Impact of Waste Rice Husk as Filler on Mechanical Behavior of Hot Mix Asphalt

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***Abstract*: The mixture of coarse aggregate, fine aggregate, filler and bitumen is known as Hot Mix Asphalt in which filler having size less than 0.075 mm, is an integral ingredient that not only fill the voids but also provides stability against mechanical actions coming over the top most layer of flexible pavements. By observing unwanted failures in the flexible pavements like as rutting and cracking before the design life, the need has been occurred to improve the properties of Hot Mix Asphalt by replacing conformist filler by a waste mineral fillers, such as rice husk as a partial replacement. The aim of this research is to investigate impact of waste rice husk as mineral filler on mechanical behavior of Hot Mix Asphalt. Usage of such material is also a way of reducing waste from the environment. To achieve the aim of research, fifteen controlled hot mixes were prepared at variable bitumen percentages 3.0% to 5.0% with an interval of 0.5%. The properties of conventional hot mixes were assessed and optimum bitumen content was obtained, at which fifteen modified samples containing variable percentages 5.0% to 15% of waste rice husk were made and inspected to relate the results with conventional hot mixes and to obtain optimum filler content. From outcomes of Marshall Tests, waste rice husk was found optimum at 10%.**

Keywords: Hot Mix Asphalt, Waste Mineral Filler, Mechanical Behavior.

I. INTRODUCTION

The flexible pavement is broadly used in Pakistan as road transportation which is comprised of a layered system and in the construction, engineering materials such as coarse aggregate, fine aggregate, filler and the bitumen are used. Material size less than no. 200 sieve, generally called as filler and the binding agent used in such pavements named as bitumen. These materials perform a key character in the performance of such pavement and provide a comfort ride to users. The combination of these materials provide a mixture called as Hot Mix asphalt (HMA). The top layer of flexible pavement is comprise of Hot Mix Asphalt, which is in uninterrupted contact with vehicular loads and weathering conditions. Such loading and weathering possessions cause part or entire failures in the top layer of the pavement which are mostly observed in Pakistan. The failure in the pavement earlier the design life may be due to the inappropriate material selection or designing. To construct a sustainable flexible pavement there is a need of material modification by using some waste materials present in the surrounding such as Waste Rice Husk (WRH) in the rural areas of Pakistan. The usage of waste rice husk in road construction has benefit in not only saving over fresh or expensive materials but also in decreasing the waste materials from the surround which are not environment pleasant but are sometimes unsafe to human health. The key objective of this research was to inspect experimentally the impact of using waste rice husk as mineral fillers in Hot Mix Asphalt (HMA) and for that persistence 15 controlled asphalt mixes were set using five different percentages of bitumen i.e. 3.0% to 5.0%, with the recess of 0.5% to find out the possessions and Optimum Bitumen Content (OBC), than using five varying percentages i.e. 5% to 15%, of waste rice husk filler at the obtained optimum bitumen content, 15 specimen were set for the analysis and comparison of the properties of modified mixes with controlled mixes. The results of Marshall Tests of the mixes having waste rice husk as mineral filler were concluded that use of 10% of waste rice husk as mineral filler, upgraded Marshall Properties of top (wearing Course) layer of the flexible pavements.

