Effect of using Lightweight Fly Ash Aggregate in Bituminous Concrete Layer

*Pratyaksh Chaturvedi[1], Dr. Rakesh Mehar[2]

[1]*Department of Civil Engineering*

[2]*Department of Civil Engineering*

Abstract: *In this study we investigate effect of using fly ash aggregate in asphalt mixture is replaced with Natural Aggregate. By using the natural aggregate the value of construction is more, to scale back the development cost we use waste present within the environment, therefore, the construction cost is reduced, and therefore the waste from the environment is decreased. In this study, we use fly ash aggregate, stone dust, cement, natural aggregate, binder (PMB 40) according to the Morth specifications. All these are mixed and prepared as a sample. Firstly all the necessary tests were performed on the materials which are to be used. We prepare four samples, firstly the sample is ready without replacement with ash aggregate, but the opposite three samples were prepared by replacing the natural aggregate 5% with ash aggregate and again similarly replacing the natural aggregate by 10% and 15 % with ash aggregate and binder PMB 40 is employed. The four samples is prepared by Marshall mix design and then we perform Marshall stability on the prepared sample. The Marshall stability test is completed to seek out the OBC of the combination. After the tests were performed the results so obtained should satisfy the need. The study is completed on all the properties of the material, we found that the combination with NA, PMB 40, and ash aggregate and filler material is employed, and will give the higher results.*

Keywords: **Fillers, Fly ash aggregate, Marshall Properties, Optimum bitumen content.**

1. Introduction

The road is a crucial mode of transportation in India. Road Transport may be critical infrastructure for the economic development of a rustic. A road may be a route between two destinations, from which goods are often transported from one place to a different using road. Delivery of products between cities, villages, & towns is feasible only through road transport. India is the biggest road network in world of about 62.20 lakh km. Road is comprised of National Highways, State Highways, Major District Roads, Other District Roads.

NHAI is liable for upkeep & management of N.H. Our study aims to use hazardous waste materials in fulfilling the aim of the development of highways without affecting the traditional properties to an excellent extent. the varied waste materials which we recommend to use in our study are fly ash aggregate, stone dust, cement, polymer-modified bitumen. Flyash aggregate is partially replaced with natural aggregate to determine the benefit-cost assessment of the study.

2. Experimental Methodology

In the present study, we investigate that using ash aggregate in the combination as a substitute with Natural Aggregate. We use stone dust, ash aggregate, cement, and PMB 40 bitumen. We prepared four samples and perform test on the sample consistent with the Marshall mix design. Before preparing the samples the required laboratory tests were performed on the fabric and every one of the values is consistent with the Morth specification.

2.1 Materials:

2.1.1 Aggregate: Course aggregates are the aggregates whose particles retain on a 4.75mm sieve. It is made of rock quarried from ground deposit. Coarse aggregate is hard, cleaned and should be well shaped. It is free from friable matter or dust.

2.1.2 Fillers: Mineral extender contain finely divided mineral matter similar as gemstone dust, sediment dust, Portland cement, fly ash, and other suitable mineral stuff. Mineral extender should poses 100 pc of the grain of sand passing 0.60 mm, 95 to at least one hundred pc pass from 0.30 mm, and 70 % passing 0.075 mm.

2.1.3 Fly Ash Aggregate: It is a pozzolana waste material; it is produced by a byproduct of the thermal power plant by burning pulverized coal. These aggregate posses unique characteristics that make them suitable for high strength & performance concrete. Concrete produced using these aggregate is approx 20% lighter & at the same time 18% more strong than normal weight aggregate.

2.1.4 Bitumen: Polymer modified bitumen is bitumen made with a combination of polymer materials. It made with a combination of bitumen with a styrene-butadiene-styrene (SBS) copolymer.PMB possesses less temperature sensitivity than plain bitumen. The properties of PMB include improvement of strength, cohesiveness, and resistance to fatigue and deformation.

