Experimental Study Of Partial Replacement Of Aggregate By Waste Foundry Sand In Flexible Pavement.

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ABSTRACT-Bituminous mixes are most commonly used all over the world in flexible pavement construction. Traditionally aggregates, sand, bitumen etc. are used for pavement construction. Commonly quarry dust is used as filler material in pavement work. Quantity of these conventional materials is reducing gradually. Also, cost of extracting good quality of traditional material is increasing. Due to the decreasing effect of traditional material we are looking for alternative materials for pavement construction, and Industrial waste materials such as Waste Foundry Sand, Fly ash, Ggbs. If these materials can be suitably utilized in pavement construction, the disposal and pollution problems can be reduced. These industrial wastes occupies large amount of space around plants and throughout the country. Keeping in mind the need for bulk use of industrial wastes in India, it was thought an expedient to test these materials and develop specifications to enhance the use of these industrial wastes in pavement construction, from which higher economic returns is possible. The aggregate mix heated to 160^0C and the mix (bitumen) is effectively mixed with aggregate. The resulted mix is used for road construction. Various percentages (0, 25, and 50%) of Foundry sand were used, and the proposed mix designs for bituminous concrete mix were conducted in accordance with Marshall Mix design.

The experiment results revealed that the addition of Foundry Sand has a significant improvement on the properties of bituminous concrete mix.

Keywords: Waste Foundry Sand(WFS),Bituminous Concrete(BC),Marshall stability & Economic returns.

I. INTRODUCTION

Waste Foundry Sand (WFS) is generated by industries that use sand to form moulds for castings. There are about 6000 foundry industries in India. In India it is currently producing nearly 10 million metric tons of Waste Foundry Sand in a year.

In India Foundry Industries had targeted to produce about 20 million metric tons in the year of 2020. This is the high volume waste and it is mostly in the cases of non-hazardous. Now a days foundry industry are looking to reduce the cost of waste disposal. The scarcity of landfill space has also resulted in costly land disposal facilities. In construction practices the Waste Foundry Sand can be used in various places such as sub-base, sub-grade, embankment and for aggregate in bituminous mixture.

II. TESTS ON AGGTEGATE.

To ensure aggregates continually meet the required specification, and thus to ensure the end product is suitable for its intended use, a series of tests will be carried out.

A. *Sieve analysis (IS : 2386 (Part I) – 1963)*

Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. A set of IS Sieves of sizes - 12.5 mm , 10 mm , 6.3 mm , 4.75 mm , 3.35 mm , 2.36 mm , 1.18 mm , 600 µm , 300 µm , 150 µm and 75 µm are used. The test sample will be dried to a constant weight at a temperature of 110 + 5 C and weighed. The sample will be sieved by using a set of IS sieves. On completion of sieving, the material on each sieve will be weighed. Cumulative weight passing through each sieve will be calculated as a percentage of the total sample weight. It is described in the table1.

Based on the weight retained on each sieve, the grain size distribution will be formulated. A mixture of these gradations in design mix help in interlocking between aggregate and reduce the air voids.

Total sample weight	=	1000 g
less than 4.75 mm	=	150 g
6.3 mm	=	260 g
10 mm	=	360 g
12.5 mm	=	80 g

Table1: Result of aggregate sieve analysis test.

B. *Aggregate impact test (IS: 2386 (Part IV) – 1963).*

The aggregate impact test is carried out to evaluate the resistance to impact of aggregates. Aggregates passing 12.5

mm sieve and retained on 10 mm sieve is filled in a cylindrical steel cup of internal die 10.2 mm and depth 5 cm which is attached to a metal base of impact testing machine. The material is filled in 3 layers where each layer is tamped for 25 number of blows. Metal hammer of weight 13.5 to 14 Kg is arranged to drop with a free fall of 38.0 cm by vertical guides and the test specimen is subjected to 15 number of blows. The crushed aggregate is allowed to pass through 2.36 mm IS sieve. The weight of aggregate passing through 2.36 mm is sieve is listed in table 2. And the impact value is measured as percentage of aggregates passing sieve (W2) to the total weight of the sample (W_1).

Aggregate impact value $=W_1/W_2 \times 100$

Sample weight	=	450 g
Pass through 2.36 mm sieve	=	112 g
Retained	=	338 g
Impact value	=	24.88 g

Table2: Result of aggregate impact test.

