



DEVELOPMENT OF ENG. PROPERTIES OF DENSE GRADE BITUMINOUS MIXES WITH COAL ASH BY USING NATURAL FIBRE

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Abstract:

Aggregates in coarse, fine and filler fractions are the main constituents of the bituminous paving mixes. In many construction sites, aggregates in different size fractions are not easily available, necessitating their procurement from long distances thereby causing exorbitant increase in cost of construction. On the other hand, 70 % of the total power generation in India is due to coal based thermal power plant, that also contribute about 112 million tons of coal ash as by-product waste in every year from 120 coal based thermal power plants. Such a huge quantity of this type of waste material does pose challenging problems, in the form of land usage, health hazards and environmental dangers. Hence to suppress the said problems related to these materials, a good number of studies have been attempted to utilize them in a productive way which will satisfy the needs of the society. This particular work is an attempt to utilize these waste materials to some extent by replacing the filler and some fractions of fine aggregates in bituminous paving mixes. Further, for delivering the performances of the pavement, various performance tests were also conducted such as moisture susceptibility test, indirect tensile strength (ITS), creep test and tensile strength ratio of bitumen mixes. The coal ash dumping which is a serious concern to everyone in respect of its disposal and environmental pollution, can find one way for its reuse in an economical way by substituting natural resources of sand and stone dust. Further, for justifying the performances of the bituminous paving mix thus developed tests for indirect tensile strength and moisture susceptibility in the form of tensile strength ratio and retained stability of bituminous mixes.

KEYWORDS: Bituminous mixture, Bottom ash, Fly ash, Tensile strength ratio.

INTRODUCTION: Aggregates in coarse, fine and filler fractions are the main constituents of the bituminous paving mixes. In many construction sites, aggregates in different size fractions are not easily available, necessitating their procurement from long distances thereby causing exorbitant increase in cost of construction. On the other hand, 70 % of the total power generation in India is due to coal based thermal power plant that also contributes about 112 million tons of coal ash as by-product waste in every year from 120 coal based thermal power plants (2010-11 data). Such a huge quantity of this type of waste material does pose challenging problems, in the form of land usage, health hazards and environmental dangers. Hence to suppress the said problems related to these materials, a good number of studies have been attempted to utilize them in a productive way which will satisfy the needs of the society. This particular work is an attempt to utilize these waste materials to some extent by replacing the filler and some fractions of fine aggregates in bituminous paving mixes. In order to enhance the properties of the paving mixes,

their modification with different types of fibers is also done. In order to offset the possible drawbacks of using the coal ashes, unlike conventional fibers, naturally, locally and abundantly available sisal fiber has been tried in possible development of sustainable bituminous paving mixes to improve the pavement performance. Sisal fiber is obtained from a plant with a botanical name *Agave sisalana*. Ali et al. observed through an experimental study on the outcome of fly ash on the mechanical properties of bituminous mixtures, that fly ash as mineral filler can be used to increase resilient modulus characteristics and stripping resistance. As per Churchill and Amirkhanian, partial substitution of fine aggregates by coal ash had a moderate detrimental effect on short-term tensile strengths. Results of a limited field study showed that 3 months after placement, metal concentrations in soils were not substantially altered. Colonna et al. studied the feasibility of bottom ash for HMA (Hot Mix Asphalt) mix used in the intermediate courses of flexible pavements. Their results show that the mixtures perform better when 15 % of bottom ash was

added to the mixture in replacement of correspond amount of sand. Kar studied the effect of sisal fiber on SMA (Stone Matrix Asphalt) and bituminous concrete (BC) mixtures and he concluded that the optimum bitumen contents for BC and SMA mixes were 5 % and 5.2 % respectively whereas optimum fiber content for each mix was 0.3 %. From the scanty literature available, it is observed that there is no study on utilization of bottom ash and fly ash together in the same bituminous mix and the use of a natural fiber in SMA and BC mixes. Hence, this was the main motivation of the present research work. In the present study, dense graded bituminous mix specimens were prepared using natural aggregate as coarse aggregates, bottom ash as partial replacement of fine aggregates and fly ash as mineral filler with sisal fiber as a stabilizing additive. Design of the mixtures was done as per Marshall procedure. For characterization of the mixes, various tests such as indirect tensile strength (ITS) and moisture susceptibility test in terms of tensile strength ratio (TSR) and retained stability were taken up.

