Effect of Waste Tyre Rubber as Filler on the Mechanical Properties of Hot Mix Asphalt

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Abstract: Hot Mix Asphalt is the integral part of flexible pavement which is the mixture of suitable proportion of coarse aggregate, fine aggregate, fillers and the binder. Fillers are of the size of less than 0.075 mm. Fillers are very essential part of Hot Mix Asphalt that fill the voids within the aggregates, provide the stability and other important properties. Various Mineral fillers have been used such as waste glass, marble dust, stone dust, ordinary Portland cement by researchers to enhance the properties of mixes, however there is still need of other material such as Waste Tyre Rubber to be used to further control the properties of the Hot Mix Asphalt. The aim of the research is to investigate the effect of waste rubber tyre powder as mineral filler on the mechanical properties of Hot Mix Asphalt. Using varying percentages of bitumen ranges from **3.0% to 5.0%** with the interval of 0.5%, fifteen conventional specimens were prepared to check the properties and to obtain the Optimum Binder Content and using that optimum bitumen content and five different percentages 5.0% to 15% of Waste Tyre Rubber powder as partial replacement of conventional filler, other fifteen mixes were prepared and examined to compare the results with the properties of controlled mixes and to obtain the Optimum Filler Content. From the results of Marshall Tests conducted for Asphalt wearing coarse Waste Tyre Rubber found optimum at 10% filler Content in the Hot Mix Asphalt.

Keywords: *Hot Mix Asphalt, Mineral Filler, Mechanical Properties*

1. Introduction

Asphalt wearing (surface) coarse is the top most layer of the flexible pavement which is in direct contact with vehicle loads and environmental effects due to which sometimes that upper layer of the pavement fails partially or totally before the design life and to overcome those failures proper material selection is needed. The materials including aggregates, binder and fillers are ingredients of the Hot Mix Asphalt (HMA). The material having passing size less than (75 micron) No. 200 standard sieve are called as the mineral fillers that fill the voids in aggregates and provide stability against various coming loads and other required properties too. Many researches has been done for the improvement of the flexible pavements by various filler materials having size less than 0.075mm as the replacement of conventional filler but those are not seemed economical. To investigate the Effect and to get the benefit from commercial waste materials as mineral filler a broad investigations have been carried out to assess the possibility of using mineral fillers such as Waste Tyre Rubber (WTR) as partial replacement of conventional fillers.

The use of the Waste Tyre Rubber (WTR) as mineral filler in Hot Mix Asphalt (HMA) for the construction of flexible pavements has benefit in not only saving over new or costly materials but also in reducing the waste materials from the surround which are not environment friendly but are sometimes dangerous to human health. The waste Rubber tires are found in huge stock piles which have no longer important use but results a bad impact on environment when burnt, The main objective of this research was to examine experimentally the effect of using Waste Tyre Rubber (WTR) as mineral fillers in Hot Mix Asphalt (HMA) and for that purpose **15** conventional Asphalt mixes were prepared using five percentages of bitumen i.e. **3.0% to 5.0%,** with the interval of **0.5%** to find out the properties and Optimum Binder Content (OBC), than using five varying percentages i.e. **5% to 15%,** of (WTR) filler at the obtained optimum binder content, **15** specimen were prepared for the investigation and comparison of the properties of modified Mixes with controlled mixes. The results of Marshall tests of the mixes containing Waste Tyre Rubber as mineral filler in the Hot Mix Asphalt for the wearing course were concluded that use of 10% of waste tyre rubber as filler, increased Marshall Stability, decreased flow, air voids, voids in mineral aggregates, and maximum voids filled with Bitumen.

2. Literature Review

An experimental study was conducted to overcome the commonly occurring issues such as Rutting, Cracking, Shoving, and bleeding in flexible pavement, in this regard Crumb Rubber Powder (CRP) and High Density Polyethylene (HDPE) were used in the bituminous mixes to check out the impact of these materials on the properties of Hot Mix Asphalt. From the conducted Marshall tests it was observed that use of High Density Polyethylene (HDPE) at

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5% and of Crumb Rubber Powder at 10% by the weight of mix, increased the Marshall properties of Bituminous Mixes (N.Madhava Reddy, M.C.Venkatasubbaiah, 2017).

