International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Exploring the Feasibility of Ferrochrome Steel Slag as A Sustainable Aggregate in Bitumen Mixture.

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ABSTRACT
Nowadays, usage of waste products as an alternative in construction industry has become necessary for achieving sustainable development. Generation of stainless steel from iron ore may release many harmful substances, one such is Ferrochrome steel slag (FCSS). Ferrochrome steel slag is a waste product generated during the production of stainless steel. It has been used as an aggregate in porous asphalt mixture. Disposal of ferrochrome steel slag into the environment may rise hazardous environmental issues. Porous asphalt mixtures are used as surface wearing course as they have greater resistance to skid. Required laboratory tests on aggregate and bitumen will be performed to determine desired bitumen content and to analyse the aggregate properties. Aggregate composition will be replaced with varying percentages of ferrochrome steel slag from 5% to 25% to obtain the accurate sample for replacement. Marshall stability test will be carried out on the replacement sample for determining optimum percentage of replacement for acquiring good strength and resistance.

Keywords: Ferrochrome Steel Slag , Porous Asphalt, Marshall Stability Test

INTRODUCTION

1. INTRODUCTION:

Over the last few decades, generation of waste products has increased rapidly due to increased industrialization and urbanization. Utilizing these products as alternatives for aggregates in the construction industry provides a solution for sustainable development and also helps in protecting the environment. Ferrochrome steel slag is a by-product generated during the extraction of ferrochrome alloy. It can be obtained from open hearth process, basic oxygen process and electric arc furnace slag process. It is mainly composed of silicon dioxide, magnesium oxide and alluminium oxide.

FCSS is mainly used in porous asphalt mixtures in bitumen pavements due to its excellent skid resistance. It possess higher water absorption capacity due to its porous structure and higher Marshall stability value when compared to lime stone aggregate. FCSS can be used for replacing either fine aggregate or coarse aggregate but not both because completely blended slag increases the concentration of air voids. Therefore,

it can be used for replacing aggregate in construction industry.

2. Properties of Ferrochrome Steel Slag:

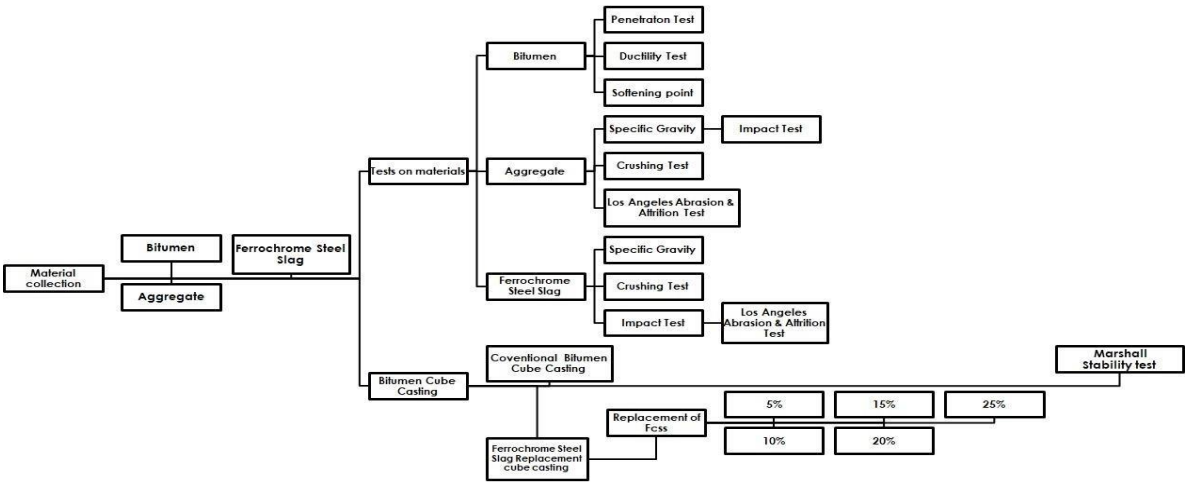
FCSS can be found in dark grey or black colour, has rougher surface texture and is highly resistant to abrasion. Size of the particle may vary depending on the cooling process. It possess higher specific gravity and bulk density when compared to lime stone aggregate. It also has great water absorbing capacity. FCSS exhibits a relatively high resistance to compressive forces. As it was generated in high thermal furnaces, it has significant thermal stability.

It is highly recommended as a construction material due to the presence of silicon, alluminium and iron oxides whose summation is only about 60% making it chemically non-reactive to be used as a component in cementitious material. Presence of magnesium oxide makes it viable for volume expansion. Due to its formation at high temperatures, it posses crystalline structure resulting in greater resistance to weathering and chemical effects.

