Characterization of Bitumen Mix Binder Prepared by using geotextile and Coal Ash

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***Abstract*: Thermal power plants that use coal as a primary material hold the key to generating power in India. The primary waste product that gets generated out of a coal thermal power plant is fly ash and there is some bottom as ash as well. With heavy dump of these wastes, there are unreasonable pollution concerns to the environment including water, air, and land apart from human health issues. With this research, we aim to offer sustained employment of ash like bottom ash as a form of fine aggregate and even fly ash could be used as a mineral filler that has fibers like sisal fiber in order to enhance the engineering features of the paving mixes in bitumen. As per national uses, the waste products that could be easily obtainable and used in an economical manner for the paving purpose of bitumen, this could assist in saving the national natural aggregate resources.**

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

I. Introduction:

We can all, roads, highways, and pavements as the backbone of our nation, and the progress and the upswing of a nation depend on these. Each of the countries generally contains a set of programs for the construction of road infrastructures or to extend an existing one. When constructing both the rigid pavements and the flexible pavement, we need a lot of investment to get a level of performance with the quality of the pavements being smooth and living for a long period of time. In our country, where highways are the major element for transportation, the Indian government has been investing a lot of money on the development and maintenance of the pavements. With a thorough engineering study, we may get to know a lot about the amount of investment with materials used for pavement. This is will help us to get the static performance of the highways in service. About flexible pavements, a couple of facts could be considered, and these are mixed design and pavement design. The latest study of research stays its focus on engineering features of bitumen mixes which are made from unorthodox or unconventional products.

From what Das et al (in 2004) considered, we can say that paving a road with bitumen was first done on the rural roads during the 1900s. The mix design method which was initially made was with the help of the Habbard field method, which was first formed for the mix of sand and bitumen. But a major issue in this process was that it was non-compatible to handle bigger aggregates. Following this, Francis Hveem, a project engineer in the California Department of Highways, brought a piece of equipment known as the Hveem Stabilometer and this could calculate the possible mixture stability. At the initial stages, Hveem had no experience getting the quantity of bitumen that would be good enough for the design mix. He took the calculation for the surface area on the concept that kept track of the concrete design mix, in order to know the amount of bitumen that was needed for the mixture. In contrast to this, Bruce Marshall came up with equipment that could test the stability and the deflection of the bitumen mix. This was taken by the Engineers of US Army Crp. in 1930 and was also used in the 1940s and 1950s.

The pavements of bitumen consist of a mix of stone chips that were graded from the normal max aggregate size or NMAS with a fraction that was smaller than the 0.077mm and these were mixed with a good amount of bitumen which could be purposely compacted with fewer voids for air and will contain a required amount of elastic and dissipative features. The major aim of the bitumen design mix is to get a normal proportion of aggregates and bitumen fraction in order to get a mixture that could be economic, durable, effective, and reliable as well.