METHODOLOGY:

In present scenario due to vast development of road infrastructure the good quality of virgin aggregates inclusive of traditional fillers like lime, cement etc. are depleting at very fast rate compelling to explore the use of waste mineral materials like fly ash as filler. At present about 100 thermal powers are in operation and are responsible for producing about 170 million tons of ash annually. As a common practice these ashes are dumped in the vicinity of available land adjoining to thermal power plants and are responsible for adverse affect to the environment besides overshadowing useful lands. have assessed that the production of ash by 2030 will reach around 600 million tons. Studies have revealed that the scope of using these ashes and other waste materials in highway sector are very much on cards as their effect on performance proves to be technically, economically and environmentally viable and acceptable and are with in the prescribed norms and specifications. the waste materials like fly ash and plastic waste can be conveniently used in the bituminous mixes of flexible pavement construction due to their supportive and pavement friendly characteristics.

CHARACTERISTICS OF MATERIAL USED IN BITUMINOUS MIX:

There are various types of mineral aggregates which can be used in bituminous mixes. The aggregates used to manufacture bituminous mixes can be obtained from different natural sources such as glacial deposits or mines. These are termed as natural aggregates and

can be used with or without further processing. The aggregates can be further processed and finished to achieve good performance characteristics. Industrial by products such as steel slag, blast furnace slag etc. sometimes used as a component along with other aggregates to enhance the performance characteristics of the mix. Reclaimed bituminous pavement is also an important source of aggregate for bituminous mixes. Aggregates play a very important role in providing strength to asphalt mixtures as they contribute a greater part in the matrix. SMA contains 70-80 percent coarse aggregate of the total Stone content. The higher proportion of the coarse aggregate in the mixture forms a skeleton type structure providing a better stone-on-stone contact between the coarse aggregate particles resulting in good shear strength and high resistance to rutting as compare to BC.

Mixture constituent:

A bituminous mix is made from aggregate, graded from maximum fraction to smaller fraction (usually less than 25mm IS sieve to the mineral filler, smaller than 0.075mm IS sieve), which are blended with bitumen binder to form a consistent mixture. This mixture is then laid and compacted to achieve an elastic body which is seamlessly impervious and hard. The study of mix design is to attain the suitable proportion of aggregate, bitumen and other additives if added.

Aggregates:

Aggregates play an important part in bituminous mix. Maximum aggregate by weight of mixture is added to take the maximum load bearing & adding strength characteristics to the mixture. Hence, the physical properties and quality of the aggregates are considerably important to pavement. There are three types of mineral aggregates used in bituminous mixes, which are given below

Coarse aggregates:

Aggregates which are retained on 4.75 mm IS sieve are called as coarse aggregates. A good quality coarse aggregate should have physical characteristic like hardness, angular in shape, toughness, durability, free from dust particles, clay, vegetation and organic matters. Aggregate with these above physical properties offers quite good compressive strength and shear strength and shows good interlocking characteristic.

Fine aggregates

Aggregates size ranging from 4.75 mm to 0.075 mm IS sieve are called Fine aggregates. As with coarse aggregate, Fine aggregate should be free from dusts, clay, vegetation, loam or organic matter. Fine aggregate fills the voids between the coarse aggregate and stiffens the binder

Mineral Filler

Aggregates those are smaller than 0.075 mm IS sieve is called as mineral filler. Filler are used to fill the voids in mix, which cannot be filled by fine aggregates. And also used to increase the binding property between the aggregates in the preparation of specimens.

Bitumen

Bitumen is essential in bituminous mix because of its visco-elastic and adhesive property. It binds the aggregate and fills the small voids which offers impermeability in mixture. At low temperature it acts like an elastic body and at high temperatures it behaves like a viscous liquid.

Additives

Additives are used in the mixture to provide better strength characteristic and engineering property. Now a days different additives such as fibers, polyethylene, minerals, polyester etc. are added either to stabilize or to improve performance property of the pavement.

Bitumen Emulsion

A bitumen emulsion is two phase system in which a significant amount of finely divided bitumen is suspended over an aqueous medium and stabilized by one or more suitable material. When the bitumen emulsion is applied on aggregate, it breaks down and start binding the aggregate. The first sign of break down occur when the color of bitumen emulsion film change from chocolate brown to black. Bituminous emulsion are especially used in patch and maintenance work. Three types of emulsion are there i.e. (i) Rapid setting (RS), (ii) Medium setting (MS), and (iii) Slow setting (SS)

Materials used in study

In this study following materials are taken in to consideration to prepare the bituminous mix.

