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The Effective Ways of Utilization of Rice-Husk-Ash in Hot Mix Asphalt

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Abstract—*Now-a-days utilization of waste product in construction industry is going on rapidly. One such types of agro-industrial waste product is Rice Husk Ash (RHA), produced abundantly in rice mills from the burning of Rice Husk (RH). In this study RHA was utilized in Hot-Mix-Asphalt (HMA) concrete in two different ways. Firstly RHA was used in HMA as mineral filler by partial replacement (1%, 2%, 3% and 4%) of Stone Dust which was used as conventional filler. Secondly RHA was used to modify the normal bitumen (80/100) by three different proportions (10%, 20% and 30%) and then these three types of modified bitumen were used to prepare HMA. Now with these two types of mixes Marshall Tests and Fatigue Tests were carried out. The mix in which RHA was used as filler (up to 3%) had shown the similar Marshall stability values as compared to conventional mix but the optimum bitumen content was increased by addition of more RHA into the mix. Also the fatigue life shown by this mix was similar up to the addition of 2 % RHA as filler in comparison with conventional mix and then the fatigue life was reduced with addition of more RHA. The second type of mix in which RHA-Modified bitumen was used had shown higher stability values than conventional mix up to 20% RHA-modification. In this mix the optimum bitumen content was also reduced with 10% and 20% modified bitumen and it was similar for 30% modified bitumen. The fatigue life was considerably enhanced by the mixes with 10% and 20% modified bitumen but it was less for 30% modified bitumen. So RHA can be effectively incorporated into asphalt mix as bitumen modifier and also as mineral filler up to certain limits.*

1. INTRODUCTION

The use of waste materials in construction industry is going on rapidly nowadays. This is being done because of mainly three reasons. Firstly, these waste materials would cost environmental hazard if these are not properly utilized and kept open in the environment. Secondly, these waste materials may enhance the strength and durability characteristics of the original materials into which these are utilized. Lastly, these materials could reduce the cost of construction incase these materials replace the conventional materials. One such types of waste material is Rice Husk Ash (RHA).

RHA is a waste product of Rice industry. It is produced in the parboiling process where rice husk, the outer covering of paddy grain, is burnt at higher temperature ranges from 225-500°C to produce steam required for the parboiling process. Rice husk contains 70% volatile matter which gets evaporated into the air when the husk is burnt. The rest 30% weight of husk is converted into ash after the burning. Now India, an agricultural country, is the second largest producer of rice worldwide. So there are plenty of tons of rice husk ash produced in India in every year. About 4.4 million tons of RHA is produced in India annually. This RHA possesses a great threat to the environment. This may cause land pollution where it is dumped or it can contaminate the ground water. So there must have some effective ways to utilize RHA. In this study an attempt has been made to utilize this RHA into hot mix asphalt (HMA) mixtures.

Asphalt mixture is a combination of coarse aggregate, fine aggregate, filler and bitumen. The aggregates provide a structural skeleton of the mix enabling it to take load, the fillers fill the void spaces between the aggregates to have a structural integrity and the binder i.e. the bitumen binds all the aggregates and holds the constituents of the mix together. HMA is prepared by heating all the aggregates and fillers and then pouring the heated bitumen into it and mixing it properly. In this study, RHA is used in two different ways in HMA. Firstly it is used as the partial replacement of stone dust, used as conventional filler in HMA and secondly as bitumen modifier. Now, in India flexible pavements are made with this HMA in accordance with Marshall Method. Now one of the major failure modes of flexible pavement is fatigue failure. So to have a prolonged life of flexible pavement fatigue mode of failure must be minimized. For these reasons Marshall Tests and Fatigue Tests have been conducted on the HMA samples with and without RHA addition into it. Finally, with all those results the effective ways of utilization of RHA into HMA has been evaluated.

2. OBJECTIVES

The objectives of this research paper are as follows:

A] To Study the effects of RHA used as filler in HMA.

B] To study the effects of RHA modified asphalt used to prepare HMA samples.

C] To evaluate the effective ways to utilize RHA into HMA mixtures i.e. whether it is giving better results when it is used as the filler or as the bitumen modifier.

