# Effect of Fiber with Coal ash (Bottom ash and Fly ash) on Dense Bituminous Mixes

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**Abstract -** *In the present study, dense graded bituminous mix specimens are prepared using natural aggregate as coarse aggregates, bottom ash as fine aggregates, fly ash as filler and jute fiber as additive. Proportion of aggregate for dense graded bituminous macadam (DBM) grading has been considered as per MORTH (2013) having nominal maximum aggregates size (NMAS) 26.5 mm. To strengthen the mix, slow setting emulsion (SS-2) coated jute fiber is added in varying percentage of 0%, 0.25%, 0.5%, 0.75% and 1% by weight of the mix, with different length variations such as 5 mm, 10 mm, 15 mm and 20 mm. The bitumen used is VG20. Detailed study with Marshall Test results were used to determine the Marshall characteristics, optimum binder content and also optimum fiber content including the optimum length of fiber. Marshall stability as high as 14.995 kN was obtained with optimum bitumen content of 5.557%, with optimum fiber content of 0.5% with optimum fiber length of 10 mm. It is finally observed that results are not only satisfactory, but also much improved engineering properties result with coal ash as fine aggregate and filler, stabilized with natural jute fiber duly coated with SS-2 emulsion in advance. Utilization of non-conventional aggregate like coal ash and natural fiber together thus may help to find a new way of bituminous pavement construction.*

***Key Words*: Bottom ash, Fly ash, Jute fiber, Emulsion, Marshall Test.**

## 1. INTRODUCTION

Pavements or highways or roads are regarded as country's backbone. A detailed engineering study may retain significant amount of investment and pavement materials, which in turn achieve a reliable performance of the in-service highway. Regarding flexible pavement, two major facts are taken into considerations i.e. pavement design and mix design. The present research study is focused on engineering property of bituminous mixes prepared from alternate or nonconventional materials. For preparation of bituminous mixes, commonly aggregates, inform of course, fine and filler fractions are used. It is reported that around 120 Million tons of ashes are producing from forty major thermal power plants per year in India. Most of the coal ash has likely to dispose Such a vast quantity of these type of waste material does pose challenging problems, in the form of land usage, health hazards, and environmental dangers. The significant scope of this study is to use coal ash as a fine material in HMA mix design and thus producing a good quality and smooth surface road which may be commercially acclaimed and can with stand in any possible environment condition. Again Utilization of non-conventional materials like coal ash and natural fibers together thus may help to find a new way of bituminous pavement construction. [3] Laboratory testing was done by using the Georgia Loaded Wheel Tester (GLWT) and Thermal Stress Restrained Specimen Tester (TSRST). Laboratory evaluations shown that, with the various percentage of bottom ash in bitumen mixes possess significantly difference in high-temperature rutting and low-temperature cracking. [4] Studied the feasibility of bottom ash for HMA that is to be used in the intermediate courses of the flexible pavements particular in binder course. The results obtained from the study explain that the mixture performed better when 15% of bottom ash was added to the mixture in replacement of correspond amount of sand.[5]He execute the experiment with various percentage of coconut fibers ranging from 0.5% to 1.50% with the increment of 0.25%. The fiber size was also varied with 5mm, 7.5mm, 10mm, and 12.5 mm. He test the bitumen characteristic with coconut fibers. From the result obtained in Marshall Properties test he found that the Marshall stability increased by 10-15%, when 0.75% of fiber content and 5-mm of fiber length was added by weight of the mixture. He also observed that with the addition of fiber in bitumen, change the bitumen property with a lower penetration value. [6] He considered sisal fiber as an additive for BC mix and stabilizing agent for SMA Mix. Fiber content varied from 0% to 0.5% by weight of total mix whereas binder content was varied from 4% to 7%. For mineral filler he used fly ash, as it has shown satisfactory result at the initial stage of experiment. For the performance test the BC and SMA mixes were test such as the Marshall Properties test it was observe, addition of fiber helps to improve the Marshall Stability and it also reduces the Drain down. He again observed that From Marshall test he found that the optimum binder content for BC and SMA were 5% and 5.2% respectively whereas optimum fiber content were 0.3%.