II. LITERATURE REVIEW

Rice Husk Ash (RHA) was used in the in the hot mixes at varying contents i.e. 25% to 100% as a replacer to traditional filler. From the extensive Marshall experimental results, which were observed improved, it came in observation that Rice Husk Ash (RHA) can be utilized as mineral filler in the Hot Mix Asphalt [1]. In Hot Mix Asphalt Palm kernel Shell Ash was tested to get improved characteristics, so for that specimens of bituminous mixes were set at the optimum bitumen content which was obtained from controlled bituminous mixes. Five replacement rates 1%, 2%, 3%, 4%, and 5%, of palm kernel ash were used for the analysis purpose, and then tested to assess their mechanical possessions. Results showed that the mixes comprising palm kernel ash as mineral filler have enhanced mechanical possessions and suitable content was observed as 3% [2]. Impact of Crumb Rubber Powder (CRP) and High Density Polyethylene (HDPE) on bituminous mixes was checked out by replacing the conformist filler in the Hot Mix Asphalt and improved properties were observed from Marshall test results of both type of mixes at 10% of CRP and 5% HDPE [3]. Waste glass and cullet has been utilized as replacer of traditional filler in asphalt mixes by many researchers to check out the prospect of using such waste materials as coarse sand over and above a fillers in asphalt surface course. Researchers used variable percentages of the waste glass and cullet in hot asphalt mixes and establish possibility of applying these mineral materials in hot mix asphalt [4]. To achieve improved mechanical behavior of hot mix asphalt, researchers used cement, ground granulated blast furnace slag and brick dust as mineral filler. Mixes were prepared using varying percentages of cement, ground granulated blast furnace slag and brick dust and inspected to equate the outcomes of reformed mixes with the controlled mixes and the prospect of using such materials as replacers of traditional fillers was perceived at respective suitable contents in mixes [5]. To overcome the early failure issues in flexible pavements, the waste plastic and waste rubber tire inspected by researchers. The modified mixes having such materials as replacers of traditional filler, gave improvement in the properties. Both the materials waste plastic and waste rubber tire found suitable to use as replacers of conformist filler, however waste rubber tire was found good at 5% and 10% from another research with improved properties of mixes [6]. Impact of lime stone powder, ordinary Portland cement and glass powder as replacer filler were used in bituminous specimens at three fractions range from 4% to 10%. These modified specimens were set at the obtained optimum binder content of controlled specimens. The enhanced Marshall test results indicated the opportunity of using such materials as replacers of traditional filler at their respective optimum filler contents [7]. Concrete dust and brick dust are generally waste materials which were used as mineral filler in the asphalt mixes to analyze their impact on Marshall Characteristics of asphalt. A number 0f 24 mixes were prepared using different percentages of cement dust and brick dust i.e. 4.5% to 6.0% and investigated in the laboratory. The obtained results were compared which revealed that asphalt specimens containing concrete dust and brick dust as fillers at the 6% bitumen content have good and improved Marshall possessions. Usage of such waste materials may result to the reduction of waste from the surrounding [8]. In Egypt a research was carried out for the perfection of asphalt wearing course layer, by using limestone powder as a replacer of conventional filler in bituminous mixes. The hot specimens were made ready at contents 4%, 6% and 8% of limestone filler and then step by step all the required tests such as Marshall and indirect tensile tests were conducted. The results were compared to the controlled specimens from which it was concluded that 4% content of lime stone powder is favorable to use in the hot mix asphalt because of enhanced characteristics [9]. An industrial waste residue such as fly ash which has major cost-effective status and environmental significance has the matching physicochemical assets with the limestone powder, which mark it feasible for replacement of lime stone filler by fly ash in the bituminous mixes [10]. W3B fillers such as W3B-hydrated lime, W3B-kaolin, W3B-granite added in the hot mix asphalt to assess the volumetric and mechanical appearances of asphalt specimens. Mixtures containing W3B-kaolin filler revealed extreme resistance against deformation as related to other two mixtures. Whereas the mixtures containing W3B-Hydrated lime as filler, similarly revealed better enhancement in the assets such as stiffness and moisture damage resistance [11].

III. MATERIALS & METHODS

Aggregates including coarse and fine aggregates, binder (bitumen), traditional filler and mineral filler i.e. waste rice husk were tested experimentally for the physical characteristics.

A. Aggregates

A number of important tests such as Sieve analysis, specific gravity, water absorption, abrasion value, impact value for aggregates were conducted and hence all the characteristics obtained good enough as desired. The different test results of aggregates are given below in the tables.

Table 1: Gradation properties of Controlled and W.R.H modified Blend Mix

SIEVE SIZE		**properties by passing weight**			
Inch	**mm**	**Controlled Blend Grading**	**W.R.H Modified Blend**	**Mid point specification**	**Specification limits**
1 1/2//	38.1	100	100	100	100
1//	25.4	100	100	100	100
3/4//	19.1	94.3	94.3	95	90—100
1/2//	12.7	76.1	76.1	---	---
3/8//	9.52	66.2	66.2	63	56—70
#4	4.76	47.1	46	42.5	35—50
#8	2.40	27.5	32	29	23—35
#50	0.30	6.3	7.5	8.5	5—12
#200	0.075	2.4	4	5	2—8

