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Effect of Rice Husk Ash and Rice Husk Fiber on the Mechanical Properties of Asphalt mix

Muhammad Irfan, Syed Naveed Raza Shah, Touqeer Ali Rind, Muhammad Farooque, Wali Murad

Abstract— In Pakistan most of pavements are flexible that faces problems like rutting, thermal cracking, and fatigue cracking. On other side Pakistan produces 7.5 million tonnes and ranked 10th in largest rice producing countries due to which a large amount of rice husk is generated. For comparison of results normal asphalt mix samples were created at 3.8% Bitumen content that is found to be optimum by Marshall mix method. To utilize the waste material, Rice husk ash is replaced with the filler material in Asphalt mix at different percentages of 15, 30, 45 & 60% and 3 samples on each percentage were created for average results then Marshall stability and flow tests were conducted and according to result the optimum percentage of RHA is 30% in replacement of filler material, Rice husk ash modified asphalt mix increases stability by 4.18% in comparison with Normal Asphalt mix. And Rice husk is also used as fiber reinforcement in asphalt mix with different percentages of 0.5, 1, 1.5 & 2% by total weight of Aggregates and 3 samples were created on each percentage, Marshall stability and flow tests were conducted result show optimum value at 0.5% RHF that increases the stability of Asphalt mix by 0.92% in comparison with Normal Asphalt mix. Also 3 samples for combined RHA & RHF modified asphalt mix were created in which optimum percentage of RHA and RHF were used, and result shows increase in stability of modified Asphalt mix by 7.39% in comparison with Normal asphalt mix. Further study can be carried out by using smaller percentages of RHF.

Index Terms— Flexible pavement, Fiber reinforced asphalt concrete, Optimum asphalt content (OAC), Rice husk ash (RHA), Rice husk fiber (RHF), Marshall stability and flow.

1 Introduction

Asphalt concrete is a material that is made of aggregates and bitumen as binder material, and it is more sensitive material in comparison of the other materials utilized in civil engineering. Fiber Reinforced Asphalt Concrete (FRAC) is the nonexclusive term used to depict the production, paving, and compaction accomplished using one of a few fiber advancements [1]. Asphalt containing a mixture of discrete fiber improves and increases the structure integrity of the asphalt. Now a days various materials used to strengthen the asphalt concrete such as polyester fiber, cellulose fiber, glass fiber etc. out of all other modifiers in asphalt mix the fiber have obtained great consideration for their constructive outcome.

Flexible pavements transmit the wheel load stresses to the below layers by the grain-to-grain transfer through the point of contact in granular structure, flexible pavement consists of different layers that are sub-grade, sub-base, base course, binder course and surface course. All layers of pavement provide defense against traffic loads. The pressure at top layer is highest while minimum at lowest layer, stresses decrease with depth. Surface course is topmost layer of flexible pavement normally 25 to 50mm, it gives qualities, for example, friction, smoothness, drainage etc. seal coat is a slim treatment used for the water proofing of surface and gives skid resistance.

Pakistan has large network of highways and most of the highways are flexible pavements that are used to carry heavy vehicle loads [2]. In flexible pavements mostly the problems are rutting, fatigue, segregation and raveling, that increases the maintenance cost. On the other hand, in construction industries there is increasing trend towards development and utilization of waste as the supplementary materials

The main kharif crop in Pakistan is rice which produces 7.5 million tonnes and ranked 10th in largest rice producing countries due to which a large amount of rice husk is generated [3]. Currently the major application of rice husk is burning it in power houses as fuel. This cycle lead the way to high amount of RHA which is often settled or released into rivers and causes environmental pollutions.

The research objectives were to investigate the effect of Rice husk ash as a filler material in Asphalt mix, Effect of Rice husk as a fiber reinforcement in Asphalt mix and effects of combined RHA and RHF modified Asphalt mix.

The scope of this research is that major problems in flexible pavements are due to increase of heavy vehicle loads, causes an increase in pavement distress such as rutting, surface wear and cracks, thus it become important to enhance the properties of asphalt mix. On the other hand, waste is significantly rising

- *Muhammad Irfan is currently pursuing master's degree program in civil engineering in Mehran UET SZABC Khairpur Mirs, Sindh, Pakistan*
- *E-mail: irfan_soomro12@yahoo.com*
- *Syed Naveed Raza Shah is currently serving as a Chairman at Civil engineering department of Mehran UET SZABC Khairpur Mirs, Sindh, Pakistan*
- *E-mail: naveedshah@muetkhp.edu.pk*
- *Touqeer Ali Rind is currently serving as a Lecturer at Civil Engineering Dept, Mehran UET SZABC Khairpur Mirs, Sindh, Pakistan*
- *E-mail: touqeerali@muetkhp.edu.pk*
- *Muhammad Farooque is currently pursuing master's degree in civil engineering at Mehran UET SZABC Khairpur Mirs, Sindh, Pakistan E-mail: muhammadfarooq.panhyar@gmail.com*
- *Wali Murad is currently pursuing master's degree program in civil engineering in Mehran UET SZABC Khairpur Mirs, Sindh, Pakistan*
- *E-mail: walimurad.kalhoro@gmail.com*

in the world, particularly in Pakistan due to its production in agriculture and produces large quantity of rice. Therefore, to reduce the wastes like rice husk ash and rice husk it is better to utilize in construction of flexible pavement. This will also help in reducing the environmental problems

