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Study of the Compressive Strength of Concrete with Various Proportions of Steel Mill Scale as Fine Aggregate

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Abstract:-*Industries are the major sources of wastes. Disposal of these wastes is found to be one of the serious issues. Most of this waste causes severe health, environmental and dumping issues. Continuous efforts have been made for the effective use these wastes in various purposes. Mill scale is a waste by product of steel industry, which is produced at the rate of 35–40 kg per ton of produced steel. In the present study, attempts were made to use the mill scale as a replacement of sand in cement concrete. The studies show that the compressive strength of concrete has increased by the replacement of sand with mill scale. The concrete with 15% replacement of sand with mill scale shows an optimum strength of 28.11N/mm^2*
Keywords - *concrete, compressive strength, fine aggregate, steel mill scale, waste management*

I. Introduction

The solid waste generation is one of the serious issues that cause many adverse effects in the environment. These wastes can be of industrial wastes, urban wastes, agricultural wastes, chemical wastes and biological wastes. There is a clear need for an efficient approach for waste management with prime aim on the waste minimization. On the other hand, emphasis should also be given on the waste segregation, recycling and processing in an energy efficient way so that the waste load reaching the landfill can be brought down to the minimum possible amount.

Industries contribute a major portion of the solid waste generation. Despite significant efforts carried out by these industrial sectors to minimize their environmental impacts worldwide, the demand for new technologies to reduce gaseous emissions. A considerable amount of solid waste in terms of variety, toxicity and volume is produced by the steel manufacturing industry [1]. The Indian steel industry has shown a phenomenon growth in the last few decades. Steel is one of the most basic materials required for industrialisation and plays a vital role in the country's economic development. On the other hand, development of steel industry has brought with it the environmental degradation due to the waste generation.

The raw material for steel production include iron ore, sinter and/or pellets; mineral coal or charcoal; and fluxing agents. By using these raw materials, the steel production is carried out in two ways, i.e., integrated or semi-integrate routes. In the integrated route, the reduction of the raw material is carried out in the blast furnace to generate pig iron, which is then refined to produce steel. On the other hand, while in the semi-integrated route, steel is directly produced in electric arc furnaces [2]. Environmental pollutants are generated in various stages of steel manufacturing process such as mining of ores, preparation of raw materials, agglomeration of fines in sinter plant, feeding of burden to blast furnace, manufacturing of coke in coke ovens, conversion of pig iron to steel, making and shaping of steel goods, granulation of slag for its use in cement plant etc. The solid waste generated during these processes includes slags, sludge, dusts, mill scale etc.

Mill scale is formed on the outer surfaces of plates, sheets or profiles when they are being produced by rolling red or hot iron steel billets in rolling mills. This may be due to the oxidation of steel surfaces when they are subjected to thermal gradients in the presence of corrosive environments or due to the natural exposure to air. The mill scale is composed of iron oxides, such as wustite (FeO), magnetite (Fe_3O_4), and hematite (Fe_2O_3), in addition to traces of non-ferrous metals, compounds of alkali metals, and oils from the rolling process. The specific production of mill scale is approximately 35–40 kg per ton of produced steel [3]. Moreover, the total iron content of mill scale is between 65% and 70% [3, 4]. About 90 % of this mill scale is recycled within the steel manufacturing industries through the sintering plant [5]. The non-recycled portion of mill scale is used in cement manufacturing or in petro-chemical industries [6]. Although there are several studies on the use of mill scale in cement manufacturing, the option of mill scale in concrete as fine aggregate is seldom explored.

Therefore, in the present study was conducted to investigate the potential of steel mill scale as the fine aggregate in concrete.

II. Materials and Methods

Mill scale used in this study was procured from Peekay Steel Castings (P) Ltd, Calicut, Kerala (Fig.1). The initial The properties such as fineness modulus, effective size, uniformity coefficient, specific gravity etc. are found out for the mill scale as well as the commonly used fine aggregate (i.e., sand) by the standard procedure.

