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Experimental Study on Partial Replacement of Waste Foundry Sand in Flexible Pavements

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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. Concerned about this, we are looking for alternative materials for pavement construction, and Industrial waste materials such as Foundry Sand are one such category. If these materials can be suitably utilized in pavement construction, the disposal and pollution problems may be reduced. These industrial wastes occupies large amount of space around plants 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 may be possible. Various percentages (0, 25, 30, 35, 40, 50, and 75%) 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 and Indirect tensile strength.**

I. INTRODUCTION

Waste Foundry Sand (WFS) is generated by industries that use sand to form moulds and cores for castings. There are about 6000 foundries in India, which is placed as rank three in the global position in terms of casting production in a year [18]. India is currently producing nearly 10 million metric tons in a year and has generated export revenue of Rs.12180 crores. Indian Foundry Industry has targeted to produce about 20 million metric tons in the year 2020.To achieve this target it has planned to pump 20,000 crores rupees in Indian Foundry Industry. This is a high volume waste and in most cases is non-hazardous. Over the past few years foundries have seen the cost of operations increase and the demands for castings decrease. One area which is being looked at by the foundry manager today is in cutting the cost of waste disposal. The scarcity of landfill space has also resulted in costly land disposal facilities. This turn of events has fostered new and innovative approaches to cost control. Constructive applications of foundry wastes may include use in embankments, sub-grades, Sub-bases, backfills, Portland cement kiln feed, Portland cement concrete aggregate, aggregates for bituminous mixtures, rock wool silica and alumina additive, and, snow and ice abrasive. In view of the benefits to be gained from the utilization of WFS as a construction material, research on this subject is desired. Unfortunately, an extensive review of the literature reveals that the amount of laboratory and field data on the properties and performance of this material for highway purposes is very limited. In order to develop constructive uses of foundry sand, a substantial database on their properties is needed.

This study presents a review of available information on the WFS, their generation process including molding and casting processes, potential variables, environmental concerns and beneficial uses of waste foundry sand.

1. Scope:

- An experimental work has been proposed to improve the properties of bituminous concrete pavement using WFS.
- Laboratory studies will be carried out on bituminous concrete mix to evaluate engineering properties using Marshall Stability and Indirect Tensile Strength studies.

2. Objective:

Main objectives of bituminous mix design are to find;

- Optimum bitumen percentage replacement in the BC mixes.
- To compare the High Performance BC mixes with the Conventional BC mixes in term of stability, flow value and indirect tensile strength.

3. Role of Foundry Sand in Bituminous Pavements

The disposal of foundry sand occupies a significant portion of landfills and causes many serious environmental problems. This study aims to investigate the feasibility of utilizing foundry sand as fine aggregates in bituminous concrete mixtures. Foundry sand is a finer material which composite with bituminous concrete and gives high stability value, indirect tensile value and low air voids present in the mixes due to particle size of the foundry sand. Material is very finer hence the mixes required high bitumen percentage compare to conventional mixes when percentage of WFS as increased. The use of foundry sand as the fine portion of aggregates can enhance resistance to moisture damage and resistance to the permanent deformation of bituminous concrete mixtures. Significant quantities of foundry sand are produced as by-product every year from casting industries. Although it can be used as an artificial source of aggregates, it is sent to landfills for disposal. For the present study, the foundry sand collected from Bradken India Private Limited, Coimbatore.

II. METHODOLOGY

This chapter deals with the project work flow methodology of our project.