2 Literature Review

[4] in this study rice husk ash is added is asphalt mix in replacement of filler material and properties were evaluated, the aim of replacing mineral filler is to enhance the performance of asphalt mixes and producing an economical asphalt mix. For this purpose, five different mixes were prepared; the first was a control mix (traditional mix) containing 100% Limestone Dust (LSD) as filler and 0% RHA. While the other mixes contain 25%, 50%, 75% and 100% of RHA as a percentage of the filler weight. Marshall test was carried out to find optimum bitumen content, also all Marshall parameters were examined. Indirect Tensile Strength Test (ITST) and Wheel Tracking Test (WTT) were conducted A. The results indicate that RHA has the potential to be used as partial substitution of mineral filler LSD in pavement construction. Adding rice husk ash increases theMarshall stiffness, reduce the rut depth, and increase in the indirect tensile strength values. Furthermore, a significant change has been found in OBC for all mixes and the optimum replacement ratio is recorded as 50% RHA: 50% LSD.

[5] In this study the effects of natural fibers on the performance of ho asphalt mix is analyzed. Most efficient method of enhancing the performance of asphalt mix is to reinforce it using natural fibers. In hot asphalt mix the palm fiber is used. Tests conducted are indirect tensile test and Marshall test on four mixtures of asphalt mix with different natural fibers (palm, sisal, corn & coconut) the percentages used are (0.1, 0.2, 0.3 0.4 & 0.5) the lengths of fibers were (0.5.1. 1.5 & 2cm). according to result obtained by Marshall test sisal and palm fibers shows best mixes in consideration Marshall criteria according to SORB specifications. The Marshall stability increased by 17% and 20% respectively.

[6] Investigated the use of rice husk ash as filler in bitumen blend and determined the mechanical properties, which were compared with conventional samples. The replacement of rice husk ash with stone dust, used with different percentages including 0,25,50,75 & 100%. The tests conducted, rutting, resilience modulus, moisture sensitivity and dynamic creep of asphalt mixture. The results improved the exhibition of asphalt mixtures with rice husk ash. Finally, optimum results were achieved at percentages of RHA content were 26.0% for the graded number 4 and 48.0% for the graded number 5 with replacement of stone powder filler.

[7] Black rice husk ash was ground with the help of grinding ball mill for 2 hours to make powder then that powder was sieved to obtain particles smaller than 75.0 μm. In laboratory, BRHA with bitumen was mixed to replace 2,4 & 6% of total weight and compared with controlled samples. Properties such as penetration, softening point, rolling thin film oven and dynamic shear rheometer were investigated. According to results the rate of penetration decreased, and bitumen becomes harder as replacement amount of BRHA increased. The performance of bitumen improved when BRHA was added to it, and BRHA can help to enhance the exhibition of pavement and it can help to decrease the effect of rutting.

[8] In this study they have used wheat Straw Fibre as Stabilizing Additive in Stone Matrix Asphalt Mix Required quantity of wheat straw fibres after being cut to small pieces approximately 5 mm long, were added directly to the aggregate sample and thoroughly mixed before adding required quantity of binder. The entire mixtures were heated separately to the prescribed mixing temperature, mixed properly, and compacted using a compactive effort of 50 blows on each side. Binder concentrations were varied from 4% to 6% while fibre concentrations were selected as 0.3% to assess the optimum binder content. Marshall Characteristics such as Marshall Stability, flow value, unit weight, air voids were tested. According to results obtained it was observed that stone matrix asphalt mix with wheat straw fibre ensure better performance as compared to stone matrix asphalt mix without fibre

[9] In order to upgrade the rheological properties of bitumen, rice husk powder is used in this research. Influence of addition of rice husk powder in asphalt binder, on its physical and rheological properties. Lignin percentage Is 43% that protects it from burning. In modified bitumen rice husk was added with different percentage of 5, 10 % 12%. Modified bitumen was prepared using a shear mixer under 4000rpm speed for one hour at the temperature of 160 ^{0}C. Using dynamic shear rheometer, the rheological and penetration test was conducted for characterization of rice husk modified bitumen. According to results obtained from rheological tests and conventional properties test. Rice husk increases viscosity, stiffness and elastic behavior of rice husk modified bitumen and reduces temperature susceptibility. Rice husk increases rutting resistance and fatigue resistance of bitumen at higher temperature and on low temperature. The optimum results obtained for rice husk modified bitumen is at 10% rice husk.