Figure 1. Steel mill scale

2.1 The Mix Design and its relevance

Concrete is most commonly used material in civil construction work all over the country. There is hardly any major original civil construction work where structural concrete is not used. Nowadays concrete is produced in batch mixing plants located either at site of construction or away from the site in a location from where concrete is carried in transit mixers to the site. The later one is commonly called Ready Mix Concrete (RMC). The proportion of various ingredients of concrete made in batch mixing plants mentioned above is usually determined in laboratory. This process is called designing (proportioning) of concrete mix and such a concrete is called design mix concrete. The designing process is a trial and error method in which right proportion of ingredients is sought to be determined so as to achieve targeted mean strength which is kept somewhat higher than the characteristic compressive strength of the concrete. Besides achieving the targeted strength, the workability and durability requirements are also required to be ensured while designing the concrete mix. All this has to be done keeping in mind the objective of achieving overall economy by reducing the content of costliest material in the concrete, i.e. the cement.

The concrete block was prepared by mixing cement, fine aggregate and course aggregate in the ratio of 1:1.5:3 and a water content of 45% by weight of cement. The mix was filled in the mould of standard vibrating machine and allowed to vibrate for a period of 2 minutes at a specified speed of 12000±400 per 8 minutes to achieve full compaction. The mould was then kept at a temperature of $27\pm2^{o}C$ for 24 hours. The above procedure was repeated by replacing the fine aggregate by mill scale by 5%, 15%, 25% and 50% of its total weight to produce concrete cubes with varying proportions of mill scale. All the concrete cubes thus prepared were then tested for its compressive strength in Universal Testing Machine (UTM).

III. Results and Discussions

3.1 Characterization of fine aggregate and mill scale

As per Indian standard the aggregate fraction from 4.75mm to 75 micron are termed as fine aggregate. Fineness modulus is defined as sum of the cumulative percentage of sand retained in the designated sieves divided by 100. The effective size, i.e. D10 represents a size, in mm such that 10% of the particles are finer then the sieve size. Where D60 is the grain diameter at 60% passing, i.e. 40% of sample is retained on that particular sieve then there is 60% passing.

The sample was brought to an air-dried condition. Then 500 gram of sand/mill scale was taken. Then sieve was arranged in the descending order of size from the top. Then the sand/mill scale was allowed to pass through the sieves by shaking it for 10 minutes. Then weight of soil that is retained in each sieve was measured and was noted down. The result of sieve analysis of fine aggregate and mill scale is shown in Table 1 and 2 respectively. Fig. 2 and 3 shows the particle size distribution curves for fine aggregate and mill scale.

Table 1: Sieve analysis for sand

Is sieve size (mm)	Weight retained (Kg)	Percentage weight retained (%)	Cumulative percentage retained (%)	Cumulative percentage passing (%)
80	0	0	0	100
40	0	0	0	100
20	0	0	0	100
10	0	0	0	100
4.75	0.03	6	6	94
2.36	0.045	9	15	85
1.18	0.122	24.4	39.4	60.6
600	0.103	20.6	60	40
300	0.154	30.8	90.8	9.2
150	0.044	8.8	99.6	.4
75	0.002	.4	100	0

Table 2: Sieve analysis for mill scale

Is sieve size(mm)	Weight retained(Kg)	Percentage weight retained (%)	Cumulative percentage retained (%)	Cumulative percentage passing (%)
80	0	0	0	100
40	0	0	0	100
20	0	0	0	100
10	0	0	0	100
4.75	0.079	15.8	15.8	84.2
2.36	0.25	50	65.8	34.2
1.18	0.093	18.6	84.4	15.6
.600	0.075	15	99.4	0.6
.300	0.003	0.6	100	0
.150	0	0	100	0
.075	0	0	100	0