1. Steps Involved in the Present Work:

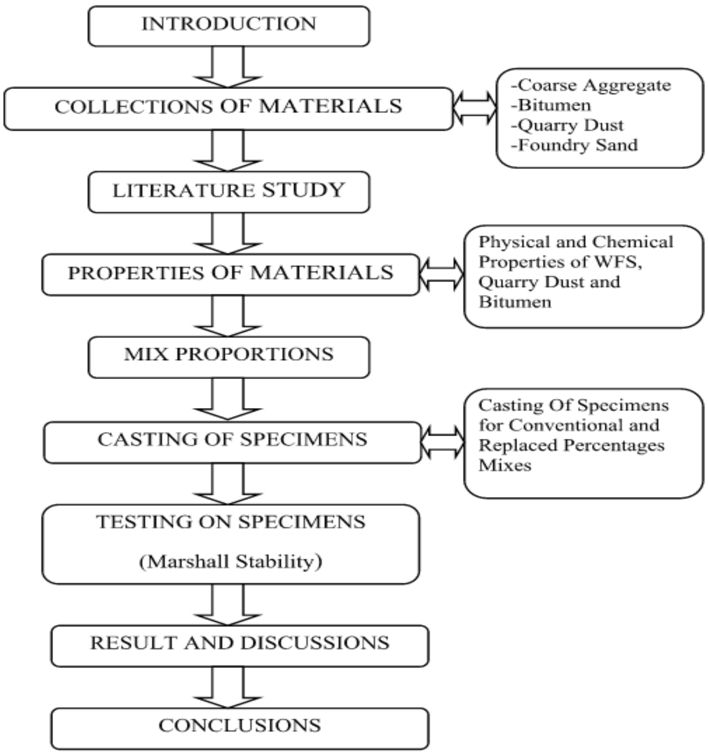

Fig 1: Work Methodology

2. Aggregates:

As per the Indian Roads Congress (IRC 29-1988). The material for the bituminous concrete mixes are selected

The basic materials used are as follows:

- Aggregates of size 19mm, 13.2mm, 6.7mm.
- Quarry dust of size lesser than 4.75mm
- Foundry sand of size lesser than 4.75mm
- Bituminous Binder of grade VG-30

Waste Foundry Sand: Waste Foundry Sand (WFS) is generated by industries that use sand to form molds and cores for castings. The annual generation of WFS in Indian is about 200,000 tons. This is a high volume waste and in most cases is non-hazardous. Over the past few years foundries have seen the cost of operation increases and the demands for castings decrease. The properties of WFS value are tabulated in table 2.

3. Micro Structural Analysis of WFS:

SEM Analysis:

SEM is an effective tool for visually examining the particles that are too small to be seen under an optical microscope. The SEM works by aiming an electron beam at the surface of the specimen.

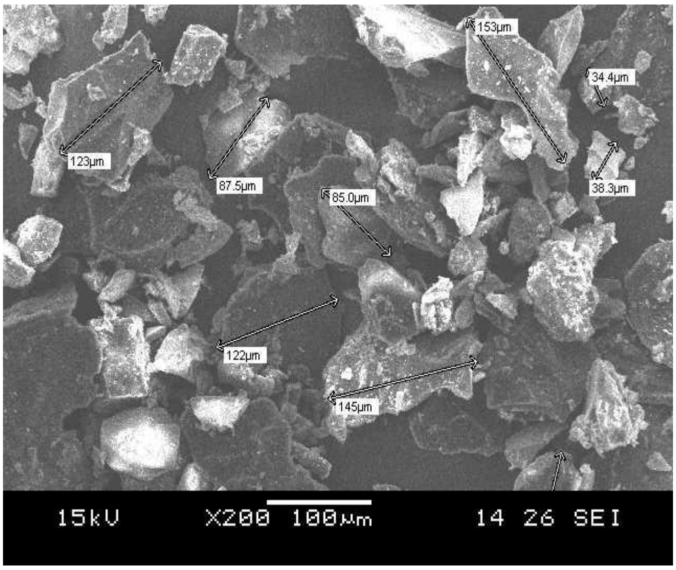

Fig 2: SEM Analysis of WFS

SEM Micrographs showing the shape and surface texture of Foundry Sand particles respectively. The SEM studies showed that the sand- and silt-size steel slag particles had sub-rounded to angular shapes. Distinct asperities and edges were visible in angular, bulky particles. Most of the sand and silt-size particles examined under the SEM had rough surface textures.