[10] This research focuses on the asphalt mix that is reinforced with short-thin pieces of wheat straws that are added directly into the mixtures. By third point flexural test, rutting test, fracture toughness test and freeze and thaw split test the performance of modified asphalt mix was evaluated. From results obtained, it shows that flexural strength increases by 23% by adding the SWSPs between 0.1 to 0.2%. dynamic stability increases by 48% (it reaches about 1592 times) and the fracture toughness by 27% while rut depth is decreasing by 44%. It shows higher temperature crack resistance are intensified with the addition of amount of SWSPs, and the result of freeze and

thaw split test shows that moisture susceptibility of WSAM is weak

3 Materials

Each material component used to produce the Asphalt mix laboratory specimens is described below:

3.1 Aggregates

Aggregates used for making Asphalt mix samples were sieved according to requirement of Marshall mix design method. Aggregates were collected from Kot bungalow in Khairpur mir's district. Aggregates were sieved from 25mm, 19.5mm, 12.5mm, 9.5mm, 4.75mm, 2.36mm, 300µm & 0.075µm and separated all sizes then aggregates weight was calculated by job mix formula.

3.2 Bitumen

The bitumen used in the production of Asphalt mix for all normal and modified specimens was a paving grade 60/70. Bitumen was tested before using in research the tests include Penetration, Ductility, Softening point, specific gravity and flash and fire test.

3.3 Rice Husk Ash

Burning Rice husk, about 75% of its weight is lost in the form of volatile organic matter and only 25% remains in the form of ash [6]. RHA is the result of burnt rice husk waste. RHA has specific properties containing chemical compounds (pozzolan) and silica (SiO2) [11]. Due to the small particle size of grains and binding properties, rice husk ash is considered to have great properties as a filler. RHA is an important product that is considered as a raw material having various capabilities. The pozzolanic activity of RHA depends on the burning situation, duration, and temperature.

3.4 Rice husk

Rice husk is an agricultural waste obtained during the production of rice in mills, it is outer most cover of rice and hard protective material usually of size (7mm length x 1.5mm width x 0.2mm thickness) [12]**.** The bulk density of (RH) rice husk is 96-160 kg/m3, risk husk contains oxygen 31 to 37%, and have 75 to 90 % organic matters i.e., lignin, cellulose etc. and remaining mineral components i.e., alkalis, silica & trace elements [13].

4 Sample preparation

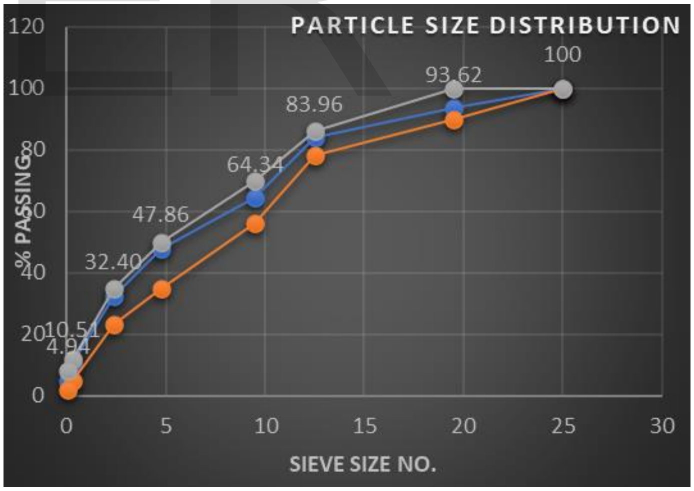
Laboratory normal mix and modified asphalt mix were prepared in molds of cylindrical shape with dimensions as 101.6mm diameter and 63.5mm height. The samples of Normal asphalt mix were prepared using aggregates and bitumen. For RHA modified asphalt the RHA was added in replacement of filler material that passes through 0.075µm sieve using percentages as (15, 30, 45 & 60%). For RHF modified asphalt mix RHF were added by total weight of aggregates using percentages of RHF as (0.5, 1. 1.5 & 2%). After finding optimum results 3 samples were prepared using combined optimum RHA & RHF modified asphalt values.

A mix design was performed to find optimum blend of aggregates and to find optimum bitumen content

The optimum blending formula of each aggregate stockpile described in table 1

Table 1 Blending of aggregates

Material	Total Blend	Target Value	Specifications
Used (%)	100		
Sieve			
25mm	100	100	100
19.5mm	93.62	95	90-100
12.5mm	83.96	82	78-86
9.5mm	64.34	63	56-70
4.75mm	47.86	42.5	35-50
2.36mm	32.40	29	23-35
300µm	10.51	8.5	5-12
0.075µm	4.94	5	2-8



Graph 1 Particle size distribution curve

Table 2 shows combined specific gravity of aggregates.