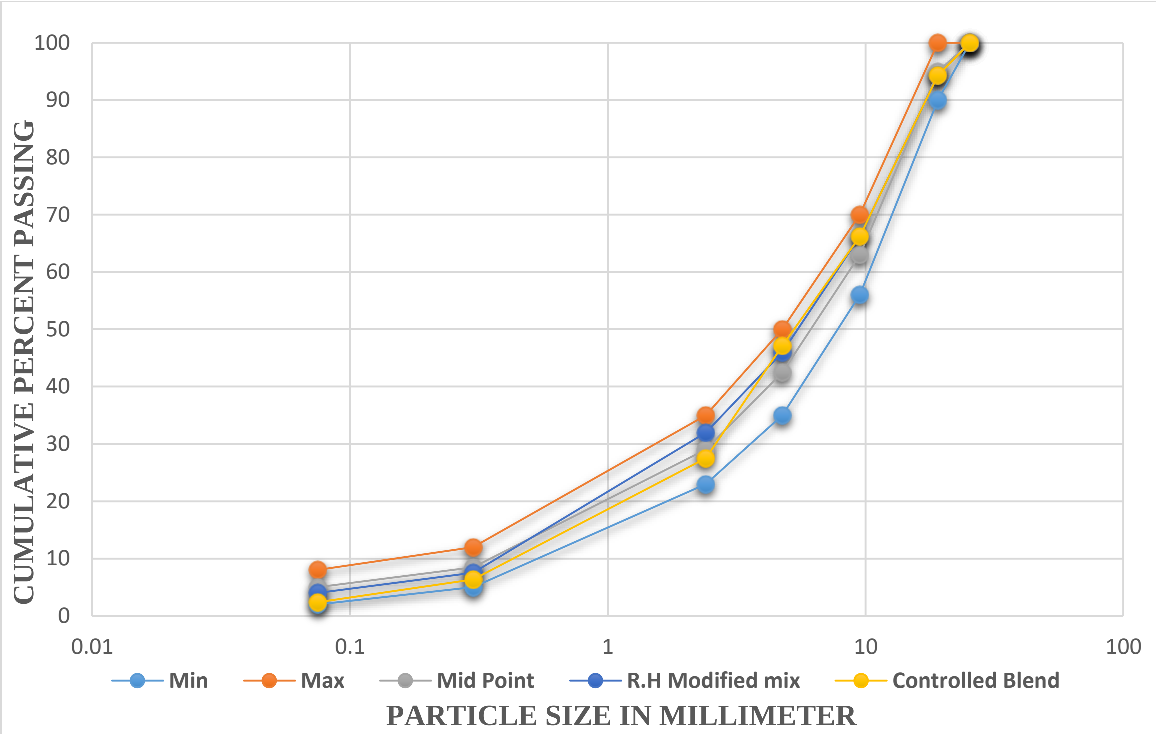

Fig. 1: Gradation Properties of Controlled and Modified Blend in graphical Presentation

Table 2: Physical Properties of the Aggregates

TEST PARTICULARS	OBTAINED TEST RESULTS
Los Angeles abrasion value, %	19.84
Aggregate impact value, %	22.25
Crushing Strength	19.10
Specific Gravity Coarse aggregate	2.57
Specific Gravity fine aggregate	2.68
Aggregates Water Absorption %	1.21

B. Bitumen

Bitumen is a binding mediator between coarse and fine aggregates and is very vital material used in flexible pavements, generally bitumen is of different grades but in this research work the bitumen of 60/70 grade was used. Different significant tests of bitumen were conducted to know the other important possession of bitumen. The names of tests and results are presented below in table.

Table 3: Physical Properties of Bitumen

TEST PARTICULARS	Test Results
Penetration at 25°C, mm	67.33 (60/70)
Softening point, °C	47.8
Flash point, °C	322
Fire Point, °C	364
Ductility at 27 °C, m	147.30
Specific gravity	1.006

C. Fillers (Conventional & Modifier)

Materials that permit through sieve No. 200 are recognized as the fillers. Other than the conventionally used fillers, waste rice husk was used in this research work as mineral filler in the asphalt mixes. Both the conventional and modifier filler were tested for physical properties which are given below in the table**.**

Table 4: Physical Properties of Traditional and Modifier Filler

TEST PARTICULARS	OBTAINED TEST RESULTS
Specific Gravity Traditional filler	2.68
Specific Gravity Replacer filler (WRH)	2.10

D. Methodology

For this research work Marshall mix design method was used to examine the impact of waste rice husk powder as filler on the features of hot mix asphalt.

An appropriate proportion of coarse aggregate, fine aggregate, filler and Bitumen was set to formulate a blend of 1200 grams, then using five unlike percentages of bitumen, fifteen hot mixes (three for every single content) were prepared by mixing in hot mini plan at a temperature of 145° to 165°C. After the completion of mixing of materials; the mix was sited in mold which was pre-heated to temperature of about 100°C to 140°C, having dia of 10 cm and height of 7.5 cm. After placing the mixture in the mold the compaction of mixes was done by applying 75 blows on each side of the specimen**.** The different required volumetric characteristics of the hot mix samples were calculated and then tested for stability and flow by Marshall Stability machine. The optimum content of binder i.e. bitumen was then achieved from the results of controlled hot mixes. By applying the same process of Marshall mix design as of controlled one, another series of 15 modified hot specimens was prepared at optimum bitumen content of controlled mixes. In modified hot specimens five varying contents (5.0%, 7.5%, 10%, 12.5%, 15%) of waste rice husk were tested in the mixes to examine the impact of using this waste rice husk on the Mechanical behavior of hot mix asphalt and the optimum percentage of waste rice husk that to be used.

