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Study On Mechanical Properties Of Concrete Made With Industrial Waste Blended With Cement And Lime

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***Abstract*— Solid waste management is the prime concern in the world to-day. Due to non availability of dumping space and land – filling area, utilization of industrial wastes in construction sector has become an attractive proposition to disposal. Acceptance of industrial waste/by-products as raw materials in concrete making has encouraged researchers in evaluating and exploring technologies. Utilization of industrial waste/by-products in concrete strengthens economy as well as ecology.**

Ferro Alloy industry is one of the industries producing huge quantity of wastes in form of ferrochrome ash & ferrochrome slag. Ferrochrome ash is the dust obtained from gas cleaning plant of Ferro alloy industries. The gas emitted from Ferro- alloy smelting furnaces contain particles of dust, dirt and incompletely combustion wood and/or coal and coke. Gas cleaning plant cleans above gases and during this process huge quantity of dust is collected which is named as ferrochrome ash (FA) in this research. Ferrochrome slag is obtained as a waste material by smelting process during the production of stainless steel. Global annual production of ferrochrome is around 6.5 to 9.5 million tons. The same is increasing at the rate of 2.8% to 3% per year. It is reported that generation of solid waste for each metric ton (MT) of ferrochrome product is about 1-1.2 MT. Odisha itself has nine numbers of Ferroalloy industries. Solid wastes from these industries are also increasing day by day. Not only these have occupied valuable space but also threatening the aquifer. Disposal and utilization of ferrochrome waste is one of the subjects essentially addressing the recent research interest. Use of ferrochrome waste in concrete making is investigated in this research work considering the requirement of ferrochrome waste disposal.

Current investigation has explored possibility on use of (i) ferrochrome ash along with lime for partial replacement of cement (ii) ferrochrome slag as coarse aggregate replacing the natural coarse aggregates for preparation of concrete.

Keywords: Ferrochrome Ash, Pozolonic property, Lime, Cement

Introduction: *It is beyond doubt that activity of primary industries often yields substantial amounts of by products .The disposal in the original industrial site is favored by economic reasons through traditional storage in nearby dumps can be impractical owing to the considerable masses involved and environmental restrictions The local exploration of these by-products is therefore a growing technological accepts of basic industries and one tenable option is there reuse as starting materials for other productions. The huge amount of industrial by products or wastes which is becoming a client for increasing environmental pollution and generation of a huge amount of utilization resources. With a view to the above, this investigation is aimed at finding out operation of such things/material/industrial consequence for value added application and also helps to solve the environmental complications. The present pieces of my research work aims at, to provide a valued input/utilization to industrial by-product/waste. The current year, the uses of the building materials of dissimilar type in addition to cement become very wide in the product of concrete as amalgamation of the Portland cement with limestone, so it is essential to examined they influence of the folder material on the concrete properties. To overcome these problems there is a need of cost effective, alternative and innovative materials. In present study, red mud is used as SCM to replace cement partially from 0% to 25% at the increment of 5%. It is generally discharged as highly alkaline slurry (pH 10- 13.5) with 15-40% solids, which is pumped away for appropriate disposal. Its chemical and mineralogical composition may temporarily change, depending on the source of bauxite and on the technological processing conditions. It is composed by six major oxides namely Al2O3, Fe2O3, Na2O, SiO2, CaO, and TiO2, and a large variety of minor elements. Its strong alkaline character (Na2O + Na OH = 2.0-20.0 wt. %), restricts the disposal conditions in order to minimize environmental problems such as soil contamination and groundwater trash. The red mud is one of the main solid wastes coming from Bayer's process of alumina invention. At present about 3 million tons of red mud is produced annually, which is not being willed or recycled reasonably. The conventional method of disposal of red mud in ponds has often* *adverse environmental impacts as during monsoons, the waste may be carried by run-off to the surface water courses and as a result of leaching may cause contamination of ground water: Further disposal of large quantities of Red mud dumped, poses increasing problems of storage occupying a lot of space.*

2. **Literature Review**

The increasing quantities of waste materials and industrial by-products have made solid waste management a global priority. With landfilling space becoming scarce and costly, recycling and utilizing these by-products in concrete production offers an attractive solution. Incorporating industrial by-products in concrete not only makes it more economical but also addresses disposal issues and helps conserve natural resources, which are being depleted due to large-scale construction.