Effect of foamed bitumen, lime, cement and active filler, was examined in to check out the impact on the asphalt concrete. After a long sectioned testing procedure it was observed that mixes containing cement, hydrated lime and common active fillers at 1%, 2%, and 1.5% content respectively have desirable resistance to cracking and other commonly occurring failures in the pavement (Elena Romeo *et al*., 2017).

Waste plastic and waste rubber tire investigated in different researches for their impact on the mechanical properties of Hot Mix asphalt. From the modified mixes, the improvement in the properties of waste plastic containing mixes was observed with the increase of filler content, whereas from one research the optimum filler content for waste rubber tyre was found 5% and 10% from another research with improved properties of mixes (Sari W. Abusharar *et al* 2016. Rokade S+ 2012).

Palm kernel shell ash was used by the researcher as mineral filler in the Bituminous mixes. The specimens were prepared at the optimum bitumen content and using five varying ratio 1% to 5% of palm kernel ash in the bituminous mixes. The tests were performed to evaluate their mechanical properties including Marshall Stability, moisture damage, permanent deformation and fatigue characteristics in Hot Mix asphalt. From this extensive investigation it was concluded that the mixes containing palm kernel ash at 3% content as mineral filler have desired mechanical properties (Nwaobakata and Agunwamba J. 2014).

Cement, ground granulated blast furnace slag and brick dust, were used in bituminous mixes as mineral filler to investigate the effects of these materials in Hot Mix Asphalt. Mixes were prepared using varying percentages of cement, ground granulated blast furnace slag and brick dust, examined to compare the results of modified mixes with the controlled mixes and observed the possibility of using these materials as replacers of traditional fillers being used. It was also concluded that the mixes containing cement as filler have good stability and other required properties as compared to the mixes containing GGBS and brick dust at different percentages (Lekhaz D *et al*, 2016).

waste glass and cullet has been used as mineral filler in bituminous mixes by two different researchers and aim was to check out the possibility of using that waste materials as coarse sand as well as a fillers in Asphalt wearing course and for that purpose, they used varying percentages of the waste Glass and cullet in Bituminous mixes and found possibility of utilizing these mineral materials in Hot Mix asphalt (Khalil Nabil Dalloul 2013. Mehmet Saltan *et al* 2015).

Another investigation was carried out by researchers to investigate the effect of lime stone powder, ordinary Portland cement and glass powder as filler by using three percentages range from 4% to 10% of these mineral fillers in Mixes at the obtained optimum binder content. The Marshall Test results showed the possibility of using these fillers at different obtained optimum filler contents (Dr. Hassan H. Jony *et al.*, 2010. A .H. AL- Saffar 2013).

An experimental study was conducted for W3B-fillers such as W3B-hydrated lime, W3B-kaolin, W3B-granite by using them in bituminous mixes. The purpose of the investigation was to find out the impact of W3B-fillers on properties of mixes using varying contents of W3B materials in the mixes at determined optimum binder content from traditionally designed mixes. All three W3B-fillers found reliable to use in the Hot Mix asphalt for improvement of properties (Anggraini Zulkati *et al.*, 2012).

To improve the properties of asphalt concrete pavements, the waste plastic (Polyethylene Terephthalate, PET) was used for the modification of binder at different percentages and required tests which include conventional bitumen tests and Marshall Stability were performed to check out the effect of modified binder on the performance of Hot Mix Asphalt. Results indicated better mechanical properties of mixes having Polyethylene Terephthalate (PET) as modifier as compared to the conventional mixes (S.Varun1 *et al.*, 2016).

3. Materials

The materials used for this research work are aggregates including coarse aggregates, fine aggregates, binder (bitumen), and the mineral fillers and were tested experimentally for the physical properties.

3. 1 Aggregates

The aggregates should be of good properties such as specific gravity, abrasion value, impact value etc. and for that purpose the aggregates for this research work were obtained from a well-known quarry of kashmore and were tested properly. The various test results of aggregates are given below in the table.