Aggregate Size	% Used	Bulk Sp. Gr. Aggregate Average	App. Sp. Gr. Aggregate Average
25 ~ 19 mm	15	2.663	2.714
19 ~ 4.75 mm	37	2.659	2.711
4.75 ~ 0.075 mm	48	2.651	2.707

Now, the apparent specific gravity of the combined aggregates representing the optimum blending formula was then calculated as follows:

G_{sb} = combined bulk specific gravity of aggregate blend

Gsb = 2.656

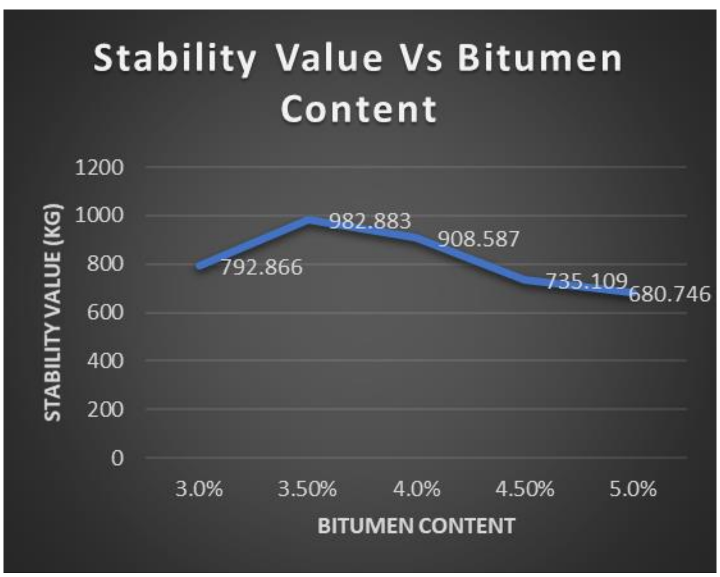
Gsa= Combined apparent specific gravity of aggregate blend

Gsa= 2.710

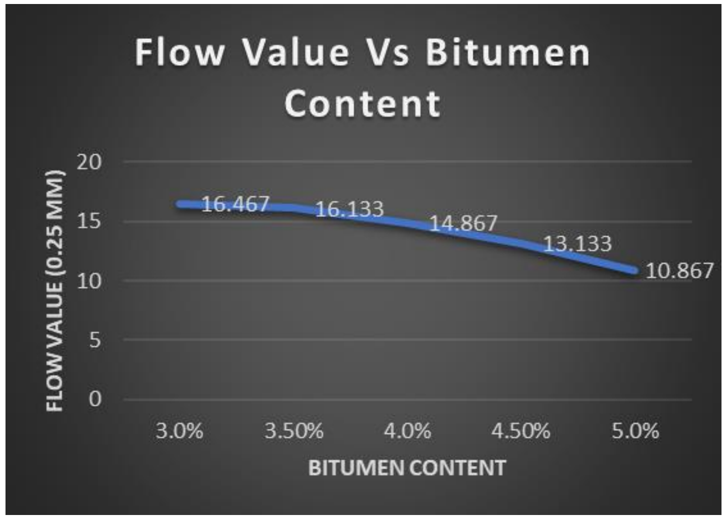
Different percentages of bitumen as (3. 3.5, 4. 4.5 & 5%) were used and 3 samples on each percentage were created and according to marshall mix design method the optimum bitumen content was found. Table 3 below provides details:

Table 3 Marshall test results for Optimum Bitumen Content

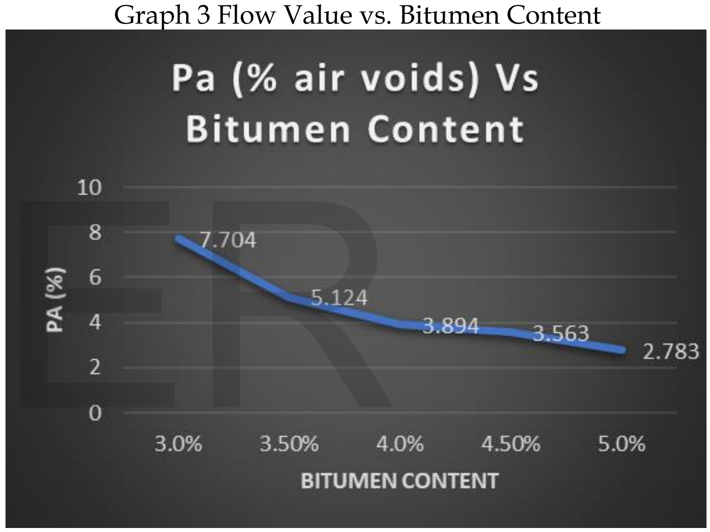
S.No.	Bitumen Content	Gmb	VMA	Pa (% air voids)	VFB	Stability Value (Kg)	Flow Value
1	3.0%	2.36	13.81	7.704	44.21	792.866	16.467
2	3.50%	2.407	12.547	5.124	59.16	982.883	16.133
3	4.0%	2.419	12.566	3.894	69.01	908.587	14.867
4	4.50%	2.409	13.381	3.563	73.37	735.109	13.133
5	5.0%	2.41	13.799	2.783	79.83	680.746	10.867