- Stone chips (as coarse aggregate)
- Bottom ash (as fine aggregate)
- Fly ash (as mineral filler)
- VG-30 (as bitumen binder)
- Sisal fiber (as additives)
- SS-1 emulsion (as fiber coating agent)

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 as shown in Figure. 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 was procured from the nearby NSPCL thermal power plant (shown in Figure), while fly ash was collected from the nearby Adhunik Metaliks Power plant

(shown in Figure. The physical properties of coarse aggregates and fine aggregates which are primarily required for paving are given in Table



Figure Fly ash

Figure Bottom ash

Figure Stone chips

Physical property of coarse aggregate and fine

Property	Code specification	Test Result	
		Natural Aggregate	Bottom ash
Aggregate impact value, %	IS:2386 part-IV	14	-
Aggregate crushing value, %	IS:2386 part-IV	13.5	-
Los Angeles Abrasion test, %	IS:2386 part-IV	18	-
Soundness test (five cycle in sodium sulphate), %	IS:2386 part-V	3	8.2
Flakiness index, %	IS:2386 part-I	11.9	-
Elongation index, %	IS:2386 part-I	12.5	-
Water absorption, %	IS:2386 part-III	0.14	10.75
Specific gravity	IS:2386 part-III	2.7	2

Bitumen The paving bitumen grade VG-30 (VG-viscosity grade) was used in this experimental study. Initially, two bitumen grades such as VG-30 and VG-10 were used to study the Marshall characteristics of mixes with the materials considered. These initial trials resulted better Marshall characteristics, especially the Marshall stability in respect of mixes made up of bottom ash, fly ash and emulsion coated fiber with VG-30 bitumen as binder. The physical characteristics of VG-30 bitumen tested as per IS standards are given in Table

Physical property of binder

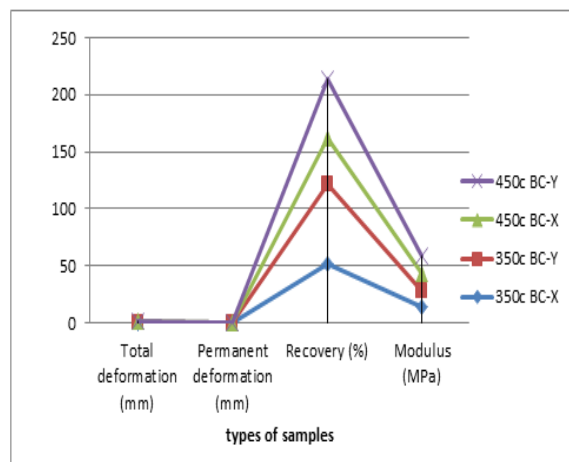
Physical Properties	IS Code	Test Result
Penetration at 25°C/100gm/5s, 0.01mm	IS:1203-1978	46
Softening Point, °C	IS:1205-1978	46.5
Specific gravity, at 27°C	IS:1203-1978	1.01
Absolute viscosity, Brookfield at 160°C, Centi Poise	ASTM D 4402	200

Chemical composition	
Composition	Test result
Cellulose, %	65
Hemicellulose, %	12
Lignin, %	9.9
Waxes, %	2
Physical property	
Property	Test result
Density, gm/cc	1.51
Tensile strength, MPa	510-640
Young's modulus, MPa	9.5-2.0
Elongation at break, %	2.0-2.5

RESULT:

Table: Test results of Static creep

Temperature (°C)	Samples	Total deformation (mm)	Permanent deformation (mm)	Recovery (%)	Modulus (MPa)
35°C	BC-X	0.25	0.11	52.23	13.60
	BC-Y	0.26	0.13	69.03	14.30
45°C	BC-X	0.20	0.08	40.21	15.40
	BC-Y	0.21	0.11	52.34	15.80