II. Literature Review:

In 1976, TS Shuler did a laboratory study on 6 samples of bottom ash gotten from Indiana and he made an effort to find the features of these materials physically. These tests contained Unit Weight, Hveen Kerosene Centrifuge Equivalent, Dry Sieve Analysis, Florida Bearing Test, Specific Gravity, Oil Ratio and even the degradation analysis. He also did the performance test with the use of the Florida Bearing Test on a mixture of ash and fine aggregates before mixing it with bituminous materials. With the use of Marshall Stability on the samples of soaked and dry conditions, it studied the Cohesion, Skid Resistance, and Hveem Stability as well. The Bitumen mixes that contained ash also showed a high value of enclosed stability in the test for water sensitivity than the mixtures that are devoid of ash. We also see that the skid resistance of the mixes gets increased by adding ash. **RE Long and RW Floyd (1982)** examined and found that the shortage of aggregates and the increase in their transportation rent have hiked the prices of their related construction elements in the regions near Texas which do not contain enough natural aggregates. Some of these may not perform according to the desires, as per the documents in terms of rutting, stripping, and other visible signals of distress of pavement all through the department. Due to these enhancing costs of construction and the process of evaluating bottom ash in District 1, in accordance with the Test and Material Dept., we made sure to make a trio of pavements for test and replaced natural aggregates with bottom ash for the part of the test in the HMAC or the hot mix asphaltic concrete. They came up with the conclusion that the mixes of bottom ash need more asphalt against natural aggregates, these mixtures come yo with less compact density, they cool faster, need enough rolling and need to be wrecked in close association with laying operations. They also have high internal friction and nil lateral displacement whole being compacted and this mixture has gotten the demanded skid value even after 14 months for interstate traffic. The cost of this bottom ash blend is slightly more because of the added asphalt and the cost of transportation. **David Q. Hunsucker (1991)** did an experiment on an overlay of bituminous surface that was taken in October 1987 on the Route 3 of Lawrence County in Kentucky. In this experiment, they used aggregates of bottom ash, sand, and limestone. He devised that the absorptive nature of the aggregates of bottom ash needed around 50 percent higher bitumen to the mixture. The increase in the content of asphalt gave more unit bid prices against the concrete material with bitumen. The combo of aggregates of bottom ash and the limestone in amalgamation with natural sand will enhance the total performance of the surface mixture with bitumen, generally where the skid-resistant features are concerned. Musselman et al (in 1994) carried out a 2-year project which started with the use of bottom ash and this was used to replace about 50 percent of the aggregates in a pavement of asphalt. This project contained sufficient tests of possible effects on the environment and the performance of the pavement in the roadway and in the laboratory. Data that was garnered and this contained analytics of the groundwater and the impact of the surface water quality run-offs on the surface and samples of suction lysimeter. They took the performance of the physical roadway with the help of remorse sensing with the use of temperature probes and strain resistance as well as the destruction analysis of the pavement and the in-situ analysis. This offered the conclusion that the employment of fly ash as a substitute to the orthodox aggregates in these pavements tends to be a credible use of the bottom Ash. For the next tests, they suggested taking the fraction of bottom ash to less than 50 percent. With the use of Gyratory tests, they predicted an enhancement in the performance of pavements with less content of asphalt as compared to the Marshall tests. This test allowed public acceptance in terms of using fly ash for the projects.

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

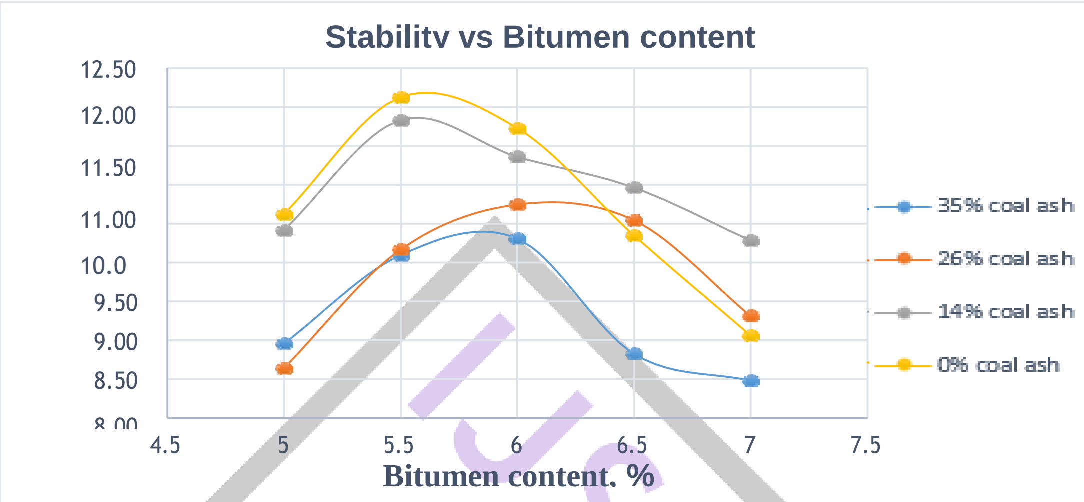
2) Methodology

- **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^{0}C 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^{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-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