C. Specific gravity of aggregates (IS 2386 (Part III) – 1963)

The specific gravity is defined by ISI as the ratio of the mass of a given volume of the aggregate to the mass of an equal volume of water, the temperature of both being specified as 27 C $\pm$ 0.1 C. The specific gravity bottle will be cleaned, dried and weighed. It will be then filled with distilled water and kept in contained for half an hour at above specified temperature. The bottle is then removed and weighed. The aggregate will be filled into specific gravity bottle up to half talking care to prevent air bubbles. The sample bottle will be allowed to stand for half an hour at temperature of 27 C and then weighed. Then the remaining space will be filled with distilled water and weighed. The table 3 shows various weights obtained in this test

The specific gravity of aggregate is given by,

G = Dry mass of aggregate /Mass of equal volume of water

W_1	=	675 g
W_2	=	1842 g
W_3	=	1545 g
W_4	=	2272 g
Specific gravity	=	2.65

Table3: Specific gravity result of aggregate.

III. TESTS ON WASTE FOUNDRY SAND.

The tests are being conducted to confirm whether the waste foundry sand is suitable for its intended use, a series of tests will be carried out.

A. Chemical Properties of Waste Foundry Sand.

The chemical property of Waste Foundry Sand is studied to determine the nature of foundry sand. The table below describes various content in WFS.

Silica content	=	70-80%
Clay	=	15-20%
Bento coal	=	5-8%
Sulphur	=	1-2%

Table4: Chemical properties of WFS.

B. Specific gravity Of Waste Foundry Sand.

The specific gravity is defined as the ratio of the mass of a given volume of the Waste Foundry Sand to the mass of an equal volume of water. The specific gravity bottle will be cleaned, dried and weighed. It will be then filled with distilled water and kept in contained for half an hour. The bottle is then removed and weighed. The Waste Foundry sand will be filled into specific gravity bottle up to half talking care to prevent air bubbles. The sample bottle will be allowed to stand for half an hour and then weighed. The table 5 shows various weights obtained in this test. Then the remaining space will be filled with distilled water and weighed.

The specific gravity of Waste Foundry Sand is given by,

G = Dry mass of Waste Foundry Sand /Mass of equal volume of water

W_1	=	675 g
W_2	=	1700 g
W_3	=	1543 g
W_4	=	2074 g
Specific gravity	=	2.07

Table5: Specific gravity result of Waste Foundry sand.

IV. TESTS ON BITUMEN.

The following conventional tests will be carried out on the bitumen being used in this study to determine the properties of binder.

A. Penetration test (IS 1203 – 1978).

The penetration value of bitumen is measured by distance in tenths of mm that a standard needle would penetrate vertically into bitumen sample under standard conditions of test. By this test we can determine the hardness or softness value of bitumen. In this test, firstly heat the bitumen above its softening point and pour it into a container of depth attest 15mm. bitumen should be stirred wisely to remove air bubbles. Then cool it to room temperature for 90 minutes and then placed it in water bath for 90 minutes. Then place the container in penetration machine adjust the needle to make contact with surface of sample. Make dial reading zero and release the needle for exactly 5 seconds and note down the penetration value of needle for that 5 seconds. Just repeat the procedure thrice and note down the average value. The table6 shows various penetration value in consecutive 5 seconds.

1^{st} 5 seconds	=	5.8 mm
2^{nd} 5 seconds	=	5.5 mm
3^{rd} 5 seconds	=	6.9 mm
Penetration value	=	6.06 mm

Table6: Penetration test result of Bitumen.

B. Ductility test (IS 1208 – 1978).

Ductility is the property of bitumen that permits it to undergo great deformation or elongation. Ductility is defined as the distance in cm, to which a standard sample or briquette of the material will be elongated without breaking. Dimension of the briquette thus formed is exactly 1 cm square. The bitumen sample is heated and poured in the mould assembly placed on a plate. These samples with moulds are cooled in the air and then in water bath at 27 C temperature. The excess bitumen is cut and the surface is levelled using a hot knife. Then the mould with assembly containing sample is kept in water bath of the ductility machine for about 90 minutes. The sides of the moulds are removed, the clips are hooked on the machine and the machine is operated. The distance up to the point of breaking of thread is the ductility value which is reported in cm. The ductility value gets affected by factors such as pouring temperature, test temperature, rate of pulling etc.