3. LITERATURE REVIEW

Although many researchers have studied the effects of RHA in concrete mixtures but a very little study has been a done to utilize RHA into asphalt mixtures. Sebnem et al (2013) had utilized rice husk ash as filler with lime in which total filler content was varied to evaluate the optimum filler content which was determined later as 5% with 4.73% optimum bitumen content. These two optimum values were obtained from Marshall Stability test. Also VMA (voids in mineral aggregate), V_f (void percentage), Marshall Stability, Flow value and VFB (voids filled with bitumen) with different bitumen contents and different filler content had been evaluated. It was concluded that Marshall Stability values of rice husk ash and lime modified asphalt (2.5% RHA+2.5% Lime Stone) are considerably increased up to a point and then decreased. So RHA can be used in asphalt mixtures [1]. Yongjie (2014) et al had modified asphalt binder with rice husk ash and wood sawdust ash. The physical properties like penetration, ductility, softening point and rheological properties like dynamic rheological behavior, rotational viscosity, high temperature storage ability and aging properties of the modified asphalt binder were evaluated. It was concluded that the blending effects under mechanical agitation was the key for modification and with the enhancement of RHA and WSA up to 20%, viscosity, complex modulus and rutting factor of the modified asphalt binders increased rapidly at high temperature [2]. Goh et al (2014) had also utilized RHA as filler into asphaltic mix. After conducting Marshall Tests on specimen containing RHA, the test results were found satisfactory by the specifications of Malaysian Public Works Department [3]. Jaafar et al (2014) had carried a study on recycling of reclaimed asphalt pavement with rice husk ash replacing the ordinary Portland cement as filler. Although the result of Marshall Stability test had shown decrease in stability value but indirect tensile test result had shown that the use of rice husk ash can increases the tensile strength of the mix. It was concluded that up to 70% reclaimed asphalt pavement materials with 27% fresh aggregates and with 3% filler (of which 2.25% is Portland cement and 0.75% rice husk ash) could be used to have a satisfied mix design criteria to be used in roadway [4]. Raja et al (2015) had carried out an experimental investigation to incorporate RHA in different percentages (2% to 4%) in hot mix asphalt as mineral filler by partial substitution of conventional filler (cement). After studying the results of modified Marshall Test it was concluded that RHA up to 4% can be used as mineral filler in asphalt concrete and in this process the parameters of Marshall Tests had been effectively enhanced to certain limit. Also the optimum bitumen content was reduced due to the addition of RHA in to asphalt mix [5].

For fatigue Life, various literatures [6-10] have suggested that the aggregate gradation, types of binder whether modified or not, testing temperature, asphalt mixtures stiffness etc are the main factors which are having significant on the evaluation of fatigue life of HMA samples.

4. MATERIALS AND METHODS

4.1 Aggregates

Aggregates, including stone dust, are collected from local crusher located by the side of NH-54, Silchar. The properties of aggregates are shown in Table 1. In this study the Dense Bituminous Macadam (DBM) type of aggregate grading is adopted from MoRTH [10].The aggregates are sieved to obtain the specified aggregate gradation. The aggregate gradation is shown in Table 2.

Table 1: Properties of aggregates

Physical property	Tests Standard	Specified value	Obtained value
Crushing	IS:2386(4)	<30%	26.3%
Impact	IS:2386(4)	<30%	24%
Abrasion	IS:2386(4)	<40%	38%
Specific gravity	IS:2386(3)	2.5-2.9	2.5
Flakiness index	IS:2386(1)	<15%	10.62%
Elongation Index	IS:2386(1)	<15%	13%
Angularity no.	IS:2386(1)	0-11	10

Table 2: Grading of aggregates

IS Sieve(mm)	Cumulative % passing(specified range)	Cumulative % passing(adopted)
37.5	100	100
26.5	90-100	95
19	71-95	85
13.2	56-80	70
4.75	38-54	45
2.36	28-42	35
0.30	7-21	15
0.075	2-8	5

4.2 Bitumen

Bitumen is collected from a local consultancy. The properties of the Bitumen are enlisted in Table 3.

Table 3: Properties of bitumen

Physical property	Test standard	Specified limit	Obtained value
Specific gravity	IS:1202	0.97-1.02	1.01
Penetration	IS:1203	80-100	95
Ductility	IS:1208	>75cm	>100cm
Flash point	IS:1209	>175°C	326°C
Softening point	IS:1205	35-70°C	40.2°C
Solubility	IS:1216	0.5%	0.49%

4.3Rice Husk Ash (RHA)

Rice Husk Ash is collected from 'R K Rice Mill' Kalna, Burdwan. Once it is collected from the mill, it is then processed in the lab for obtaining desired qualities. As the water content in it was high, it was first heated and then it was sieved by 300µm IS sieve for using it as filler in asphalt mix. It was also sieved by 75µm IS sieve for using it as bitumen modifier. The specific gravity of RHA is found to be 2.