2.2 Marshall Test:

It is a simple and low-cost laboratory test method adoptive in utmost parts of the world for the design and evaluation of bituminous mix (Kar et al., 2014). In this study also, the same test method has been adoptive to determine optimum bitumen content (OBC) for four different bituminous blend combinations. As per this, the OBC corresponds to the normal of bitumen contents at maximum Marshall Stability, maximum unit weight, and % air voids. This test is also used to estimate the different mixtures and the parameters considered are stability, inflow value, unit weight, air voids, voids in mineral aggregates, voids filled with bitumen, and Marshall Quotient. The bituminous composites were prepared according to MORTH specifications (2013). Firstly all the necessary tests were performed on the material which is to be used and then the sample was prepared according to Marshall mix design. The test performed on aggregate and results are shown in table 1 similarly test performed on bitumen and result is shown in table 2. The samples are prepared and testing of samples is shown in figure 1.

Figure1. Marshall Stability Test

Table 1. Physical Properties of Aggregate used in BC

Properties	Test Method	Natural Aggregate	Fly ash Aggregate	Morth Specification (2013)
Aggregate Impact Value	IS:2386 (IV)	16.23%	35.22%	Max 24%
Los Angeles Abrasion Value	IS: 2386(IV)	18.50%	39.53%	Max 30%
Water Absorption Value	IS:2386 (III)	1%	10.15%	Max 2%
Specific Gravity	IS:2386 (III)	2.8	2.2	2.5-3.0
Combined Flakiness and Elongation Index	IS:2386 (I)	28.23%	_	Max 35%

Table 2. Physical Properties of Bitumen used in BC

Properties	Test Method	PMB-40 Results	MORTH & specification (2013)
Penetration (100 gram, 5second at 25°C)	IS 1203	40	30 – 50
Softening Point °C (Ring and Ball Apparatus)	IS 1205	70	60
Ductility at 27 °C (5cm/ minute pull),cm	IS 1208	63	50
Viscosity at 150 °C, Poise	IS 1206 (Part 2)	7	5 – 9
Flashpoint, °C, minimum	IS 1209	240	220
Fire point, °C, minimum	IS 1209	250	247

After performing the Marshall stability test the values so obtained is tabulated in Table 3 and the graphs are also plotted for the obtained values.

Table 3. Properties of BC Mix using NA

S.No.	Property Tested	Bitumen Content by weight of Aggregate				
		4.6	**5**	**5.4**	**5.8**	**6.2**
1	**Marshall Stability (KN)**	12.2	13.25	12.5	11.34	11.1
2	**Flow value (mm)**	3.1	3.25	3.5	3.7	4.1
3	**Unit Weight (g/cc)**	2.3	2.38	2.36	2.35	2.33
4	**Volume of void, Vv (%)**	3.6	3.9	4.1	4.35	4.54
5	**Void in Mineral Aggregate, VMA (%)**	14.3	13.25	14.5	15.5	16.45
6	**Void filled with Bitumen, VFB (%)**	70.1	74.25	76.3	77.2	78.1
7	**Marshall Quotient(KN/mm)**	4.15	4.1	3.5	3.2	3

Now we took the mean values from the Table 3 and plotted the graphs. Graphs are plotted between percentage of bitumen content and the following parameters:

1) **Marshall Stability:**

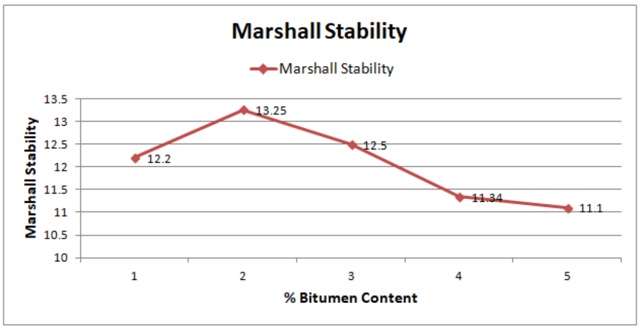

Figure 2. Marshall Stability vs Bitumen Content

Figure 2 shows the graph between marshall stability and bitumin content.We observe in this graph that marshall stability increase with increase with bitumin content at certain extent, after that the bitumin content is continuosly increases but the marshall stability value will decrease.

