A Spatial Study on Characterization of Bitumen Binder by the help of Geosynthetic

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Abstract: - Coal-based thermal power plants have been a key source of power generation in India. The prime waste product of a coal thermal power plant are fly ash and bottom ash. Heavy dumping of these waste products causes fatal environment pollution to air, water, and land, besides impairing human health. This research work is done to deliver the optimum use of ash, namely bottom ash as fine aggregate and fly ash as mineral filler with natural fiber (such as sisal fiber) used to improvise the engineering properties of bituminous paving mixes. For national interest these waste products, which are available easily and abundantly cane be used economically for bituminous paving purpose, which ultimately helps in saving the natural aggregate resources of the nation.
In this study, we form a mix of dense graded bitumen with the help of natural aggregates that are used as coarse aggregates. Fine aggregates would be bottom ash, fly ash would be a filler and the additive would be sisal fiber. The proportion taken for DBM or bitumen macadam in a dense form is considered according to MORTH (in 2013) with the max size of the aggregates being 26.5mm. To enhance the mixture, we have SSI or slow-setting emulsion that is coated to the sisal fiber and this is added in varying percentages such as 0 percent, 0.25 percent, 0.5 percent, 0.75 percent and 1 percent by weight of mixtures and length varying like 5mm, 10mm, and 15mm and 20mm. In the initial period of our research, we prepare the specimen in 2 kinds of paving bitumen which are VG10 and VG30. Out of these, the first trials gave an outcome of better Marshal features with VG30 and hence this was accepted for further studies. We take a detailed study of the Marshall Test results which helped us to know the Marshall features, content for binder, and also the content of fiber with the length of the fiber that was optimum. We obtain a Marshall stability which was reaching a high of 15kN while the content of bitumen was 5.57 percent and the content of fiber was about 0.5 percent, while the length of the optimum fiber was 10mm. Apart from these, to get better performances in the pavements, we also conduct some performance tests and these include tests for moisture susceptibility, ITS test, creep test and to find the ratio of tensile strength of the mixes of bitumen. It is seen that not just the needed ones but much enhanced engineering features when coal ash acts like fine aggregates and fibers as fillers, and these natural sisal fibers were coated in advance with SS-1 emulsion. The use of unorthodox aggregates such as natural fibers and coal ash jointly would help to get a novel way of constructing bitumen pavement. The dumping of coal ash, which is a big problem for all, with respect to environmental pollution and disposal, can find an easy and effective way to get reused economically by replacing natural resources such as stone dust and sand.

Keyword: Bitumen, Aggregate, Marshall Mix, Unit Weight, Fly Ash, Air Voids.

I. Introduction:

Pavements or highways or roads are regarded as country's backbone, upon which its upswing and progress depend on. All countries normally have a series of programs for building a new road infrastructures or emerging the existing one. Construction of both flexible and rigid pavement include a gross amount of investment to reach better performance oriented and smooth quality of pavement that will endure for long time. In India, where highways are considered as the primary function of transportation, Government of India have been investing a huge amount of money for developing the pavement construction and maintenance. 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.
From the review of Das et al. (2004); it is known that the bituminous paving technique was first introduced on rural roads during 1900's. The formal mix design method was first made possible by Habbard field method, which was originally developed for the sand-bituminous mixture. But one of the focal limitation of this technique was its incompatible of handling large aggregates. Later on, a project engineer Francis Hveem of California Department of Highways, developed an instrument called Hveem stabilometer to calculate the possible stability of the mixture. At the early stage, Hveem did not have any experience to estimate the amount of optimum bitumen that will just be right for mix design. He adopted the surface area calculation concept used for cement concrete mix design, to assess the quantity of bitumen vital for the mixture. On the other hand, Bruce Marshall developed equipment to test stability as well as deflection of the bituminous mixture. It was adopted by the US Army Corpse of Engineers in 1930's and successively adapted in 1940's and 50's.
Bituminous pavement comprises of a mixture of stone chips, graded 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. 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. For preparation of bituminous mixes, commonly aggregates, inform of coarse, fine and filler fractions are used. In many locations, the aggregates in different size fractions are not easily available, use of which needs procurement from long distances and hence increases the cost exorbitantly. On the other hand, a number of coal-based thermal power plants have been set up to somewhat cater to the power supply requirement. 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 of either dry or wet to an open areas, which are available near the factory or by grounding into artificial lagoon or dumping yards. 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. Both in disposal as well as in utilization, utmost care has to be taken to safeguard the interest of human life, wildlife and environment. Hence to suppress the wretched effect of these materials, a detailed study is necessary to utilize them in a productive way that will satisfy the society need.