IV. RSEULTS

The obtained Marshall and volumetric test results such as Stability, Flow, Unit weight, Percentage air voids, percentage voids in mineral aggregates and percentage voids filled with bitumen of controlled and modified i.e. waste rice husk containing mixes are presented in table and graphical presentation with discussions.

Table 5: Marshall Properties of Controlled mixes at Variable Bitumen Content

Properties	% Bitumen Content				
	3.0	**3.5**	**4.0**	**4.5**	**5.0**
Stability (Kg)	1328	1475	1516	1390	1321
Unit Weight g/cc	2.32	2.33	2.35	2.34	2.30
Flow in 0.01"	10.9	13.2	15.2	15.3	14.3
% V.T.M	5.3	4.0	2.5	2.5	3.4
% V.M.A	12.4	12.5	12.2	13.1	15.0
% V.F.A	57.3	68.0	79.5	80.9	77.3

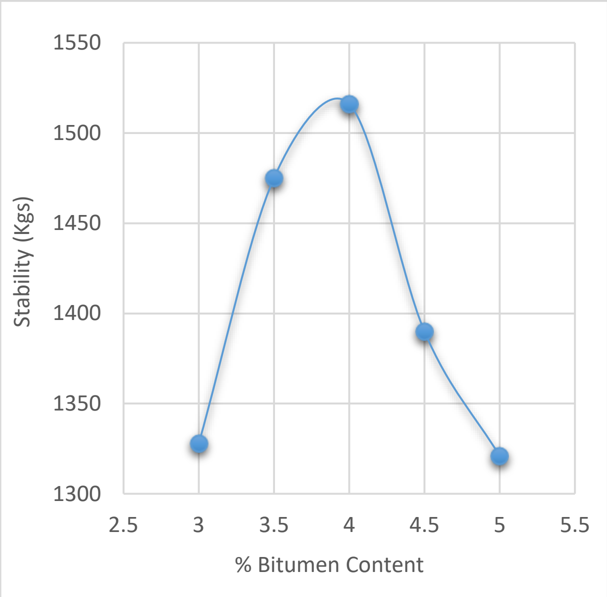

Fig. 2: stability results of Controlled mixes V/S Bitumen content

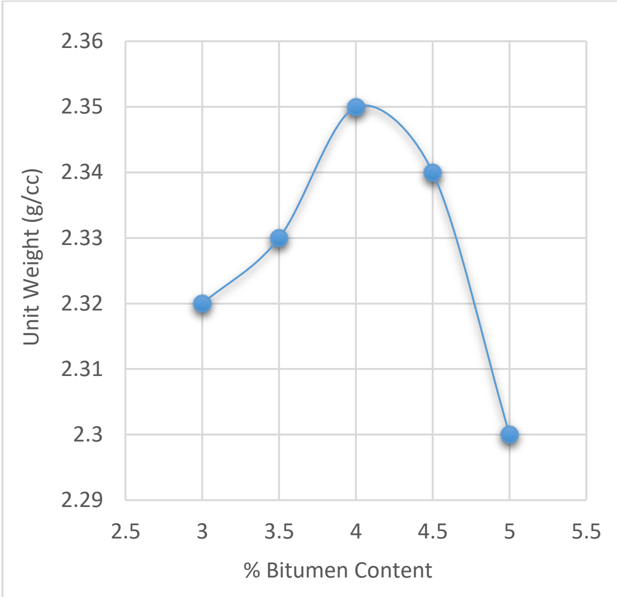

Fig. 3: Unit weight results V/S Bitumen Content

Fig (2) shows the correlation between the stability (Kgs) of controlled mixes and bitumen content. Stability of the mixes increases with the enhancement of bitumen up to a value of 4.0% and then it falls with more enhancement. Figure displays that extreme stability of controlled bituminous mixes as 1515 kgs at 3.83% of bitumen.

Fig (3) shows the correlation between the Unit weight (g/cc) of controlled bituminous mixes and bitumen content. Unit weight of the controlled mixes increases maximum at 4.0% of bitumen then falls. Figure shows maximum Unit weight 2.35 g/cc at 4.0% bitumen, though further enhancement of bitumen in the mix causes reduction in unit weight.