Various industrial by-products, such as coal bottom ash, recycled fine aggregate, sewage sludge ash, stone dust, and glass cullet, can replace natural aggregates in concrete. This approach has shown potential in improving the mechanical and durability properties of concrete. For instance, incorporating limestone powder as a filler in concrete enhances early strength and reduces bleeding, while reducing CO2 emissions and conserving mineral resources. Studies have demonstrated that industrial by-products like copper slag, steel aggregates, and fly ash can enhance the strength and durability of concrete when used as partial replacements for fine and coarse aggregates and cement.

Moreover, the use of waste materials like marble aggregate and chemical foundry sand has proven beneficial in enhancing concrete's compressive and tensile strength. These practices not only mitigate the environmental impact of waste disposal but also promote sustainable construction by reducing reliance on natural resources.

EXPEREMENTAL PROGRAMME

3.1 GENERAL

This chapter deals with the details of experimental programmes to measure physical property of cement; fresh, hardened, non-destructive and durability properties of concrete.

Physical properties of cement are measured through its consistency, soundness, setting time. Fresh concrete properties are determined by slump test and density. Hardened concrete properties include compressive strength, flexural strength, split tensile strength, bond strength and modulus of elasticity. Durability properties are determined in forms of acid resistance, sulphate resistance, abrasion resistance, water permeability & sorptivity. Non – destructive test includes rebound hammer and ultra sonic pulse velocity.

3.2 MATERIALS USED

3.2.1 Cement

Ordinary Portland Cement (OPC), 43 Grade conforming to Indian standard specification IS 8112:1989 are used in this research work. Test results of various properties are presented in Tables 3.1 to 3.6.

Table 3.1 Physical Properties of Ordinary Portland Cement (OPC) 43Grade

Physical Properties	**Test Result Obtained**	**Requirements as per BIS:8112:2013**
Soundness(Le-chatelier apparatus)(mm)	0.7	Maximum 10
Setting Time (Min)		
Initial	127	Minimum 30
Final	218	Maximum 600
Compressive Strength(MPa)		
3 day	35.7	Minimum 23
7 day	44.7	Minimum 23
28 days	57.1	Minimum 43 Maximum 58
Standard consistency (%)	28.1	-
Fineness (M^2/Kg)	326	Minimum 225

Table 3.6 Chemical Properties of Ordinary Portland Cement (OPC) 43Grade

Chemical Properties	**Test Result Obtained**	**Requirements as per BIS:8112:2013**
Ratio of % of Lime to % of Silica, Alumina and iron oxide	0.92	Maximum 1.02 Minimum0.66
Ratio of % of Alumina to % of Iron Oxide	1.38	Minimum 0.66
Insoluble residue %	0.93	Maximum 4.0
Magnesia %	1.1	Maximum 6.0
Sulphuric Anhydride %	1.78	Maximum 3.5
Total loss on ignition%	2.32	Maximum 5.0
Chloride Content%	0.01	Maximum 0.1
Tricalcium Aluminates	7.99	-

3.2.2 Fine Aggregate

Natural sand collected from local river having maximum size 4.5mm was used as fine aggregate in the study. The physical properties and sieve analysis of above fine aggregate are presented in tables in 3.7 & 3.8

Table 3.7 Physical Properties of Fine Aggregate.

