

Cost of the rice husk ash is not certain in Nepalese markets, since it is not sold commercially. Rice husk used in this research was obtained from a local rice mill in Nawal-Parasi district. Rice husk ash are the by-product of combustion of rice husks. The ash can be obtained from local rice mills, Paper industries, noodle industries and industries that use rice husk as a source of heat energy. The ashes were haphazardly thrown in the environment by the industries since it can be of little to no use.

Cost of rice husk ash is taken as average of three industries Nawal-Parasi district viz. local rice mill industry in Bardaghat, Paper mill in Parasi and Noodles factory in Parasi district.

Table 4. 6 Rice husk ash price.

S.No.	Industry/Factory	Cost in NRs. (per ton)	
		Season	Off-season
1	Local rice mill	1000	500
2	Paper mill	1800	1100
3	Noodles factory	1700	1250

Average rate used for RHA is NRs. 1225 per ton.

Norms used for rate analysis is Norms for rate analysis of road and bridge works 2075, Department of Roads, Nepal. Nawal-Parasi district rate 2076/077 is used for equipment hire rates, labor rates and material rates.

Proportion used is as below:

Rates are taken from Nawal-Parasi district rate for F/Y 076/077.

Table 4. 7 Proportion for rate analysis.

S.No.	Item	Bitumen (OBC) %	Aggregate %			Filler %
			(20-10) mm	(10-5) mm	5 mm down	
1	Stone dust filler	5.82	20	35	40	5
2	2% RHA	5.65	20	35	43	2
3	3% RHA	6.05	20	35	42	3
4	4% RHA	6.15	20	35	41	4

Table 4. 8 Cost analysis

	Unit	Rate	Quantity			
			Stone dust filler	2% RHA	3% RHA	4% RHA
Density of the compacted mix(gm/cc)			2.358	2.305	2.300	2.290
Labor						
Unskilled labor	md	550	5	5	5	5
Skilled labor	md	800	15	15	15	15
Material						
Bitumen (VG-30)	kg	73	12363.90	11772.08	12530.72	12670.51
Aggregates 20-10 mm	Cum	1875	28.37	27.78	27.62	27.47
Aggregates 10-5 mm	Cum	1350	49.65	48.62	48.33	48.07
Aggregates 5 mm and below	Cum	1350	56.75	59.73	57.99	56.31
Stone dust filler	ton	1500	10.64			
Rice husk ash filler	ton	1225		4.17	6.21	8.24
Equipment						
Pneumatic roller	hr	1000	6.00	6.00	6.00	6.00
Paver finisher	hr	1400	6.00	6.00	6.00	6.00
Batch mix HMP	hr	500	6.00	6.00	6.00	6.00
Generator	hr	150	6.00	6.00	6.00	6.00
smooth wheeled roller	hr	500	12.00	12.00	12.00	12.00
Cost			12,088.15	11,537.92	12,112.22	12,214.86

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Cost analysis used above does not include transportation costs, royalty and collection rates of materials.

4.6 Limitations

- Study was limited to VG-30 grade bitumen only, other grades were not studied.
- Effect of aggregate gradation was not taken into consideration.

4.7 Discussion and Conclusion

This research investigates the use of rice husk ash as filler in asphalt mix and evaluates the Marshall parameters of the prepared samples. RHA as mineral filler was used at varying contents (2%, 3% and 4%) with varying bitumen contents (4.5% to 6%, with increment of .5%). Stone dust was used to produce control mix. The prepared samples were tested for different Marshall Properties. Moisture susceptibility of the samples were also tested as per Marshall Immersion Test. The Marshall parameters fall well within the range specified by DoR.

Following conclusions can be drawn:

Conclusions

i. Stability value improves significantly due to 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 6.05%.

ii. 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.

iii. 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.

iv. RHA mixes are not greatly influenced by moisture as shown in Marshall Immersion Test.

v. Mixes using RHA fillers cost lesser than that for existing filler materials which substantially reduce the costs.