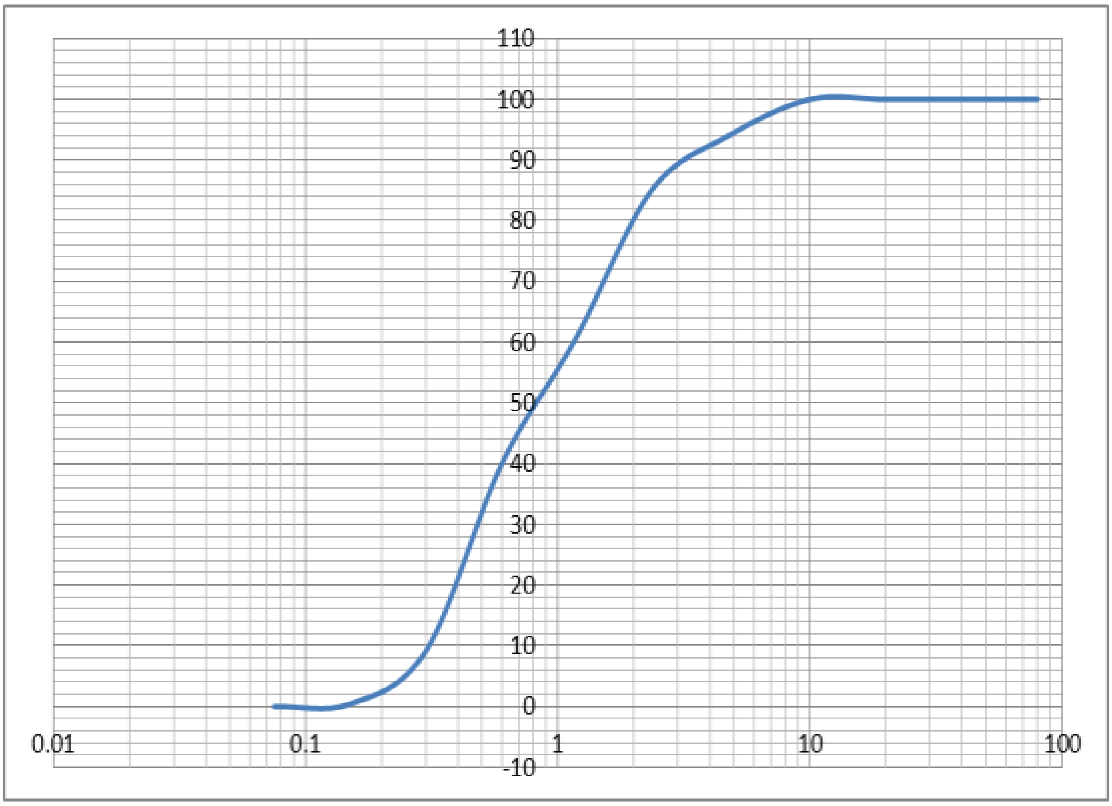

Figure 2: Particle size distribution curve for fine aggregate

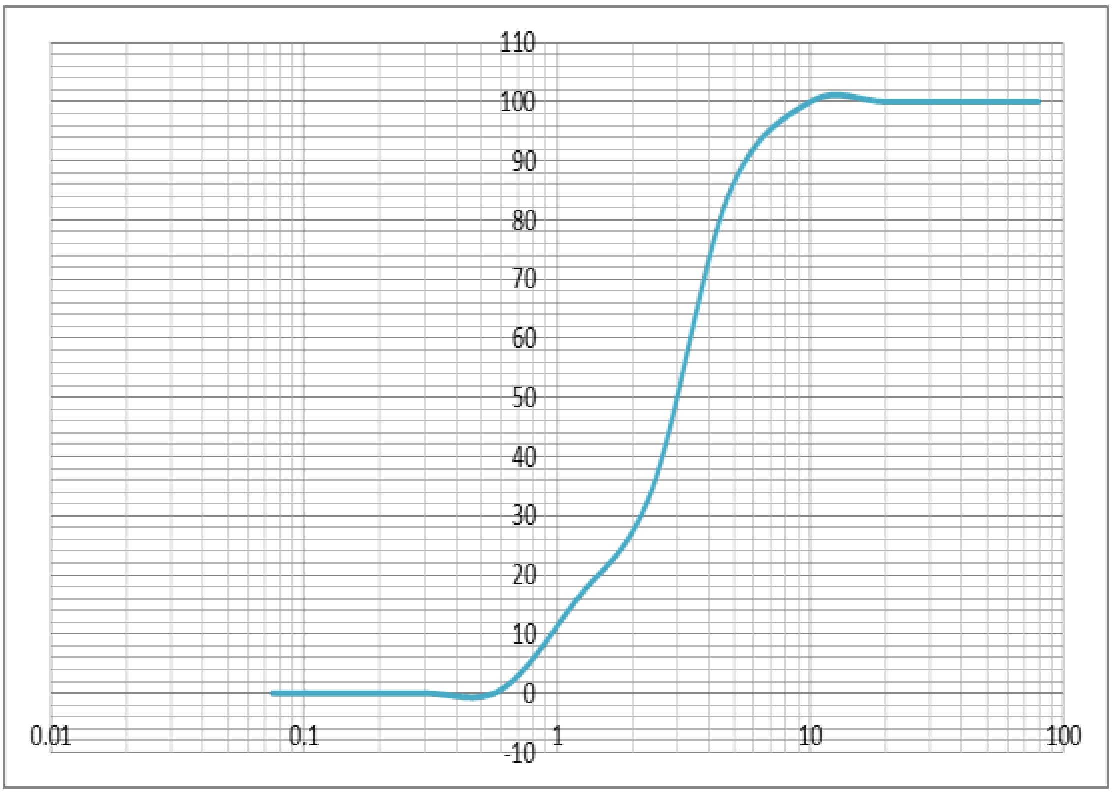

Figure 3: Particle size distribution curve for mill scale

The fineness modulus, effective size (D_{10}), uniformity coefficient (D_{60}/D_{10}), and average size of the particles (D_{50}) were then calculated from the sieve analysis results as shown in Table 3.

Table 3 Characterization of fine aggregate and mill scale

Property	Fine Aggregate	Mill scale
Fineness modulus	6.89	5.35
Effective size (mm)	0.3	1
Uniformity coefficient	4	3.4
Average size (mm)	0.8	3

The specific gravity of fine aggregate and mill scale was calculated by Pycnometer method. The observations of the Pycnometer method are shown in Table 4. From the observations, the specific gravity of sand and gravel is calculated as 2.74 and 6.02.

Table 4 the observations of Pycnometer method of fine aggregate and mill scale

Mass (g)	Fine Aggregate(sand)	Mill scale
Surface dry sample	600	600
Sample+water+pycnometer(B)	1930	2048
Water+pycnometer(C)	1547	1547
Oven dry Sample(D)	596	596

3.2 The Mix Design of concrete