2) **Marshall Flow Value (mm):**

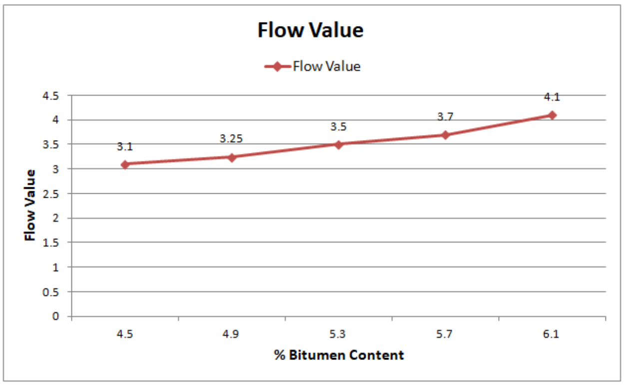

Figure 3. Flow Value vs Bitumen Content

Figure 3 shows the graph between the Marshall Flow Value and Bitumen Content. we've observe that rise in bitumen content flow value is additionally increasing.

3) **Unit Weight (g/cc3):**

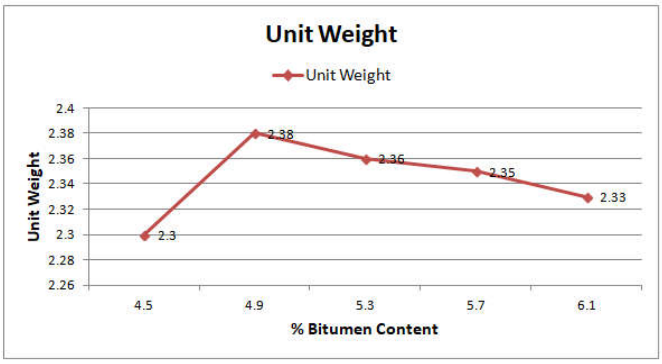

Figure 4. Unit Weight vs Bitumen Content

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Figure 4. shows graph between the bitumen content and unit weight of BC mixes. It observed that, increase in bitumen content the unit weight of combination also increases up to some extent then decreases.

4) Void in Mineral Aggregate VMA (%):

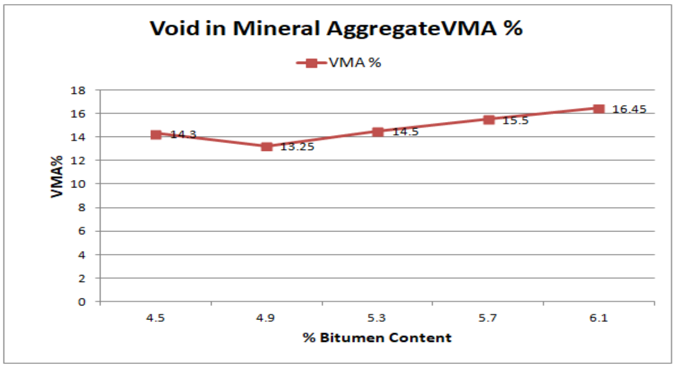

Figure 5.Voids in Mineral vs Bitumen Content

Figure 5 shows the graph between the percentage of void mineral aggregates and bitumen content. It shows with increase in bitmen content, the decrease in %VMA to certain extent then again the bitumen content increase then %VMA is additionally increase.

5) Void Filled with Bitumen:

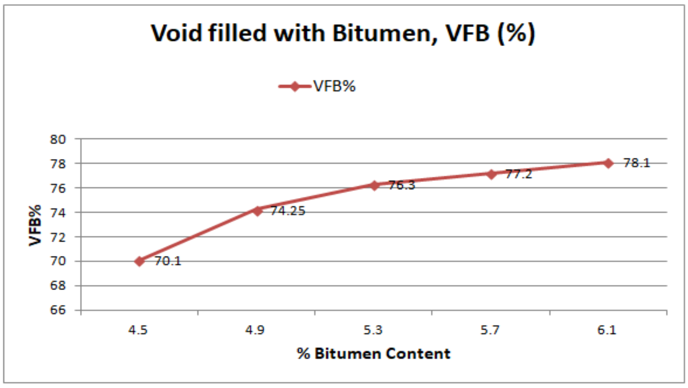

Figure 6. Void Filled with Btumen vs Bitmen Content

Figure 6 shows the graph between the percentage of voids crammed with bitumen content. This shows that the rise in bitumen content the rise in %VFB. This graph shows the parabolic relation between VFB and bitumen content.