The aim of bituminous mix design is to determine the fair proportion of bitumen and aggregates fraction to yield a mixture that is effective, durable, reliable and economical. from nominal maximum aggregates size (NMAS), through the fine fraction smaller than 0.075 mm mixed with appropriate amount of bitumen that can be compacted adequately with smaller air voids and will have adequate dissipative and elastic properties.

### 1.1 Objectives of study

This experimental study has done to enable the most appropriate use of coal ash as nonconventional aggregate along with natural fiber (Jute fiber) as an additive by ensuring the adequate performance result in the field of fatigue, moisture susceptibility, and creep value. Again the possible effects of fiber on bitumen mixes are also taken into consideration, and comprehensive study was done to find the optimum fiber content and fiber length that will increase the engineering property of bituminous mix.

## 2. Materials used in study

Stone chips (as coarse aggregate)
Bottom ash (as fine aggregate
Fly ash (as mineral filler)
VG-20 (as bitumen binder)
Jute fiber (as additives)
SS-2 emulsion (as fiber coating agent)

### I Aggregate

Coarse aggregates comprised of stone chips were procured from a nearby crusher and were stored by sieving in to different sizes. For this study, stone chips comprising coarse aggregate fractions and upper size fractions of fine aggregates ranged from 26.5 mm to 0.3 mm were used For lower fractions of fine aggregates and mineral filler, bottom ash and fly ash were respectively used to the extent of 9% and 5% by weight of total mix. Bottom ash and fly ash was procured from the nearby. The physical properties of coarse aggregates and fine aggregates which are primarily required for paving are given in table no 1.

Table no 1. Physical properties of coarse and fine aggregate

| Property | Code specification | Natural Aggregate | Bottom ash and fly ash |
|---|---|---|---|
| Aggregate crushing value, % | IS:2386 part-IV | 13.7 | - |
| Aggregate impact value, % | IS:2386 part-IV | 14.25 | - |
| Los Angles Abrasion test, % | IS:2386 part-IV | 18.92 | - |
| Flakiness index, % | IS:2386 part-I | 11.89 | - |
| Elongation index, % | IS:2386 part-I | 12.59 | - |
| Water absorption, % | IS:2386 part-III | 0.13 | 10.54 |
| Specific gravity | IS:2386 part-III | 2.7 | 2 |

**II Bitumen-**The paving bitumen grade VG20 (VG-viscosity grade) was used in this experimental study. Bitumen is used in pavement construction because of its good water repellent properties and adhesion. Especially the Marshall stability in respect of mixes made up of bottom ash, fly ash with VG20 bitumen as binder. The physical characteristics of VG20 bitumen tested as per IS standards are given in Table 2.

Table 2 Physical properties of binder

| Physical Properties | IS Code | Test Result |
|---|---|---|
| Penetration at 25 ˚C | IS:1203-1978 | 72.7 |
| Softening Point, ˚C | IS:1203-1978 | 48.5 |
| Flash Point, ˚C | IS:1209-1978 | 226 |
| Specific gravity, at 27 ˚C | IS:1202-1978 | 1.01 |
| Kinematic Viscosity, 135˚C, CST | IS 1206 (Part 3) | 305 |

### III Additives (Jute Fiber)-

The jute fiber, a naturally and locally available product has been used as a modifier for improving the engineering properties of conventional DBM mixtures. Jute fibers were coated with slow setting emulsion (SS-2) and stored at 110˚C in hot air oven for 24 hrs. The physical and chemical property of jute fiber are given table no 3.