Sl. No	**Properties**	**Observed Value**
1	Bulk Density(Kg/m^3)	1652
2	Specific Gravity	2.7
3	Water absorption %	0.73
4	Fineness Modulus	2.39

Table 3.8 Sieve Analysis of Fine Aggregate

Weight of sample taken =500 grams

I.S. Sieve size in mm	Weight retained in grams	%Weight retained in grams	Cumulative % of weight retained.	% Passing	Requirementfor Zone-III as perIS:383-1970
10	0	0	0	100	100
4.75	8.8	1.77	1.8	98.23	90-100
2.36	44.7	8.93	10.7	89.30	85-100
1.18	38.5	7.70	18.4	81.60	75-100
0.60	76.0	15.2	33.6	66.40	60-79
0.30	189.0	37.8	71.4	28.60	12-40
0.15	112.0	22.4	93.8	6.20	0-10

The above fine aggregate sample conforms to grading Zone III of IS: 383-1970.

3.2.3 Coarse Aggregates

Black hard coarse crusher broken granite natural stone aggregates with maximum 20 mm size are used in this study. The aggregates are tested as per I.S.383-1970. Different test results are recorded in Tables 3.9 & 3.10

Table 3.9 Physical Properties of Coarse Aggregates

Sl.No	Properties	Observed Value
1	Bulk Density(Kg/m^3)	1698
2	Specific Gravity	2.83
3	Water absorption %	0.2
4	Fineness Modules	5.95
5	Abrasion value %	18.6
6	Impact value %	15.3

Table 3.10 Sieve Analysis of Coarse Aggregates

Weight of sample taken=5000 grams.

I.S. Sieve size in mm	Weight retained in grams	%Weight retained in grams	Cumulative % of weight retained.	% Passing	Requireme as per IS:38 1970
40	0.00	0.00	0.00	100	100
20	135.00	2.70	2.70	97.30	95-100
10	2440.00	48.80	51.50	48.50	25-55
4.75	2110.00	42.20	93.70	6.30	0-10

The coarse aggregate sample conforms to 20 mm graded aggregates of nominal size as per table-2 of IS: 383:1970.

3.2.4 Water

Water used in this research work was tested as per the requirements of IS: 456-2000.

The test results are presented in table 3.11

Table 3.11: Properties of Water

Sl No	Properties	Observed Value
1	pH value	7.1
2	Dissolved solids(mg/l)	290
3	Suspended Solids	Nil

Figure 3.3 Lime

Fig 3.4 Ferrochrome Ash

3.2.5 Ferrochrome Slag

Ferrochrome slag which is shown in Fig. 3.3 is obtained as a waste material by smelting process during the production of stainless steel. These are available in shape of coarse aggregates. The detail property and its source are discussed in chapter 1.

Figure 3.5 Ferrochrome Slag.

A. *Description of Concrete Mixes*

Mix Name.	Mix composition	Mix Proportion
M-1	OPC +0% lime + 0% Ash	1:2:4
M-2	OPC +0% lime + 0%Ash + 100% Slag aggregate	1:2:4
M-3	OPC + 7% lime + 10%Ash + 100% Slag aggregate	1:2:4
M-4	OPC + 7% lime + 20%Ash + 100% Slag aggregate	1:2:4
M-5	OPC + 7% lime + 30%Ash + 100% Slag aggregate	1:2:4
M-6	OPC + 7% lime + 40%Ash + 100% Slag aggregate	1:2:4
M-7	OPC + 0% lime + 0% Ash+100% Slag aggregate	1:1.5:3
M-8	OPC + 7% lime + 40% Ash+100% Slag aggregate	1:1.5:3

Table 3.16 Details of Mix Ingredients (M-1 TO M-8)