4.4 Modified Bitumen

The normal bitumen is heated at a temperature of 160-175◦C at first. Then the conditioned RHA, finer than 75µm, is mixed and stirred with the normal bitumen. Then it is placed on a heater and the overall assembly is placed in the 'Mini Mixer Machine' specially designed to modify bitumen. The mixing in the mixer machine, having an rpm of 1500, is continued for 50 minutes. After the mixing is done the modified bitumen is collected and used for evaluation of physical properties and later it is used for preparation of HMA samples. The normal bitumen is modified with RHA by three different percentages i.e. 10%, 20% and 30% of total weight of bitumen. The physical properties of modified bitumen are shown in Table 4.

Table 4: Properties of modified bitumen

Physical property	'%' of RHA modified bitumen	Obtained value
Penetration	10	50
	20	46
	30	35
Ductility	10	>100 cm
	20	76 cm
	30	42 cm
Specific gravity	10	1.04
	20	1.07
	30	1.08

4.5 Marshall Test

Marshall Test is done primarily on HMA samples with Stone Dust (5%) as conventional filler by varying the percentage (4.5%, 5%, 5.5% and 6%) of normal bitumen in the mix. These Marshall tests have been done as per The Asphalt Institute Manual MS2, suggested by MoRTH for DBM mixes. So a total of 4 nos. of samples are prepared and tested for this conventional mix.

Now, Marshall Samples are prepared with RHA added into the mix as filler as partial replacement of stone dust as 1%, 2%, 3% and 4% and also with four different bitumen percentages (4.5%, 5%, 5.5% and 6%). So a total of 16 (4×4) nos. of samples are prepared and tested for this purpose.

Again, with three different types of modified bitumen (10%, 20% and 30%), Marshall Samples are prepared again with four different bitumen percentages (4.5%, 5%, 5.5% and 6%) but 5% stone dust is kept fixed as filler. So in this case a total of 12 (4×3) nos. samples are prepared and tested.

For each and every mix the total filler content is kept fixed at 5%.The results of these tests are shown in the next section [section-5].

4.6 Fatigue Test

The Fatigue tests of different types of asphalt mixtures have been done in Strain controlled 'Four Point Bending Beam Fatigue Testing Machine' on beam samples [Dimensions: 380×63×70 mm and Weight: 3555 grams(approx.)] with 10 Hz frequency and 150 micro-strains in room temperature (29.4◦C). For compaction of these samples, a self compacting compactor provided by Matex is used. This fatigue testing is done according to AASTHO T321. The first beam sample is prepared and tested with above mentioned specifications by taking stone dust (5%) as filler and using optimum bitumen content as found out in Marshall Test for conventional mix.

Now four beam samples are prepared and tested in fatigue testing machine with 1%, 2%, 3% and 4% RHA added as filler into the mix by partial replacement of stone dust. The optimum bitumen content, found out for each of these four mixes in Marshall Tests, is taken for preparing these mixes.

Again three beam samples are prepared and tested for fatigue life prediction while three types of modified bitumen are used for mix preparation. In this case, stone dust is taken as filler and the percentage of stone dust is kept fixed as 5%. Here also the optimum bitumen content obtained from Marshall Test is taken for sample preparation.

So a total of 8 nos. of beam samples are prepared and tested for prediction of fatigue life with above mentioned testing parameters. The results of these tests are shown in next section [section-5].

5. RESULTS & DISCUSSION

At first, the comparison in the results of the Marshall Tests between the conventional mix and the mix with RHA as filler is shown.