3. Results

3.1. Optimum Bitumen Content of Natural BC mix:

After plotting the graphs between bitumen content and BC mix, we selected the OBC for the natural mix. The OBC is measured by the value of bitumen content at which the utmost values of the Marshall Stability and minimum values of Marshall Flow Value. Figure 2 & Figure 3 show Optimum Bitumen Content is measured and that is 5 % for Natural mix.

3.2. Results of Modified BC mix:

We have selected three different proportions of FA and replaced it with natural aggregate. After mixing these ingredients the specimens of modified BC mixes were prepared and then the Marshall test performed over them. The Marshall property & volumetric property of modified BC mixes tabulated in table 4.

Table 4. Properties of Modified BC Mixes at OBC

S.No.	Property Tested	Types Of Mixes		
		NFA1	*NFA2*	*NFA3*
1	Marshall Stability	12.8	11.1	10.4
2	Flow Value (mm)	2.9	2.75	2.5
3	Bulk Density (g/cc)	2.4	2.18	2.3
4	Volume of Voids Vv (%)	4.1	3.95	3.7
5	Void in Mineral Aggregate VMA (%)	14	13.4	13.05
6	Void Filled With Bitumen VFB (%)	71.8	69.6	70.25
7	Marshall Quotient (KN/mm)	4.1	3.75	3.6
8	Optimum Bitumen Content OBC%	5%		

3.3. Comparison of Properties of BC mixes at OBC between N mix & FA mix:

The natural aggregate is replaced by Flyash aggregate by 5%, 10%, and 15% respectively. Here N represents the natural aggregate, NFA1 represent the 5% replacement, NFA2 represent 10%, replacement and NFA3 represent 15% replacement with natural aggregate. According to these values so obtained, we prepare a bar graph of those and is compared with the natural aggregate values obtained. The Marshall properties & volumetric properties of modified BC mixes is shown and compare natural aggregate values with FA values, all the values so obtained is consistent with Morth(2013) is shown in table 5.

Table 5. Properties of FA Based BC mixes at OBC

S.No.	Properties	Type of Mixes				Requirements of BC Mixes(MORTH, 2013)
		N	*NFA1*	*NFA2*	*NFA3*	
1	Marshall Stability (KN)	13.25	12.8	11.1	10.4	9
2	Flow value (mm)	3.25	2.9	2.75	2.5	2 – 4
3	Bulk density (g/cc)	2.38	2.4	2.18	2.3	_
4	Volume of void, Vv (%)	3.9	4.1	3.95	3.7	3 – 6
5	Void in Mineral Aggregate, VMA (%)	13.25	14	13.4	13.05	Minimum 14
6	Void filled with Bitumen, VFB (%)	74.25	71.8	69.6	70.25	65 – 75
7	Marshall Quotient(KN/mm)	4.1	4.1	3.75	3.6	2 – 5

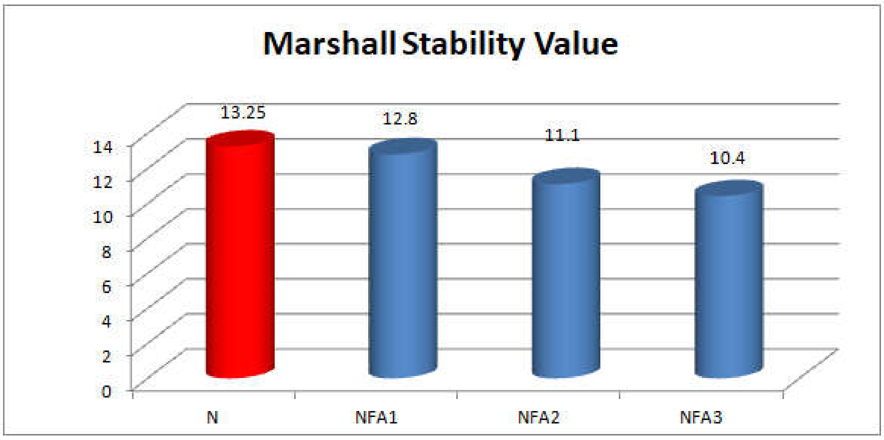

Figure 7. Marshall Stability Value of BC mixes at OBC

From figure 7 we observed that the Marshall Stability Value of N and NFA1 mixes is approximately an equivalent and also satisfies the need of BC mixes as per MoRTH, 2013. So we will replace the NA with FA in BC mixes.