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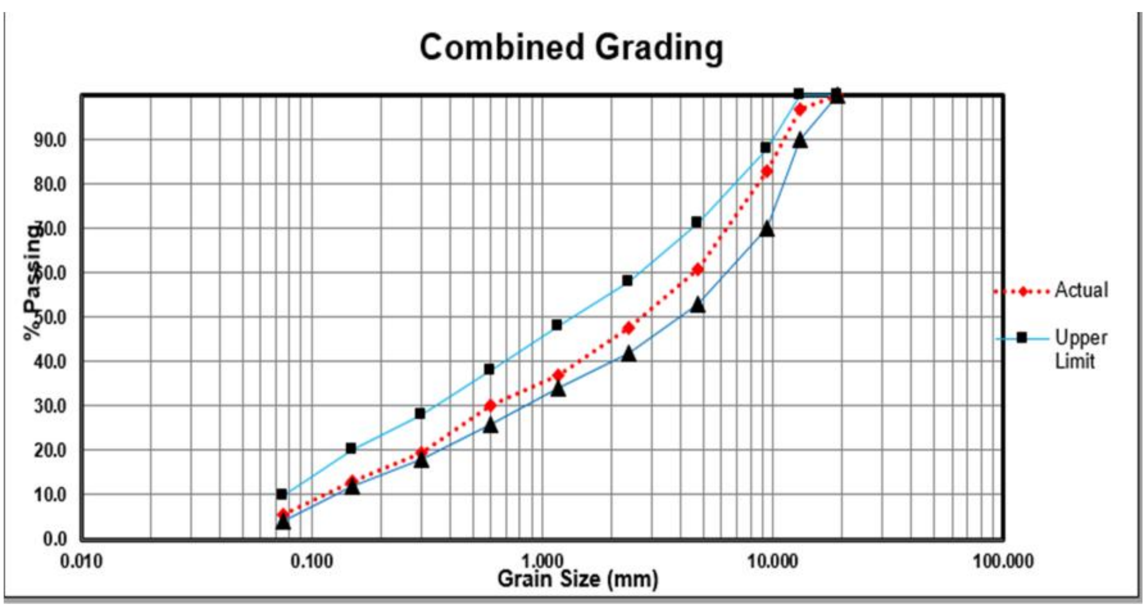
6.0 APPENDIXES

APPENDIX 1: Combined Aggregate Grading

SEIVE SIZE (mm)	INDIVIDUAL GRADING			COMBINATION			ALL-IN AGG	SPEC. LIMIT	
	Percent passing (%)			10-16mm	5-10mm	DUST (0-5)			
	CA-19mm	CA-10mm	Fine agg (5 mm down)	20.0 %	35.0 %	42.0 %		Lower	Upper
19.0	100.00	100.00	100.00	20.00	35.00	45.00	100.00	100	100
13.2	83.25	100.00	100.00	16.65	35.00	45.00	96.65	90	100
9.5	18.70	97.15	100.00	3.74	34.00	45.00	82.74	70	88
4.75	22.31	36.21	97.20	4.46	12.67	43.74	60.88	53	71
2.36	21.80	26.10	75.78	4.36	9.14	34.10	47.60	42	58
1.180	15.14	22.30	58.25	3.03	7.81	26.21	37.05	34	48
0.600	12.17	29.81	38.28	2.43	10.43	17.23	30.09	26	38
0.300	9.18	10.14	31.00	1.84	3.55	13.95	19.34	18	28
0.150	8.15	14.20	14.16	1.63	4.97	6.37	12.97	12	20
0.075	5.80	7.10	4.55	1.16	2.49	2.05	5.69	4	10



APPENDIX 2: Sieve Analysis of Rice Husk Ash Filler

Seive Size (mm)	Retained	Retained %	Cumulative Retained	Cumulative Retained %	Cumulative pass %
0.600	0.1	0.2	0.2	99.8	99.8
0.300	5.12	10.24	10.4	89.6	89.6
0.075	35.75	71.5	81.9	18.1	18.1
Pan	9.03	18.06	100.0	0.0	0.0

APPENDIX 3: Aggregate Tests

LOS ANGELES ABRASION TEST

Gradation used is Grade-B.

Total weight of sample taken= 5000 gms.