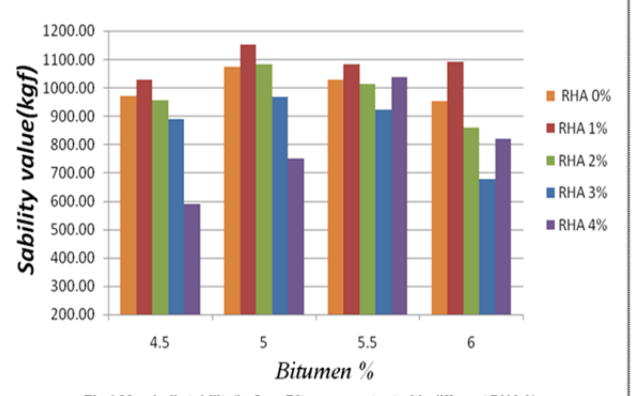

Fig 1.Marshall stability(kgf) vs Bitumen content with different RHA %

The minimum stability value for DBM mixes is 900kgf as per MoRTH. From the above figure it is clear that the addition of RHA by 1% with every bitumen percentages has given the better stability value as compared to conventional mix [RHA 0% in Fig.1]. Also the addition of RHA up to 2 % into the mix is giving more or less similar results as conventional mix.

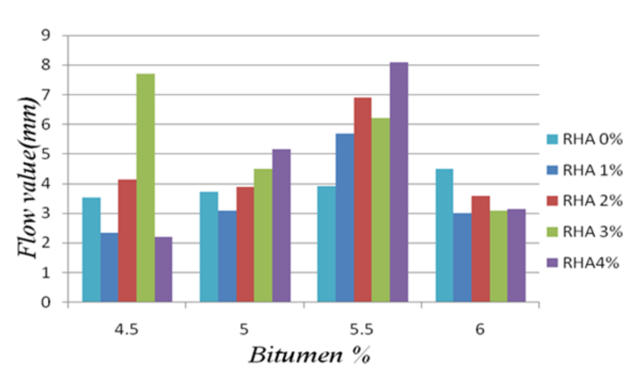

Fig2.Flow value vs Bitumen content with different RHA %

The flow value for DBM should be within 2-4 mm according to MoRTH. From the above figure it is clear that the samples, apart from those which are prepared with 5.5% bitumen, are showing better results than conventional mix.

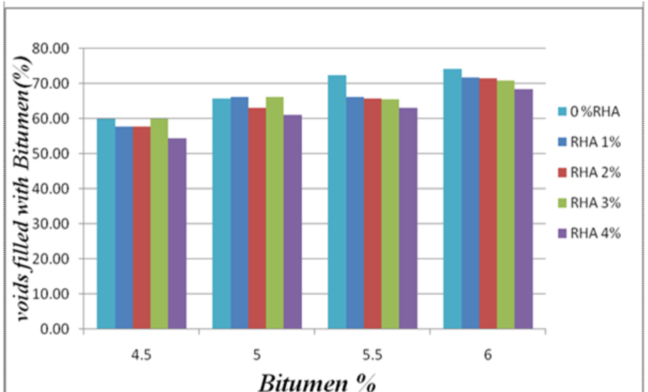

Fig3.VFB vs Bitumen content with different RHA %

The VFB values should be within 65%-75% for DBM mixes as per MoRTH. From the above figure it is clear that the samples apart from those prepared with 4.5% bitumen is satisfying the criteria as specified by MoRTH.

Now, the optimum bitumen content for each of these mixes is found out by averaging the following three bitumen contents:-

- Bitumen content corresponding to maximum stability,
- Bitumen content corresponding to 4.5% air void and
- Bitumen content corresponding maximum unit weight.

The changes in the optimum bitumen content for each type of mixes, where RHA is used as filler, are shown below.

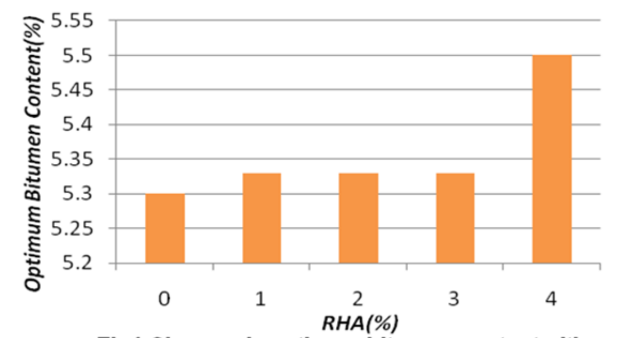

Fig4.Changes in optimum bitumen content with different percentages of RHA

From the above figure it is clear that optimum bitumen content is incresed from 5.3% to 5.33%, when RHA is added as filler into the mix upto 3%. The optimum bitumen content is further increased to 5.5% with the addition of 4% RHA into the mix.

