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Effect of LDPE Coated Flaky Aggregates on the Properties of Bituminous Concrete Mixes.

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Abstract

The shape and gradation of the aggregate influence the interlocking of the particles in bituminous mixes. Bituminous mixes with angular particles show better stability when compared with the mixes comprising of considerable flaky and elongated particles. The shape of the particles also has greater impact on workability and voids in the mix. The flaky and elongated particles tend to break during compaction and affect the stability of the mix. In order to improve the performance of the flaky material, in the present study, the aggregates are coated with LDPE plastic and the mechanical properties are determined. These plastic coated aggregates, both angular as well as flaky particles are used in the bituminous mixes and the properties are studied. Results show that considerable improvement in the case of plastic coated aggregate.

***Key Words*:**bituminous mix; flakinesse index; LDPF plastic; optimum binder content.

1 INTRODUCTION

Reliable road network is the prime requirement of any country, particularly for a vast and diverse country like India it is utmost necessary to provide connectivity to the rural areas for social and economic progress. With the government schemes like Pradhan Mantri Gram Sadak Yojana (PMGSY) the road construction scenario has taken a big leap forward. Lack of good quality construction materials in near vicinity is one of the hurdles that considerably hamper the process. So the construction method should be such that with the available construction material it should be possible to have long lasting roads. Construction of flexible pavements is preferred in India because of their low initial cost and adaptability for stage construction. A flexible pavement is a layered structure that receives the axle loads directly and transmits the same to the underneath layers without being overstressed. Aggregates constitute major part of the pavement structure. The engineering properties of the aggregates, as well as its shape (i.e. form and angularity) and texture, substantially affect the overall performance of the pavement. A number of researchers reported that form and surface texture of aggregates have significant effect on the mechanical properties of the bituminous mixes, such as shear resistance, durability, stiffness, fatigue resistance, rutting resistance, workability etc. Mineral aggregates constitute approximately 90% to 95% of Hot Mix Asphalt (HMA) by weight. The transfer of load is influenced by the aggregate interlock, particle friction and cohesion for stability (Ioannides and Korovesis, 1990) The gradation of aggregates affects considerably the performance of different types of HMA (Aodah HH et al, 2012) The overall strength of the compacted bituminous concrete and aggregate-bitumen bond would largely influenced by the aggregate shape and surface texture.

Considerable research has been carried out to determine the suitability of plastic waste as a modifier in construction of bituminous mixes (Schroceder, 1994; Punith and Veeraragavan, 2007). Additives such as styrene based polymers, polyethylene based polymers, polychloroprene, gilsonite, various oils, and many other modifiers including tall oil have been added to bitumen to enhance various engineering properties of binder (Al- Hadidy and Tan, 2008). Studies showed that the coating of waste plastics on stone aggregate

improves the physical properties of aggregates as well as mechanical properties of mixes such as Marshall Stability, indirect tensile strength and rutting of bituminous concrete mixes (Sabina et al., 2009). Proper geometry and shape of road aggregates play a vital role in the performance of bituminous mixes, because, flaky particles prevent the mixture to compact sufficiently (Roberts, Kandhal, Lee and Kennedy 1991), leading to the increase of air voids in mineral aggregates (VMA) (Brown, McRae, and Crawley 1989; Vavrik, Fries and Carpenter 1999). They are also vulnerable to the crushing during the compaction process and expose uncoated aggregate surfaces (Prowell, Zhang, and Brown 2005). Some researchers have investigated the effect of flaky particles on aggregate breakdown during the compaction process. Brown et al. (1989) have performed grading tests on aggregates recovered from an asphaltic mixture which was compacted with Marshall Apparatus using 50 blows on each side. It was found that flaky particles are more prone to breakdown during the compaction (Brown, McRae, and Crawley 1989). The particle shape determines the compatibility of the mix to a dense configuration and also influences the internal resistance of a mix. Four particle shapes were evaluated for their rutting resistance and compatibility. The results showed that the cubical aggregate possess the best rutting resistance. The presence of Flaky and/or elongated aggregates resulted in lower compatibility and higher breakage (Chen, Jian-Shiuh Hsieh, Weichou Liao, Min-Chih, 2013 ; Kandhal and Parker, 1998).

These broken aggregates will create more uncoated aggregate in the bituminous mix, making it more susceptible to moisture damage and subsequent pavement distress (Sterling, V. A. 2011). Krutz and Sebaaly (1993) found a direct correlation between the rutting potential of HMA mixtures and the shape and texture of coarse aggregate particles. Oduroh (2000) showed that the orientation of the flaky and elongated aggregate in bituminous mixture has significant effect and reduces the mix resistance against shear deformation leading to premature failure. In the present study an attempt is made to study the mechanical properties of flaky aggregates by coating them with different plastic contents varying from 2% to 10% in increments of 2%.

2 OBJECTIVES

The objectives of this investigation are to observe the followings:-

- Study the mechanical properties of aggregates by varying flaky material ranging from 0% to 50% in increments of 10%.
- Study the mechanical properties of aggregates by adding waste plastic varying from 0% to 8% in increments of 2%.
- To study the volumetric properties of bituminous mix specimen by using plastic coated aggregates with varying amounts of waste plastic material and flaky material.
- To compare the volumetric properties of bituminous mix specimen with and without the plastic coated flaky aggregates.

