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Environmental Feasibility in Utilization of Foundry Solid Waste (Slag) for M20 Concrete Mix Proportions

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Abstract: *Slag utilized here is obtained from the blasting process of the metal ore in a Cupola furnace .Slag is a by-product of the iron and steel manufacturing process. Generally a blast furnace operates on a continuous basis and produces approximately 250 — 300 kg of slag per tons of iron produced. The slag is collected in a foundry in Coimbatore and it is approximately graded to the size of a coarse aggregate used in M20 grade concrete (i.e size of a 20mm jelly) and partial replacement of the coarse aggregate is seen in initial fractions. Also the fine aggregate used in M20 concrete mix ratio is completely replaced by use of quarry dust which is a cheaper material when compared to sand. Ratio of fine and coarse aggregates replacement are prepared and accordingly the cubes are casted as per IS:456-2000 M20 mix ratio. Then the cubes are set for curing in water for 28 days. The leachate analysis is carried out by taking water samples for every consecutive four days till the 28th day and the samples are analyzed for metals which are of high environmental concern. After the curing process the cubes are taken out and tested for compressibility .So in this project "WEALTH FROM WASTE" concept is established by using foundry solid waste (slag) and quarry dust as a replacement for normal coarse and fine aggregate, such that both civil and environmental concerns are taken into account.*

Keywords: *Slag, Coarse aggregate, Fine aggregate, Leachate analysis, compressibility test.*

I. Introduction

Coimbatore is a major industrial city in Tamilnadu. There are about 450 foundries, 300 motor manufacturing units, 200 wet grinder manufacturing units, about 300 brick kilns and 210 textiles dyeing and bleaching units in operation. In Coimbatore, as in other Indian cities, there is no separate zone for industrial/commercial activities. Therefore, some industries (mainly foundries) are located in residential areas resulting in severe pollution of the environment as a whole. Though the foundry industry dates back to the Harappa period, the most independent era has witnessed a phenomenal growth of foundries. According to published data, there are about 5000 foundries in India with an installed capacity of around 28.16 lakhs Tons per annum with the ferrous foundry accounting for 95% of the total units. It is estimated that the cupola.
Based ferrous foundry units numbering around 1000 are operating in and around Coimbatore with an annual

Output of around 6 lakhs tonnes per annum.These foundry units cannot be totally absolved of causing

Pollution since the foundry process by its nature is more pollution prone than many other activities. This has now engaged the attention of all for its effects on population and environment. Most of the foundries in and around Coimbatore are in the SSI (small scale industries) sector and equipped with cupola furnaces with the melting capacities ranging from 1-6 tons per hour. In cupola furnaces, the coke is employed as the main source of energy to melt down the mat allies.

Reuse of waste material has become very important during the past decade because of the reinforcement of environmental regulations that requires minimizing waste disposal mechanisms, i.e. incorporating some cleaner technology options. Steelmaking operations are specifically concerned by this problem because of generation of a huge quantity of by-products .i.e SLAG. Different kinds of slag constitute the major part of by-products from the iron and steel industry. At an integrated steel plant the production of one tonne steel results in about half a tonnes of by-products.

During the production of iron and steel, fluxes (limestone and/or dolomite) are charged into blast furnace along with coke for fuel. The coke is combusted to produce carbon monoxide, which reduces iron ore into molten iron product. Fluxing agents separate impurities and slag is produced during separation of molten steel. Slag is a non-metallic inert by-product primarily consists of silicates, alumina silicates, and calcium-alumina-silicates. Generally a blast furnace operates on a continuous basis and produces approximately 250 — 300 kg of slag per tonnes of iron produced. The total steel production in India is about 72.20 Million Tones and the waste generated annually is around 18 Million Tones (considerably higher than the world average) but hardly 25% are being used mostly in cement production. Remaining 75% of waste i.e. SLAG are just thrown away as land-fills causing adverse environmental effects.