Table 3 chemical and Physical Properties

| Chemical Composition | | Physical Properties | |
|---|---|---|---|
| | | | |
| Cellulose | > 65% | Tensile strength, MPa | 393-773 |
| Hemi-cellulose | > 22.5% | Specific Gravity | 1.48 |
| Lignin | > 11% | Elongation at break, % | 1.16-1.5 |
| Fat and Wax | > 0.3% | Density, gm/cc | 1.46 |
| Water Soluble Materials | > 1.2% | Moisture Content, % | 1.1 |

**IV Emulsion (SS-2)-**percentage residue content in SS-2 emulsion is found to be 71.484% in 100 ml of emulsion by residue evaporation method mentioned in IS 8887 (2004)

## 3. Experimental Design-

The adopted gradation for DBM sample has been considered as specified in MORTH (2013) Table no 4.

Table no 4 Aggregation Gradation

| Sieve size (mm) | Adopted gradation (% passing) | Specified limit (% passing) |
|---|---|---|
| 37.5 | **100** | 100 |
| 26.5 | **95** | 90–100 |
| 19 | **83** | 71–95 |
| 13.2 | **68** | 56–80 |
| 4.75 | **46** | 38–54 |
| 2.36 | **35** | 28–42 |
| 0.3 | **14** | 7–21 |
| 0.075 | **05** | 2–8 |

Throughout the experimental study the aggregate gradation given in was followed and the following tests were performed. The aggregate gradation curve is shown in figure no 1. After adopting the above aggregate gradation the subsequent test were made to ensure the performance characteristics.

- *Marshall test of mixes to evaluate volumetric analysis*

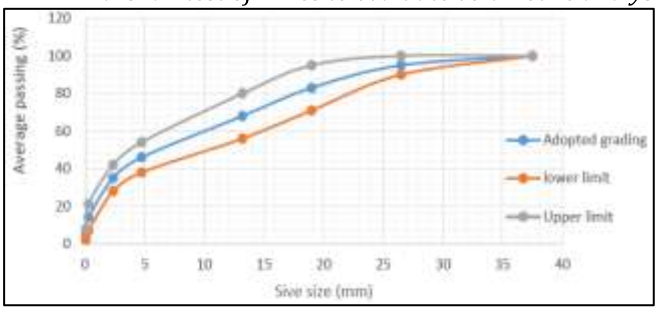


Figure no 1 Gradation Curve

## 4. Experimental Methodology

The DBM mixtures were prepared in accordance with the Marshall procedure specified in ASTM D6927-2015. All ingredients of mixture, such as coarse aggregates, fine aggregates, filler, fiber and VG-20 bitumen were mixed in a specified procedure. Before preparing the samples, fibers were coated with SS-2 emulsion and stored in a hot air oven at 110$^0$C .Coated fiber are stored for 24 hours to ensure proper coating around each fiber and to drain down extra bitumen that may adhere to fiber. Then the fibers were cut into specified lengths of about 5 mm, 10 mm, 15 mm and 20 mm. The aggregates and bitumen were heated separately to the mixing temperature of 155$^0$C to 160$^0$C. The temperature of the aggregates was maintained 10$^0$C higher than that of the binder. Required quantities of bitumen VG-20 and coated emulsion fiber pieces were added to the pre-heated aggregates and thoroughly mixed. Shown in figure no 1. The Marshall Voids analysis were done before the Marshall Stability test. In this voids analysis bulk specific gravity (Gmb), air voids (VA), voids in mineral aggregate (VMA), voids filled with bitumen (VFB). Results were discussed by comparing all this properties with bitumen content in %.

**Fig no 1.**Oven dry coated fiber

Marshall Property of DBM mix that is prepared with coal ash, it is observed that, coal ash cannot deliver satisfactory result when used alone. The stability and flow values are not within the specification made for DBM mix. Also the volumetric analysis such as air void, unit weight, VMA and VFB, are lagging behind the conventional mix. Therefore the Marshall Properties study is done by using coal ash and jute fiber as an additive. The percentage of coal ash is taken as 14% as it shown better result than other coal ash content. The fiber content varied from 0% to 1% with 0.5% increment, along with fiber length ranging from 5 mm, 10 mm, 15 mm, and 20 mm.

