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Characterization of Mill Scale for Potential Application in Construction Industry

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General Note

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ABSTRACT

The physical and chemical characterization of mill scale is attempted in the current work and the literature available on the same is compiled as a part of systematic experimental investigations on the feasibility studies of mill scale as partial replacement of fine aggregates in concrete. The specific gravity of mill scale is high and can aid in achieving dense concrete. The elemental characterization by inductively coupled plasma of mill scale indicates the presence of ample iron content, while X-ray diffractometer studies confirm these results. It could be concluded from the preliminary results that fine aggregates can be potentially replaced by mill scale, thereby providing a sustainable solution to the ever-increasing quantities of mill scale.

Keywords: Mill scale, fine aggregate, concrete, sustainability.

1. INTRODUCTION

Mill scale is a bluish black flaky material composed mainly of iron oxides and is formed on the outer surface of steel during hot rolling process. These scales are usually less than a millimeter thick. It acts as a protective coating to steel from atmospheric corrosion as it is cathodic to steel unless it is cracked. But the presence of mill scale proves detrimental to steel, because it can peel off easily. Nearly 35-40Kg of mill scale is produced for every ton of hot rolled steel [1]. Mill scale is reported to be used as raw material in sintering plants [2] and as briquette in steelmaking. [3- 5]. Apart from these scarce uses, most of the mill scale is dumped in landfills, which pose grave environmental hazard due to leaching of heavy metals in soil.

Currently, dramatic emphasis is laid on the utilization of agricultural and industrial wastes in construction industry. In this regard, researchers across the globe are actively participating to provide alternates to the natural resources like aggregates and sand in concrete construction and a significant amount of literature could be found in this regard. [6-11]. Although application of such industrial and agricultural waste in concrete may not be the best way to label a construction as sustainable, these methods provide some respite to the exploitation of natural aggregates. The current investigation provides preliminary insight to the feasibility studies of application of mill scale in the purview of potential replacement of fine aggregates. The experimental investigation involves study of physical, chemical and micro-structural characterization of mill scale. This provides the step one for its feasibility study in concrete industry. Before getting into the experimental results, a brief overview of the current research scenario is presented in the forthcoming section.

2. LITERATURE REVIEW

The morphological characterization of mill scale and its gaseous reduction by thermogravimetry was studied by Bagatini *et. al*. [12] for potential application of mill scale in self-reducing briquettes. The scanning electron micrographs indicated that porous iron was present in samples that were reduced at a temperature of 1100 ºC and 1200ºC. Benchiheub et. al. [13] also studied the reduction behavior of mill scale at a temperature range of 750 ºC -1050 ºC and concluded that maximum iron content of 98.04% was obtained by reduction of mill scale at 1050 ºC for 180 minutes and that the iron obtained by the reduction process was suitable for powder metallurgy. There are a significant number of research works which elaborate the findings as discussed above and deal with the reduction kinetics of mill scale for potential application in powder metallurgy or briquettes [14-17].

Only a few works could be found in literature which described the application of mill scale in the construction industry. Murthy [18] studied the stabilization of black cotton soil with varying percentages of mill scale. The results were found to be promising in terms of strength characteristics. Singhal et. al. [19]studied the partial replacements of fine aggregate by mill scale and reported maximum tensile strength at 60% replacement for M35 grade concrete. However, the compressive strength results provided maximum values at 60% and 100% replacement. It was reported that the partial replacement of fine aggregate by mill scale resulted in increased water demand.

From the above discussion, it could be inferred that a systematic approach for understanding the structural behavior of concrete containing mill scale is required. Hence, the primary objective of the current research is the characterization of mill scale with the motive to study the effects on concrete performance.

3. RESULTS & DISCUSSION

The physical and chemical characterization of mill scale was carried out in order to study the various properties for its potential application in concrete technology. The characterization was hence done to study the feasibility of this industrial waste in concrete.

Physical Characterization: The physical properties of mill scale are presented in Table 1. It is seen that the specific gravity of mill scale is 4.96, which is nearly two times that of sand (typical values being ≈ 2.65). This means that if mill scale is used as partial replacement of fine aggregates in concrete it would result in denser concrete and hence can be used in high density concreting. Further, the material has negligible water absorption. This also makes it a suitable material for concreting. The particle size distribution of mill scale is shown in Fig.1. It could be inferred that a majority (nearly 90%) of particles of mill scale lie below 1mm particle size. This particle size distribution will further ensure a denser packing arrangement of fine aggregates, thereby contributing to improved density of the resulting concrete.

Table 1

Physical properties of mill scale.