XRD Analysis:

In the next step X-Ray Diffraction (XRD) analysis is performed to determine the silica phase of the samples. The samples are scanned by an X-Ray diffract-meter which is shown in Figure.

XRD report summarizes all of the mineral phases that were identified in the Foundry sand samples. The mineral phases identified in the Foundry sand samples were determined as major or minor phases depending on the intensity of the peaks, which is an indication of the quantity of the minerals present in the samples. The most abundant mineral phase present in steel slag is Silicon oxide 75.43% (SiO_2), % Carbon 23.41%, and % Sulphur 1.156%

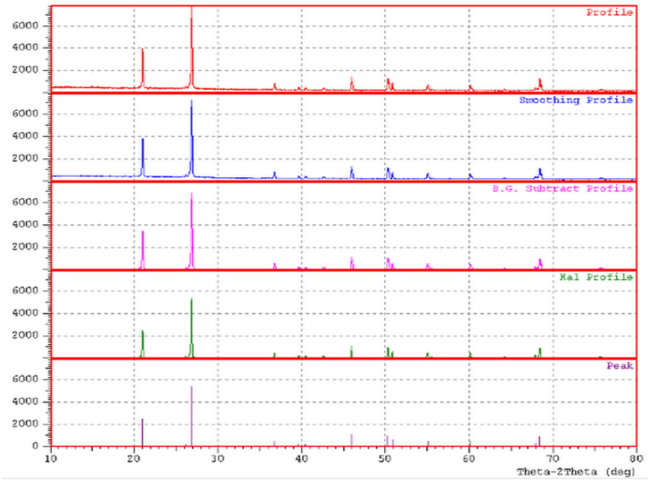

Fig 3: XRD Analysis of WFS

Table: 1: Chemical Properties Of Foundry Sand

Chemical properties	
% of SiO_2	75.434
% Carbon	23.41
% Sulphur	1.156
Appearance	Black

4. Properties of Material:

The physical properties of the foundry sand, quarry dust, coarse aggregate and bitumen are the tested as per the standard codes, the specified properties of the materials as follows.

Properties of Quarry Dust and Foundry Sand:

Table 2: Properties Of Foundry Sand And Quarry Dust

S.No	PROPERTIES	FOUNDRY SAND	QUARRY DUST	STANDARD VALUE
1	Specific gravity	2.31	2.73	2.2-2.85
2	Fineness modulus	3.68	3.95	2.2-3.2
3	Gradation(Zone)	Zone-IV	Zone-II	I – IV

Coarse Aggregate:

Table 3: Properties of Coarse Aggregate

S.No	PROPERTIES	REFERENCES	OBSERVED VALUES	STANDARD VALUES
1	Specific gravity	IS:2386-1963 Part-2	2.69	2.6-2.9
2	Water absorption	IS:2386-1963 Part-3	1.08%	Max 2%
3	Crushing value	IS:2386-1963 Part-4	18.15%	Max 30%
4	Impact value	IS:2386-1963 Part-4	18.81%	Max 20%
5	Abrasion test	IS:2386-1963 Part-4	11.05%	Max 40%

Bitumen:

Table 4: Properties of Bitumen

S.No	NAME OF TEST	REFERENCES	EXPERIMENAL VALUE	STANDARD VALUE
1	Penetration	IS:1203-1978	61	60-70mm
2	Ductility	IS:1208-1978	41	38 to 45cm
3	Softening point	IS:1206-1978	49^{o}C	40^{o}C to 59^{o}C
4	Specific gravity	IS:1202-1978	1.35	Min 0.99

III. TESTING DETAILS

1. Marshall Stability Test:

As per ASTM D1559 (Marshall Mix Design Method) Marshall Stability testing setups was used. Tests were performed to determine the Marshall stability, flow value, optimum bitumen content and amount of bitumen required for mix types containing different percentage of filler

Table 5: Compactions of Specimens

Type of traffic	No. of blows
Low traffic	35
Medium traffic	50
Heavy traffic	75

Fig 4: Marshal Test Apparatus

Table 6: Replacement Percentage

% of Replacement	WFS (%)	Q.Dust (%)
0	0	100
25	25	75
50	50	50
75	75	25
100	100	0

The partial replacement percentages were taken based on the study of literatures on use of Foundry sand as filler material replacement in the asphalt paving mixes.