### A. Marshall Stability

It is observed from the stability and bitumen content graph, shown in figure 6.to figure 9 that with increase in bitumen content and fiber content as well as fiber length the stability value increased to certain limit and then decreased. From the optimum binder content analysis it is found that the maximum stability of 14.995 kN was achieved at an optimum binder content of 5.557% with optimum fiber content of 0.5% by weight of mixture along with fiber length of 10 mm which was duly coated with SS-2 emulsion and cured for 24 hours at 110 ± 1$^0$C.

### B. Marshall Flow

At the initial stage sample prepared with coal ash has shown increased flow value than the conventional DBM mix. But with the addition of jute fiber the flow value decreased. The length of jute fiber has significant influence on flow value. It is seen that with increase in fiber length flow value decreased, which is because of the stiffness of the mixture cause by adding jute fiber. Shown in figure 10 to figure 13.

### C. Unit weight

From the graph it is clear that with addition of fiber the unit weight decrease as compare to the conventional mix. It was also observe that not only addition of fiber but also coal ash reduced the unit weight too. This is because of both fiber and coal ash are lighter material than bitumen. The fiber content and fiber length has a significant effect on minimizing the unit weight. Shown in figure 14 to figure 17

**D. Air voids**

Generally DBM have HMA due to well graded aggregates. But at the initial stage of the study, the DBM sample prepared with coal ash have higher air voids in compare to conventional mix. Due to this reason jute fiber is added to somewhat minimize the air voids and as a result from the graphs it is clear that with increase in fiber content and fiber length the air void in the mixture decreases as compare to normal DBM mix. It has also observe that the air void was 14% less as compared to conventional DBM mix, when prepare with optimum coal ash content and optimum jute fiber property. Shown in figure 18 to figure 21

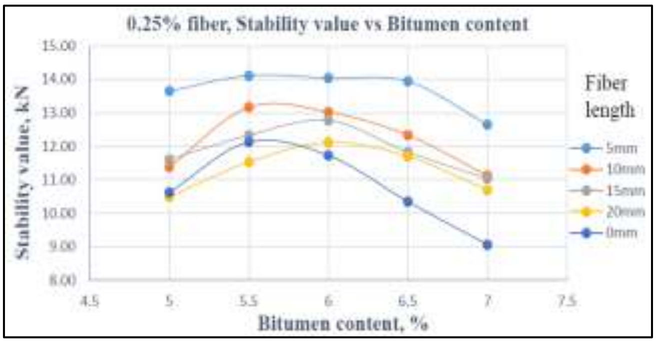


Figure 6.Variation of Stability value with bitumen content in 0.25% fiber content at different fiber length

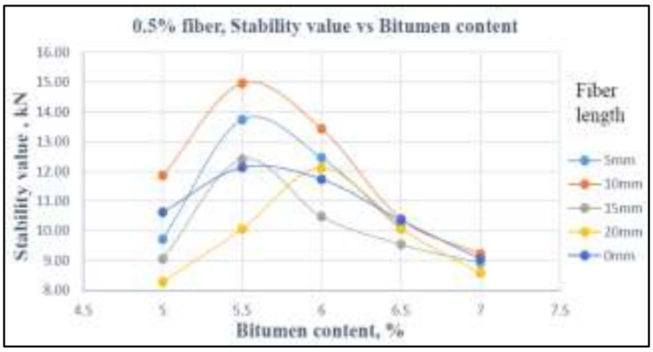


Figure 7 Variation of Stability value with bitumen content in 0.5% fiber content at different fiber length

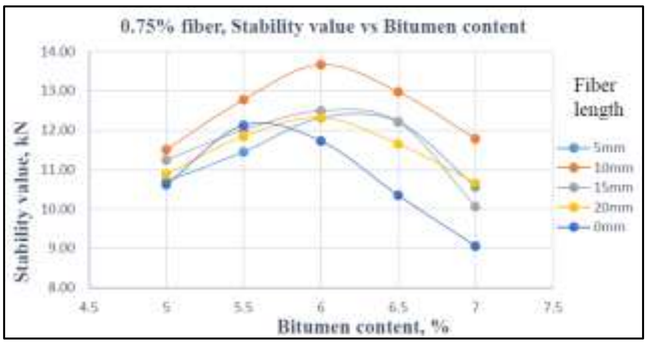


Figure 8.Variation of Stability value with bitumen content in 0.75% fiber content at different fiber length