S.No.	Physical Property	Value
1	Color	Bluish black
2	Specific gravity	4.96
3	Water absorption	< 0.5%
4	Magnetic properties	Present
5	Texture	-
6	Plasticity	Nil
7	Permeability	Moderate

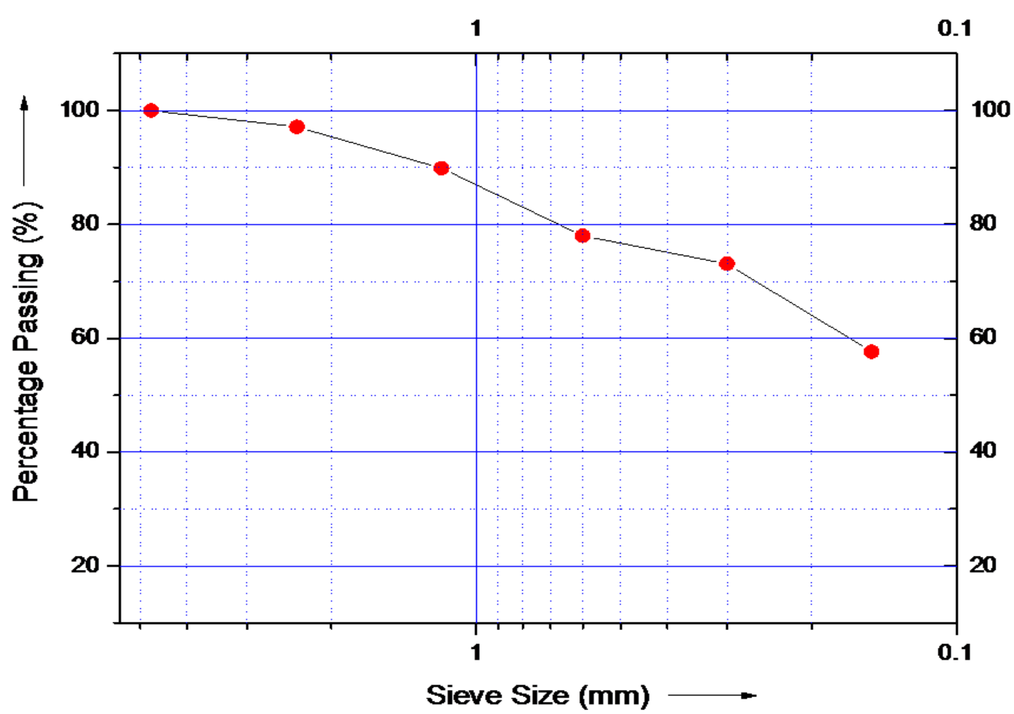

Figure 1

Particle size distribution of mill scale.

Chemical Characterization: The chemical analysis of mill scale was carried out by different methods. The initial analysis was carried out by volumetric methods. The results thus obtained were further ascertained by inductively coupled plasma and X-ray differactometer. The results of volumetric methods are presented in Table 2. It is evident that the primary content of mill scale is

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Fe_2O_3 and Al_2O_3 followed by SiO_2. The loss on ignition test was performed in conformance to IS: 1727-1967. For this test, approximately 1.00gm of air-dried, finely ground sample was placed in a platinum crucible which in turn was placed in muffle furnace for considerable time and the masses before and after were measured accurately upto two decimal places. The value of 5.81% indicates that less amount of un-burnt deleterious particles are present. It is also interesting to note that considerable amounts of Fe_2O_3, Al_2O_3 and SiO_2 are present. All these compounds provide significant strength characteristics to cement.

Table 2

Chemical Analysis Of Mill Scale

S.No.	Particulars	Percentage content
1	Loss in Ignition	5.81
2	SiO_2	8.35
3	R_2O_3 (Al_2O_3 + Fe_2O_3)	81.18
4	Others	4.66

The elemental characterization of mill scale was carried out by Ultima 2 Inductively Coupled Plasma-optical emission spectrometer (ICP-OES). The results of the same are shown in Table 3. Since, the ICP cannot estimate the quantity of oxygen present, the sum total of the mass percentage of all the elements is not 100%. Nevertheless, this chemical analysis provides us with a clearer picture of the constituents of mill scale. The results of ICP compared with those of the volumetric methods show similar trends in chemical identification.