2. Batching Of Materials:

The combinations of materials were taken from following percentage of 1200grams.

19mm-12%

13.2mm -20%

6.7mm-23%

Dust-45% (Dust and WFS)

Bitumen -5%, 5.5%, 6% and 6.5%

Testing of Sample: Marshall Test is a simple and low cost standard laboratory test adopted all over the world for design and evaluation of bituminous mixtures.

Before **after testing**

Fig 5: Tested Samples

3. Design Parameters:

As per ASTM D7263, the following parameters are studied and they are calculated from the obtained values.

- Bulk specific gravity of aggregate
- Bulk specific gravity of compacted mixture
- Maximum specific gravities of mixtures
- Air voids in compacted mixture
- Voids in mineral aggregate
- Voids filled with asphalt
- Indirect tensile strength (ITS)

IV. RESULT AND DISCUSSIONS

This chapter deals with the results obtained from the Marshall Stability test, and the calculations are tabulated below.

1. Conventional Mix:

This table results shows the without replacement of the waste foundry sand in the mix, the obtained and calculated values as follows.

Table 8: 0%Replacement Results

BC %	Wt in air (g)	Wt in Water (g)	Stability (kg)	Flow value (mm)	VMA (%)	AV %	VFB (%)	Strength (N/mm^2)
5	1256	741	1332	2.84	4.76	3.97	16.74	1.32
5.5	1268	746	1634	3.7	5.21	3.84	26.37	1.62
6	1272	750	1855	3.5	5.66	3.03	46.49	1.79
6.5	1273	754	1561	4.4	6.10	1.89	69.08	1.54

From the values obtained for the conventional bituminous concrete mixes, it is observed that strength and stability increases at 6% of binder content.

2. High Performance Bituminous Concrete With 25% WFS:

Table 9: 25%Replacement Results

BC %	Wt in air (g)	Wt in Water (g)	Stability (kg)	Flow value (mm)	VMA (%)	AV (%)	VFB (%)	Strength (N/mm^2)
5	1260	752	1368	2.91	4.762	2.9	37.15	1.34
5.5	1266	754	1819	3.81	5.213	2.8	46.85	1.77
6	1271	758	1937	4.17	5.660	2.1	63.62	1.88
6.5	1274	761	1490	4.1	6.103	1.3	78.46	1.45

From the values obtained for the high performance bituminous concrete mixes (25%), it is observed that strength and stability increases at 6% of binder content. And also the volume increases slightly compare to conventional mixes due to its density of WFS.

3. High Performance Bituminous Concrete With 50% WFS:

Table 10: 50%Replacement Results

BC %	Wt in air (g)	Wt in Water (g)	Stability (kg)	Flow (mm)	VMA %	AV %	VFB %	Strength (N/mm^2)
5	1269	741	1301	3	4.76	4.6	3.78	1.19
5.5	1272	741	1650	3.8	5.21	4.4	15.6	1.51
6	1272	734	1978	3.97	5.66	5.2	8.94	1.81
6.5	1273	731	1783	3.25	6.10	5.3	13.2	1.63

From the values obtained for the high performance bituminous concrete mixes (50%), it is observed that strength and stability increases at 6% of binder content.

4. High Performance Bituminous Concrete With 75% WFS:

Table 11: 75%Replacement Results

BC %	Wt in air (g)	Wt in Water (g)	Stability (kg)	Flow mm	VMA %	AV %	VFB %	Strength (N/mm^2)
5	1240	716	970	2.04	4.76	4.65	2.27	0.87
5.5	1242	718	1025	3.08	5.21	4.01	23.1	0.92
6	1245	719	1453	4.08	5.66	3.66	35.3	1.3
6.5	1247	721	1706	4.21	6.10	3.03	50.3	1.53

From the values obtained for the high performance bituminous concrete mixes (75%), it is observed that strength, flow value and stability increases at 6.5% of binder content.