CALCULATION

Original weight of the Test Sample (W1) = 5000.00 gms

Final weight of the test sample passing 1.7 mm sieve (W2) =1453.50 gms

Percentage of loss : (W1-W2)/W1 * 100

Los Angeles Abrasion Value = 29.07%

Aggregate Impact Value TEST

Weight of sample passing 12.5 mm and retained on 10 mm sieve taken (W1)= 400 gms

Weight passing 2.36 mm sieve (W2)= 83.68 gms
AIV value= W2/W1 *100 20.92%

Aggregate Crushing Value TEST

Weight of sample passing 12.5 mm and retained on 10 mm sieve taken (W1)= 600 gms

Weight passing 2.36 mm sieve (W2) = 129.2 gms
ACV value= W2/W1 *100 21.53%

APPENDIX 4: Bitumen Tests

SOFTENING POINT OF BITUMEN

(RING & BALL)

ASTM-D-36

Material Description :- Jal Bitumen VG 30

Temperature when ball no.1 touches Bottom Plate		T 1	48	°C
Temperature when ball no.2 touches Bottom Plate		T 2	49	°C

SOFTENING POINT = (T1+T2)/2 = 48.5 °C

REPORTED SOFTENING POINT = 48.5 °C

DUCTILITY TEST

Material Description :- Jal Bitumen VG 30

Temperature of Water Bath 25 ◦c

Determination no.	1	2	3
Ductility value in cm	96	96	93
Average ductility value		95	

Reported ductility value= 95 cm.

PENETRATION OF BITUMEN

Material Description :- Jal Bitumen VG 30

Temperature of Water Bath 25 ◦c [SDT=25◦c]

Determination no.	1	2	3
Penetration (1/10mm)	55	62	60
Average Penetration		59.00	

Reported Penetration (1/10) = 59.00.

APPENDIX 5: Specific gravity tests

All weights are in grams.

Aggregate (19-10 mm)

Sample weight = 2000

Weight of Saturated Surface Dry (SSD) sample in water (A) = 1305.6

Weight of Saturated Surface Dry (SSD) sample in air (B) = 2038

Weight of oven dried sample (C) = 1968

Specific gravity= C/(B-A) = 2.687

Aggregate (10-5 mm)

Sample weight = 1000

Weight of Saturated Surface Dry (SSD) sample (A) in air =1008.3

Weight of gas jar, sample and water (B) =2209.0

Weight of gas jar, and water (C) =1580.7

Weight of oven dried sample (D) = 995.8

Specific gravity= D/A-(B-C) =2.621

Fine Aggregate (0-5 mm)

Sample weight = 500

Weight of Saturated Surface Dry (SSD) sample (A) in air = 508.9

Weight of pycnometer, sample and water (B) =1780.3

Weight of pycnometer, and water (C) = 1456.9

Weight of oven dried sample (D) = 498.5

Specific gravity= D/A-(B-C) =2.686

Rice husk ash filler

Sample weight = 50

Weight of pycnometer (m1) =318.4

Weight of pycnometer, and sample (m2) =368.4

Weight of pycnometer, sample and water (m3) =1482.1

Weight of pycnometer, and water (m4) =1455.7

Specific gravity = (m2-m1)/ [(m4-m1)-(m3-m2)] = 2.12

Bitumen

	Determination No.	1	2	Unit
	Temperature	25	25	**°C**
A	Wt. of Pycnometer	42.33	24.8	gms
B	Wt. of Pycnometer+sample	62.97	35.05	gms
C=(B-A)	Wt. of Sample	20.6	10.3	gms
D	Wt. of Pycnometer+sample+water	90.4	49.9	gms
E	Wt. of Pycnometer+water	89.55	49.5	gms
C\(C+E-D)	Specific Gravity	1.043	1.040	
	Average Specific Gravity	1.042		

APPENDIX 6: District Rates

Item	Unit	Rate (NRs.)
Labor		
Unskilled labor	md	550
Skilled labor	md	800
Material		
Bitumen (VG-30)	kg	73
Aggregates 20-10 mm	Cum	1875
Aggregates 10-5 mm	Cum	1350
Aggregates 5 mm and below	Cum	1350
Stone dust filler	ton	1500
Rice husk ash filler	ton	1225
Equipment		
Pneumatic roller	hr	1000
Paver finisher	hr	1400
Batch mix HMP	hr	500
Generator	hr	150
smooth wheeled roller	hr	500