Table 3

Elemental characterization of mill scale using ICP-OES

Element	Fe	Al	Si	Mn	Cr	Ni
Mass (%)	70	2	3.3	0.78	0.43	0.05

The results were further verified by XRD measurements using Bruker D8 Advance X-ray diffractometer using powder technique. The X-rays were produced using a sealed tube and the wavelength of x-ray was 0.154nm Cu Kα radiation at 45kV and 40mA. The x-rays were detected using a fast counting detector based on Silicon strip technology (Bruker LynxEye detector). The XRD spectrum was acquired from 10° to 90° angle 2θ with a step size of 0.02°. The experimental X-ray pattern of mill scale is shown in Fig. 2. The phase identification is done using X'pert HighScore Plus Rietveld Analysis software in combination with Pearson's crystal structure Database. Since no significant peaks were observed after 62°, the results are shown only for this region. The results of XRD analysis consisting of various phases present along with the reliability factors as obtained by Rietveld analysis are tabulated in Table 4.

Table 4

Phases identified in Mill Scale by XRD and Reliability factors.

Phase name	Phase composition	Reliability Factors		
		R_e	R_{wp}	S
Hematite	Fe_2O_3	17.156	21.729	1.604
Magnetite	Fe_3O_4			
Wustite	FeO			

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	Al_2O_3			
	SiO_2			

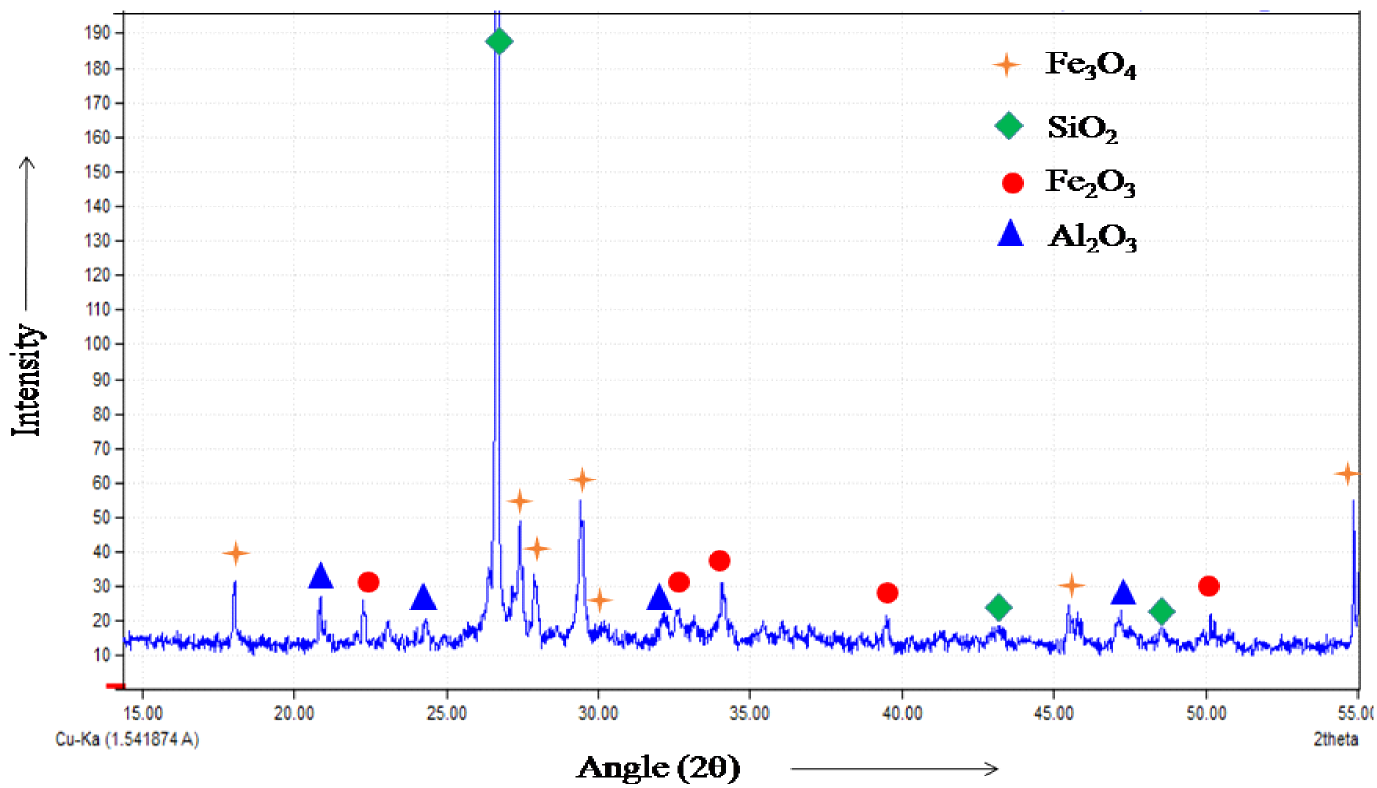

Figure 2

XRD Pattern of Mill Scale

5. CONCLUSION

From the above results, it could be inferred that mill scales are fine particles of size less than 1mm having high specific gravity. This implies that when incorporated in concrete as fine aggregate, mill scale will lead to denser concrete. Further, iron, alumina and silica are essential ingredients in cement and aid in the formation of C_2S, C_3S, C_4AF and C_3A, which in turn provide strength characteristics to concrete. Hence, the partial replacement of fine aggregate by mill scale in concrete can be attempted.