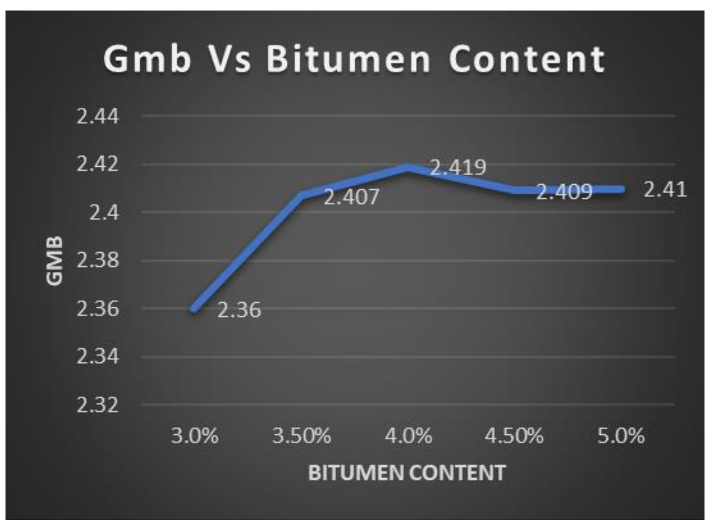
Graph 2 Stability value (kg) vs. Bitumen Content



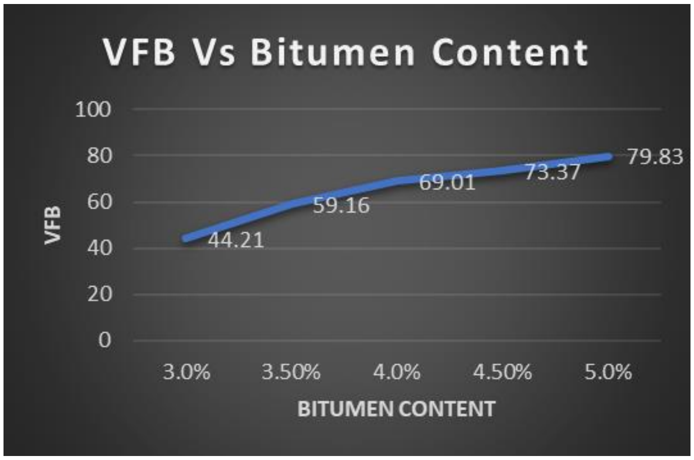
Graph 3 Flow Value vs. Bitumen Content



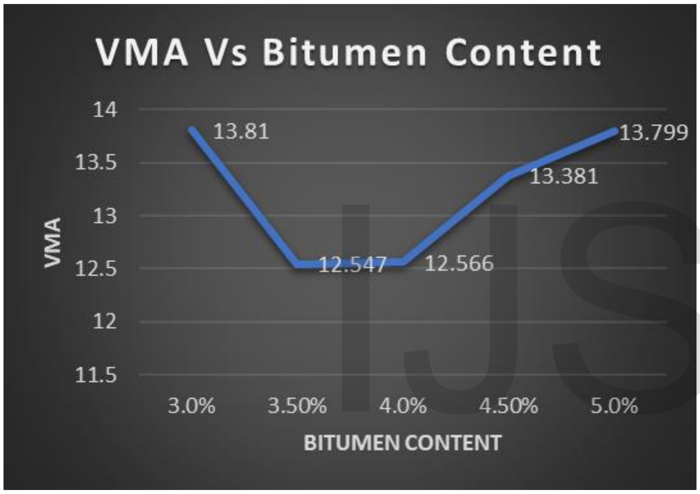
Graph 4 Percentage air voids (Pa) vs. Bitumen content



Graph 5 Density (Gmb) vs. Bitumen Content



Graph 6 VFB vs. Bitumen Content



Graph 7 VMA vs. Bitumen Content

Optimum Bitumen Content:

B1= Bitumen content at maximum stability = 3.5%

B2= Bitumen content at maximum 4% Air voids = 3.9%

B3=Bitumen content at maximum density (unit weight) = 4%

OBC = (B1+B2+B3)/3

Optimum Bitumen Content = 3.8%

Asphalt mix design three samples are prepared on each of five different percentage of bitumen content. Marshall test specimen of 101.6 mm diameter were prepared. Total 1200g batch meeting the blending formula were prepared for each of total 15 samples. Each aggregate batch was heated in oven prior to mixing in the oven at 175-190 ^{0}C. and the bitumen was preheated at temperature of 121-125 ^{0}C. the heated aggregates and bitumen were thoroughly mixed in a pan on the heater at temperature of 150-160 ^{0}C. immediartly after the mixing the material was placed in Marshall mold of 101.6mm diameter and compacted with 75 blows on each side of the sample by a 4.5kg Marshall hand hammer. The samples were prepared in four different cateogories. The first category sample were normal mix (conventional) with no modification. The second category samples were made using RHA in replacement of filler material. The third category samples produced using RHF by total weight of aggregates, different percentages of RHF were used. In the fourth and last category three samples were prepared using combined RHA & RHF optimum quantities and tested their Marshall stability and flow values.