Table.1. GRADATION OF SELECTED AGGREGATE

SIEVE SIZE		**Properties by passing weight**			
Inch	**mm**	**Cotrld. mix**	**Modfd mix**	**Midpoint specif.**	**Specif: 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	66.3	63	56-70
#4	4.76	47.1	46.1	42.5	35-50
#8	2.40	27.5	30	29	23-35
#50	0.30	6.3	9.4	8.5	5-12
#200	0.075	2.4	3.2	5	2-8

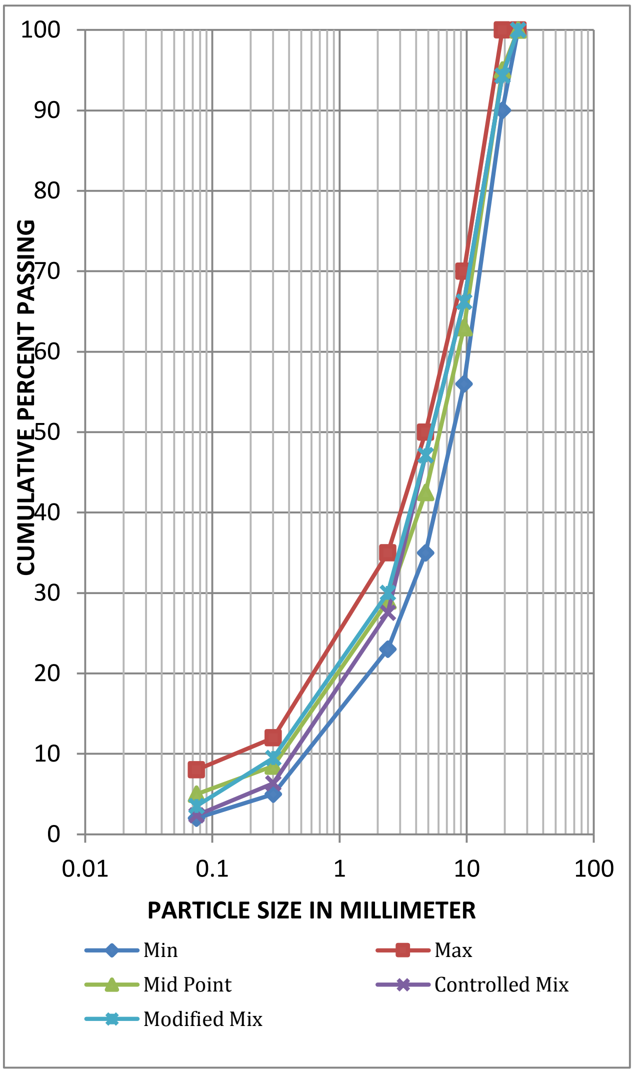

Figure.1.Aggregate Gradation Curves

Table.2. PHYSICAL PROPERTIES OF AGGREGATES

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

3.2 Binder (Bitumen)

Bitumen is a binding agent between coarse and fine aggregates and is very essential material used in Hot Mix Asphalt design, it may be of the different grades but for this research work the bitumen of 60/70 grade was used and was brought from Karachi refinery. Different important tests of bitumen were conducted and the achieved results are presented below:

Table .3. PHYSICAL PROPERTIES OF BITUMEN

TEST PARTICULARS	Test Results
Penetration at 25°C, mm	65-68-70
Softening point, °C	48°C
Flash point, °C	320°C
Fire Point, °C	365°C
Ductility at 27 °C, m	140+
Specific gravity	1.005

3.3 Mineral Filler

The Fine materials that pass through No. 200 sieve are known as the mineral fillers. Other than the traditionally used fillers, Waste Tyre Rubber (WRT) was used in this research work as mineral fillers in the Bituminous mixes, was tested for physical properties which are given below in the table:

Table.4. PHYSICAL PROPERTIES OF MINERAL FILLERS

Filler	Specific gravity
Aggregate Filler	2.68
Waste Tyre Rubber Powder	1.05

4. Methodology

For this research Work Marshall Mix design Method was used to investigate the effects of Waste Tyre Rubber powder as filler on the characteristics of Hot Mix Asphalt. Using five different percentages of Binder content three specimens for each and a total number of fifteen specimens were prepared.

A suitable proportion of coarse aggregate, fine aggregate, filler and Bitumen was set to prepare a blend of 1200 gms. At a temperature of 150 to 170°C, the heating of aggregates was done. The Asphalt (Mixture of Coarse aggregates, Fine aggregates, Fillers and Bitumen) was heated to a temperature of 145°C to 165°C, after the completion of mixing of materials; the mix was placed in mould which was pre-heated to temperature of about 100°C to 140°C, having dia of 10 cm and height of 7.5 cm. the compaction of mixes was done by applying 75 blows on each side of the specimen. The unit weight and other required volumetrics of the specimens were calculated and then tested for stability and flow through Marshall Stability Machine.