In this study solid waste which is known as SLAG produced in foundries in and around Coimbatore, are not just thrown away in land-fill but also can be converted into a useful product without environmental effects .i.e. WEALTH FROM WASTE concept. It was established from this study that it is of vital importance to be familiar with the technical significance of the secondary application of waste materials, and also with their possible environmental effects. Even though their application in construction reduces the quantity of landfills, which is why it can be considered as partial or total waste management, some waste materials might contain increased concentrations of substances harmful to human health or to the environment, especially when it reacts with water. So here in addition to utilization of slag as a replacement for coarse aggregate (gravel) the water which is used for curing is analyzed for leachate (metals).

On the basis of data from previously published works. Recycled materials used in construction may be classified according to their source:
a) Industrial waste and/or by-products (mining waste rock, metallurgical slags, foundry sand, coal fly ash, municipal solid waste incinerator ash, etc.)
b) Road by-products, such as reclaimed concrete pavement materials, and reclaimed asphalt pavement materials.

At the same time, having in mind that the national environmental strategy defines waste management as national priority with the so-called no-landfill concept, for the realization of which one should close the circle of avoiding the very creation of waste, reducing the quantity and harmfulness, recycling and reuse and some industrial waste materials . Thanks to their composition and structures, by which it can be used as secondary raw materials in construction.

II. Experimental Programme

Object of Testing

The main objective of testing was to know the behavior of concrete with replacement of coarse and fine aggregate with foundry slag and quarry dust respectively at room temperature. The main parameters studied were compressive strength and leachate analysis (metals). The materials used for casting concrete samples are described.

Materials used in Present Work

Cement

IS mark 53 grade cement was used for all concrete mixes. The cement used was fresh and without any lumps.

Coarse aggregates

Locally available coarse aggregates having the maximum size of 10 mm to 20mm were used in the present work. The 20mm aggregates were first sieved through 20mm sieve and then it was washed to remove dust and dirt and was dried to surface-dry condition.

Fine aggregate

Fine aggregate can be naturally or crushed. The specification required that it should consists of hard, dense, durable, uncoated fragments and shall be free from impurities such as dust, clay, silt, mica and organic matter, soft and flaky particles. The sand particles should also pack to give minimum water. The sand used for the experimental programme was locally procured and conformed to grading zone III as per IS: 383-1970. The sand was first sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm and then was washed to remove the dust.

Foundry slag

Investigations were made on foundry slag procured from the Foundries located in and around Coimbatore region, Tamilnadu. The chemical and physical properties of the foundry slag used in this investigation are listed in Table 3.1 and Table 3.2 respectively.

Table.1 Physical Properties of Slag

S.No	Physical properties	Value
1	Specific Gravity	2.38
2	Specific Gravity	0.39%
3	Water Absorption	1058 kg/cum
4	Dry loose bulk density	0.90%
5	Soundness	3.14
6	Fineness modulus.	I
7	Zone	1.38%

Table.2 Chemical Properties of Slag

Chemical Properties		
S.No	**Constituents**	**%**
1	LOI	1.80
2	Silica	30.20
3	R_2O_3	20.20
4	Fe_2O_3	0.60
5	Al_2O_3	19.60
6	CaO	32.40
7	MgO	9.26
8	SO_2	0.27
9	Insoluble matter	0.80

Quarry dust

Quarry dust is a rock particle obtained when huge rocks break into smaller particles in quarries. It is like sand but mostly grey in color. In addition it has got some mineral particles. Here we are using the quarry dust to replace the fine aggregate (sand) completely. And also it is economically feasible when compared to sand. So here we are completely replacing the fine aggregate by the use of quarry dust.

Water

Water is an important component of concrete as its activities participate in the chemical reaction with the cement. The strength of the cement concrete mainly comes from the binding action of hydrated cement gel. The requirement of water should be reduced to the required chemical reaction of un- hydrated cement as the excess water would end up in only formation of undesirable voids (and /or capillaries) in the hardened cement paste in concrete. It is generally stated that the water fit for drinking is fit for making concrete. In the present investigation drinking water was used for both mixing and curing of concrete cubes.