This experimental study has done to enable the most appropriate use of coal ash as nonconventional aggregate along with natural fiber (Sisal 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.

II. Literature Review:

Shuler, T. S. (1976) performed a laboratory study on six bottom ash obtained throughout the state of Indiana and tried to physically characterize the materials. Tests included Unit weight, Florida Bearing Test, Hveem Centrifuge Kerosene Equivalent and Oil Ratio Specific Gravity, Dry Sieve Analysis, and a degradation analysis. Performance tests are also done by Florida Bearing Test on fine aggregate-ash mixtures prior to mix with bitumen; Marshall Stability on specimens in the dry as well as the soaked condition, Hveem Stability and Cohesion and Skid Resistance.

Bituminous mixtures with ash demonstrated higher values for retained stability in the Water Sensitivity Test than mixtures without ash, Skid resistance of the mixtures was enhanced with the addition of ash

R. E. Long and R.W. Floyd (1982) studied that aggregate shortages and increased transportation costs have greatly increased prices of related construction items in areas of Texas which is not blessed with natural aggregates. Some natural aggregates are not performing up to expectations as documented bystripping, rutting and other visual signs of pavement distress noted throughout the Department. Because of these spiralling construction costs and need to field evaluate bottom ash, District 1, supported by the Materials and Tests Division, decided to construct three field test pavements substituting bottom ash for part of the natural aggregates in hot mix asphaltic concrete (HMAC).

They conclude that that bottom ash blend mixes require more asphalt than natural aggregates, mixes produce lower compacted density, mixes cool fast, requiring adequate rollers working closely behind the laying operation, mixes exhibit high internal friction with no lateral displacement during compaction, this mix has maintained acceptable skid values after 14 months of interstate traffic, the cost of bottom ash blend mixes is somewhat higher based on additional asphalt used and aggregate transportation costs.

David Q. Hunsucker (1992) conducted an experimental bituminous surface overlay, which was placed in October 1987 on State Route 3 in Lawrence County, Kentucky. The experimental section utilized bottom ash aggregate, limestone and natural sand aggregate. He conclude that because of the absorptive characteristics of bottom ash aggregate, nearly fifty percent more bitumen is required in the mixture. The increased asphalt content results in a higher unit bid price for the bituminous concrete material. The combination of bottom ash aggregates with limestone and natural sand aggregate appears to improve the overall performance of a bituminous surface mixture, especially with respect to its skid resistant properties.

Musselman et al. (1994) performed a two year demonstration project has been initiated where bottom ash was used as a 50% substitute aggregate in a asphalt pavement. The demonstration project includes noteworthy testing of possible environmental influences and pavement performance both in the laboratory and at the demonstration roadway. Data was gathered which include analytical data on groundwater and surface water quality impacts, surface run-off and suction lysimeter samples. Physical roadway performance was monitored through remote sensing using strain resistance and temperature probes as well as in situ and destructive pavement analysis.They conclude that the use of bottom ash as a fractional substitute for conventional aggregate in pavement seems to be a feasible ash utilization skill. Bottom ash fraction of somewhat less than 50% is suggested for future testing. Gyratory test methods were done which was successful in predicting better pavement performance at a lower asphalt content in comparison with the Marshall test methods. Public acceptance of the concept of ash utilization in this fashion was obtainable for this demonstration project.