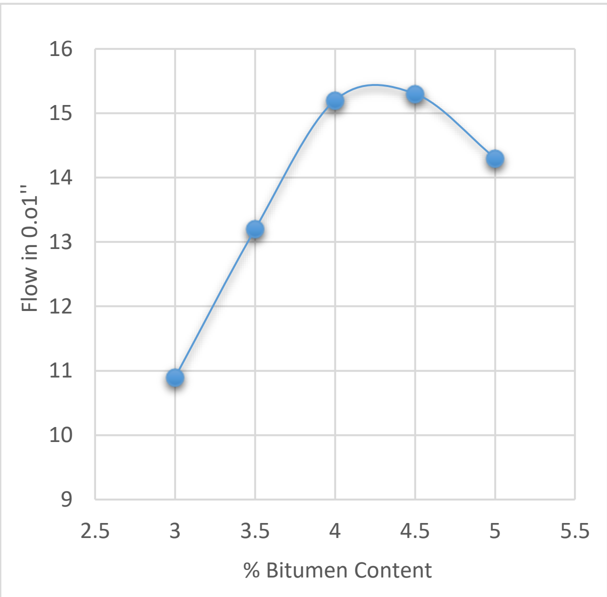

Fig. 4: Flow Value results V/S Bitumen Content

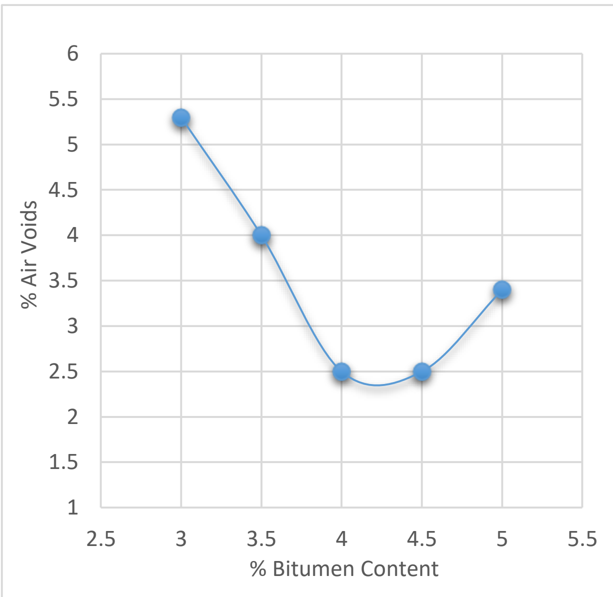

Fig. 5: Air Voids result V/S Bitumen content

Fig (4) shows the correlation between the flow value of controlled mixes and bitumen content. Flow value increases with the enhancement of bitumen in the mix. Figure displays maximum flow value 15.3 of the mixes at 4.5% of bitumen.

Fig (5) shows the correlation between the percentage air voids in the controlled mixes and bitumen content. Figure displays maximum decline of air voids with the rise of bitumen content and it is due to increase of voids occupied with bitumen in the mixes. The least air voids are noted at the 4.0% bitumen.

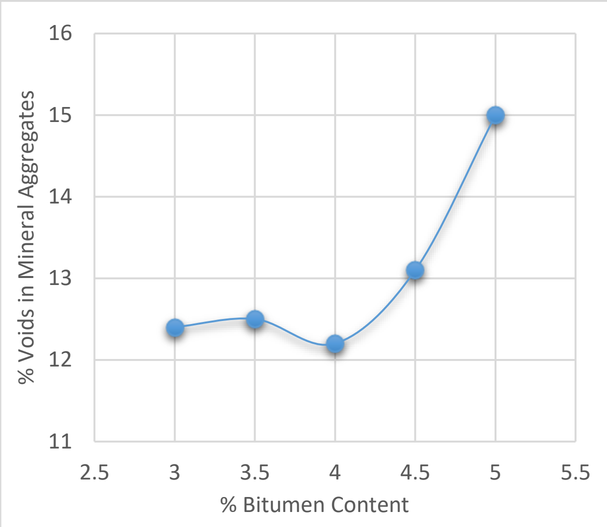

Fig. 6: %V.M.A V/S Bitumen Content

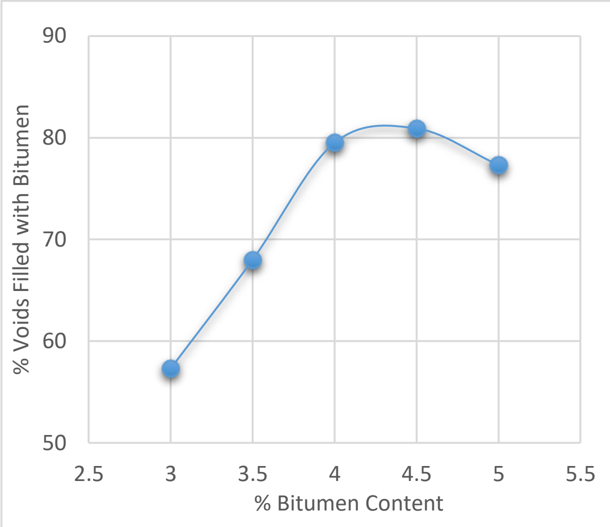

Fig. 7: %V.F.B V/S Bitumen Content

Fig (6) shows the correlation between the percentage voids in mineral aggregates and bitumen content. The figure displays dissimilar values for %VMA with the rise of bitumen in the controlled mixes. The extreme decrease in %VMA can be observed at the 4.0% bitumen.