APPENDIX 7: Experimental data for stone dust filler

MARSHALL TEST RESULTS

Flow Guage 1 Div=(mm) 0.01

Proving ring factor 41.69 N

Bitumen Content (%)	Sample No.	Thickness (mm)	Marshall Stability				Flow (Div)	Mean Flow (Div)	Mean Flow (mm)	Remarks
			PR Reading	Correction Factor	Corrected Load (N)	Mean Stability (KN)				
4.5	1	65.73	250	0.93	9692.9	10.2	225.00	208.33	2.08	
	2	65.08	290	0.96	11606.5		200.00			
	3	68.20	250	0.89	9276.0		200.00			
5.0	1	64.43	300	0.93	11631.5	11.5	190.00	240.00	2.40	
	2	64.00	290	0.96	11606.5		260.00			
	3	67.70	305	0.89	11316.8		270.00			
5.5	1	61.73	360	1.00	15008.4	13.7	280.00	278.33	2.78	
	2	63.73	330	1.00	13757.7		270.00			
	3	64.83	310	0.96	12406.9		285.00			
6.0	1	63.53	295	1.09	13405.4	12.6	245.00	265.00	2.65	
	2	63.73	290	1.00	12090.1		300.00			
	3	64.67	305	0.96	12206.8		250.00			
6.5	1	65.21	280	0.96	11206.3	11.1	240.00	281.67	2.82	
	2	67.20	310	0.86	11114.6		295.00			
	3	61.60	255	1.04	11056.2		310.00			

DENSITY TESTS

BITUMEN Content (%)	Specimen No.	Wt. of Dry Specimen in Air (gm)	Wt. of SSD Specimen in air (gm)	Wt. of Specimen in Water (gm)	Volume of Specimen (ml)	Density of Specimen (gm/ml)	Mean Density (gm/ml)	Thickness (mm)	Remarks
4.5	1	1202.6	1204.4	684.3	520.1	2.312	2.297	65.73	
	2	1200.1	1202.6	685.4	517.2	2.320		65.08	
	3	1202.6	1206.0	673.4	532.6	2.258		68.20	
5.0	1	1201.7	1208.0	693.9	514.1	2.337	2.331	64.43	
	2	1195.7	1203.3	692.0	511.3	2.339		64.00	
	3	1196.5	1199.5	683.3	516.2	2.318		67.70	
5.50	1	1201.5	1206.5	698.3	508.2	2.364	2.357	61.73	
	2	1205.8	1210.0	699.1	510.9	2.360		63.73	
	3	1211.1	1215.0	698.7	516.3	2.346		64.83	
6.0	1	1205.3	1212.2	701.2	511.0	2.359	2.358	63.53	
	2	1212.3	1216.9	705.7	511.2	2.371		63.73	
	3	1197.8	1213.3	702.3	511.0	2.344		64.67	
6.5	1	1201.3	1201.8	698.3	503.5	2.386	2.366	65.21	
	2	1202.7	1203.1	685.2	517.9	2.322		67.20	
	3	1196.8	1198.4	697.4	501.0	2.389		61.60	

MAXIMUM THEORETICAL DENSITIES

A. COMBINED AGGREGATE

S.N	COMPONENT	MATERIALS	DENSITY (a)	COMPONENT FRACTION (b)	COMPONENT VALUE (a) x (b)	REMARKS
1	19-10 mm	AGGREGATE - 1	2.687	0.200	0.537	
2	5-10 mm	AGGREGATE - 2	2.621	0.350	0.917	
3	(0-0.075)mm	Rice Husk Ash	2.120	0.000	0.000	
4	(0-5)mm	STONE DUST	2.686	0.450	1.209	

DENSITY OF COMBINED AGGREGATE (TOTAL) $g_a =$2.663

B. DENSITY OF BITUMEN, $g_b =$ 1.042 gm/cc Jal Bitumen (VG 30)

C. THEORETICAL DENSITY OF A.C. MIXES

S.N.	BITUMEN CONTENT (%)	BITUMEN CONTENT FRACTION	TOTAL AGGREGATE FRACTION	VOLUME OF BITUMEN	VOLUME OF AGGREGATE	TOTAL VOLUME	MAXIMUM DENSITY (gm/cc)
	P	p = P/100	(1-p)	$v_a = p/g_b$	$v_b = (1-p)/g_a$	$V = v_a + v_b$	g = 1/ V
1	4.5	0.045	0.955	0.0432	0.3586	0.4018	2.489
2	5.0	0.050	0.950	0.0480	0.3567	0.4047	2.471
3	5.5	0.055	0.945	0.0528	0.3548	0.4076	2.453
4	6.0	0.060	0.940	0.0576	0.3529	0.4105	2.436
5	6.5	0.065	0.935	0.0624	0.3510	0.4134	2.419

APPENDIX 8: Experimental data for 2% RHA

MARSHALL TEST RESULTS
(75 Blows Compaction)