III. Materials and Methods

1) Materials

In the study of the materials that were taken into consideration to prepare a mix of bitumen, here are they:

- Stone chips used ad coarse aggregates
- Bottom ash is used as fine aggregates
- Fly ash used as mineral filler
- VG-30 used as bitumen binder
- Sisal fiber used as additives
- SS-1 emulsion used as a coating agent for fibers

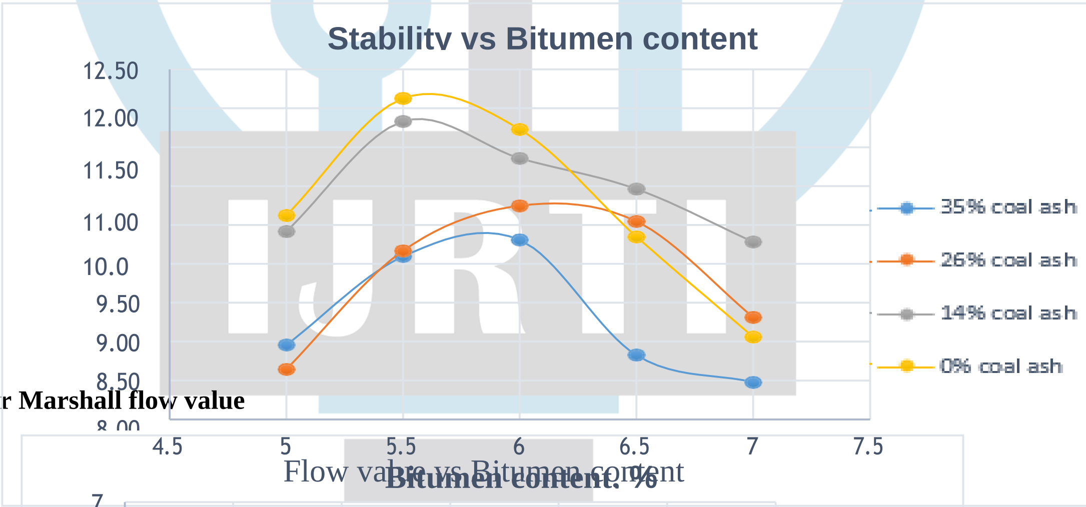
2) Methodology

- **Experimental Design:-** The adopted gradation for DBM sample has been considered as specified in MORTH (2013) and is given in Table-4.1. Throughout the experimental study the aggregate gradation given in Table4 was followed, and the following tests were performed. The aggregate gradation curve is shown in figure.4.1.
- **Design mix:-** 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-30 bitumen were mixed in a specified procedure. Before preparing the samples, fibers were coated with SS-1 emulsion and stored in a hot air oven at 110^0C as shown in Figure 4.3. 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, as shown in Figure 4.3 [26 and 27]. Then the fibers were cut into specified lengths of about 5mm, 10mm, 15mm and 20mm as given in figure 4.4. The aggregates and bitumen were heated separately to the mixing temperature of 155^0C to 160^0C. The temperature of the aggregates was maintained 10^0C higher than that of the binder. Required quantities of bitumen VG-30 and coated emulsion fiber pieces were added to the pre-heated aggregates and thoroughly mixed as shown in Figure 4.5.