3 METHODOLOGY

The work is carried out in 3 stages. In the first experimental phase, mechanical properties of aggregates are determined by varying the flaky material. All the flaky particles are separated from the aggregates collected. Six different aggregate mixtures are prepared by changing the percentage of flaky aggregates as 0, 10, 20, 30, 40, 50 in the total aggregates. The mechanical properties of the aggregates such as impact value, crushing value, water absorption and Los angeles abrasion are determined with different percentages of flaky particles. The results are shown below in Table 1. In the second stage, The LDPE waste plastic are segregated cleaned and dried to remove impurities from them. Then, cut into a size of 2 - 3 mm using shredding machine. The aggregate mix is heated to 165°C and the shredded plastic is added in increments of 2 8% by weight of aggregate in increments of 2%. Aggregates are cooled to room temperature and tests are conducted as per IS 2720.

In the third stage, bitumen mix is prepared with Plastic coated aggregate with a plastic content of 6% by weight of aggregate. Mixes are prepared with plastic coated flaky aggregates with varying percentages of flaky material ranging from 10% to 50% in increments of 10%. Volumetric properties are determined. Marshall specimens were prepared in the laboratory giving 75 blows on each

side to arrive at the optimum bitumen content. Optimum bitumen content was determined for different plastic coated flaky aggregates. Volumetric properties of specimens containing different amounts of LDPE coated flaky material such as air voids content and VMA were calculated. Stability of the specimens was determined using Marshal Apparatus.

3.1 Material Properties

TABLE I PROPERTIES OF BITUMEN

S.No	Property	Value	Test Method
1	Penetration Grade	60/70	IS: 1203-1978
2	Softening Point, 0C	57	IS: 1205-1978
3	Ductility, Cms	87	IS: 1208-1979
4	Specific gravity	1.02	IS: 1202-1980
5	Flash Point, 0C	285	IS: 1209-1981
6	Fire Point, 0C	330	IS: 1209-1981

3.2 Aggregate

The aggregates are procured from local crusher unit and physical and mechanical properties are determined as per the IS 2720.

3.3 Plastic

Waste plastic of carry bags made up of Low Density Polyethylene (LDPE) is used in the study. These plastic carry bags are shredded and used for the present investigation. They are cut in to 2 - 3 mm in order to have uniform distribution when blended with aggregate.

4 RESULTS AND DISCUSSION

4.1 Effect of LDPE coated Flaky material on Mechanical Properties of aggregates

The particle shape of aggregates is one of the important physical properties of aggregates, which affect the performance of unbound base course as well as bitumen mixes. The interlocking properties of the aggregates tend to get affected because of breaking of the

flaky particles during traffic operations. From the results it is observed that the as the flakiness index is increased, the performance of the particles tend to reduce. It is observed that the aggregate crushing value increases by 70.62 %, Los Angeles abrasion value also increases by 61.97 % , aggregate impact value increases 37.96% by and water absorption increases by 300% when the flakiness index increases to 50%. The results are tabulated in Table II, Table III, Table IV and Table V. From the tables, it is also evident that the performance of flaky particles is much better when the particles are coated with LDPE plastic. As the plastic content is increased, the mechanical properties have improved considerably. At a plastic content of 6% by weight of aggregates, the particles have become impermeable.

TABLE II AGGREGATE CRUSHING VALUE

Plastic Content %	% Flaky Material					
	0	10	20	30	40	50
0	22.67	24.22	26.14	29.35	33.62	38.68
2	17.44	19.04	23.84	26.78	32.06	36.05
4	15.91	16.25	19.28	22,38	29.76	34.38
6	13.20	13.95	16.56	20.65	28.43	32.50
8	11.38	12.25	14.20	19.32	24.54	30.32

TABLE III AGGREGATE IMPACT VALUE

Plastic Content %	% Flaky Material					
	0	10	20	30	40	50
0	24.92	26.24	27.78	29.56	32.6	34.38
2	19.27	21.65	23.15	26.35	30.74	32.56
4	12.25	14.35	17.32	18.54	23.54	27.85
6	10.96	11.7	13.15	16.75	19.54	22.45
8	8.33	9.38	11.48	13.69	17.85	20.75

TABLE IV LOS ANGELES ABRASION VALUE

Plastic Content %	% Flaky Material					
	0	10	20	30	40	50
0	24.56	27.85	30.15	33.12	37.45	39.78
2	23.66	25.26	27.16	30.82	33.76	37.65
4	17.86	19.14	21.25	24.32	27.18	28.39
6	16.53	18.29	19.56	22.68	24.15	25.56
8	15.89	16.35	17.44	18.45	21.86	23.75

TABLE V WATER ABSORPTION VALUE

Plastic Content %	% Flaky Material					
	0	10	20	30	40	50
0	1.1	1.5	1.8	2.5	3.0	3.2
2	0.6	0.8	1.2	1.4	1.5	1.7
4	0.1	0.1	0.2	0.3	0.4	0.6
6	0	0	0	0	0	0
8	0	0	0	0	0	0

4.2 Effect of Flaky aggregate on Volumetric properties of Bitumen Mixes.

In order to fulfill the structural and fundamental requirements of bituminous pavements, it is imperative to design a bituminous mix which can withstand the design traffic loads. The volumetric properties of the bituminous mix such as theoretical maximum specific gravity, bulk unit weight percentage air voids, voids in the mineral aggregate voids filled with bituminous are the parameters to be considered to produce a desirable mix.