Mix No.	M-1	M-2	M-3	M-4	M-5	M-6	M-7	M-8
Cement OPC(Kg/m^3)	330	330	273.9	264	207.9	174.9	420.0	222.6
Fine aggregate(Kg/m^3)	660	660	660	660	660	660	630	630
Coarse aggregate (Kg/m^3)	1320							
Water cement ratio	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Water(Kg/m^3)	148.5	148.5	148.5	148.5	148.5	148.5	189	189
Super plasticizer(%)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Super plasticizer(L/ m^3)	1.513	1.513	1.513	1.513	1.513	1.513	1.926	1.926
Lime (%)	0		7	7	7	7		7
Lime (kg/m^3)	0		23.1	23.1	23.1	23.1		29.4
Ferrochrome ash (%)	0		10	20	30	40		40
Ferrochrome ash(kg/m^3)	0		33	66	99	132		168
Ferrochrome slag (%)		100	100	100	100	100	100	100
Ferrochrome slag (kg/m^3)		1320	1320	1320	1320	1320	1260	1260
Slump (mm)	66	110	90	75	68	57	95	62
Air temperature (^{0}c)	28	28	29	28	27	28	27	27
Concrete temperature (^{0}c)	27	27	28	27	27	27	26	26

RESULTS AND DISCUSSION

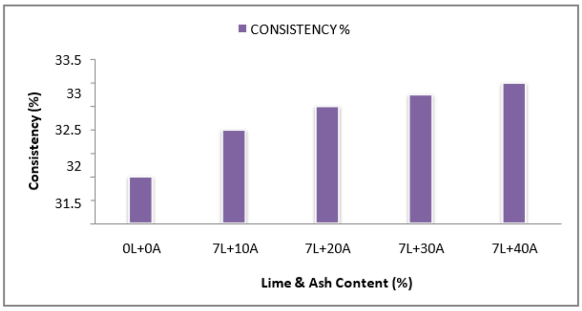

Figure 4.2.1 Effect of lime and ferrochrome ash (FA) on consistency of OPC

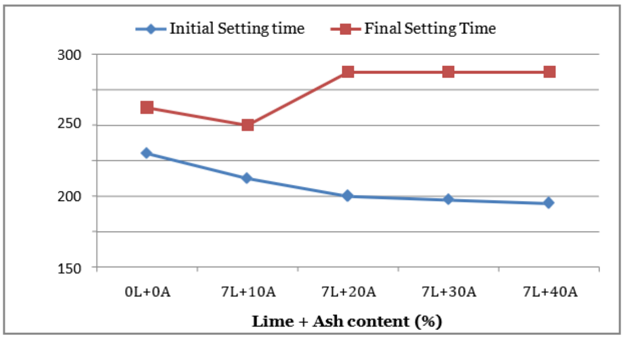

Figure 4.6 Effect of lime and ferrochrome ash (FA) on setting time of OPC

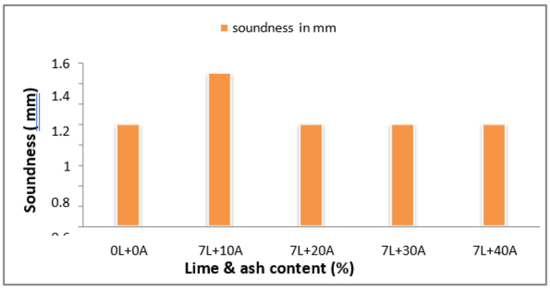

Figure 4.7 Effect of lime and ferrochrome ash (FA) on soundness of OPC

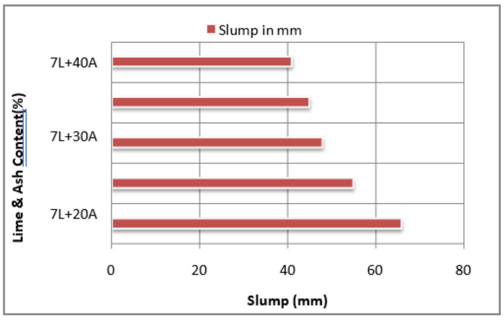

Figure 4.8 Workability of concrete made of OPC blended with lime & ferrochrome ash

