International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 7 Issue 6 Ver II || June 2018 || PP 91-94

Utilization of Basic oxygen furnace slag as aggregate in Bituminous mix

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Abstract; *Demand for the natural aggregates have lead to rapid depletion of natural resources predominantly. On the other hand waste products produced from the industries is enormous, with the problems of landfill and dumping of materials for longer period which causes greater pollution and effects on the environment. Hence to control these problems, some industrial wastes are being used in road applications. Some of the industrial wastes that are successfully used in the road industry are Fly ash, steel slag, Crumb rubber , plastics etc. In the present study, the Basic Oxygen Furnace Slag a major type in LD slag has been used in partial replacement of both coarse and fine aggregates in different combinations for preparing BC grade-II mixes. The Marshall properties of the slag replaced BC mixes have been compared with that of the conventional BC mixes. Slag replaced BC mixes has shown better results with reference to the Marshall properties. 40% of replaced slag showed satisfying results such as 3.8% of higher stability, 0.42% of lesser density, and 5.6 of % lesser Air Voids than conventional BC mixes. 60% slag showed higher air voids, increased OBC as compared to 40% of slag replaced BC mixes. So 40% slag replacement is considered to be optimum.*
Key Words*: BOF Slag, bituminous mix, marshal test*

Date of Submission: 25-05-2018 Date of acceptance: 11-06-2018

I. Introduction

The developments in highway constructions are increasing day by day to improve the country's economy. For future road construction, large consumption of virgin aggregates is to be required and this will increase in the cost of the projects as there is demand for the natural aggregates. The environmental pollution is the major problem associated with rapid industrialization and urbanization for developing countries, the high quantities of waste products accumulating in stockpiles and landfills throughout the world are causing disposal problems that are both economically and environmentally expensive. Industrialization is a must but on the other hand the waste materials produced by industries cause serious impacts on the environment. In order to reduce dependence on natural aggregates as main source especially in road construction, the artificial aggregates produced from industries has to be replaced. Therefore, we can minimize the waste materials disposal and natural resources are conserved effectively.

Slag a by-product of steel, produced during the process of steel manufacture in steel industries was also considered as a waste material in earlier days. Slag predominantly consists of iron oxide in large content; it is a hard and heavy material, also having more density. Use of slag in road construction, not only reduces landfills but also reduces materials costs, and when used as replacement for natural aggregates conserves the natural resources and also eliminates environmental pollution. In this study, the Basic Oxygen Furnace Slag was used; it is the major type of steel slag produced from steel making industries and co-product of iron steel slag. It contains greater amount of chemical components such as iron oxide, manganese, sulfur oxide, magnesium oxide, calcium oxide and phosphorous. Therefore the steel slag results in higher density and also accounts for its increased hardness compared to other slag.

II. Objectives

To study the laboratory properties i.e. Marshall Properties, for BC grade II mix prepared using BOF steel slag in partial replacement of coarse and fine aggregates and identifying the optimum replacement of slag based on the mechanical properties

III. Materials

The basic properties of natural aggregates, BOF slag and bitumen was determined. **Natural Aggregates:** Basic test on aggregates were conducted in the laboratory as per the specified test methods to determine the physical properties of virgin aggregates

Table; 1 physical properties of aggregate

Properties	**Results**
Specific gravity (20mm down)	2.64
Specific gravity (12.5mm down)	2.65
Specific gravity (4.75mm down)	2.75
Water absorption (%)	0.36%
Impact value (%)	22%
Crushing strength test (%)	22%
Combined index (%)	21%
Stripping (%)	98%

Binder: Binder grade of VG-30 was considered for preparing the BC-II mixes. The basic properties of VG-30 were evaluated as per IS-73 specifications.

Table: 2 physical properties of bitumen

Properties	**Result**
Penetration (mm)	63 mm
Softening point (˚C)	52˚C
Ductility (cm)	98cm
Viscosity, Flow at 60˚C Flow at 25˚C	 10.67sec 22.67sec
Specific gravity at 25˚C	1.00

BOF Steel slag: Steel slag procured from JSW steel plant Bellary District has been used in this work.