5 Tests & Results

5.1 Bitumen

Bitumen was tested before using in Asphalt mix. Table 4 provides results of tests.

Table 4 Bitumen test results

Laboratory Test	**Results**
Penetration (AASHTO T-49, ASTM D-5)	68
Ductility (AASHTO T-51, ASTM D-113)	138 cm
Softening point (AASHTO T-53, ASTM D-36)	51 ^{0}C
Specific gravity (AASHTO T-288, ASTM D-70)	1.013 Kg/cc
Flash and fire point (AASHTO T-48, ASTM D-92) 1) Flash point 2) Fire point	321 ^{0}C 360 ^{0}C

5.2 Normal Asphalt mix

After finding optimum bitumen content three samples were prepared for finding stability and flow value, following table 5 provides results of Normal asphalt mix.

Table 5 average stability and flow of Normal Asphalt mix

Bitumen content	Average stability (kg)	Flow average (mm)
3.8%	957.997	15.2

5.3 RHA modified asphalt mix

Results of stability and flow obtained by testing of RHA modified asphalt mix in comparison with normal asphalt mix are provided in Graph 8 and Graph 9.

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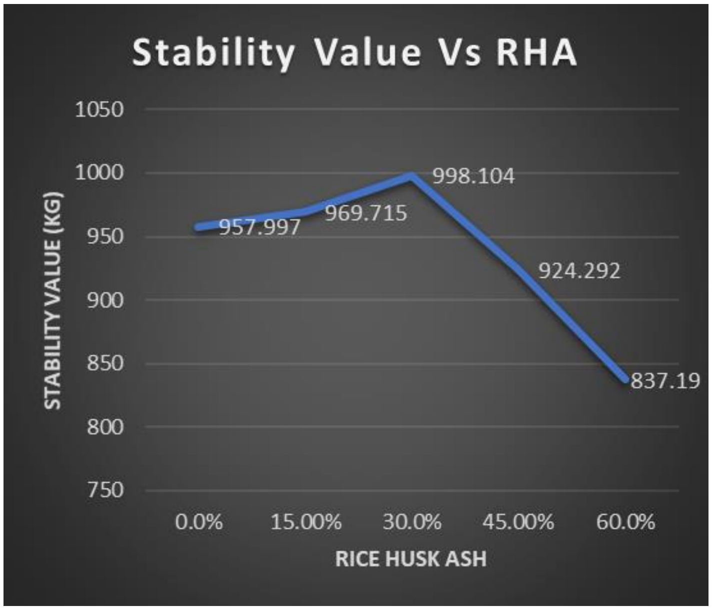
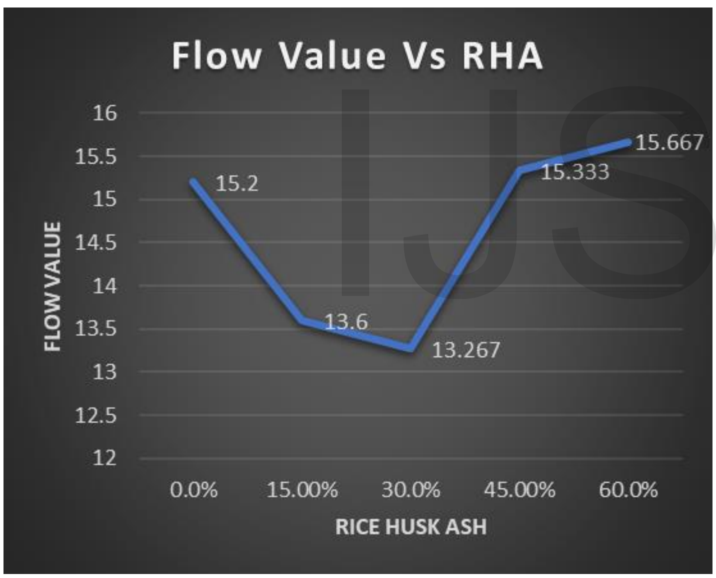