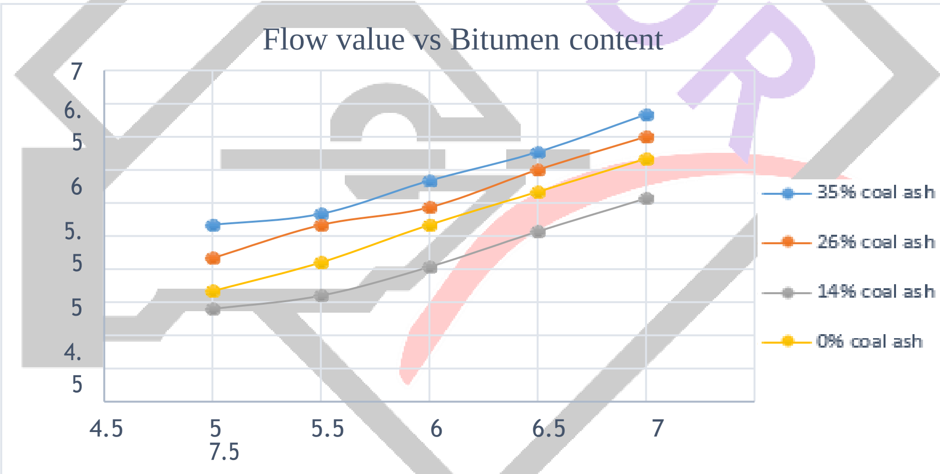
fiber length. The test was conducted as per Texas department of transportation (2005) specification. The specimens were placed in a hot air oven maintained at a temperature of 40°C for three to five hours prior to start of the test. Then 125 lb. (556 N) load was applied for one hour followed by 1 min 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