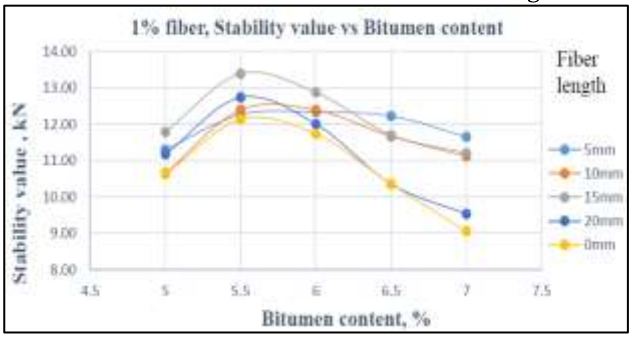


Figure 9. Variation of Stability value with bitumen content in 1% fiber content at different fiber length

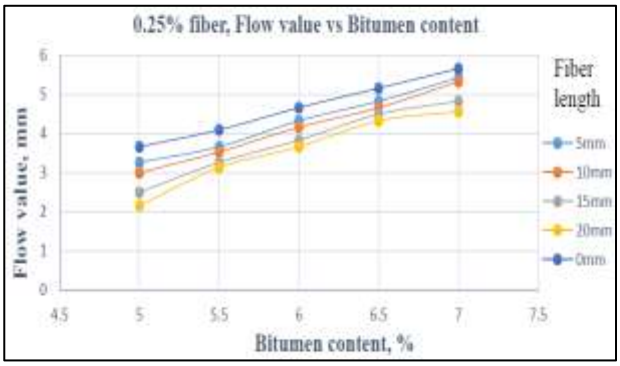


Figure 10 Variation of Flow value with bitumen content in 0.25% fiber content at different fiber length

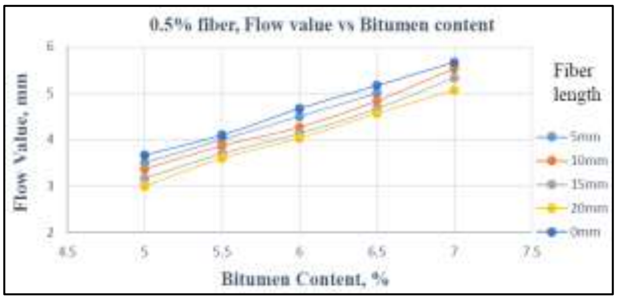


Figure 11 Variation of Flow value with bitumen content in 0.5% fiber content at different fiber length

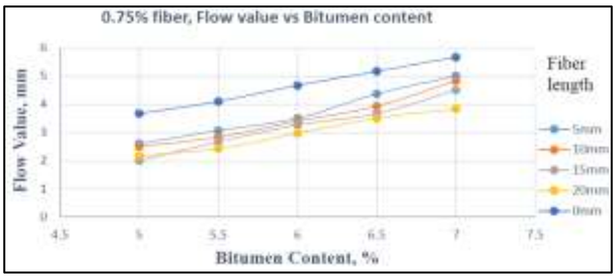


Figure 12 Variation of Flow value with bitumen content in 0.75% fiber content at different fiber length

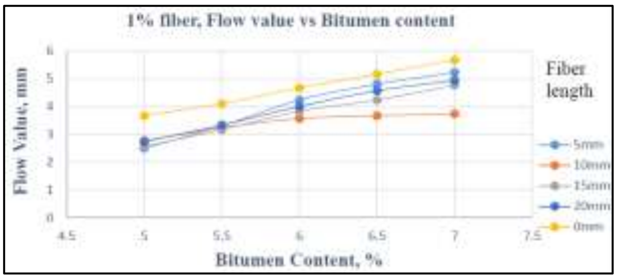


Figure 13 Variation of Flow value with bitumen content in 1% fiber content at different fiber length