Fig (7) shows the correlation between the percentage voids filled with bitumen in controlled mixes and bitumen content. It can be perceived from figure presented above that %VFB rises with the enhancement of bitumen and the extreme increase in %VFB found as 80.9% at 4.5% of bitumen.

E. Optimum Bitumen Content

The Optimum Bitumen Content was attained by ordinary formula as follows:

$$\mathbf{O.B.C} = \frac{B1 + B2 + B3}{3} = ?$$

Where:
B1= Percentage of Bitumen Content at Maximum stability
B2= Percentage of Bitumen Content at Maximum Unit weight
B3= Percentage of Bitumen Content at 4% air voids in compacted Mix

$$\mathbf{O.B.C} = \frac{4.0\% + 4.0\% + 3.5\%}{3} = 3.83\%$$

Table 6: Results of Controlled Mix at OBC

Marshall Test Results of Controlled Mixes at OBC=3.83%	
Properties	**Results**
Stability (Kg)	1515
Unit Weight g/cc	2.342
Flow in 0.01"	14.0
% V.T.M	2.9
% V.M.A	12.5
% V.F.A	78.0

Table 7: Marshall Properties of Modified Mixes at Variable Contents of WRH

Mineral Filler	**Content**	**Marshall Properties of Filler modified mixes at O.B.C =3.83%**					
		Stability in (Kgs)	**Flow in 0.01"**	**Unit Weight g/cc**	**% V.T.M**	**% V.M.A**	**% V.F.B**

	5%	1250	12.8	2.29	6.5	14.3	54.3
	7.50%	1390	13.9	2.32	4.5	13.2	65.8
Waste Rice Husk	**10%**	1510	14.3	2.33	3.7	13	71.5
	12.50%	1560	15.2	2.31	3.7	10.2	63.7
	15%	1260	15.3	2.31	3.7	10.2	63.7

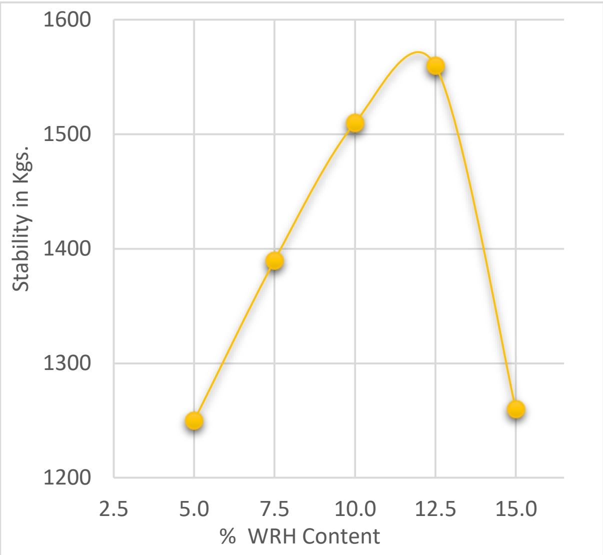

Fig. 8: Marshall Stability of Modified mixes V/S Variable Contents of WRH

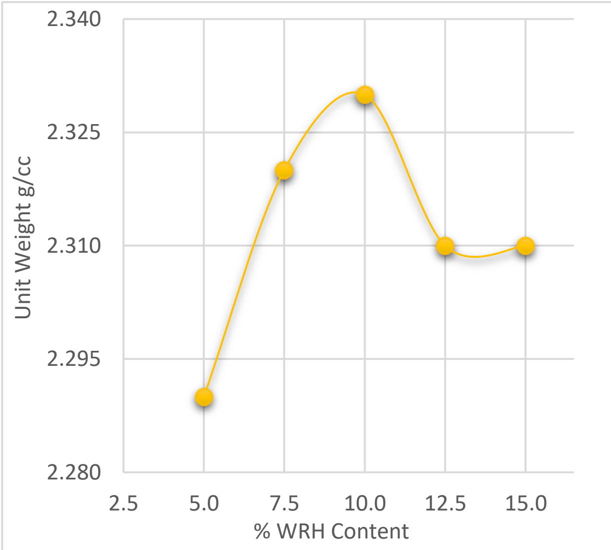

Fig. 9: Unit Weight of Modified Mixes V/S Variable contents of WRH

Fig (8) shows the correlation between Marshall Stability of modified mixes and waste rice husk filler content. The outcomes show extreme stability of 1560 kgs at 12.50% content of waste rice husk in the mixes. The stability of modified mixes is obtained greater as compared to the controlled mixes at optimum bitumen content 3.83%.