Now, the Marshall Test results of the samples prepared with different types of modified bitumen and the samples prepared with conventional mix are compared and shown below.

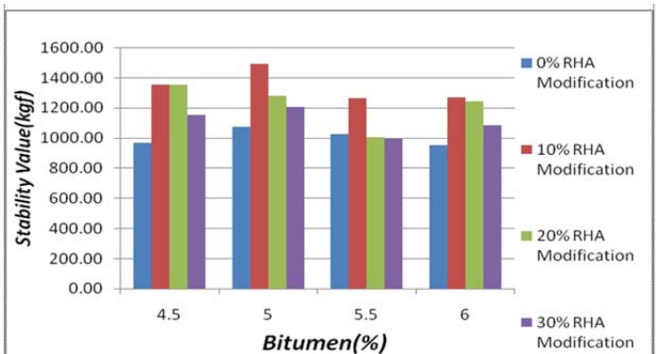

Fig.5Changes in stability value with different percentages of modified bitumen

From the above figure it is clear that the samples, prepared with 10% and 20% RHA modified bitumen, with every percentages of bitumen, is giving much higher stability value as compared to the conventional mix [0% RHA Modification].

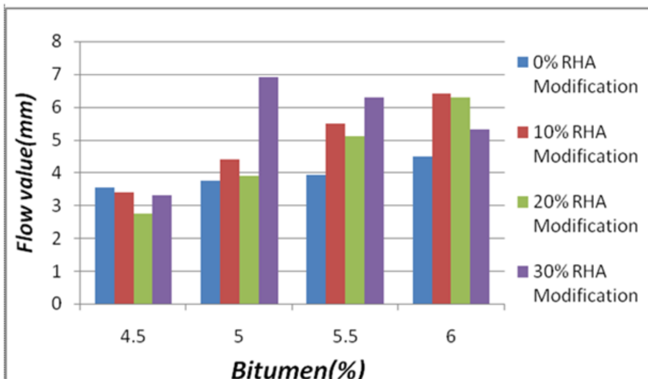

Fig6.Changes in Flow value

Although 10% modified bitumen is giving better result than the rest. With 30% modified bitumen, the stability values are more or less similar to the conventional mix.

Although the flow values of the samples prepared with 5.5% and 6% of modified bitumen are higher than the specified value but for the samples made with 4.5% and 5% of modified bitumen the flow values are within the range.

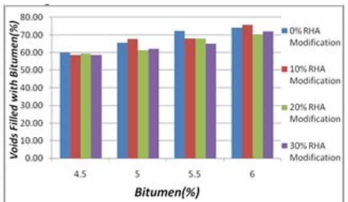

Fig 7.Changes in VFB(%)

From the above figure it is clear that the VFB values are getting higher with higher percentages of bitumen. Also the samples prepared with modified bitumen are showing satisfactory VFB values.

Now, the optimum bitumen content for each type of mixes prepared with modified bitumen is shown. The optimum bitumen content for conventional mix is shown with the legend '0% RHA Modification'.

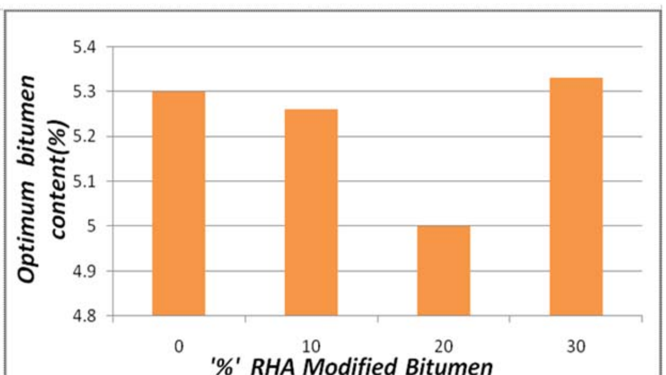

Fig 8.Optimum binder content changes with different '%'s RHA modified bitumen

From the above figure it is clear that the optimum bitumen content gets reduced for the mixes prepared with 10% and 20% RHA modified bitumen. For 30% RHA modified bitumen the value is higher as compared to the conventional mix.

These are the Marshall Test results of the three types of mixes namely the conventional mix, the mix with RHA added as filler and the mix prepared with different '%' modified bitumen.