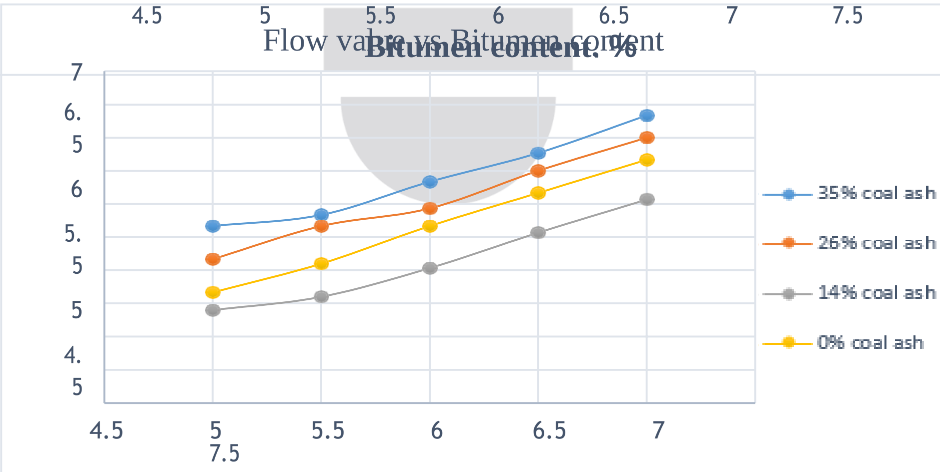
- **Static indirect tensile test:-** Static indirect tensile test of bituminous mixes was performed in accordance to ASTM D 6931 (2007) to assess the resistance to thermal cracking for a Marshall cylindrical specimen that is loaded in vertical diametrical plane as shown in figure 4.7. This tests were carried out on DBM specimen which were prepared at their optimum binder content, optimum fiber content and optimum fiber length as calculated from Marshall propeties analysis. The effect of temperature on the Indirect Tensile Strength (ITS) of mixes with and without fiber was also studied. The load at which tensile crack were develop in the specimen were noted down from the dial gauge of the proving ring and was calculated.
- **Resistance to moisture damage (Tensile Strength Ratio (TSR)):-** The resistance to moisture susceptibility of bitumen mixes were measured by tensile strength ratio. The test is similar to Static Indirect Tensile test only the specimen were prepared in gyratory compactor with 7% air void and 150 mm diameter to 62.5 mm height specimen dimension as shown in figure 4.8. Six sample of equal avg. air void was prepared and divided into two subset. One subset was partially saturate to be moisture conditioned with distilled water at room temperature using a vacuum chamber by applying a partial vacuum of 70 kPa or 525 mm Hg (20 in. Hg) for a short time such as five min. after that the partially saturated samples are cured to be moisture conditioned in distilled water at $60^{\pm}1.0$°C for 24 hour.
- **Retained stability test:-** The loss of stability in bituminous mixes due to penetration of moisture are measure in the form of Retained stability test. This test also shows the sign of percentage striping of bitumen from aggregate. The test was conducted in accordance with the STP 204-22 with standard Marshall Samples, prepared according to the Marshall procedure specified in ASTM D6927-2015. Six specimen were prepared with 4% air void and divided into two subset. Each of the subset were conditioned with water at $60^{\pm}1^{0}$C for half an hour and 24 hours and tested in accordance to Marshall stability test. A minimum of 75% retained stability is required as per MORTH-2013 to claim the mixture can with stand moisture.
- **Static creep test:-** This test method is used to determine the resistance to permanent deformation of bituminous mixtures at specific temperatures. For Static Creep test sample were prepared at their optimum binder content, optimum fiber content and fiber length. The test was conducted as per Texas department of transportation (2005) specification. The specimens were placed in a hot air oven maintained at a temperature of 40°C for three to five hours prior to start of the test. Then 125 lb. (556 N) load was applied for one hour followed by 1 min initial loading rest. This allows the loading platens to achieve more uniform contact with the specimen. The deformation was registered in each 5 min intervals starting from 0 min to 60 min by using a dial gauge graduated in units of 0.002 mm. After then the load was removed and its recovery was registered up to next 5 min at 1 min intervals. A graph has been plot between time and deformation.