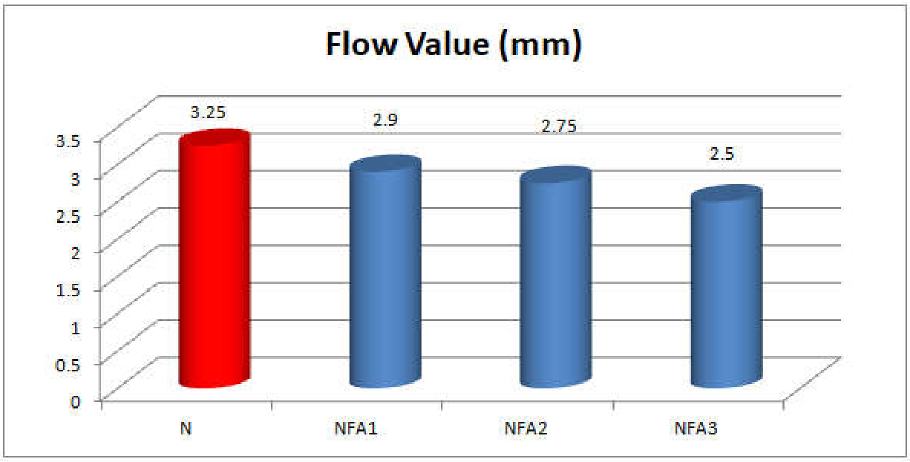

Figure 8. Flow Value of BC mixes at OBC

From figure 8 We observed that the flow values of N mixes are approximately same with the flow values of NFA1 mix. We also see that the NFA mixes is less because of the presence of lightweight Fly ash aggregate.

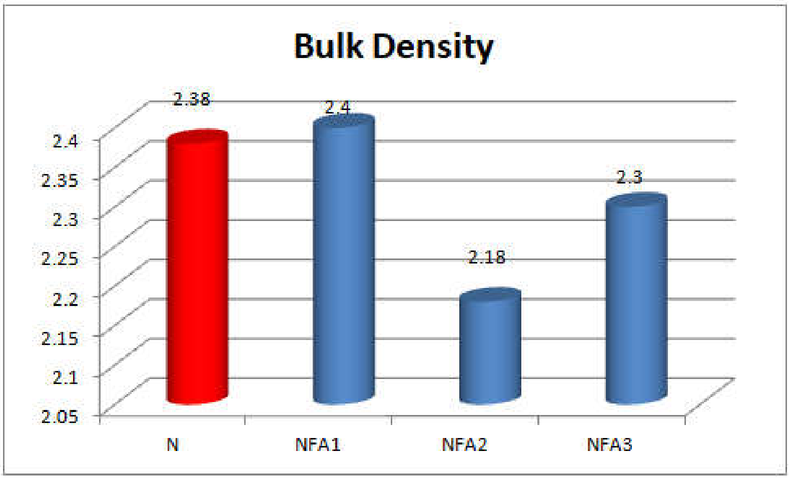

Figure 9. Bulk Density of BC mixes at OBC

From figure 9 it is observed that the Bulk Density of NFA1 mix are approximately to Bulk Density of N mix at OBC. This shows that we can replace FA with NA in BC mixes. As the Marshall Stability Value of NFA1 mix is approximately to N mixes are satisfied with the minimum requirement of the BC mix.