Flow Guage 1 Div = (mm) 0.01
Proving ring factor 41.69 N

Bitumen Content (%)	Sample No.	Sample Thickness (mm)	Marshall Stability				Flow (Div)	Mean Flow (Div)	Mean Flow (mm)	Remarks
			PR Reading	Correction Factor	Corrected Load (N)	Mean Stability (KN)				
4.0	1	68.50	375	0.83	12976.0	13.0	290.00	278.33	2.78	
	2	70.30	425	0.86	15237.7		265.00			
	3	70.80	305	0.86	10935.3		280.00			
4.5	1	67.40	410	0.86	14699.9	14.3	320.00	300.00	3.00	
	2	66.36	480	0.93	18610.4		295.00			
	3	70.73	265	0.86	9501.2		285.00			
5.0	1	65.63	385	0.89	14285.1	16.1	390.00	331.67	3.32	
	2	66.66	560	0.93	21712.2		305.00			
	3	66.03	320	0.93	12406.9		300.00			
5.5	1	64.09	345	0.93	13376.2	14.0	355.00	321.67	3.22	
	2	66.03	325	0.93	12600.8		250.00			
	3	66.33	415	0.93	16090.3		360.00			
6.0	1	70.73	195	0.86	6991.4	11.4	390.00	280.00	2.80	
	2	66.76	350	0.89	12986.4		220.00			
	3	67.80	385	0.89	14285.1		230.00			

DENSITY TESTS OF MARSHAL TEST SPECIMENS

BITUMEN Content (%)	Specimen No.	Wt. of Dry Specimen in Air (gm)	Wt. of SSD Specimen in air (gm)	Wt. of Specimen in Water (gm)	Volume of Specimen (ml)	Density of Specimen (gm/ml)	Mean Density (gm/ml)	Thickness (mm)	Remarks
4.0	1	1189.8	1193.5	664.3	529.2	2.248	2.232	68.50	
	2	1195.5	1196.1	657.9	538.2	2.221		70.30	
	3	1200.6	1198.8	659.9	538.9	2.228		70.80	
4.5	1	1203.7	1203.9	676.2	527.7	2.281	2.263	67.40	
	2	1196.4	1196.7	669.2	527.5	2.268		66.36	
	3	1215.4	1217.0	674.6	542.4	2.241		70.73	
5.00	1	1199.7	1203.9	681.2	522.7	2.295	2.291	65.63	
	2	1201.2	1200.2	684.8	515.4	2.331		66.66	
	3	1210.6	1226.3	687.9	538.4	2.249		66.03	
5.5	1	1206.6	1204.9	685.3	519.6	2.322	2.299	64.09	
	2	1206.5	1208.5	684.7	523.8	2.303		66.03	
	3	1208.7	1220.4	688.1	532.3	2.271		66.33	
6.0	1	1204.7	1205.3	690.2	515.1	2.339	2.335	70.73	
	2	1202.1	1202.8	691.4	511.4	2.351		66.76	
	3	1214.5	1215.4	691.2	524.2	2.317		67.80	

MAXIMUM THEORETICAL DENSITIES

A. COMBINED AGGREGATE

S.N	COMPONENT	MATERIALS	DENSITY (a)	COMPONENT FRACTION (b)	COMPONENT VALUE (a) x (b)	REMARKS
1	19-10 mm	AGGREGATE - 1	2.687	0.200	0.537	
2	5-10 mm	AGGREGATE - 2	2.621	0.350	0.917	
3	(0-0.075)mm	Rice Husk Ash	2.120	0.020	0.042	
4	(0-5)mm	STONE DUST	2.686	0.430	1.155	

DENSITY OF COMBINED AGGREGATE(TOTAL) g_a 2.652

B. DENSITY OF BITUMEN, g_b = 1.042 gm/cc Jal Bitumen (VG 30)

C. THEORETICAL DENSITY OF A.C. MIXES

S. N.	BITUMEN CONTENT (%)	BITUMEN CONTENT FRACTION	TOTAL AGGREGATE FRACTION	VOLUME OF BITUMEN	VOLUME OF AGGREGATE	TOTAL VOLUME	MAXIMUM DENSITY (gm/cc)
	P	p = P/100	(1-p)	$v_a = p/g_b$	$v_b = (1-p)/g_a$	$V = v_a + v_b$	g = 1/ V
1	4.0	0.040	0.960	0.0384	0.3620	0.4004	2.498
2	4.5	0.045	0.955	0.0432	0.3601	0.4033	2.480
3	5.0	0.050	0.950	0.0480	0.3582	0.4062	2.462
4	5.5	0.055	0.945	0.0528	0.3563	0.4091	2.444
5	6.0	0.060	0.940	0.0576	0.3544	0.4120	2.427