DUCTILITY VALUE	=	770 mm

C. Specific gravity test (IS 1202 – 1978).

The specific gravity is defined by ISI as the ratio of the mass of a given volume of the bituminous material to the mass of an equal volume of water, the temperature of both being specified as 27 C $\pm$ 0.1 C. The specific gravity bottle will be cleaned , dried and weighed. It is then filled with distilled water and kept in container for half an hour at above specified temperature. The bottle will be removed and weighed. The bituminous material will be heated to pouring temperature and will be poured into specific gravity bottle up to half talking care to prevent air bubbles. The sample bottle will be allowed to stand for half an hour at temperature of 27 C and then weighed. Then the remaining space will be filled with distilled water and weighed. The table7 describes various weight obtained while conducting this test. Bitumen with low range of specific gravity will have higher penetration value.

The specific gravity is given by,

G = Weight of bituminous material / Weight of equal volume of water.

W_1	=	0.093 g
W_2	=	0.187 g
W_3	=	0.293 g
W_4	=	0.295 g
Specific gravity	=	1.02

Table7: Specific gravity result of bitumen.

In case the bitumen contains mineral impurity, the specific gravity will be higher.

V. TESTS ON MARSHALL SPECIMENS.

In the Marshall method, each compacted test specimen is subjected to tests and analysis in the order listed below.

1. Air voids.
2. Stability.
3. VFB (Voids Filled with Bitumen).
4. % of air voids.
5. Voids in mineral aggregate.

The equipment required for the testing of the 102 mm diameter X 64 mm height specimen is Marshall Testing Machine, a compression testing device. It is designed to apply loads to test specimens through cylindrical segment testing heads at a constant rate of vertical strain of 51 mm per minute. Two perpendicular guide posts are included to allow the two segments to maintain horizontal positioning and free vertical movement during the testis is equipped with a calibrated proving ring for determining the applied testing load. A universal testing machine equipped with suitable load and deformation indicating devices may be used instead of the Marshall testing frame. Here by the table 8,9,10 shows the result of conventional mix, 15%and 25% replacement of aggregate by Waste Foundry Sand respectively.

- Conventional mix:

BITUMEN CONTENT (%)	5	5.5	6
WEIGHT IN AIR (g)	1260	1266	1272
STABILITY (N)	1830	1842	1853
FLOW VALUE	2.92	3.27	3.5

BITUMEN CONTENT (%)	5	5.5	6
VOIDS IN MINERAL AGGREGATE (%)	5.90	5.75	5.66
% OF AIR VOIDS	3.27	3.72	3.03
% OF VOIDS FILLED IN BITUMEN	44.53	45.73	46.96

Table8: Result of conventional bitumen mix.

- 15% replacement of aggregate by WFS in mix:

BITUMEN CONTENT (%)	5	5.5	6
WEIGHT IN AIR (g)	1260	1266	1272
STABILITY (N)	1894	1906	1917
FLOW VALUE	3.05	3.42	3.65
VOIDS IN MINERAL AGGREGATE (%)	5.55	5.36	5.02
% OF AIR VOIDS	3.18	3.04	2.90
% OF VOIDS FILLED IN BITUMEN	47.81	49.06	52.40

Table9: Results for 15% replacement of aggregate by WFS in mix.

- 25% replacement of aggregate by WFS in mix:

BITUMEN CONTENT (%)	5	5.5	6
WEIGHT IN AIR (g)	1260	1266	1272
FLOW VALUE	2.89	3.22	3.52
VOIDS IN MINERAL AGGREGATE (%)	5.71	5.53	5.29
% OF AIR VOIDS	3.20	3.07	3.01
% OF VOIDS FILLED IN BITUMEN	46.05	47.55	50.85

Table10: Results for 25% replacement of aggregate by WFS in mix.

VI. CONCLUSION.

The conclusions drawn from this study are as follows:

- While increase in percentage of replacement of aggregate by WFS material the binding capacity and tensile strength also gradually increased.
- As a result the use of WFS material reduces the maintenance cost of pavement.
- However, WFS has little effect on top-down fatigue cracking resistance and moisture susceptibility of the sample mixes.
- Based on result obtained, WFS appear to be especially beneficial for the NH and SH Infrastructure works.
- The stability value and split-tensile strength of the Marshall Stability test tends to decrease when increase in proportion of WFS materials.
- 25 % replacement of WFS materials stuff results in reduction of stability and split-tension strength when compare to 15% replacement for the 6% of binder content.
- Hence the replacement percentage increases by 5% starts from 15% and increase for the each bitumen content.
- From this study it is observed that Waste Foundry Sand may be used as an alternative for aggregate as partial replacement where 15% replacement with quarry dust, which is used for flexible pavements works.

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