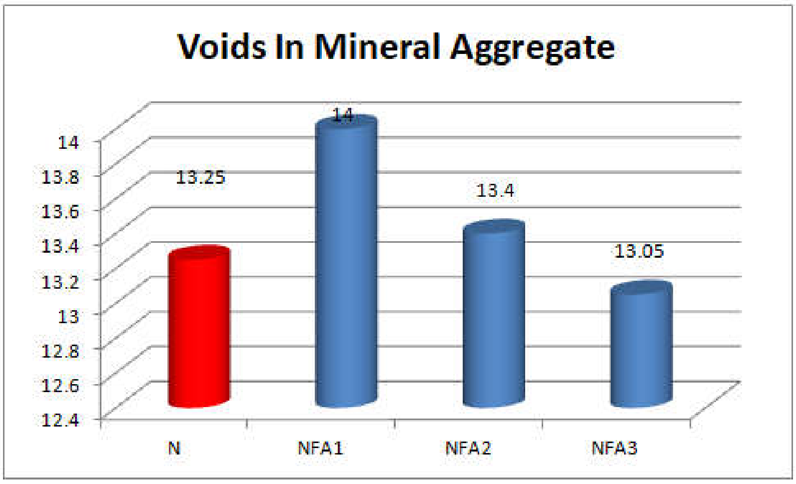

Figure 10. Volume of Voids of BC mixes at OBC

From figure 10 it is clear that at OBC the NFA mixes show higher values as compared to N mix because of the presence of more air voids present in FA.

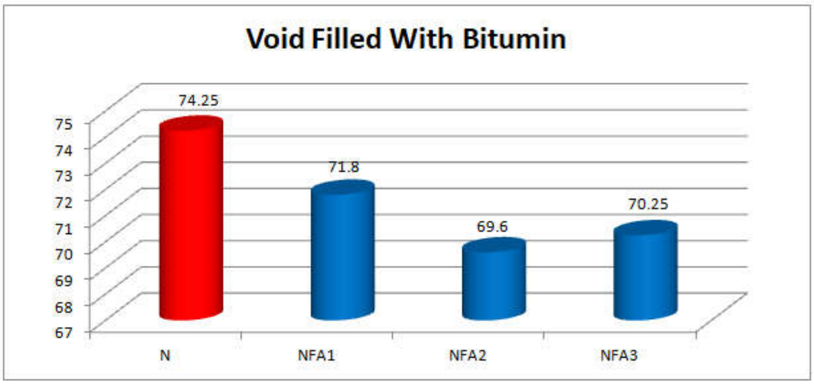

Figure 11. Voids filled with Bitumen of BC mixes at OBC

From figure 11 the graph shows that as we increase the percentage of plastic-coated marginal aggregates in mixes the void filled with bitumen in the mixes decreases.

4. Conclusions and Recommendations

4.1 Conclusions:

- In this study we replace natural aggregate with the fly ash aggregate and used binder PMB40.
- All the necessery laboratory tests were performed on aggregate, fly ash aggregate and bitumen.
- We replace natural aggregate with the ash aggregate by 5%, 10%, and 15% respectively and therefore the binder used is PMB40. The binder PMB40 also shows improved properties for pavement constructions than other conventional bitumen. The values so obtained are under specifications.
- During this study it had been found that the BC mix is repaired and should possess improved Marshall Characteristics. It's also observed that the Marshall Stability value increases with a rise in bitumen content up to 5 % then decreases
- This system proposed the utilization of waste in construction so this will reduce the waste from the environment. The waste materials like ash aggregate, stone dust were utilized in this research work.
- By using the waste in construction reduces the value of construction of road and procure an improved pavement with good strength and long life period and at an equivalent time reduce the additional consumption of naturally available aggregates.

4.2. Recommendations for Future Study:

- Study on use of fly ash aggregate in mix, the flyash aggregate is well coated with waste plastic material.
- Experimental study on Artificial Ash Aggregate Concrete.
- Study of Super Pave Technology can be done to design bituminous mixes.