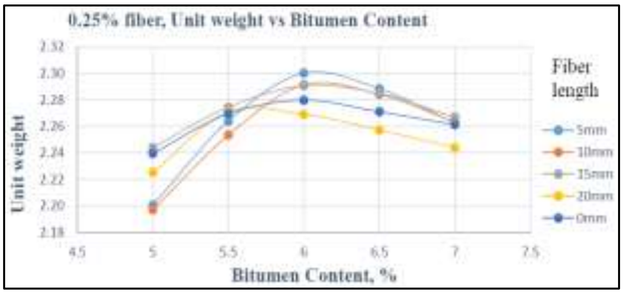


Figure 14 Variation of Unit weight value with bitumen content in 0.25% fiber content at different fiber length

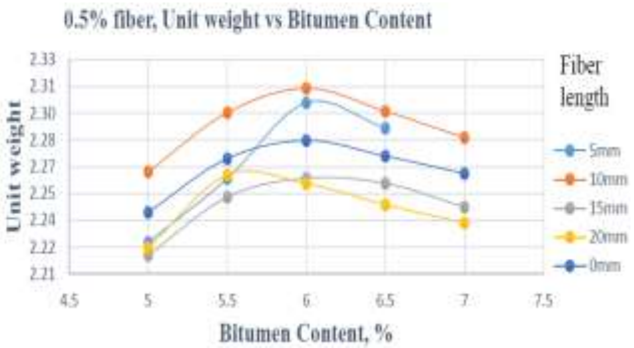


Figure 15 Variation of Unit weight value with bitumen content in 0.5% fiber content at different fiber length

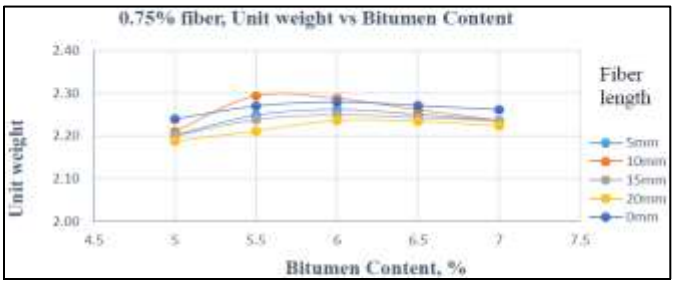


Figure 16 Variation of Unit weight value with bitumen content in 0.75% fiber content at different fiber length

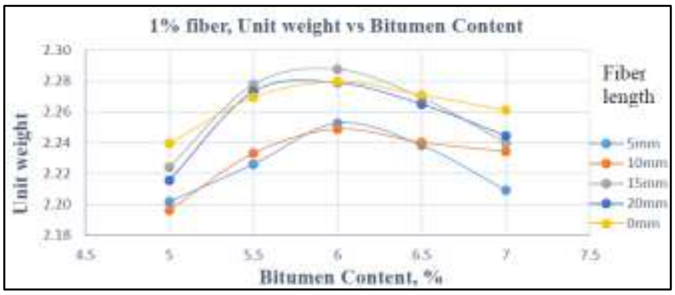


Figure 17 Variation of Unit weight value with bitumen content in 1% fiber content at different fiber length

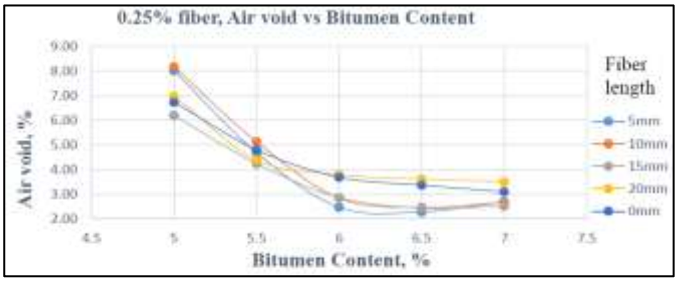


Figure 18 Variation of Air void value with bitumen content in 0.25% fiber content at different fiber length