The Optimum Bitumen content (O.B.C) was then obtained from the achieved results of specimens prepared at five different bitumen contents.

By applying the same procedure Marshall Mix Design as of Conventional one, another series of 15 specimens was prepared at optimum bitumen content, using five varying contents (5.0%, 7.5%, 10%, 12.5%, 15%) of Waste tyre Rubber (W.T.R) in the mixes to examine the effect of using this mineral filler on the Mechanical properties of Hot Mix Asphalt (HMA) and the Optimum percentage of Waste tyre Rubber that to be used.

Table.5. Shows Mechanical Properties of Mixes at Different 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

The obtained Marshall properties of the mixes at different Bitumen Contents are also presented in graphical form with discussion below:

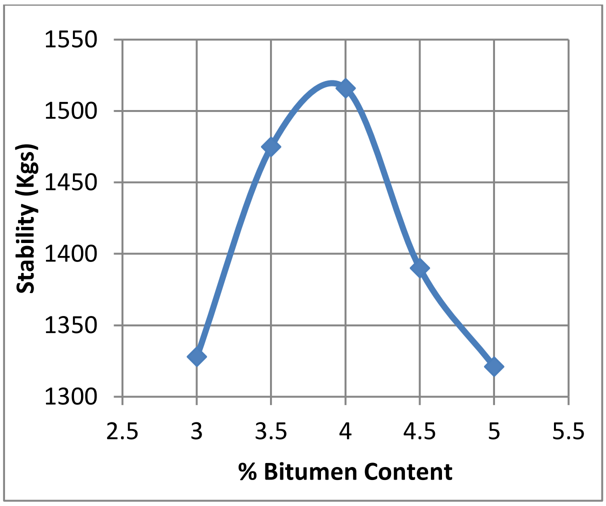

Figure.2. The correlation between Stabilty and Bitumen Content

Figure (2) shows the correlation between the stability (Kgs) and % Bitumen content. It can be noticed from the Marshall stability of the mixes increases with the increase od Bitumen up to a content of 4.0% and then it decreases with further enhancement. Graph shows that maximum stability of bituminous mixes is 1515 kgs at 3.83% bitumen content.

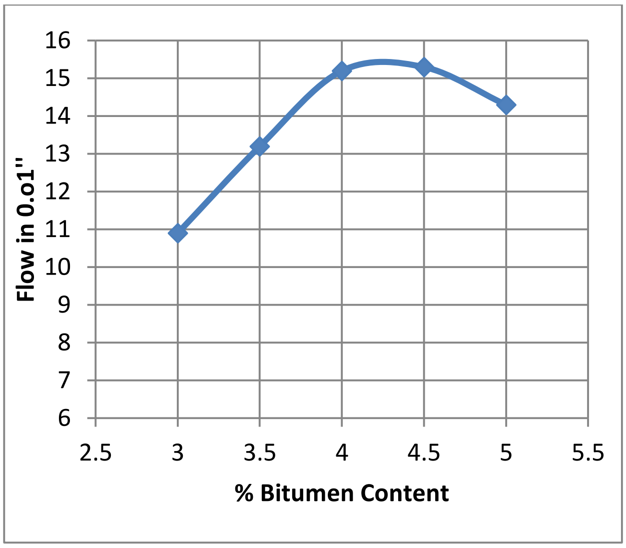

Figure.3. The correlation Between Flow and Bitumen Content

Figure (3) shows the correlation between the Flow in o.o1" and % Bitumen content. It increases with the increase of Bitumen content in the mix. The figure shows maximum flow value (15.3) of the mixes at 4.5% bitumen content.