Fig (9) shows the correlation between Unit Weight (g/cc) of modified hot mixes and the mineral filler content. The outcomes show that the unit weight of waste rice husk contained mixes, at the optimum content bitumen (3.83%) increases from 2.29 to 2.33 at 10% of mineral filler content and then reduced with further rise of filler, though the controlled mix has the maximum unit weight 2.35 g/cc at the same bitumen content.

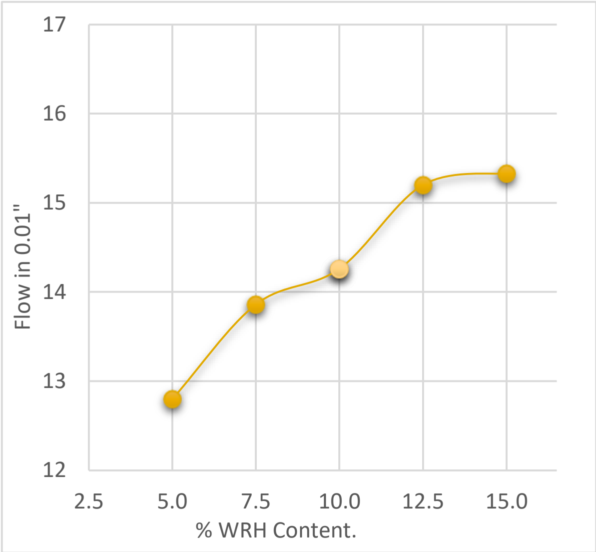

Fig. 10: Flow Value of Modified Mixes V/S Variable contents of WRH

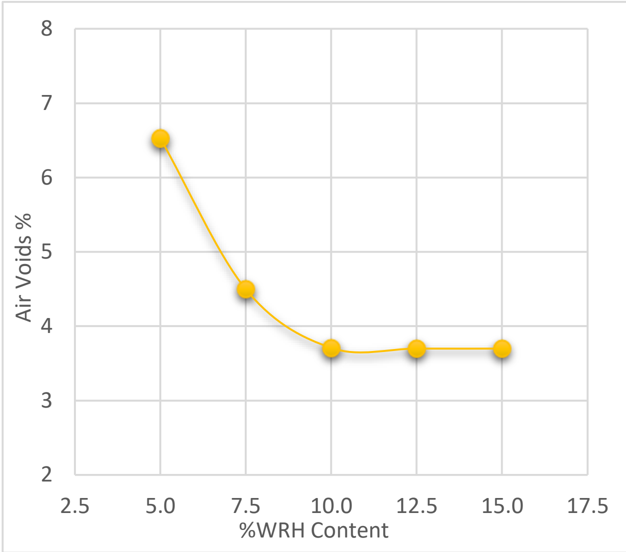

Fig. 11: Percentage Air Voids in Modified Mixes V/S Variable Contents of WRH

Fig (10) shows the correlation between flow value of modified mixes and percentage mineral filler content. The outcomes show that flow value increased, with the rise of waste rice husk content in the modified mixes. The extreme flow of modified mixes is found 15.3%, but the extreme flow value for controlled mixes, was found 14.3% which is lesser than that of the modified mixes.

Fig (11) shows the correlation between percentage air voids in the modified mixes and the mineral filler content. The outcomes show that, with rise of waste rice husk powder content from 5.0% to 15.0%, at the optimum bitumen content, the air voids were reduced to a rate of 3.7%, while the decrease in air voids of the controlled mixes at the optimum bitumen content is 2.9%. However the air voids of modified mixes are found within the acceptable limits.