Graph 8 Stability value vs. RHA

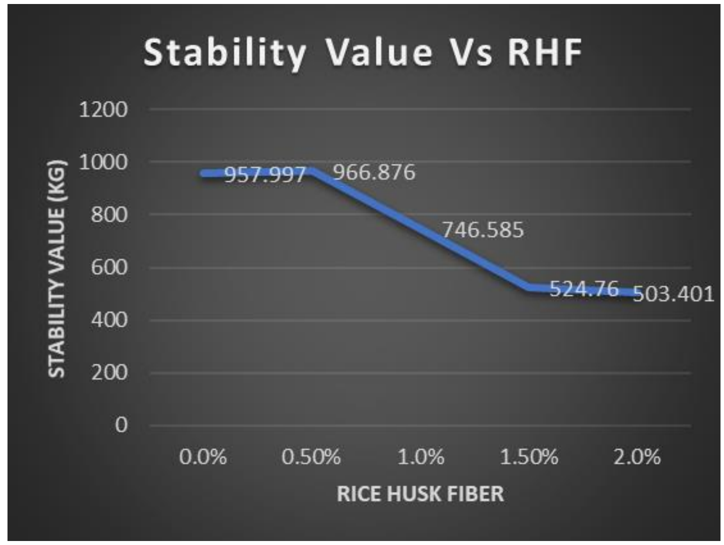


Graph 9 flow value vs. RHA

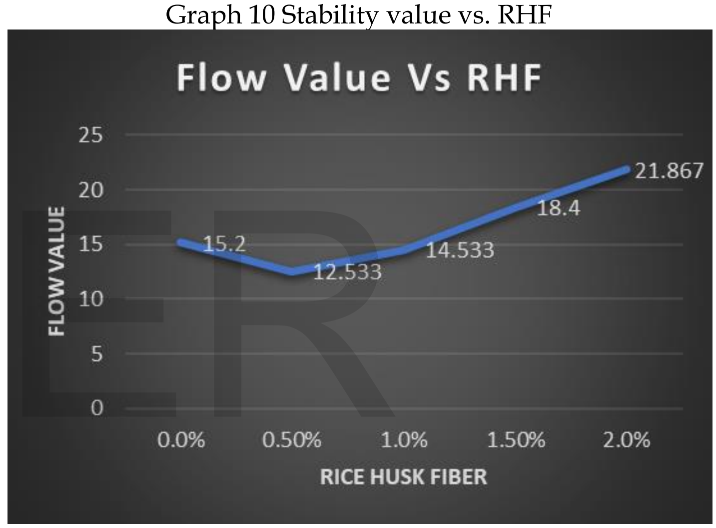
From stability value graph, we can see that the stability of asphalt mix increases from 0 to 30% RHA and value decreases with further increase of RHA. So, at 30% RHA optimum results are obtained.

5.4 RHF modified Asphalt mix

Results of stability and flow obtained by testing of RHF modified asphalt mix in comparison with normal asphalt mix are provided in Graph 10 & Graph 11.



Graph 10 Stability value vs. RHF

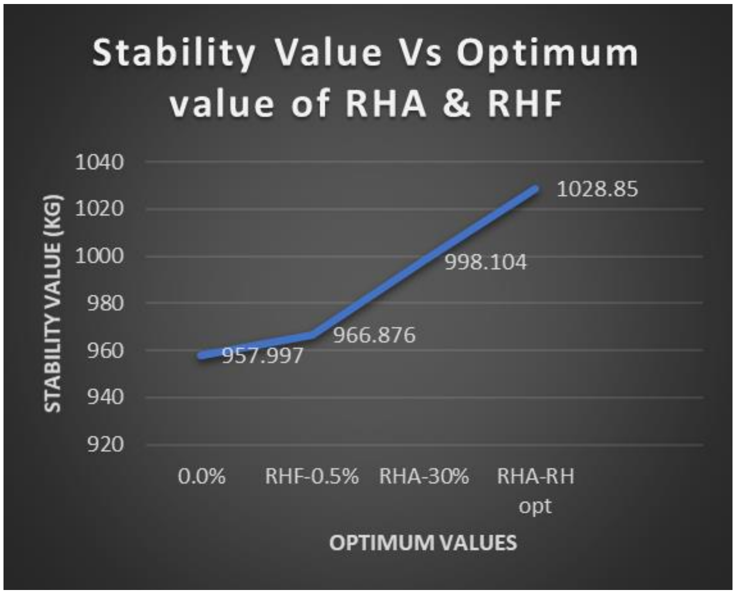


Graph 11 Flow value vs. RHF

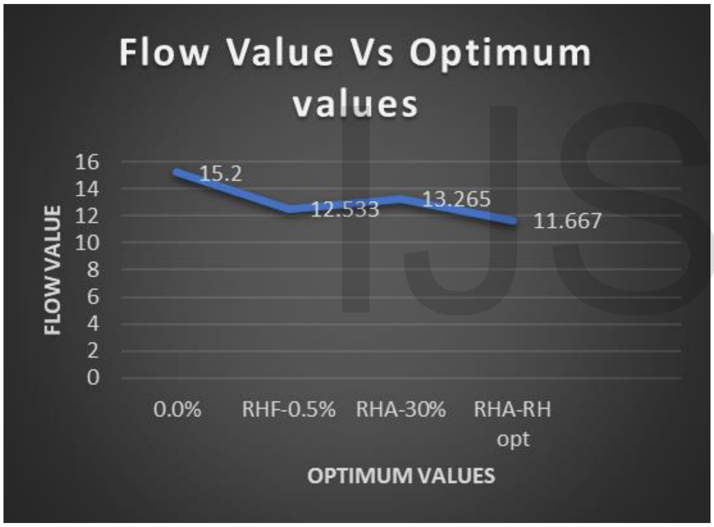
From values of stability graph, we can observe that the stability of Rice husk fiber modified asphalt mix shown better results at 0.5% RHF and with further increase of RHF material the stability values decrease very rapidly. Hence optimum RHF content is at 0.5% by total weight of Aggregates.