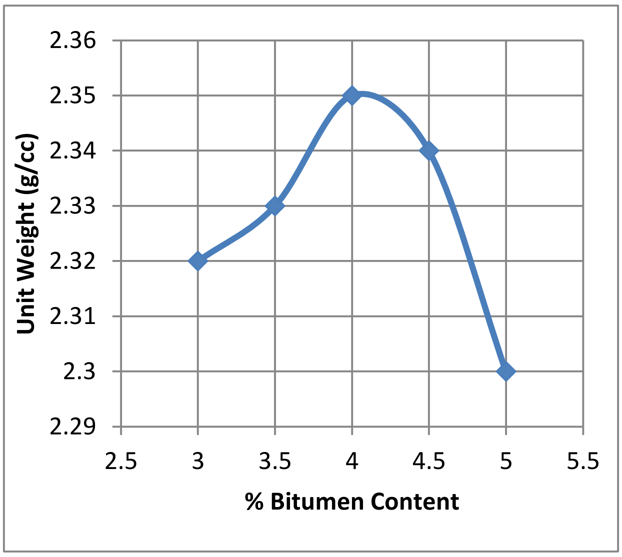

Figure.4. The correlation Between Unit Weight and Bitumen Content

Figure (4) shows the correlation between the Unit weight (g/cc) and % Bitumen content. The Unit weight of the mix increases to a peak value at 4.0% content of Bitumen then decreases. The figure shows maximum Unit weight i.e. 2.35 g/cc at 4.0% bitumen content, however further increase of Bitumen in the mix results decrease in unit weight.

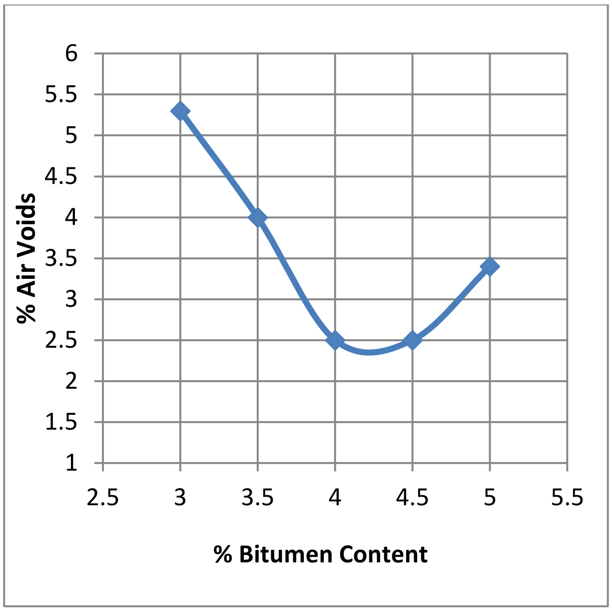

Figure.5. The correlation between % Air Voids and Bitumen Content

Figure (5) shows the correlation between the % Air Voids and % Bitumen content. The figure shows maximum reductions in air voids with the increase of bitumen content and it is due to increase of voids filled with bitumen in the mixes. The minimum air voids are noticed at the 4.0% bitumen content.

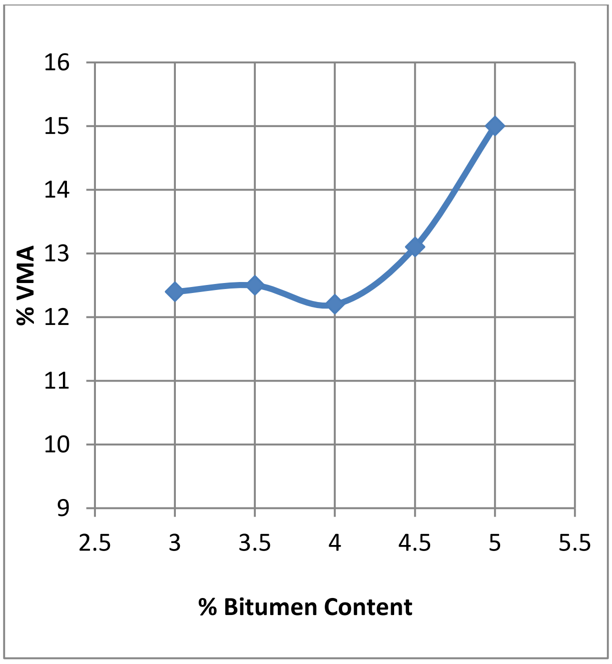

Figure.6. The correlation between % VMA and Bitumen Content

Figure (6) shows the correlation between the % voids in Mineral aggregates and % Bitumen content. The figure shows different values for %VMA with the increase of bitumen content. The maximum reduction in %VMA can be noticed at the 4.0% bitumen content.