The design of the concrete mix was carried out in the laboratory as per Indian standard (IS 10262:2009) stipulating guidelines for concrete mix proportioning (Table 5). The mass of cement, fine aggregate and course aggregate was taken in the ratio of 1:1.5:3 and the corresponding mass of cement, fine aggregate, course aggregate and water taken to caste the concrete mix was 2 kg, 2.618 kg, 5.131 kg and 0.56 kg respectively.

Table 5: Concrete mix design (As per IS 10262-2009)

M-20 Concrete Mix Design		
As per IS 10262-2009		
A-1	**Stipulations for Proportioning**	
1	Grade Designation	M20
2	Type of Cement	PPC
3	Maximum Nominal Aggregate Size	20 mm
4	Maximum Water Cement Ratio (MORT&H 1700-3 A)	0.45
A-2	**Test Data for Materials**	
1	Cement Used	PPC
2	Sp. Gravity of Cement	3.15
3	Sp. Gravity of Water	1.00
4	Sp. Gravity of 20 mm Aggregate	2.69
5	Sp. Gravity of Sand	2.74
6	Water Absorption of 20 mm Aggregate	0.334%
7	Water Absorption of Sand	0.671%
8	Sieve Analysis of Fine Aggregates	Separate Analysis Done
A-3	**Selection of Water Cement Ratio**	
1	Water Cement Ratio	0.45
A-4	**Mix Calculations**	
1	Volume of Concrete in m^3	1.00
2	Volume of Cement in m^3 (Mass of Cement) x1000 / (Sp. Gravity of Cement)	0.1818