Table: 3 physical properties of BOF slag

Properties	**Results**
Specific gravity	3.62
Water absorption (%)	1.8% for Coarse 2.41% for fines
Impact value (%)	19.32%
Crushing strength (%)	22.44%
Combined index (%)	14%
Stripping (%)	97%

Fig: 1. Stripping test on slag aggregates

IV. EXPERIMENTAL WORK

Marshall Mix design method was adopted to design and determine the properties of bituminous mix. The bituminous Mix for BC-II was designed by marshal method of mix design based on ASTM D-1559-96 and mixes were prepared with the partial replacement of steel slag as coarse and fine aggregates in the proportion of 0%, 20%, 40% and 60% by varying the binder content. The aggregates were proportioned and required quantity of bitumen percentages in increment of 0.5%,i e 5,5.5,.6,6.5% by weight of aggregate was heated and thoroughly mixed with heated bitumen (VG-30) at a desired temperature of 150- 165º C. The mix was placed in preheated Marshall Mould of 101.6mm diameter and 63.5mm height with base plate and collar. After leveling the top surface, the mix was compacted by means of rammer of 4.54kg weight with 457mm height of fall with 75 blows on each face. Three specimens were prepared for each bitumen content trials. The compacted specimens were kept overnight to allow the temperature fall; later the specimen was extracted using specimen

extractor. The mean height, weight in air and water was noted for the calculation of bulk density. The specimens were kept in a thermostatically controlled water bath maintained at 60±1°C for 30 - 40 minutes. Then the specimens were taken out and placed in Marshall Head and tested to determine Marshall Stability value, which is the maximum load taken by specimen before failure, and the flow value, which is the deformation of the specimen in mm at the maximum load. For the determination of OBC, graphs were plotted with bitumen content on the X-axis and following values on the Y-axis.

i. Marshall Stability
ii. Flow Value
iii. Bulk Density/Unit weight
iv. Percent of Air Voids in total mix
v. Percent Voids filled with bitumen, VFB

Fig: 2. Marshall Mix preparation

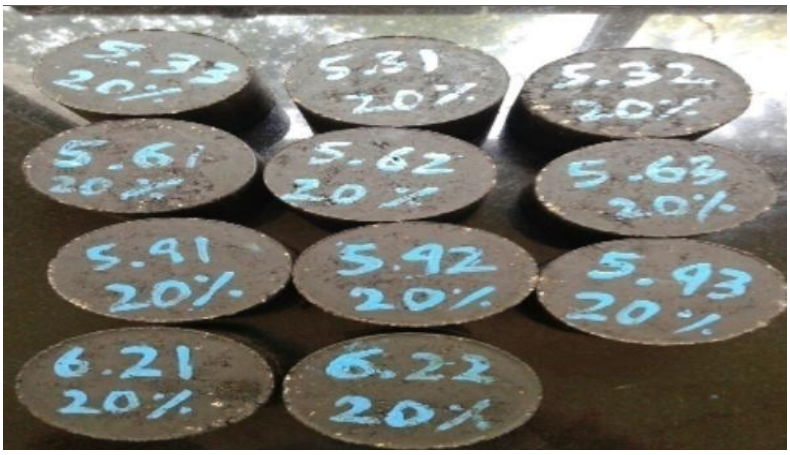

Fig: 3. Marshall Specimen

Table: 3 summary of Marshal Result

Marshall properties	Virgin Aggregates	Virgin Aggregates + 20% BOF Slag	Virgin Aggregates + 40% BOF Slag	Virgin Aggregates + 60% BOF Slag
OBC (%)	5.7	5.9	5.8	6.1
Density g/cc	2.40	2.42	2.39	2.42
Stability(kN)	17.82	17.9	18.51	18.22
Flow(mm)	2.92	3.100	3.35	3.34
Air voids (%)	5.05	4.55	4.78	9.67
VMA(%)	18.05	19.68	18.36	24.12
VFB (%)	72.51	75.92	74.31	70.59

V. Conclusion And Discussion

1. Physical properties of BOF basically satisfy the Requirements for design of BC mix
2. Slag replaced BC mixes has shown improvement in results with reference to the Marshall properties.
3. 20% slag replaced BC mixes was similar as conventional BC mixes hence there is no much variations between 0% and 20% replacement.

4. 40% of replaced slag showed better results which is 3.8% of higher stability, 0.42% of lesser density, and 5.6% of lesser Air Voids than conventional BC mixes.
5. Higher replacement of slag is not preferable since the replacement of 60% slag showed higher air voids, increased OBC and also not fulfilled Marshall Parameters as compared to 40% of slag replaced BC mixes. Therefore 40% slag replacement is considered as optimum.

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Vishwanath B J "Utilization of Basic oxygen furnace slag as aggregate in Bituminous mix "International Journal of Engineering Science Invention (IJESI), vol. 07, no. 06, 2018, pp 91-94