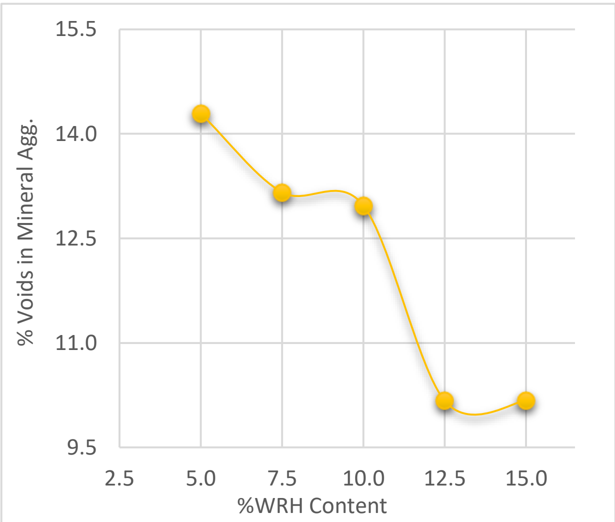

Fig. 12: Percentage V.M.A in Modified Mixes V/S Variable Contents of WRH

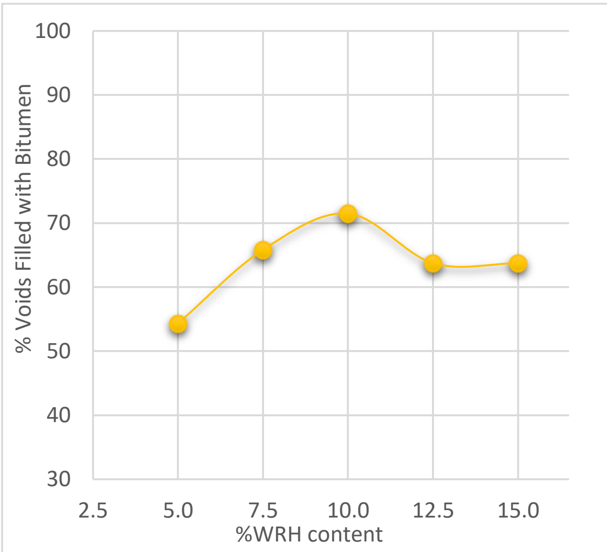

Fig. 13: Percentage V.F.B in Modified Mixes V/S Variable Contents of WRH

Fig (12) shows the correlation between voids in mineral aggregates of modified mixes and mineral filler content. The outcomes show maximum value of percentage V.M.A 14.3% at the 5.0% content of waste rice husk while reduction in the percentage voids in mineral aggregates is observed with the enhancement of mineral filler content. The least value of percentage V.M.A is 10.2% at the mineral filler contents 12.5% and 15.0%.

Fig (13) shows the correlation between percentages voids filled with bitumen in the modified mixes at mineral filler contents. From the results it can be perceived that the percentage voids filled bitumen increases with the rise of waste rice husk content up to of 12.5%, but also decline with the extra enhancement of mineral filler content. The outcomes denotes a extreme value of %V.F.B as 71.5% at the waste rice husk content 12.5%.

F. Optimum Waste Rice Husk Content

The Optimum waste rice husk content was attained by ordinary formula as follows:

$$\mathbf{O.B.C} = \frac{\text{F1} + \text{F2} + \text{F3}}{3} = ?$$

Where:

1. F1= Waste Rice Husk Filler Content at the maximum stability = 12.50%
2. F2= Waste Rice Husk Filler Content at the maximum value of bulk density = 10%
3. F3= Waste Rice Husk Filler Content at the median of (3% --5%) of air voids = 8.50%

$$\mathbf{O.F.C} = \frac{12.5\% + 10\% + 7.20\%}{3} = 9.9\% \text{ say } 10\%$$

Table 8: Marshall Results of Modified Mixes at Optimum Content of WRH

Marshall Properties at Optimum R.H Content = 10% Bitumen Content =3.83% (OBC)	
Properties	**Results**
Stability (Kg)	1525
Unit Weight g/cc	2.335
Flow in 0.01"	14.05
% V.T.M	3.43
% V.M.A	12.70
% V.F.B	73.0

V. CONCLUSION

This research study was grounded on the theoretical as well as on the experimental work from which it could be summarized that: The controlled mixes revealed extreme stability of 1515 kgs at the optimum content of bitumen (3.83%) as related to the filler changed hot mixes which revealed enhanced Marshall stability value of 1525 kgs at the 10% content of waste rice husk at same bitumen content (3.83%), that is improved one than the stability of controlled hot mixes. Obtained results of modified hot mixes at 10% content of waste rice husk are found within requisite values. The maximum value of Unit weight was detected at the 10% content of waste rice husk in bituminous mixes. Flow value of the waste rice husk powder containing hot mixes found augmented to a concentrated value, the air voids decreased to a minimum value of 3.43% with the increase of waste rice husk Content in the mixes, whereas other essential volumetric characteristics such as %VMA, %VFB were observed within suitable ranges. At the end it is conclude that waste rice husk can be utilized in construction of flexible pavements.

VI. RECOMMENDATIONS

In this research the aggregates were carried from the well-known quarry of kashmore, but to examine more the influence of waste rice husk as modifier filler on the mechanical behavior of hot mix asphalt, the aggregates from other quarries can be used.

Bitumen used in this research was of 60/70 grade so it is recommended that the same research can be carried out using bitumen of variable grades such as 50/60, 80/100 grade.

It is recommended that to examine the impact of waste rice husk powder on the mechanical behavior of hot mix asphalt, more research work can be carried out by varying the mineral filler content in the mixes such as 10%, 15%, 20% and 25%.

To increase the Marshall assets of hot mix asphalt by using some cost-effective materials, it is recommended to use appropriate waste materials as much as probable, which are present in our nearby and are also sometimes unsafe to the environment.

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