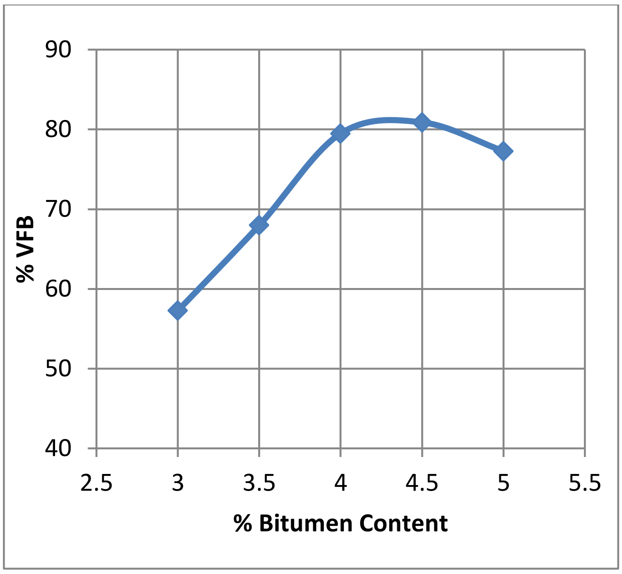

Figure.7. The correlation between % VFA and bitumen Content

Figure (7) shows the correlation between the % voids filled with bitumen and % Bitumen content. It can be noticed from figure presented above %VFB increases with the increase of bitumen and the maximum increase in %VFB is 80.9% that is at 4.5% of bitumen content.

5. Determination Of Optimum Bitumen Content (O.B.C)

The Marshall Test results tabulated below in the table No.5 and also presented graphically, show the Marshall Stability, Flow, unit weight, %V.T.M, %V.M.A, %V.F.B at five different Bitumen Contents. The Optimum Bitumen Content was obtained by standard formula given below:

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

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

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

The O.B.C was found equal to 3.83%.

5.1 Results at O.B.C

The results Obtained at O.B.C are Given Below in the Table:

Table.6. Marshall test results at O.B.C = 3.83%.

Marshall Test Results At O.B.C=3.83%	
Properties	**Values at O.B.C**
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%

6. Results Of Filler Modified Mixes

The Results Of the mixes containing different Percentages of Waste Rubber Tyre Powder As filler at the optimum Bitumen Content are given below in the tabular and graphical presentation to Compare and discuss the Results.

% Filler	Marshall Properties of Filler modified mixes at O.B.C =3.83% Mineral Filler: Waste Tyre Rubber					
	Stabiliy in (Kgs)	**Flow in 0.01**	**Unit Wt: g/cc**	**% V T M**	**% V M A**	**% V F B**
5	1252	10.9	2.3	5.8	13.9	58.3
7.5	1340	11.5	2.32	5.3	13.2	59.8
10	1595	11.6	2.34	5.2	12.4	58.1
12.5	1278	12.4	2.31	4.9	13.6	64
15	1183	14.7	2.29	4.5	14.2	68.3

Table.7. The Table Shows Marshall Test Results of mixes at Different Filler Content.

The results of the mixes containing waste tyre rubber as mineral filler are presented below in graphical form along with discussion and comparison.

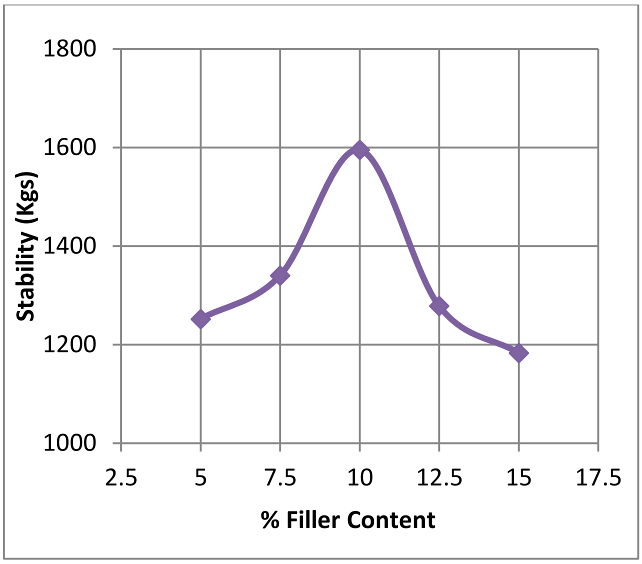

Figure.8. The correlation between % filler content and stability.

Figure (8) shows the correlation Between Marshall stability and % filler content, the results shows the maximum Marshall stability of 1595 kgs at 10% content of Waste Tyre rubber in the mixes at optimum Bitumen content. The stability of modified mixes is higher as compared to the controlled mixes at optimum bitumen content.