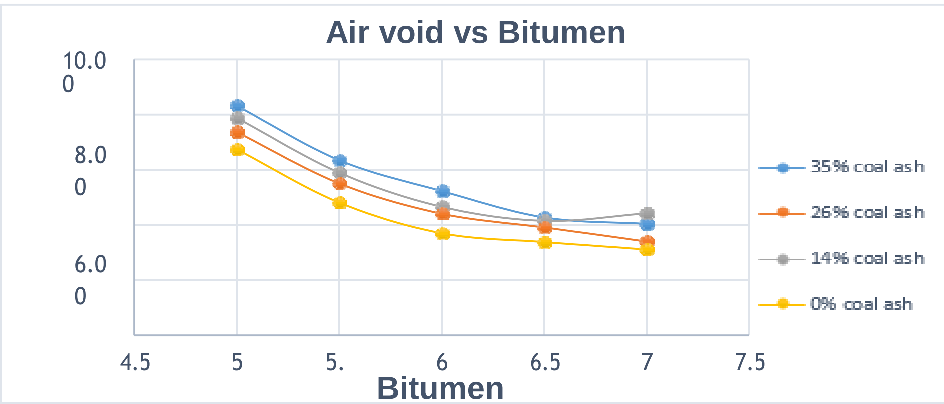
- **Result for Marshall Stability**



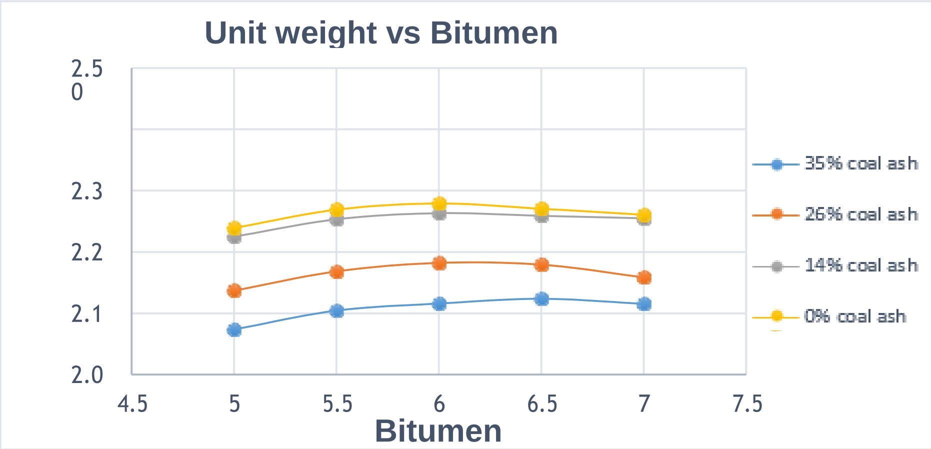
- **Result for Marshall flow value**



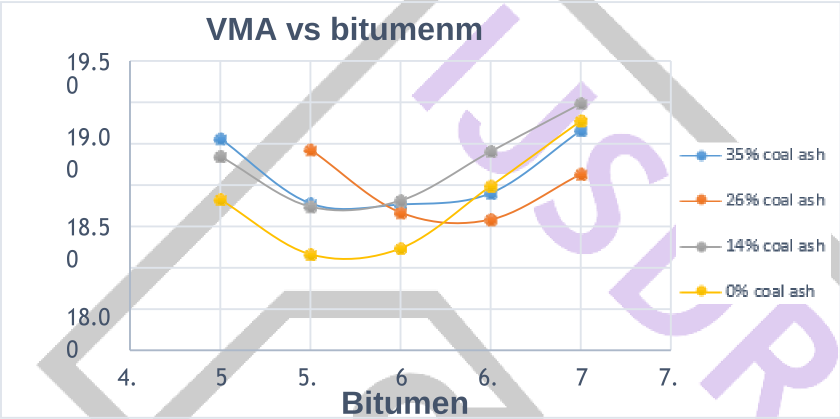
- **Results for Air Voids**



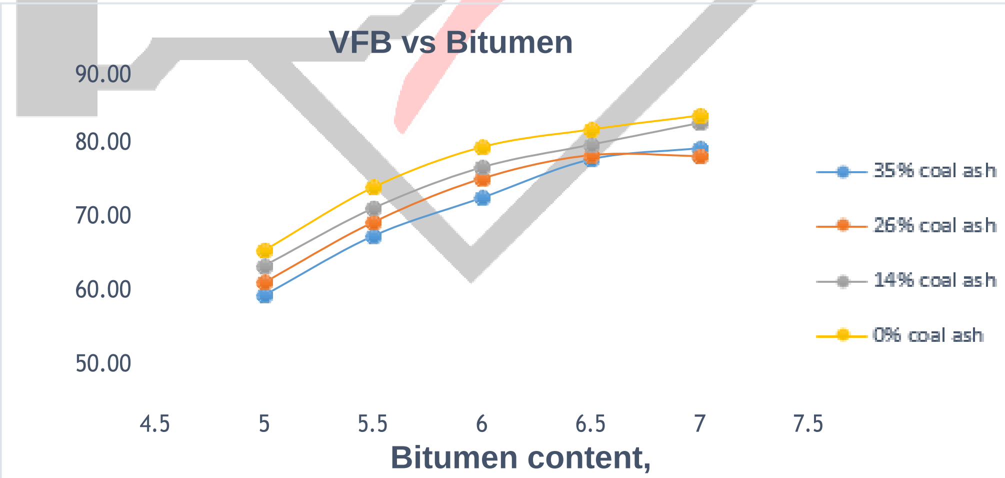
- **Result for Unit Weight**



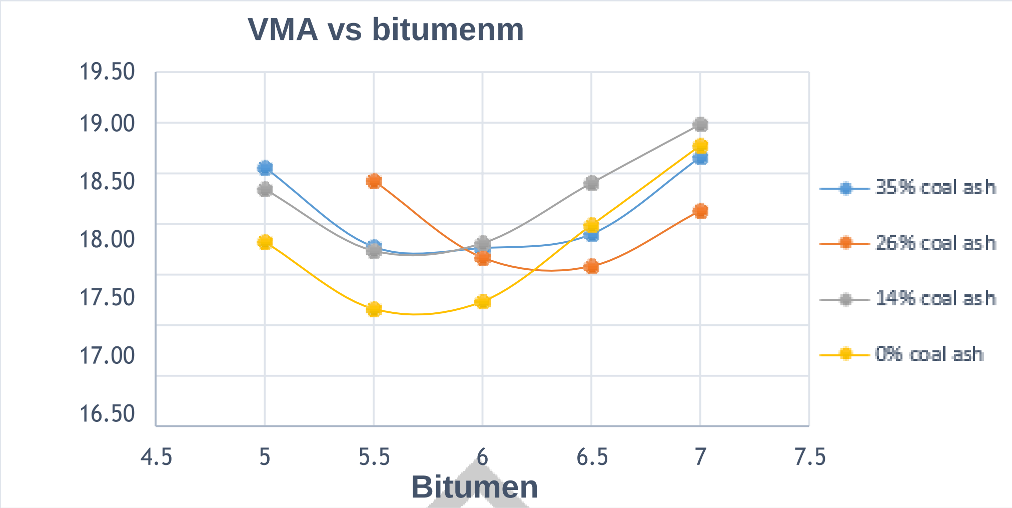
- **Result for Voids in Mineral Aggregate (VMA)**



- **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
0.25	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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