IV. Results

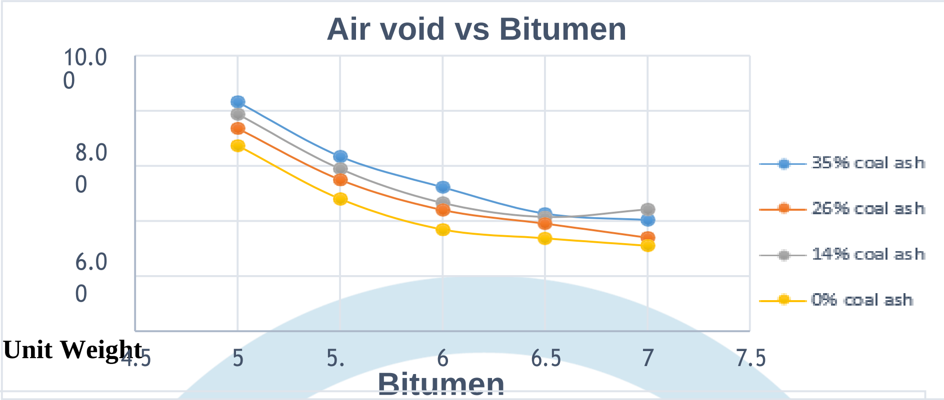
- **Result for Marshall Stability**



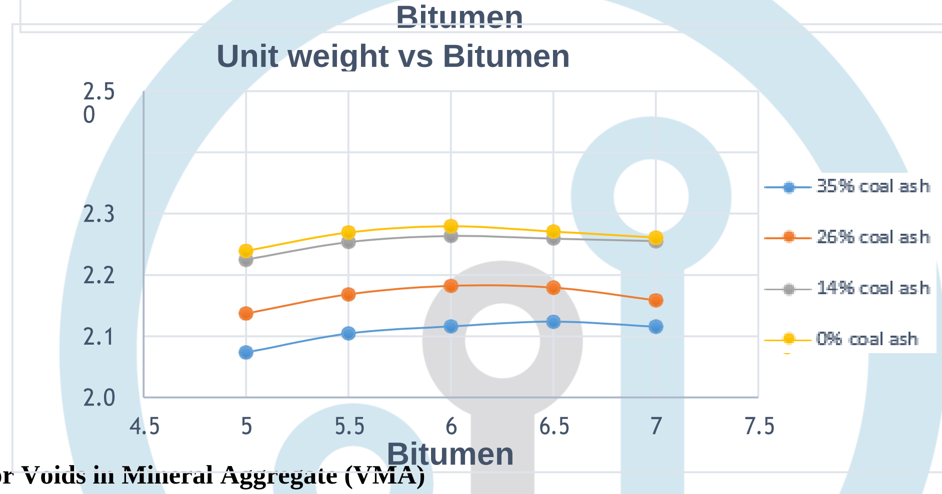
- **Result for Marshall flow value**



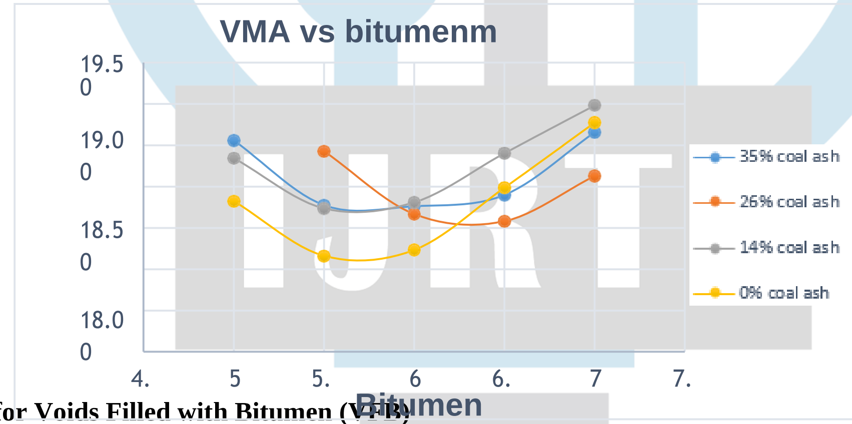
- **Results for Air Voids**



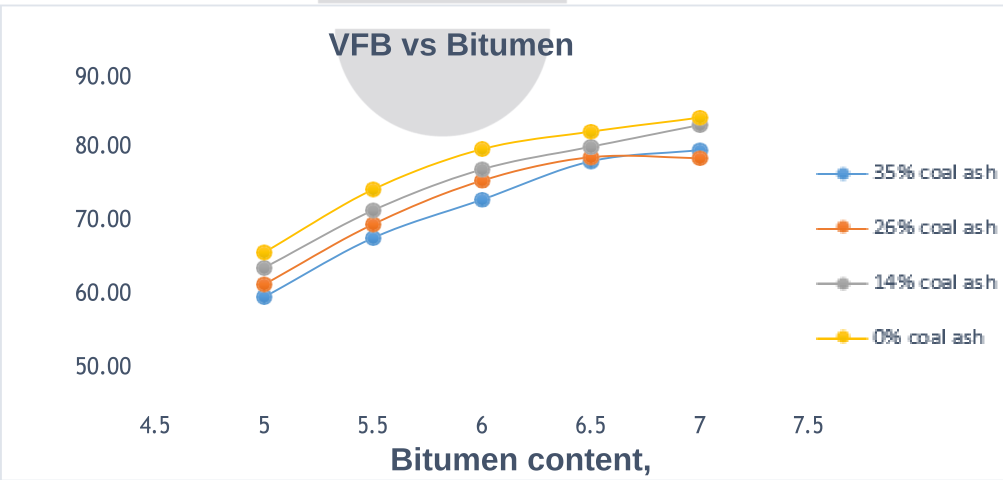
- **Result for Unit Weight**



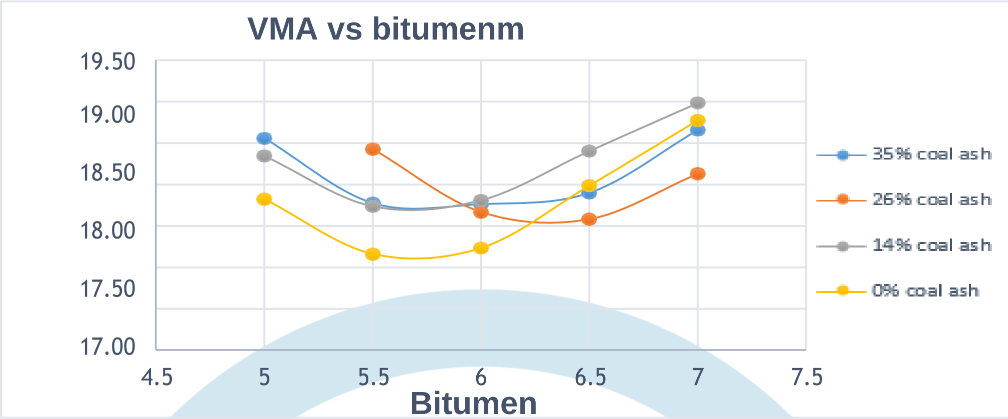
- **Result for Voids in Mineral Aggregate (VMA)**



- **Result for Voids Filled with Bitumen (VFB)**



- **Marshall Properties Analysis**



Fiber content, %	Fiber length, mm	OBC, %	Optimum stability, kN	Flow value, mm	VA, %	VMA, %	VFB, %	Gmb
0.2 5	0	5.60	11.40	3.15	2.40	15.30	84.00	2.33
	5	5.70	14.20	4.00	3.60	16.70	79.00	2.28
	10	5.78	13.20	3.50	3.60	17.00	76.00	2.28
	15	5.87	12.80	3.80	3.10	16.60	80.00	2.27
	20	5.73	11.90	3.80	4.00	17.00	77.00	2.27
Fiber content, %	**Fiber length, mm**	**OBC, %**	**Optimum stability, kN**	**Flow value, mm**	**VA, %**	**VMA, %**	**VFB, %**	**Gmb**
1	0	5.60	11.40	3.15	2.40	15.30	84.00	2.33
	5	5.93	12.30	4.20	3.70	17.60	80.00	2.24
	10	5.77	12.50	3.40	4.40	17.65	76.00	2.24
	15	5.55	13.40	3.20	2.90	16.10	82.00	2.28
	20	5.63	12.65	3.8	2.40	16.20	83.00	2.28

Conclusion

Based on experimental study the following conclusions were drawn,

- From the results of the Marshall tests it was observed that the DBM mixes prepared with bottom ash and fly ash used respectively in 300-75 micron sizes and passing 75 micron resulted best mixes satisfying the Marshall criteria when bitumen content, fiber content and fiber length were 5.6%, 0.5% and 10mm respectively.
- It is also observed that Marshall stability and flow values are quite acceptable when the coal ash content is within 15%.
- It is also observed that with increase in fiber content and fiber length, air-void and flow decreases and Marshall Quotient increases which in turn is due to higher stability value.
- An increase in fiber content and fiber length resulted in higher requirement of optimum bitumen content and emulsion for coating of the fibers.
- From the indirect tensile strength test it is perceived that the indirect tensile strength of sample increased due to the addition of emulsion coated fiber and coal ash, which gives an excellent engineering property for DBM sample to endure thermal cracking.
- It is also observed the use of emulsion coated fiber, coal ash or both in DBM mix increases the resistance to moisture induced damages determined in terms of tensile strength ratio and retained stability values.

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