APPENDIX 9: Experimental data for 3% RHA

MARSHALL TEST RESULTS

Flow Guage 1 Div=(mm) 0.01
Proving ring factor 41.69 N

Bitumen Content (%)	Sample No.	Sample Thickness (mm)	Marshall Stability				Flow (Div)	Mean Flow (Div)	Mean Flow (mm)	Remarks
			PR Reading	Correction Factor	Corrected Load (N)	Mean Stability (KN)				
4.5	1	66.60	465	0.93	18028.8	16.7	350.00	360.00	3.60	
	2	66.30	465	0.93	18028.8		360.00			
	3	69.90	405	0.83	14014.1		370.00			
5.0	1	67.70	510	0.86	18285.2	18.0	370.00	370.00	3.70	
	2	67.60	510	0.86	18285.2		340.00			
	3	71.20	490	0.86	17568.2		400.00			
5.5	1	66.20	415	0.93	16090.3	16.0	320.00	340.00	3.40	
	2	69.00	425	0.83	14706.1		290.00			
	3	67.40	480	0.86	17209.6		410.00			
6.0	1	66.80	470	0.86	16851.1	14.5	345.00	331.67	3.32	
	2	67.00	375	0.86	13445.0		340.00			
	3	65.70	355	0.89	13172.0		310.00			
6.5	1	64.20	290	0.93	11243.8	12.0	455.00	328.33	3.28	
	2	66.60	305	0.93	11825.4		270.00			
	3	67.40	360	0.86	12907.2		260.00			

DENSITY TESTS OF MARSHAL TEST SPECIMENS

BITUMEN Content (%)	Specimen No.	Wt. of Dry Specimen in Air (gm)	Wt. of SSD Specimen in air (gm)	Wt. of Specimen in Water (gm)	Volume of Specimen (ml)	Density of Specimen (gm/ml)	Mean Density (gm/ml)	Thickness (mm)	Remarks
4.5	1	1207.5	1208.9	667.5	541.4	2.230	2.222	66.60	
	2	1207.1	1207.3	669.6	537.7	2.245		66.30	
	3	1210.6	1213.7	661.1	552.6	2.191		69.90	
5.0	1	1208.4	1208.9	671.4	537.5	2.248	2.232	67.70	
	2	1210.8	1211.2	673.2	538.0	2.251		67.60	
	3	1205.3	1206.3	657.7	548.6	2.197		71.20	
5.50	1	1214.9	1215.0	681.3	533.7	2.276	2.258	66.20	
	2	1212.5	1213.9	671.0	542.9	2.233		69.00	
	3	1193.0	1193.3	666.7	526.6	2.265		67.40	
6.0	1	1215.0	1215.7	688.2	527.5	2.303	2.298	66.80	
	2	1203.0	1203.7	686.1	517.6	2.324		67.00	
	3	1230.0	1236.6	693.9	542.7	2.266		65.70	
6.5	1	1200.9	1201.4	690.3	511.1	2.350	2.318	64.20	
	2	1215.6	1216.6	689.4	527.2	2.306		66.60	
	3	1211.6	1212.1	685.2	526.9	2.299		67.40	

MAXIMUM THEORETICAL DENSITIES

A. COMBINED AGGREGATE

S.N	COMPONENT	MATERIALS	DENSITY (a)	COMPONENT FRACTION (b)	COMPONENT VALUE (a) x (b)	REMARKS
1	19-10 mm	AGGREGATE - 1	2.687	0.200	0.537	
2	5-10 mm	AGGREGATE - 2	2.621	0.350	0.917	
3	(0-0.075)mm	Rice Husk Ash	2.120	0.030	0.064	
4	(0-5)mm	STONE DUST	2.686	0.420	1.128	