- Permanent deformation in mm BC-X
- Permanent deformation in mm BC-Y

Graph: Static creep test of different BC mixes at 35°C

Resilient Modulus (MR) Test: It is one of the most important mechanistic properties of bituminous mixes. The repeated loading indirect tensile strength test was performed as per ASTM D4123 on compacted bituminous mix containing fly ash-plastic waste composite material as filler in order to find resilient modulus values at different temperatures. The test was conducted by applying a compressive load in the form of haversine wave at 25°C, 35°C and 45°C for two Bituminous mixes (BC-X and BC-Y). The samples were conditioned for 5 hour in environmental chamber at given temperature and then subjected to repeated loading pulse width of 100 ms, and pulse repletion of 100 ms. The results are plotted. The particle size of shredded plastic is in the range of 2-8 mm which lies in the conformity of findings of earlier researchers. The melting temperature of plastic waste is around 125°C which melts at the heating temperature of the aggregates and fly ash. The decomposition temperature of plastic waste is 392°C, where the chemical properties of plastic waste changes. Therefore plastic waste can be conveniently used from temperature range of 120-180 °C. Test results on fly ash as shown in table 5 indicate that fly ash was non plastic. A lower value of methylene blue indicates lesser amount of clay and organic material in the fly ash. As shown in table-5 the optimum bitumen content was 5.2% for fly ash and 5.3% for fly ash-plastic waste composite by weight of aggregate. The damage caused by ingress of water is generally assessed by TSR value. The value of TSR of BC-X and BCY were recorded as 84.53% and 93.83%. Bituminous concrete with fly ash-plastic waste composite filler has tensile strength ratio 11% higher as compared to only fly ash (BC-X) indicates better resistance to moisture damage. On the basis of results obtained the bituminous concrete containing plastic waste composite as filler can be used in high rainfall locations. Rutting plays very important role for design and performance study of bituminous concrete mixes. observed rut depth values of bituminous concrete mixes are in the range of 3.15 to 4.0 mm VG-30 bitumen binder with fly ash and fly ash- plastic waste composite as filler. The value of creep modulus is higher for bituminous concrete mix containing fly ash-plastic waste composite. The value of permanent deformation was more in Bituminous concrete containing fly ash- plastic waste composite but at the same time percentage recovery was high for fly ash-plastic waste composite. Resilient modulus is the

measure of pavement response in forms of dynamic stress and corresponding strains. The plot of data in show that use of fly ash- plastic waste composite as filler has improved the diametric resilient modulus of the mixes in comparison of BC mixes with fly ash at all temperatures. The value of 1735 MPa was observed for BC mix containing fly ash- plastic waste composite at 45°C as compared to 1445 MPa without plastic waste. The average value of resilient modulus at 35°C was increased from 2900MPa to 4400 MPa upon addition of composite material as filler in BC mixes. The values of resilient modulus at 45°C are very high and are responsible for reduced rutting behavior of BC mixes when tested by wheel tracking test at same temperature.

CONCLUSIONS: Based on experimental study the following conclusions were drawn,

1. 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.

2. It is also observed that Marshall stability and flow values are quite acceptable when the coal ash content is within 15%.

3. 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.

4. An increase in fiber content and fiber length resulted in higher requirement of optimum bitumen content and emulsion for coating of the fibers.

the fly ash-plastic waste composite was responsible to increase the indirect tensile strength of the bituminous mix. The value of modulus of resilient at 35°C and 45°C was also increased due to incorporation of fly ash-plastic waste composite. It was observed that fly ash-plastic waste composite reduced rutting in bituminous concrete mix during wheel track testing. The creep modulus and creep recovery was also improved due to introduction of fly ash-plastic waste composite in bituminous concrete mixes.

REFERENCES:

[1] AASHTO T 283, "Standard method of test for resistance of compacted asphalt mixtures to moisture-

induced damage", American association of state highway and transportation officials.

[2] Ali, N., Chan, J. S., Simms, S., Bushman, R., & Bergan, A. T.; "Mechanistic evaluation of fly ash asphalt concrete mixtures". Journal of Materials in Civil Engineering, (1996), 8(1), 19-25.

[3] Al-Suhaibani, A. S., & Tons, E. T.; "Properties of fly ash-extended-asphalt concrete mixes." Transportation Research, (1991).

[4] ASTM D 1559, "Test method for resistance of plastic flow of bituminous mixtures using Marshall Apparatus", American society for testing and materials.

[5] ASTM D 6931, "Indirect Tensile (IDT) Strength for bituminous mixtures", American society for testing and materials, (2007).

[6] ASTM D 792, "Standard test methods for density and specific gravity of plastic by displacement", American society for testing and materials, (2008).

[7] Boyes, A. J.; "Reducing moisture damage in asphalt mixes using recycled waste additives" Diss. California Polytechnic State University, San Luis Obispo, (2011).

[8] Chakroborty, P., & Das, A. "Principles of Transportation Engineering", Prentice Hall of India, New Delhi, (2010), pp 294-299.

[9] Colonna, P.; Berloco, N., Ranieri, V., & Shuler, S. T. (2012), "Application of bottom ash for pavement binder course.", Procedia-Social and Behavioral Sciences 53 (2012): 961-971.

[10] Gunalaan, V.; "Performance On Coal Bottom Ash In Hot Mix Asphalt" International Journal of Research in Engineering and Technology, (Aug 2013) eISSN: 2319-1163 | pISSN: 2321-7308.

[11] Hadiwardoyo, S. P.; "Evaluation of the addition of short coconut fibers on the characteristics of asphalt mixtures." Civil and Environmental Research 3.4 (2013): 63-73.