3. Materials Required:

Fig (1) Ferrochrome Steel Slag Fig (2) Bitumen Fig (3) Aggregate

4. Methodology:



5. Tests on Aggregate and Results:

S No	Tests Conducted	Obtained	Standard	Result
1.	Specific gravity	2.96 g/cc	2.5 to 3.0 g/cc	Preferable
2.	Aggregate crushing test	16.04%	<40%	Preferable
3.	Aggregate impact test	3.72%	<10%	Preferable
4.	LA Abrasion test	35.28%	<40%	Preferable
5.	LA Attrition test	2.72%	<30%	Preferable

Fig (4) LA Abrasion test for Hardness

6. Tests on Bitumen and Results:

S No	Tests Conducted	Obtained	Standard	Result
1.	Penetration test	11.83mm	3 to 300mm	Preferable
2.	Softening point test	62.2^{o}c	55^{o}c 80^{o}c	Preferable
3.	Ductility test	89.3cm	50 to 100cm	Preferable

Fig (5) Bitumen Ductility Test

7. Tests on FCSS and Results:

S No	Tests Conducted	Obtained	Standard	Result
1.	Specific gravity	3.18 g/cc	3 to 4 g/cc	Preferable
2.	Crushing test	22.3%	<30%	Preferable
3.	Impact test	2.6%	<10%	Preferable
4.	LA Abrasion test	10.1%	<40%	Preferable

8. Comparison of Test Results of FCSS and Aggregate:

S No	Tests Conducted	FCSS	Aggregate
1.	Specific gravity	3.18 g/cc	2.96 g/cc
2.	Crushing test	22.3%	16.04%
3.	Impact test	2.6%	3.72%
4.	LA Abrasion test	10.1%	35.28%

9. Cube Casting:

The mould preparation process is a series of steps taken to ready a mould for the introduction of a material, like molten metal, plastic, or resin, to create a final product. This process is crucial for ensuring the quality, accuracy, and ease of production of the desired part. Generally, metal moulds are used for bitumen cubes, these moulds should satisfy the specific dimensions and tolerate the testing standards. Clean and lubricate the metal mould. Heat the bitumen at a specific and controlled temperature till it achieves a pourable viscosity. Mix the aggregate in the hot bitumen thoroughly for some time. Carefully pour the bitumen mix into the mould to ensure complete filling and evenly distribution. Give necessary blows to the bitumen mixture for eliminating air voids and gaps in between using Marshall compactor. Allow the mould to cool for some time at room temperature ensuring for solidification. Carefully remove the bitumen cubes from the mould to avoid damage. Inspect the cubes for defects and then perform the required tests, such as Marshall stability test.

10. Casting of Replacement Cubes:

Perform necessary tests to determine the gradation, specific gravity, water absorption and abrasion resistance of the slag. Remove all kinds of contaminants from the obtained slag.

Now, replace the natural aggregate with FCSS starting from 5% and reducing the aggregate weight to 95% Mix the aggregate, FCSS and hot bitumen thoroughly and pour it in the mould for complete filling. Give necessary blows to the cube to remove the air entrapped and allow it to cool for sometime at room temperature. Remove the mould from the apparatus and perform necessary tests. Similarly, aggregate was replaced with 10%, 15%, 20% and 25% and cubes were cast.

Fig (6) Cube casting

11. Conventional Sample:

12. FCSS Samples:

13. Marshall Stability Test:

The Marshall Stability Test is a laboratory procedure used to evaluate the strength and deformation characteristics of bitumen pavements. The specimen is removed from the water bath before testing and placed in a Marshall testing machine. The machine consists of a loading head that applies a compressive load to the sides of the cylindrical specimen through curved breaking heads. The machine applies a vertical load at a constant rate of deformation, as the load increases, the specimen deforms. The maximum load the specimen can withstand before failure is recorded as the Marshall stability, measured in kilonewtons (KN). The

amount of deformation of the specimen at the point of maximum load is recorded as the Marshall flow. A higher stability value indicates a stronger and more resistant mix to deformation. Hence, the Marshall Stability test provides crucial data for designing and evaluating asphalt pavements. This test was performed on the samples and the results were shown in the following table:

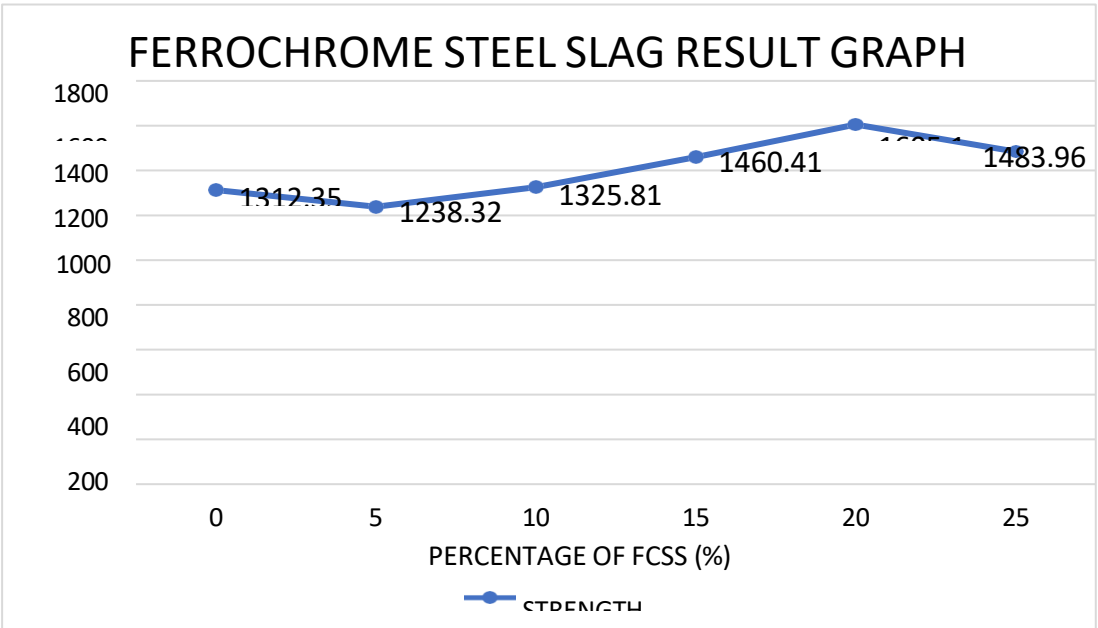
14. Marshall Stability Test Observations for Conventional and FCSS Cubes:

S No	Weight of Aggregate (g)	Percentage of bitumen	Percentage of FCSS	Marshall Stability reading (KN)
1.	1200	10%	Conventional	131.235
2.	1140	10%	5%	123.802
3.	1080	10%	10%	132.581
4.	1020	10%	15%	146.041
5.	960	10%	20%	160.51
6.	900	10%	25%	148.396

15. Result:

Bitumen cubes were casted using Ferrochrome steel slag with varying percentages from 5% to 25%. Maximum strength was observed at 20% replacement.

16. Graph:



17. Advantages:

1. FCSS has shown excellent mechanical and physical properties such as abrasion resistance, impact resistance and volume stability.
2. Its better interlocking property helps in resisting permanent deformation due to heavy loads.
3. It offers higher abrasion resistance and improves the stiffness of the pavements.
4. It reduces the requirement of natural aggregate and also reduces the disposal risks.
5. It helps in providing an advantageous reuse of industrial by product
6. It offers a cost-effective alternative for sustainable development and environmental friendly solution for transportation infrastructure development.

18. Scenario of the Project:

Ferrochrome steel slag is a by-product emerged from the production of stainless steel from ferrochrome alloy at high temperatures. This slag can be used as a replacement in the aggregate and bitumen mixture for paving bitumen roads to reduce the aggregate content and to increase the stability and durability of the pavements, additionally, nullifying the effects of disposal of FCSS in the environment. Required tests on aggregate and bitumen were performed for analysing their properties and for determining the desired content of the materials.

The slag chips were added to the coarse aggregate by means of weight starting from 5% replacement to 25%. Bitumen cubes were cast using bitumen of 10% of the weight of the aggregate, aggregate of size 10mm-12.5mm along with slag. A maximum of 10 cubes were cast for observing their performance and strength. By conducting Marshall stability test these cubes were compared with the conventional sample. Hence, the percentage replacement where maximum strength was observed, was considered ideal for utilization in the bitumen mix pavements.

19. Acknowledgement:

We would like to express our sincere gratitude to Mrs. B. Ramya, Assistant Professor in Civil Engineering Department, Dr. Lankapalli Bullayya College of Engineering, Resapuvanipalem, Visakhapatnam, Andhra Pradesh, India, for the esteemed guidance to achieve the goals of the project and for providing essential facilities and resources for completing the project successfully.

CONCLUSION

1. Ferrochrome utilization as an aggregate in bitumen mixtures has shown significant results in terms of durability, resistance and stability.
2. So, addition of 20% ferrochrome steel slag with the key aggregate in bitumen mixture has achieved the required Marshall stability specification.
3. The incorporation of ferrochrome steel slag has improved the mechanical properties and its resistance to moisture effect.
4. Hence, FCSS posses enough potential as a substitute to the natural aggregate and provides feasible structures.

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