REFERENCES

1. International Iron and Steel Institute. (1987). The management of steel industry by-products and waste. Brussels Committee on Environmental Affairs.
2. R. C. Nascimento, G. Lenz, D. Martins, C. Takano and M. B. Mourão.(2004). V Japan-Brazil Symposium. on Dust Processing-Energy-Environment in Metallurgical Industries – ABM, Sao Paulo, 5, 507.
3. T. Umadevi, M.G. Sampath Kumar, P.C. Mahapatra, T. Mohan Babu, Madhu Ranjam(2009). *Ironmaking Steelmaking*, 36, 409-412.
4. S. R. Balajee, P. E. Callaway, Jr. and L. M. Keilman: Steelmaking Conf. Proc., Vol. 78, ISS, Warrendale, PA, (1995), 51.
5. D. A. Dukelow, J. P. Werner and N. H. Smith: Steelmaking Conf. Proc., Vol. 78, ISS, Warrendale, PA, 1995, 67.

6. Yong Cheng, Wen You, Chaoyong Zhang, Huanhuan Li, Jian Hu. (2013), The Implementation of Waste Sawdust in Concrete, *Engineering*, 5, 943-947
7. C. Meyer, N. Egosi, and C. Andela, (2001).Concrete with Waste Glass as Aggregate" in "Recycling and Re-use of Glass Cullet", Proceedings of the International Symposium Concrete Technology Unit of ASCE and University of Dundee, March 19-20.
8. Rafat Siddique, Gurpreet Singh, (2011). Utilization of waste foundry sand (WFS) in concrete manufacturing Resources, Conservation and Recycling 55, 885– 892.
9. U. Johnson Alengaram, Hilmi Mahmud, Mohd Zamin Jumaat and S. M. Shirazi . (2010).Effect of aggregate size and proportion on strength properties of palm kernel shell concrete, International Journal of the Physical Sciences Vol. 5(12), pp. 1848-1856.
10. Mirjana Malešev, Vlastimir Radonjanin and Snežana Marinković (2010). Recycled Concrete as Aggregate for Structural Concrete Production, *Sustainability*, Vol *2*, pp. 1204-1225.
11. Nasir Shafiq, Muhd Fadhil Nuruddin and Salmia Beddu. (2010). Properties of concrete containing used engine oil, *International Journal of Sustainable Construction Engineering & Technology*, Vol 2(1), pp. *72-82*
12. Maurício Covcevich Bagatini, Victor Zymla, Eduardo Osório and Antônio Cezar Faria Vilela, (2011) Characterization and Reduction Behavior of Mill Scale, *ISIJ International*, Vol. 51 (7), pp. 1072–1079
13. O. Benchiheub, S. Mechachti, S. Serrai, M.G. Khalifa, (2010). Elaboration of iron powder from mill scale *Journal of Material and Environmental Science,* Vol. 1 (4), *pp.267-276*
14. Seungyoun Cho and Joonho Lee (2008), Metal Recovery from Stainless Steel Mill Scale by Microwave Heating *Metals And Materials International*, Vol. 14 (2), pp. 193-196
15. N. A. El-Hussiny, F. M. Mohamed, and M. E. H. Shalabi (2011). Recycling of Mill Scale in Sintering Process *Science of Sintering,* Vol.43, pp.21-31
16. M.A. Legodi, D. de Waal (2007). The preparation of magnetite, goethite, hematite and magnetite of pigment quality from mill scale iron waste, *Dyes and Pigments* , Vol. 74, pp.161-168.
17. N. M. Gaballah1, A. F. Zikry1, M. G. Khalifa, A. B. Farag, N. A. El-Hussiny, M. E. H. Shalabi, (2013). Production of Iron from Mill Scale Industrial Waste via Hydrogen, *Open Journal of Inorganic Non-Metallic Materials*, Vol.3, pp. 23-28
18. Y.I.Murthy (2012). Stabilization of Expansive Soil Using Mill Scale *International Journal of Engineering Science and Technology*, Vol. 4 (2), pp. 629-632
19. A.Singhal, D. Bhunia, B. Pande (2015). Effect of sand replacement by mill scale on the properties of concrete. *International Journal of Engineering Technology Science and Research*, Vol. 2 pp.60-67