Moulds

Cubical mould of size 150x150x150 mm was used to prepare the concrete specimens for the determination of compressive strength of foundry slag concrete at various replacement levels. Care was taken during casting and proper compaction was established by use of steel rod. The casted cubes are then immersed in water for 28 days of curing in separate tubs.

Mix Designation

Concrete mix has been designed based on Indian Standard Recommended Guidelines IS: 456-2000 (M20 grade). The proportions for the concrete, as determined were 1:1.5:3 with water cement ratio of 0.65 by weight. The mix designation and quantities of various materials for each designed concrete mix have been tabulated in Table 3.3 for cubes

Table.3 Mix Designation for Cubes

S.No	CEMENT (IN PARTS)	FINE AGGREGATE (IN PARTS)		COARSE AGGREGATE (IN PARTS)	
		SAND	**QUARRY DUST**	**GRAVEL**	**SLAG**
Control	1	1.5	0	3	0
Sample-1	1	0	1.5	2.5	0.5
Sample-2	1	0	1.5	2.0	1.0
Sample-3	1	0	1.5	1.5	1.5
Sample-4	1	0	1.5	1.0	2.0
Sample-5	1	0	1.5	0.5	2.5
Sample-6	1	0	1.5	0	3

Tests on Fresh Concrete

Fresh concrete or plastic concrete can be mould into any shape, using freshly mixed materials. The relative quantities of cement, aggregate and water mixed together control the wet state as well as hard state.

Workability is the important quality of fresh concrete. Workability is defined as the ease with which a given state of material can be mixed into concrete and subsequently handled, transported, placed and compacted without loss of homogeneity.

Measurement of Workability

Slump Test

The mould for the slump test is in the form of a cone of bottom diameter 20cm, top diameter 10cm and height 30cm. The mould is filled with fresh concrete in four layers, each approximately one quarter of the height of the mould. Each layer shall be compacted by using tamping rod. After the top layer has been rodded and top surface is leveled, the mould is removed from the concrete by raising it slowly in vertical direction. The concrete subside at the slum is measured immediately by determining the difference between the height of the mould and height point of the specimen being tested. The test determines the consistency of the fresh concrete and gives comparable result in the case of wet mixes.

Leachate Analysis

Analysis of metals

The casted cubes are soaked in different tubs containing water, which is of potable standard, for a period of 28 days (curing period). The water samples from each tub were collected for every consecutive four days in separate sample container till the 28^{th} day is achieved. The samples collected are immediately analyzed for metals such as copper, zinc, iron and nickel and was compared with that of BIS standards of drinking water quality. The analytical procedure was carried out as per BIS-IS: 10500-2012 manual.

Physico-chemical analysis

Initially the water used for curing is analyzed for various physico-chemical parameters such as pH, total hardness, conductivity, chlorides and total alkalinity (i.e. before the curing period). Then the water samples from each tub were analyzed for above parameters (i.e. after 28 days of curing period). The analytical procedure was carried out as per BIS-IS: 10500-2012 manual.

III. Results and Discussion

General

Various properties of concrete incorporating foundry slag and quarry dust at various replacement levels with normal coarse and fine aggregates were studied. Results were compared and checked for compressive strength and leachate analysis of foundry slag mix with that of control.

Compressive Strength

Concrete is strong in compression and in construction also concrete is mainly used in compression. Higher the compressive strength better is the durability and bond strength. Resistance to abrasion and volume stability improve with the compressive strength which is very important in quality control of concrete.15cm, cube size is normally used. The apparatus used are Cube moulds 15cm size, trowels, tamping rod 16mm diameter and 60cm long, compression testing machine.