Percentage Air Voids : (Va) It represents the percentage of air voids present in the total compacted mix. The properties such as permeability and durability depend to a great extent on percentage of air voids. Mixes with unacceptably high percentage air voids tend to undergo further compaction under the application of traffic wheel loads causing rutting and permanent deformation in bituminous layer. It is observed that tha air voids increase as the flaky material increases.

VMA : Voids in mineral aggregate The stability of bitumen mix depends on the bond between the aggregate particles. The bitumen film around the aggregates help adequate bond between the aggregates. In order to have adequate bitumen film thickness, sufficient inter granular space between compacted aggregates, known as voids in mineral aggregates, VMA is necessary. It is observed that VMA increases with increase in Flakiness Index. Flow Mixes with high air voids are subjected to more deformation under the applied loads. The flow value increases as flakiness index increases.

Percentage Voids Filled with Bitumen: It represents the % voids in the mineral aggregates (VMA) filled with bitumen. Low VFB indicates the deficiency of bitumen in the mix which results in inadequate coating of the aggregates with bitumen in the mix which

results in low binding and subsequent rutting on the other hand excess bitumen signifies that maximum voids are occupied with bitumen and at higher pavement temperatures, results in bleeding.

Marshall Quotient (MQ) also known as rigidity ratio is the ratio of stability to flow value of the mixture and the Marshall Quotient is determined for different bituminous mixes. It is found that as the flaky material increases, the mix shows lower Marshall Quotient values. The mixes with LDPE coated aggregates have shown higher values when compared with uncoated aggregates. Higher Marshall Quotient implies better resistance against permanent deformations due to their high stability can be used in pavements where stiff bituminous mixture is required.

TABLE VI VOLUMETRIC PROPERTIES WITH DIFFERENT PERCENTAGES OF FLAKY AGGREGATES

Flakiness Index (%)	Gb	Vv (%)	Vb (%)	VMA(%)	VFB (%)	Flow (mm)	Stability (in kN)	Marshall Quotient
0	2.415	3.89	11.71	15.6	75.1	2.25	10.430	4.635
10	2.389	4.05	11.96	16.01	74.7	2.25	9.825	4.36
20	2.360	4.1	12.33	16.43	75.04	2.25	9.025	4.01
30	2.340	4.2	12.84	17.04	75.35	2.50	8.305	3.32
40	2.300	4.3	13.31	17.61	75.6	2.75	7.395	2.69
50	2.280	4.4	13.34	17.74	75.2	3.00	6.520	2.27

TABLE VII VOLUMETRIC PROPERTIES OF BITUMEN MIX WITH DIFFERENT PERCENTAGES OF 6% LDPE COATED FLAKY AGGREGATES

Flakiness Index (%)	Gb	Vv(%)	Vb(%)	VMA (%)	VFB(%)	Flow(mm)	Stability (in kN)	Marshall Quotient
0	2.371	3.5	8.91	12.41	71.8	2.75	18.825	7.46
10	2.26	3.7	9.22	12.92	71.36	2.75	18.1	6.84
20	2.246	3.9	9.64	13.54	71.2	2.75	17.025	6.2
30	2.22	4.2	9.65	13.85	69.65	3.25	15.305	4.71
40	2.19	4.4	9.98	14.38	69.4	3.5	12.395	3.54
50	2.16	4.6	10.65	15.43	69.02	3.75	11.820	3.152

5 CONCLUSIONS

- The mechanical properties of aggregates with and without plastic coating are studied with different percentages of flaky

material.

- The aggregate crushing value, Impact value and Los Angeles abrasion value increases as the percentage of flaky material increases for the aggregate with and without LDPE plastic coating.
- The water absorption for flaky material is high when compared with aggregates with plastic coating. At 6% plastic coating, the aggregates have become practically impervious.
- The plastic coated aggregates have shown better Marshall stability values when compared with the aggregates without plastic. At a flakiness Index of 50% the bitumen mix with 6% plastic coated aggregates showed a stability of 11.82 kN, where as aggregates without plastic coating have resulted 6.52 kN. With the addition of plastic coating, the Marshall stability value increases by 81%.
- Increase of flakiness index decreases the stability due to poor performance of flaky aggregates in the mix. It is evident that flaky aggregates are weak and tend to break during compaction. Flaky material do not have a good interlocking ability to form a good bond with adjacent aggregates.
- The performance of Plastic coated aggregates is better when compared with aggregates without plastic coating.

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