DENSITY OF COMBINED AGGREGATE(TOTAL) g_a 2.646

B. DENSITY OF BITUMEN, $g_b = 1.042$ gm/cc Jal Bitumen (VG 30)

C. THEORETICAL DENSITY OF A.C. MIXES

S. No.	BITUMEN CONTENT (%)	BITUMEN CONTENT FRACTION	TOTAL AGGREGATE FRACTION	VOLUME OF BITUMEN	VOLUME OF AGGREGATE	TOTAL VOLUME	MAXIMUM DENSITY (gm/cc)
	P	p = P/100	(1-p)	$v_a = p/g_b$	$v_b = (1-p)/g_a$	$V = v_a + v_b$	$g = 1/V$
1	4.5	0.045	0.955	0.0432	0.3609	0.4041	2.475
2	5.0	0.050	0.950	0.0480	0.3590	0.4070	2.457
3	5.5	0.055	0.945	0.0528	0.3571	0.4099	2.440
4	6.0	0.060	0.940	0.0576	0.3552	0.4128	2.422
5	6.5	0.065	0.935	0.0624	0.3533	0.4157	2.406

APPENDIX 10: Experimental data for 4% RHA

MARSHALL TEST RESULTS

Flow Guage 1 Div=(mm) 0.01

Proving ring factor= 41.69 N

Bitumen Content (%)	Sample No.	Sample Thickness (mm)	Marshall Stability				Flow (Div)	Mean Flow (Div)	Mean Flow (mm)	Remarks
			PR Reading	Correction Factor	Corrected Load (N)	Mean Stability (KN)				
4.5	1	68.50	375	0.83	12976.0	13.0	290.00	305.00	3.05	
	2	70.30	425	0.86	15237.7		305.00			
	3	70.80	305	0.86	10935.3		320.00			
5.0	1	67.40	410	0.86	14699.9	14.3	380.00	300.00	3.00	
	2	66.36	480	0.93	18610.4		295.00			
	3	70.73	265	0.86	9501.2		225.00			
5.5	1	65.63	385	0.89	14285.1	16.1	425.00	328.33	3.28	
	2	66.66	560	0.93	21712.2		250.00			
	3	66.03	320	0.93	12406.9		310.00			
6.0	1	64.09	345	0.93	13376.2	14.0	355.00	321.67	3.22	
	2	66.03	325	0.93	12600.8		250.00			
	3	66.33	415	0.93	16090.3		360.00			
6.5	1	69.82	355	0.86	12728.0	12.1	360.00	330.00	3.30	
	2	65.21	285	0.89	10574.7		320.00			
	3	66.52	335	0.93	12988.5		310.00			

DENSITY TESTS OF MARSHAL TEST SPECIMENS

BITUMEN Content (%)	Specimen No.	Wt. of Dry Specimen in Air (gm)	Wt. of SSD Specimen in air (gm)	Wt. of Specimen in Water (gm)	Volume of Specimen (ml)	Density of Specimen (gm/ml)	Mean Density (gm/ml)	Thickness (mm)	Remarks
4.5	1	1212.9	1190.5	654.3	536.2	2.262	2.208	68.50	
	2	1205.1	1196.1	647.9	548.2	2.198		70.30	
	3	1209.3	1198.8	639.9	558.9	2.164		70.80	
5.0	1	1211.4	1204.9	676.2	528.7	2.291	2.225	67.40	
	2	981.7	983.6	537.0	446.6	2.198		66.36	
	3	1201.0	1213.9	664.6	549.3	2.186		70.73	
5.50	1	1205.9	1203.9	674.6	529.3	2.278	2.256	65.63	
	2	1201.9	1200.2	669.0	531.2	2.263		66.66	
	3	1207.2	1226.3	684.1	542.2	2.226		66.03	
6.0	1	1203.9	1204.9	680.2	524.7	2.294	2.283	64.09	
	2	1203.9	1205.5	670.8	534.7	2.252		66.03	
	3	1202.8	1217.4	694.9	522.5	2.302		66.33	
6.5	1	1211.3	1212.2	681.4	530.8	2.282	2.310	69.82	
	2	1201.6	1203.8	685.8	518.0	2.320		65.21	
	3	1203.9	1208.2	691.2	517.0	2.329		66.52	

MAXIMUM THEORETICAL DENSITIES

A. COMBINED AGGREGATE

S.N	COMPONENT	MATERIALS	DENSITY (a)	COMPONENT FRACTION (b)	COMPONENT VALUE (a) x (b)	REMARKS
1	16 mm	AGGREGATE - 1	2.687	0.200	0.537	
2	5-10 mm	AGGREGATE - 2	2.621	0.350	0.917	
3	(0-0.075)mm	Rice Husk Ash	2.120	0.040	0.085	
4	(0-5)mm	STONE DUST	2.686	0.410	1.101	