5.5 Combined RHA & RHF modified asphalt mix

After obtaining optimum result of RHA modified asphalt mix at 30% in replacement of filler material and RHF modified asphalt mix at 30%, three samples are prepared, and their results are compared with other results in Graph 12 and Graph 13 provided below:



Graph 12 Stability value vs. Optimum values of RHA & RHF



Graph 13 Flow vs. Optimum values of RHA and RHF

6 Conclusions

- Optimum Bitumen content for this research is found at 3.8%.
- Maximum stability of Asphalt mix is achieved at 30% RHA in replacement of filler material. May be due to presence of silica and RHA is Pozzolanic material. With Higher percentages of RHA the stability of Asphalt mix decreases.
- Rice Husk as a fiber reinforcement provides optimum result at 0.5% RHF and with higher percentages the stability of Asphalt mix decreases, this may be due to light weight of Rice husk and occupy more space.
- At 30% RHA replacement with filler the stability of Asphalt mix increases by 4.18% in comparison with Normal Asphalt mix.
- By 0.5% RHF as reinforcement the stability of Asphalt mix increases by 0.92% in comparison with Normal Asphalt mix
- Combined RHA and RHF samples increased the stability of Asphalt mix up to 7.39%

7 Recommendtions

- ✓ For further study Rice husk should be burned under controlled temperature.
- ✓ As Rice husk is light weight material smaller percentages as 0.1, 0.2, 0.3, 0.4 & 0.5 can be used for futher study and better results might obtained.
- ✓ In this study 60/70 grade of bitumen is used, which is mostly used in hot regions. Further research can be carried out by using different grade of bitumen.

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References

[1] McDaniel, R.S., 2015. Fiber additives in asphalt mixtures (No. Project 20-05 (Topic 45-15)).

[2] Javed, M.G.F., 2005. Sustainable financing for the maintenance of pakistan's highways. Transport and communications bulletin for Asia and the Pacific, (75), p.83

[3] *USDA Foreign Agricultural Service,"Grain: World Markets and Trade"* (PDF), *May 2018.* Retrieved 9 June 2018

[4] Helal, M.M.E., Mahdy, H.A.E. and Ibrahim, M.F., 2020. Effect of Rice Husk Ash on the Performance of Hot Asphalt Mixes. Bulletin of the Faculty of Engineering. Mansoura University, 45(2), pp.8-19.

[5] Mahmood, O.T. and Ahmed, S.A., 2020. Influence of Natural Fibers on the Performance of Hot Mix Asphalt for the Wearing Course of Pavement. *ARO-THE SCIENTIFIC JOURNAL OF KOYA UNIVERSITY*, *8*(2), pp.57-63.

[6] Shafabakhsh, G.A., Divandari, H. and Sajadi, S.R., 2018. Evaluation of Optimum Content of Rice Husk Ash to Improve the Hot Asphalt Concrete Performance. International Journal of Engineering and Technology, 7(4.20), pp.338-346.

[7] Romastarika, R., Jaya, R.P., Yaacob, H., Nazri, F.M., Agussabti, Ichwana and Jayanti, D.S., 2017, August. Effect of black rice husk ash on the physical and rheological properties of bitumen. In AIP Conference Proceedings

(Vol. 1875, No. 1, p. 030012). AIP Publishing LLC.
[8] Poonam Singh, Mohit Takhalate, Pranav Thepe, Dr Subrat Roy., 2017. Use of Wheat Straw Fibre as Stabilizing Additive in Stone Matrix Asphalt Mix. *International Journal of Innovative Research in Science, Engineering and Technology*, 10.15680/IJIRSET.2017.0607354
[9] Nahi, M.H., Kamaruddin, I. and Napiah, M., 2016. Using rice husks powder to upgrade the rheological properties of bitumen binder.
[10] Yin, J. and Wang, S., 2016. Improving the performance of asphalt mixture by addition of short-thin wheat straw pieces. *International Journal of Pavement Engineering*, *17*(6), pp.528-541.
[11] Kamil, M., Anggraini, R. and Suryani, F.M., 2011, December. The performance of asphalt-concrete wearing-course (ac-wc) mixture by using rice husk ash as filler with the addition of asbuton in asphalt pen 60/70 as binder. In Proceedings of The Annual International Conference, Syiah Kuala University-Life Sciences & Engineering Chapter (Vol. 1, No. 2).
[12] Johar, N., Ahmad, I. and Dufresne, A., 2012. Extraction, preparation and characterization of cellulose fibres and nanocrystals from rice husk. Industrial Crops and Products, 37(1), pp.93-99
[13] Kumar, S., Sangwan, P., Dhankhar, R.M.V. and Bidra, S., 2013. Utilization of rice husk and their ash: A review. Res. J. Chem. Env. Sci, 1(5), pp.126-129