3	Volume of Water in m^3 (Mass of Water) x1000 / (Sp. Gravity of Water)	0.160
4	Volume of All in Aggregate in m^3	0.818
5	Volume of Coarse Aggregate in m^3	0.545
6	Volume of Fine Aggregate in m^3	0.273
A-5	**Mix Proportions for One Cum of Concrete (SSD Condition)**	
1	Mass of Cement in kg/m^3	573
2	Mass of Water in kg/m^3	160
3	Mass of Fine Aggregate in kg/m^3	748
4	Mass of Coarse Aggregate in kg/m^3	1466
5	Mass of Admixture in kg/m^3	1.90
6	Water Cement Ratio	0.45

3.3 Compressive strength of the prepared concrete mix

Concrete cube of 50 X 50 X 50 mm^3 was prepared and cured for 7 days. The compressive strength of the concrete with fine aggregate replaced by different amount of mill scale was analysed in the Universal Testing Machine. The results are tabulated in Table 6.

Table 6: Mass of mill scale in each observation

S No	Percentage of mill scale (%)	Mass of sand (Kg)	Mass of mill scale (Kg)	Strength on 7 days of curing (N/mm^2)	Increase in strength with mill scale addition (%)
1	0	2.618	0	20.48	0
2	5	2.4871	.1309	25.28	23.43
3	15	2.2253	.3927	28.11	37.25
4	25	1.9635	.6545	24.41	19.18
5	50	1.309	1.309	21.79	6.39

IV. Conclusion and Recommendations

The mill scale which is the waste product in the rolling process of steel manufacturing was used as fine aggregate in concrete mix. The result shows that the mill scale can replace sand in the concrete as the mill scale concretes showed better performance towards compressive strength. The seven day compressive strength of concrete cubes increases for all the proportions of mill scale added to replace the sand. The strength increased for the sand replacement by the mill scale proportion from 5% to 15% and then showed a decreasing trend. The maximum compressive strength of 28.11 N/mm^2 was obtained by using 15% of mill scale. However, 5% and 15% mill scale replacement with sand is very effective for practical purpose. The mill scale concrete can be effectively used for the pavement construction to protect the structure from corrosion.

Reference

[1]. Cristina, N., Lobato, C., Villegas, E. A., Mansur, M.B, Management of solid wastes from steelmaking and galvanizing processes: A brief review, Resources, Conservation and Recycling 102 (2015) 49–57.

[2]. Fruehan, R.J., 1998. The Making, Shaping, and Treating of Steel, 11th ed. Pittsburgh PA: The AISE Steel Foundation

[3]. Martín, M.I., López, F.A., Torralba, J.M., 2012. Production of sponge iron powder by reduction of rolling mill scale. Ironmak Steelmak 39 (3), 155–162.

[4]. Umadevi, T., Brahmacharyulu, A., Karthik, P., Mahapatra, P.C., Prabhu, M., Ranjan, M., 2012. Recycling of steel plant mill scale via iron ore sintering plant. Ironmak Steelmak 39 (3), 222–227.

[5]. Fleischanderl, A. M, Managing Steel Wastes and By- Products: Crisis and Opportunity, Gorham/Intertech's 13th International Iron and Steel Development Forum, Antwerp, 11-14 May 1998, 45-50.

[6]. Osing, D. Reuse of Metallurgical Fines, Patent Wo 96/ 31630, 1996, A. Poulalion, Process of Recycling Mill Scale of Alloyed Steel in an Electric Furnace into a Ferro-Silicon Product," Patent Ep 1122319, 2001..