Compressive strength, $C = P/A$ where,

P= load in Newton

A= area of cross section of cube in mm²

In this research the values of compressive strength for different replacement levels of foundry slag contents(16.67%,33.33%,50% ,66.6%83.33% and 100%) at the end of curing periods (28 days,) are given in Table 4.1. These values are plotted in figs. 4.1, which show the variation of compressive strength with coarse and fine aggregate replacements respectively. It is evident from Fig. 4.1 that compressive strength of concrete mixtures with 16.67%,33.33% and 50% of foundry slag for gravel replacement was higher than the standard value i.e.20N/mm² and concrete mixtures with 66.6% , 83.33% and 100% of replacement of coarse aggregate with slag is more or less equal to the standard value. Fig. 4.1 shows that compressive strength decreases with the increase in foundry slag. Figs. 4.1 show the compressive strength ratio (at 28 days) with respect to percentage replacement of gravel by foundry slag.

Table.4 Compressive Strength of concrete cubes (N/mm^2) for M20 Mix at 28 days of Curing.

Cube Designation	Avg. Ultimate Compressive Strength of Concrete in (N/mm^2) at 28 days of Curing
Control	25.18
Sample-1	22.88
Sample-2	21.55
Sample-3	20.44
Sample-4	18.66
Sample-5	17.22
Sample6	17.11

Physico-Chemical Analysis

Initially the water used for curing is analyzed for various physico-chemical parameters such as pH, total hardness, conductivity, chlorides and total alkalinity (i.e. before the curing period). Then the water samples from each tub were analyzed for above parameters (i.e. after 28 days of curing period). The values are compared and were found to be within the permissible limits.

Table.5 Drinking water quality standards (BIS IS: 10500-2012)

Parameters	Permissible Limits
pH	6.5-8.5
Electrical Conductivity	Less than 250 µs/cm
Total hardness	200 mg/l as caco3
Total alkalinity	200 mg/l
Chloride	250 mg/l

Before Curing

Table.6 Physico-chemical Parameter of Water Before Curing

Parameters	Permissible Limits
pH	7.5
Electrical conductivity	0.45 µs/cm
Total hardness	20 mg/l as $CaCO_3$
Total alkalinity	20 mg/l
Chloride	40 mg/l

After Curing

Table.7 pH Level in Leachate Sample

Characteristics	pH
Control	9.40
Sample-1	9.47
Sample-2	9.65
Sample-3	9.52
Sample-4	9.59
Sample-5	9.85
Sample6	9.60

Table.8 Concentration of Electrical Conductivity in Leachate Sample

Characteristics	Electrical Conductivity (µs/cm)
Control	0.57
Sample-1	0.62
Sample-2	0.52
Sample-3	0.46
Sample-4	0.62
Sample-5	0.60
Sample6	0.66

Table.9 Concentration of Total Hardness in Leachate Sample

Characteristics	Total Hardness (As Caco3) (Mg/L)
Control	20
Sample-1	20
Sample-2	30
Sample-3	20
Sample-4	40
Sample-5	20
Sample6	30

Table.10 Concentration of Total Alkalinity

in Leachate Sample

Characteristics	Total alkalinity (as HCO3) mg/L
Control	40
Sample-1	20
Sample-2	20
Sample-3	10
Sample-4	10
Sample-5	10
Sample6	10

Table.11 Concentration of Chloride in Leachate Sample

Characteristics	Chloride (as Cl) mg/L
Control	89.7
Sample-1	39.7
Sample-2	49.6
Sample-3	39.7
Sample-4	29.7
Sample-5	39.7
Sample6	39.7

Leachate Analysis
Analysis of metals

The casted cubes are soaked in different tubs containing water, which is of portable standard, for a period of 28 days (curing period). The water samples from each tub were collected for every consecutive four days in separate sample container till the 28th day is achieved. The samples collected are immediately analyzed for metals such as copper, zinc, iron and nickel and was compared with that of BIS standards of drinking water quality. The test for presence of metals (leachate analysis) was found to be within the permissible limits.

Table.12 BIS-IS: 10500-2012 Drinking water quality standard.