DENSITY OF COMBINED AGGREGATE(TOTAL) g_a 2.641

B. DENSITY OF BITUMEN, $gb_=$ 1.042 gm/cc Jal Bitumen (VG 30)

C. THEORETICAL DENSITY OF A.C. MIXES

S. No.	BITUMEN CONTENT (%)	BITUMEN CONTENT FRACTION	TOTAL AGGREGATE FRACTION	VOLUME OF BITUMEN	VOLUME OF AGGREGATE	TOTAL VOLUME	MAXIMUM DENSITY (gm/cc)
	P	p = P/100	(1-p)	$v_a = p/g_b$	$v_b = (1-p)/g_a$	$V = v_a + v_b$	g = 1/ V
1	4.5	0.045	0.955	0.0432	0.3616	0.4048	2.470
2	5.0	0.050	0.950	0.0480	0.3597	0.4077	2.453
3	5.5	0.055	0.945	0.0528	0.3578	0.4106	2.435
4	6.0	0.060	0.940	0.0576	0.3560	0.4136	2.418
5	6.5	0.065	0.935	0.0624	0.3541	0.4165	2.401

APPENDIX 11: Mixing Proportion

Mix Proportion for stone dust filler

Bitumen %	Aggregate-1	Aggregate-2	Rice Husk Ash	Stone Dust	Bitumen	Total Weight
4.5	233.49	408.61	0.00	525.36	52.54	1220
5	232.38	406.67	0.00	522.86	58.10	1220
5.5	231.28	404.74	0.00	520.38	63.60	1220
6	230.19	402.83	0.00	517.92	69.06	1220
6.5	229.11	400.94	0.00	515.49	74.46	1220

Mix Proportion for 2% RHA filler

Bitumen %	Aggregate-1	Aggregate-2	Rice Husk Ash	Stone Dust	Bitumen	Total Weight
4	234.62	410.58	23.46	504.42	46.92	1220
4.5	233.49	408.61	23.35	502.01	52.54	1220
5	232.38	406.67	23.24	499.62	58.10	1220
5.5	231.28	404.74	23.13	497.25	63.60	1220
6	230.19	402.83	23.02	494.91	69.06	1220

Mix Proportion for 3% RHA filler

Bitumen %	Aggregate-1	Aggregate-2	Rice Husk Ash	Stone Dust	Bitumen	Total Weight
4.5	233.49	408.61	35.02	490.33	52.54	1220
5	232.38	406.67	34.86	488.00	58.10	1220
5.5	231.28	404.74	34.69	485.69	63.60	1220
6	230.19	402.83	34.53	483.40	69.06	1220
6.5	229.11	400.94	34.37	481.13	74.46	1220

Mix Proportion for 4% RHA filler

Bitumen %	Aggregate-1	Aggregate-2	Rice Husk Ash	Stone Dust	Bitumen	Total Weight
4.5	233.49	408.61	46.70	478.66	52.54	1220
5	232.38	406.67	46.48	476.38	58.10	1220
5.5	231.28	404.74	46.26	474.12	63.60	1220
6	230.19	402.83	46.04	471.89	69.06	1220
6.5	229.11	400.94	45.82	469.67	74.46	1220

APPENDIX 12: Laboratory Recommendation

नेपाल सरकार
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सडक विभाग
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बेलहिया-बुटवल सडक
मणिग्राम, रुपन्देही

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आ.व. ०७६/७७
च.नं.:- १८२

मिति:- २०७६।०८।१६

विषय :- सिफारिस गरिएको बारे ।

श्री सिभिल ईन्जिनियरिङ्ग विभाग,
पुल्चोक ईन्जिनियरिङ्ग क्याम्पस,
ललितपुर ।

प्रस्तुत विषयमा यस व्यापारिक मार्ग विस्तार आयोजना अन्तर्गत संचालित ल्याब प्रयोगशालामा तहाँ विभाग अन्तर्गतको MSc in Transportation Engineering कार्यक्रममा अध्ययनरत विद्यार्थी शिशु खत्री (Roll No.072/MST/267) ले "Experimental investigation of Bituminous concrete mix using rice husk ash as a mineral filler" मा Master's Thesis कार्यको लागि आवश्यक Asphalt कार्य अन्तर्गत Marshal Test हरु यस कार्यालयको प्रयोगशालामा गरेको व्यहोरा जानकारी गराईन्छ ।

अमरनाथ यादव
(ल्याब अफिसर)