Hence, the bitumen percentage increases with increase in the foundry sand percentage. This happens due to the fineness properties of material.

It is Studied that, the strength and stability reduces for the for the foundry sand replacement of 75% in bituminous mixes, hence for the better conclusion, in this present work 30%, 35%, and 40% are analysed.

5. High Performance Bituminous Concrete With 30% WFS:

Table 12: 30%Replacement Results

BC %	Wt in air (g)	Wt in Water (g)	Stability (kg)	Flow mm	VMA (%)	AV %	VFB %	Strength (N/mm^2)
5	1268	753	1424	3.18	4.76	3.4	28.3	1.37
5.5	1272	757	1971	4.1	5.21	2.6	50.3	1.9
6	1273	761	2156	4.8	5.66	1.4	74.9	2.08
6.5	1276	762	1968	3.9	6.10	1.1	82.6	1.9

From the values obtained for the high performance bituminous concrete mixes (30%), it is observed that strength and stability increases due to decrease in air voids at 6% of binder content.

6. High Performance Bituminous Concrete With 35% WFS:

Table 13: 35%Replacement Results

BC %	Wt in air (g)	Wt in Water (g)	Stability (kg)	Flow mm	VMA %	AV %	VFB %	Strength N/mm^2
5	1260	748	1768	4.25	4.76	3.17	33.4	1.68
5.5	1261	748	1930	4.42	5.21	2.76	46.9	1.8
6	1262	751	2300	4.59	5.66	1.79	68.2	2.18
6.5	1270	752	1962	4.3	6.10	2.01	67.2	1.86

From the values obtained for the high performance bituminous concrete mixes (35%), it is observed that strength and stability increases due to decrease in air voids at 6% of binder content.

7. High Performance Bituminous Concrete With 40% WFS:

Table 14: 40%Replacement Results

BC %	Wt in air (g)	Wt in Water (g)	Stability (kg)	Flow mm	VMA %	AV %	VFB %	Strength (N/mm^2
5	1258	738	1786	3.75	4.76	4.53	4.98	1.67
5.5	1260	739	1976	4.39	5.21	4.05	22.3	1.85
6	1262	741	2259	3.58	5.66	3.4	40.0	2.11
6.5	1258	740	2143	4.24	6.10	2.65	56.7	2.0

From the values obtained for the high performance bituminous concrete mixes (40%), it is observed that strength and stability increases due to decrease in air voids at 6.5% of binder content.

Table 15: Percentage of Increases

BC %	Stability(Kg)		% of Increases	Indirect Tensile Strength(N/mm^2)		% of Increases
	Conventional	35%		Conventional	35%	
5	1332	1768	24.7	1.32	1.68	21.4
5.5	1634	1930	15.3	1.62	1.8	10.1
6	1855	2300	19.3	1.79	2.18	17.8
6.5	1561	1962	20.4	1.54	1.86	17.2

This graph shows the representations of the Stability value and bitumen content of 6% for the various replacements of the WFS.

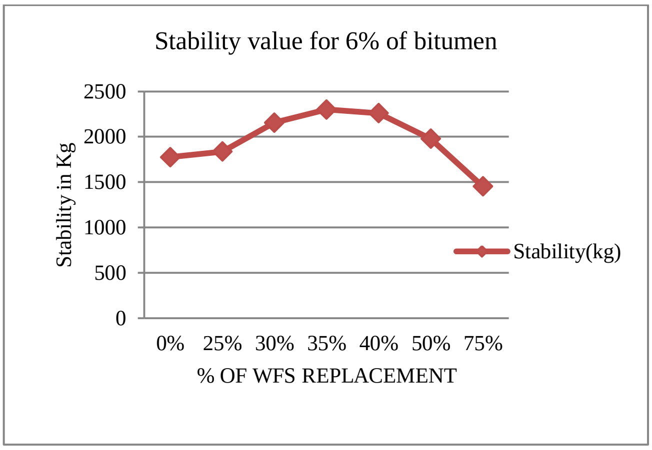

Fig 6: % of WFS Vs Stability for 6% BC

From the % of WFS Vs and Stability, 35 % of Replacement of WFS stability values higher than previous mix values.