Now, the Fatigue test results of the samples prepared with RHA as filler are shown below. In fatigue test, the fatigue life of the samples is counted as the nos. of cycles these beams can sustain upto 50% reduction of their initial stiffness.

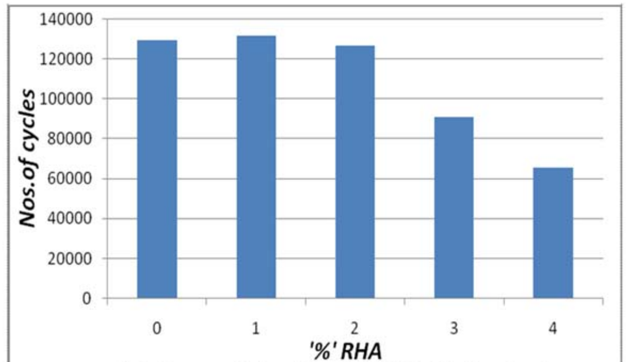

Fig 9.Changes of fatigue life with '%' RHA added into the mix as filler

From the above figure it is clear that the fatigue life of the samples prepared with 1% and 2% RHA, added as filler, is more or less similar as comapred with the conventional mix [0% RHA]. The samples prepared with 3% and 4% RHA are showing lesser values of fatigue life.

Now the fatigue test results of the samples prepared with different types of modified bitumen are shown.

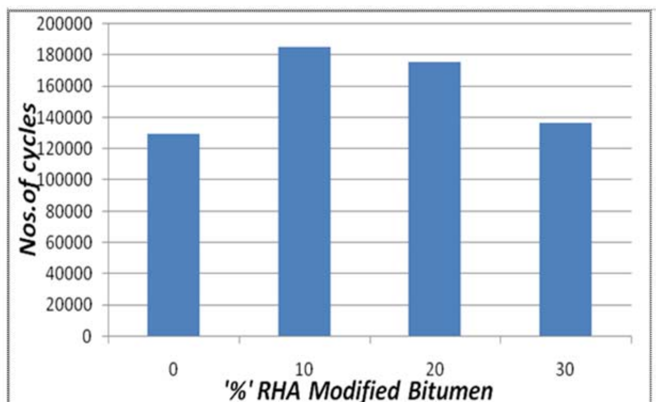

Fig 10.Changes of fatigue life with different '%'s RHA Modifed Bitumen

From this figure it is very clear that the fatigue life of conventional mix is increased by about 44%, when 10% and 20% RHA modified bitumen is used. The fatigue life of the sample prepared with 30% RHA modified bitumen is somewhat similar to the conventional sample.

6. CONCLUSIONS AND FUTURE SCOPES

In this study RHA has been utilized in two different ways into asphalt mixtures i.e as the filler and as the bitumen modifier. The Mashall Tests and Fatigue tests have been conducted on the samples prepared with these types of mixes. After doing all these experiments the following conclusions can be drawn.

a) RHA, upto 2%, can be used as partial replacement of conventional filler (i.e. stone dust in this case) into the aspahlt mixtures. In both the tests, the samples prepared with 1% and

2% RHA have given the satisfactory result, even the results are more than satisfactory when 1% RHA has been used.

b) The 10% and 20% RHA modified bitumen can be used in producing aspalt mixtures. In this case also both the tests have shown satisfactory results for this two types of modified bitumen. Although the 10% RHA modified bitumen has shown the best result as comapared to the conventional mix, the mix with RHA as filler and the mix with the other types of modifed bitumen(20% and 30%).

c) The optimum bitumen content has been slighty inceased when RHA (upto 2%) is used as filler but it gets reduced when 10% and 20% RHA modified bitumen is used.

So Rice Husk Ash should be effectively utilized into the asphalt mixtures in both the ways. Although the best way to utilize the RHA is when it is used as bitumen modifier.

Now, this study is done with only one type of aggregate gardation [Table 2]. There are certain other gradadtions are there in MoRTH. One of the important types gradation is Bituminous Concrete which is mostly used for surface course. So this entire experimental study could be done by taking the aggregate gradation of Bituminous Concrete. Futhermore in this study the fatigue life of the beam samples has been done at a single temperature i.e room temparature(29.4°C) and keeping the strain value fixed as 150 microstrain. So fatigue testing could be done at different temparatues with different strain value. So, these are some of the future scopes this paper is having.

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