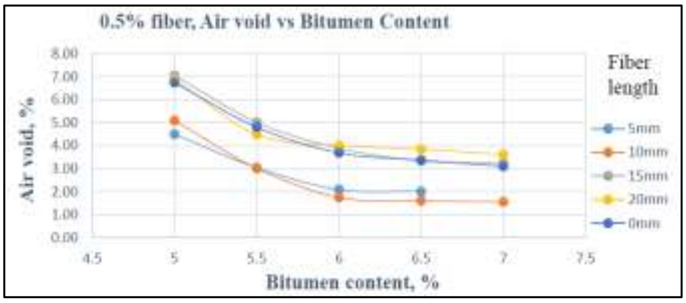


Figure 19 Variation of Air void value with bitumen content in 0.5% fiber content at different fiber length

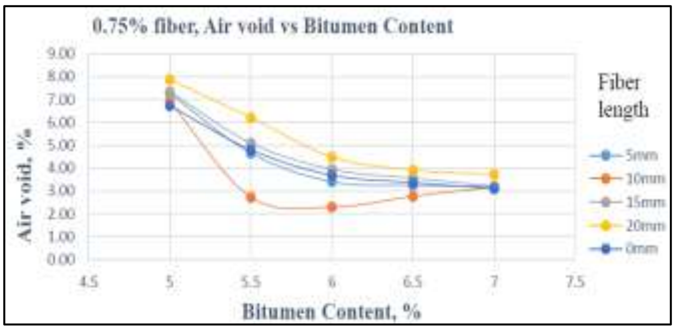


Figure 20 Variation of Air void value with bitumen content in 0.75% fiber content at different fiber length

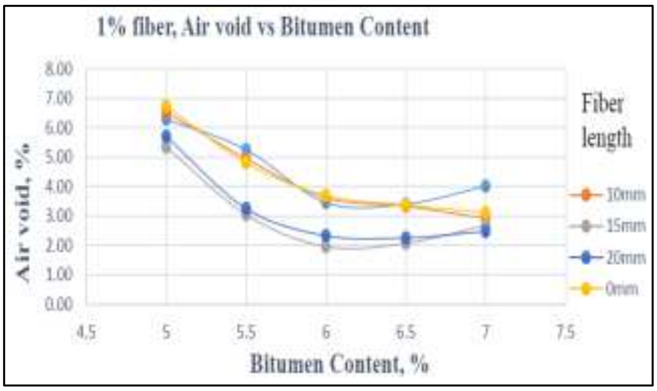


Figure 21 Variation of Air void value with bitumen content In 1% fiber content at different fiber length

## 5. Conclusions

Based on the results of a laboratory study the following conclusions are drawn.

I) The DBM mixes prepared with bottom ash and Fly ash used respectively in 300-75 micron sizes and Passing 75 micron resulted best mixes considering the Marshall criteria as per MORTH specifications when bitumen content, fiber content and fiber length Were 5.6, 0.5 % and 10 mm respectively and satisfying other engineering properties studied.

II) A higher value of bitumen content is observed in contrast to the normal requirement of 4.5 % for DBM mix; this is due to the increase in fiber content and fiber length.

III) It is also observed that with increase in fiber content and fiber length up to a given level, air-void and flow value decreases whereas Marshall Quotient increases. The latter is a good indication of rutting resistance of bituminous paving mixes in case of the recommended mix composition

IV) It is further observed the use of either emulsion Coated fiber or coal ash or both in DBM mix, increases The resistance to moisture.

V) It can be concluded that the coal ash in finer fractions can be used in DBM layer of a pavement. There can be further Improvement in engineering properties of DBM Mixes by utilizing non-conventional, yet abundantly and locally available natural fibers.

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