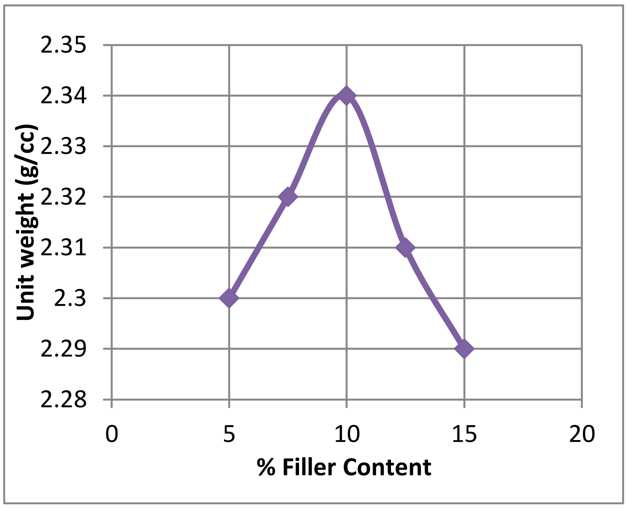

Figure.09. The correlation Between % filler Content and Unit Weight.

Figure (9) shows the correlation between Unit Weight (g/cc) and the % Filler content, the results show that the values of unit weight for waste tyre rubber powder contained mixes, at the optimum bitumen content, increase from 2.30 to 2.34 at 10% of filler Content and then decreased with further increase of filler. However the controlled mix has the maximum unit weight i.e. 2.35 g/cc at the same bitumen content

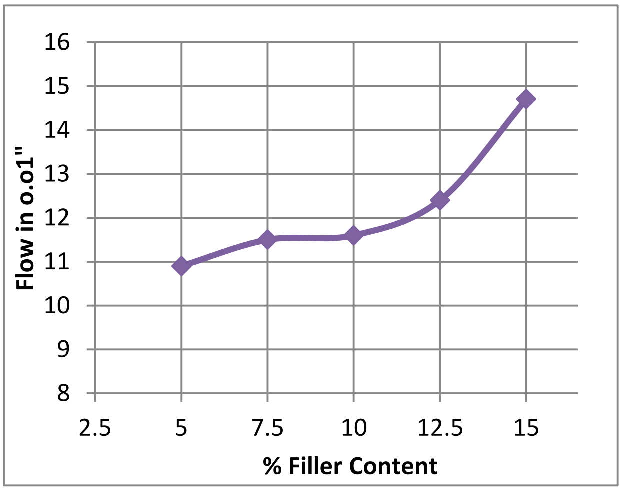

Figure.10. The correlation between % filler content and Flow.

Figure (10) shows the correlation between Marshall Flow and the % Filler Content, the results show that the flow was increased, with the increase of Waste Tyre Rubber content in the Bituminous mixes. The maximum flow of modified mixes is found 14.7% but the maximum flow value of controlled mixes, was found 14.3% which is lesser than that of the modified mixes.

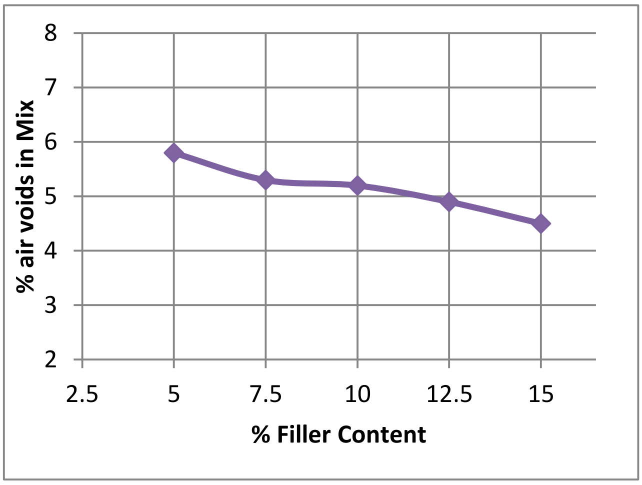

Figure.11. The Correlation between %Filler Content and %Air Voids

Figure (11) shows the correlation between % Air voids and the % filler content, the results shows that with increase of Waste Tyre Rubber Powder content from 5% to 15%, at the optimum bitumen content, the air voids were decreased to a value of 4.5%, whereas if we see the reduction 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.

Figure (12) shows the correlation between % voids in Mineral Aggregates and % filler content, the results shows that the Void in Mineral aggregates decreased to a value of 12.4%, with the increase of Waste tyre Rubber powder up to 10% content but with the further increase of Waste tyre Rubber filler, the voids in mineral aggregates found increased.