- The laboratory test are often done over the BC mixes and therefore the Indirect lastingness Test are often conducted to work out the tensile properties of Asphalt mixtures which are further want to analyze the cracking properties of the pavement.
- The labortory test can be done over the BC mixes and Flexure Fatigue Test can be conducted to determine the life of bituminous mixes prepared.
- The Rut Resistance Test can be done over the BC mixes to determine the ability of pavement to resist against permanent deformation under repeated loading. This test can be conducted by Wheel Rut tester machine.
- The Skid Resistance Test can be done over the BC mixes to analyze the resistance offered by pavement against skid and slip on wet and dry surfaces. It can be conducted by instrument called as British pendulum skid resistance test in lab as well as on site.
- In this study we use binder as PMB 40 but further studies can be done using different binders such as VG 10, VG 30, VG 40 etc**.**

5. References

[1] *ASTM D6926-10. Standard Practice for Preparation of Bituminous Specimens Using Marshall Apparatus. Annual book of ASTM standards, West Conshohocken, Pa; 2010.*

[2] *Freddy L. Roberts, Prithivi S. Khandal et.al Hot Mix Asphalt Materials, Mixtures, Design and construction NAPA Foundation Maryland 1991.*

[3] *ASTM. 1976a. Standard Test Method for Softening Point of Bitumen (Ring and Ball Apparatus). Standard ASTM D36-76. American Society for Testing and Materials, West Conshohocken,Pa.*

[4] *ASTM. 1976b. Standard Test Method for Specific Gravity and Density of Semi-Solid Bitumenous Materials (Pycnometer Method). Standard ASTM D70-76. American Society for Testing and Materials, West Conshohocken,Pa.*

[5] *ASTM. 1978. Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester. Standard ASTM D92-78. American Society for Testing and Materials, West Conshohocken,Pa.*

[6] *ASTM. 1979b. Standard Test Method for Density, Relative Density, Absorption of Fine Aggregate. Standard ASTM C128-79. American Society for Testing and Materials, West Conshohocken,Pa.*

[7] *IRC: 37, 2018. Guidelines for the design of flexible pavements. Indian Road Congress: New Delhi.*

[8] *Carpenter ,C.A. 1952. A comparative study of fillers in asphaltic concrete,Public Roads, 27; 101-110.*

[9] *Churchill, E.V., and Amirkhanian, S.N. 1999. Coal ash utilization in asphalt concrete mixtures . Journal of Materials in Civil Engineering.*

[10] *Saravanan, Sathyapriya, "Study on Sintered Fly Ash Aggregate as Columnar, Inclusion on Soft Clay", International Journal of Combined Research & Development (IJCRD)*

[11] *Arvind Kumar and Dilip Kumar "Strength Characteristics of Concrete with Sintered Flyash Aggregate"Journal of IJSRD Volume 2, Issue 7, Sept-2014.*

[12] *MoRTH (Ministry of Road Transport and Highways), 2013. Specifications for road and bridge works. In Indian Road Congress. New Delhi, India: Author.*

[13] *Motter, J.S., Miranda, L.F.R. and Bernucci, L.L.B., 2015. Performance of hot mix asphalt concrete produced with coarse recycled concrete aggre gate. Journal of Materials in Civil Engineering, 27(11), p.04015030.*

[14] *S. Shanmugasundaram at al (2010) " Study on Utilization of Fly Ash Aggregates in Concrete".*

[15] *Mistry, R. and Roy, T.K., 2016. Effect of using fly ash as alternative filler in hot mix asphalt. Perspectives in Science, 8, pp.307-309.*

[16] *Ramamurthy, K. and Harikrishnan, K.I., 2006. Influence of binders on properties of sintered fly ash aggregate. Cement and Concrete Composites, 28(1), pp.33-38.*

[17] *Nadesan, M.S. and Dinakar, P., 2017. Structural concrete using sintered fly ash lightweight aggregate: A review. Construction and Building Materials, 154, pp.928-944.*

[18] *Kumar, D.P., Ransinchungh, D.G. and Anupam, A.K., 2012, February. Waste Materials-An Alternative to Conventional Materials in Rural Road Construction.*

[19] *IS: 73, 2013. Paving bitumen–specification.*

[20] *Khanna, S., Justo, C. and Veeraragavan, A., 2000. Highway Materials and Pavement Testing (Laboratory Manual). Nemchand and Bros: Roorkee, India.*