This graph shows the representations of the Air voids, strength and % of WFS Replacement.

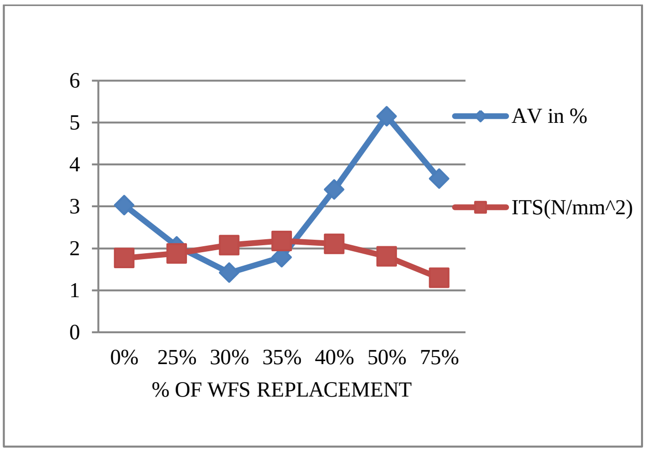

Fig 7: % of WFS Vs Air voids 6% BC

This graph shows the representations of the % of WFS Vs Air Voids. For the 30% and 35% Replacements are slightly increased compared with other binder content.

From the % of WFS Vs Strength values, the indirect tension values are decreases when the replacement % was increased due to increases of volume of specimens.

This graph shows the overall comparison for indirect tensile strength for the various % of WFS and binder content.

Cost Comparison:

Table16: conventional cost

Material	Quantity	Rate/m^3	Total
Coarse Aggregate	0.75Cu.mt	2400	1800
Fine Aggregate (Quarry Dust)	0.65Cu.mt	1600	1040
bitumen	50.3Kg	47/Kg	2364
Total			5204

Table 17: Cost of WFS material

Material	Quantity	Rate/m^3	Total
Coarse Aggregate	0.75Cu.mt	2400	1800
Fine Agg.(WFS)	0.65Cu.mt	-	-
bitumen	50.3Kg	47/Kg	2364
Total			4164

This estimated material and cost for the Bituminous Concrete for the 40mm thick. Therefore saving in cost per10 m^2 is Rs.1040 by using foundry sand replacement for fine aggregates in bituminous mix. Hence saving in cost for 1 m^2 is Rs.104

V. CONCLUSION

Waste Foundry Sand, which is waste material obtained from the Casting industry, is a promising candidate for use as fine aggregate in BC mix. Overall Foundry sand as fine aggregate replacement shows the potential for excellent performance when used in a proper BC mix design.

The conclusions drawn from this study are as follows:

- The stability value and split-tensile strength of the Marshall Stability test tends to decrease when increase in proportion of WFS materials.
- When the WFS material replacement percentage was increased, binder content also gradually increased.
- 50 % replacement of WFS materials stuff results in reduction of stability and split-tension strength when compare to 35% replacement for the 6% of binder content.
- Hence the replacement percentage increases by 5% starts from 25% and increase for the each bitumen content.
- From this replacement percentages, stability and split tension values are gradually increased up to 35% replacement and decreased for the 40% of WFS replacement for the 6% of binder content.
- From this study it is observed that Waste Foundry Sand may be used as an alternative for fine aggregate as partial replacement where 35% replacement with quarry dust, which is used for flexible pavements works.
- However, WFS has little effect on top-down fatigue cracking resistance and moisture susceptibility of the sample mixes. Based on laboratory test results, WFS appear to be especially beneficial for the NH and SH Infrastructure works.

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