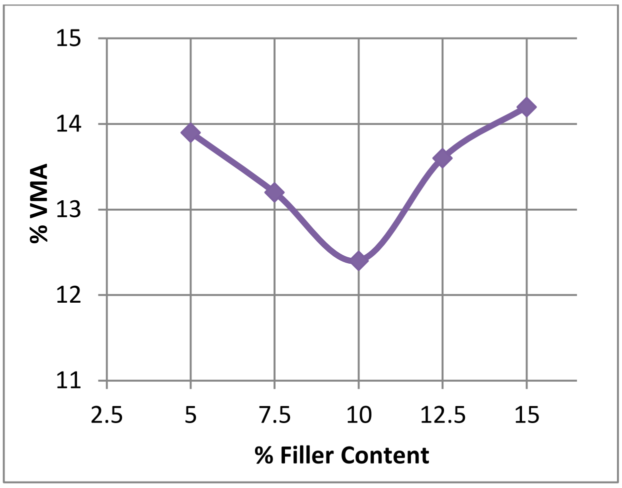

Figure.9. The correlation between % filler content and %V.M.A

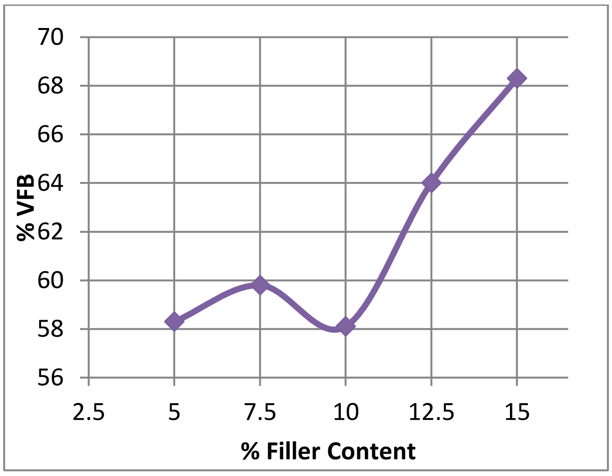

Figure.10. The correlation between % Filler Content and % V.F.B

Figure (13) shows the correlation between % voids filled with Bitumen and the % filler Content, the results shows, increase in the values of % voids Filled with bitumen for waste tyre Rubber Powder containing mixes to a value of 68.3% with the increase of filler up to 15%, while in case of controlled mixes the % voids filled with bitumen, found 78% at the optimum bitumen content While.

7. Conclusion

The Research was based on the theoretical as well as on the experimental study from which it can be summarized that:
The controlled mixes showed maximum stability of 1515 kgs at the optimum bitumen content as compared to the filler modified mixes which showed stability value of 1595 kgs with 10% content of waste tyre rubber at same bitumen content, which is improved than the stability of controlled mixes. Values of modified mixes at 10% filler content is within required values. The maximum value of Unit weight was observed at the 10% content of Waste tyre powder in bituminous mixes. Flow value of the waste tyre rubber

powder containing mixes is found increased to a maximum value, whereas the air voids decreased to a minimum value of 4.5% with the increase of waste tyre Rubber Content in the mixes. The %VMA found minimum for Waste rubber tyre at the 10% of filler content, while %VFB increased with the increase of filler content. From the results it is concluded that waste tyre rubber can be used in the Hot Mix Asphalt at 10%, as the partial replacement of traditional fillers, because the stability is found maximum and all other characteristics including flow value, air voids, %VMA, %VFB are obtained within the internationally specified ranges.

8. Recommendations

1. For this research work the aggregates were brought from the well-known quarry of kashmore, but to investigate further the impact of same mineral fillers on the mechanical properties of Hot Mix Asphalt, the aggregates from other quarries can be used.
2. In this research the bitumen of grade 60/70 was used as a binder material, it is therefore recommended that the same research can be carried out using Bitumen of 50/60, 80/100 grade also.
3. It is recommended that to investigate the effects of Waste rubber tyre powder on the Marshall properties of Hot Mix Asphalt, further research can be carried out by changing the filler content in the mixes such as 6%, 8%, 11% and 14%.
4. To improve the Marshall properties by using some economical materials, it is recommended to use suitable waste materials as much as possible which are present in our surrounding and are also sometimes dangerous to the environment.

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