Metals	Permissible Limits (mg/l)
Copper	0.05-1.5
Iron	0.3
Zinc	5-15
Nickel	0.02

Table.13 Concentration of Copper in Leachate Sample

S.No	Characteristics	Average leachate of copper ,(mg/l)
1	Control	0.0625
2	Sample-1	0.0825
3	Sample-2	0.105
4	Sample-3	0.135
5	Sample-4	0.1625
6	Sample-5	0.135
7	Sample6	0.1425

Table.14 Concentration of Iron in Leachate Sample

S.No	Characteristics	Average leachate of Iron,(mg/l)
1	Control	0.1275
2	Sample-1	0.1475
3	Sample-2	0.17
4	Sample-3	0.18
5	Sample-4	0.1975
6	Sample-5	0.21
7	Sample6	0.21

Table.15 Concentration of Zinc in Leachate Sample

S.No	Characteristics	Average leachate of zinc,(mg/l)
1	Control	0.02
2	Sample-1	0.0268
3	Sample-2	0.0263
4	Sample-3	0.0268
5	Sample-4	0.0373
6	Sample-5	0.0503
7	Sample6	0.0513

Table.16 Concentration of Nickel in Leachate Sample

S.No	Characteristics	Average leachate of Nickel,(mg/l)
1	Control	0.00175
2	Sample-1	0.00225
3	Sample-2	0.003
4	Sample-3	0.0035
5	Sample-4	0.0045
6	Sample-5	0.011
7	sample-6	0.01175

IV. Conclusion:

- The analysis of metals for leachate was found to be within limits. Hence there is no environmental pollution in use of foundry solid waste(slag) and quarry dust in concrete preparations.
- And also the compression strength of cubes was found to be effective i.e more or less equal to 20 N/mm². The result also shows decreasing strength with the increase in replacement percentage of coarse aggregate. So here we are suggesting the mix ratio with above solid waste for pavers and hollow-block constructions only.
- The use of quarry dust (1 unit= Rs. 1200) to replace the fine aggregate is economically feasible when compared to normal river sand (1 unit=Rs. 3500 to 4000).
- Also the use of slag (simply thrown away in landfills). to replace the coarse aggregate is economically feasible when compared to normal blue metal(20mm gravel 1 unit= Rs. 2800 to 3000)
- In this study both environmental and civil aspects are satisfied.
- Hence, it could be recommended that slag could be effectively utilized as partial replacement of normal coarse aggregate and quarry dust as complete replacement of fine aggregate(sand) in most applications as per this part of study.

Pictures

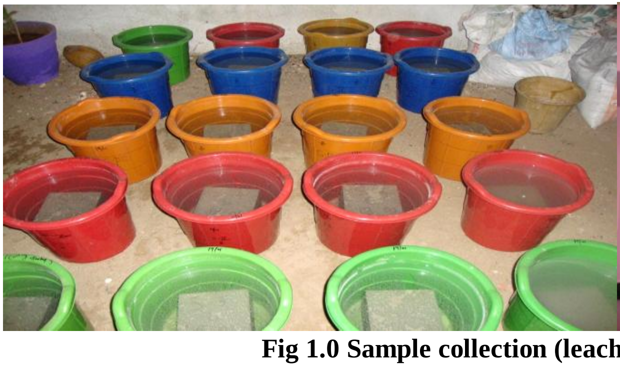

Fig 1.0 Sample collection (leachate analysis for metals)

Fig 2.0 Compression test of M20 concrete cube

V. Future Work:

In this study the compressibility test and leachate analysis of concrete cubes casted by the use of quarry dust and foundry slag was found to be good. Presently we are suggesting our work only for making pavers and for hollow-block constructions. In our future work, the workability and durability of different ratios of coarse aggregate (slag) and fine aggregate (quarry dust) of M-20 mix proportions will be studied in detail. Also a detailed leachate analysis (for various metals) by using nitric acid method will be carried out in the future part of our study.

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