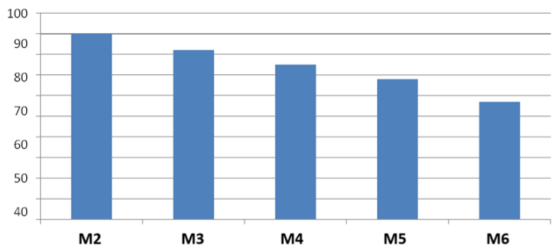

Figure 4.10 Workability of concrete using ferrochrome slag with ferrochrome ash andlime in OPC

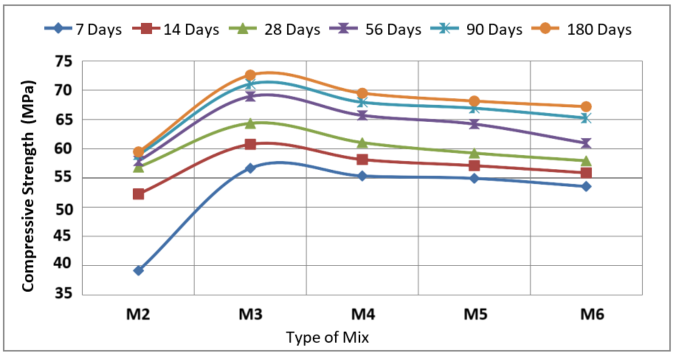

Figure 4.31 Compressive strength of concrete with ferrochrome slag as coarse aggregate verses lime and ferrochrome ash content.

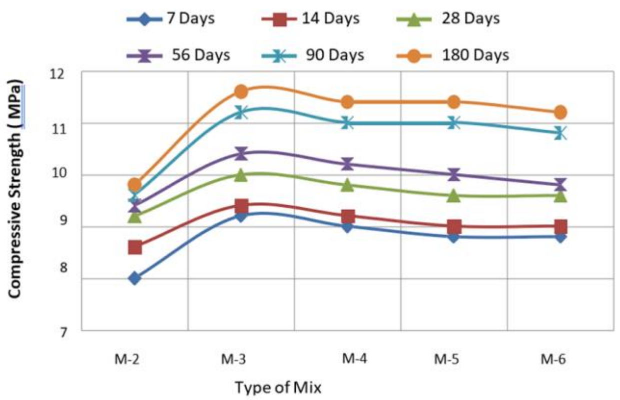

Figure 4.45 Flexural strength of concrete made of OPC with ferrochrome slag as coarse aggregate verses lime and ferrochrome ash content.

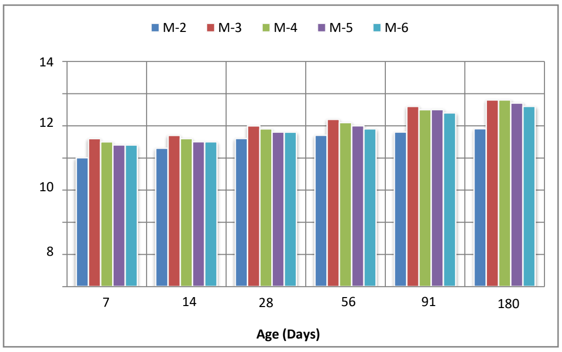

Figure 4.46 Flexural strength of OPC blended with lime &ferrochrome ash containing ferrochrome slag as coarse aggregate verses age

5.1. Conclusions:

1. • Due to inclusion of 7% lime and 10% - 40% ferrochrome ash on cement replacement to concrete made with OPC, containing natural coarse aggregate, the compressive strength increased 66.94 - 51.49% at 7 days, 13.58 -1.38% at 28 days, 24.14 -11.00% at 91 days, 35.36 -11.59% at 180 days in comparison to normal concrete. Results showed high rise in short term strength, rise in 28 days strength and appreciable rise in long term strength.

• Compressive strength reduced with increased % of cement replacement. However, at cement replacement level of 47%, 7% by lime and 40% by ferrochrome ash, 7 days strength was 51.49%, 28 days strength was 1.38%, 91 days strength was 11% and 180 days strength was 11.59% more than the control mix.

• Compressive strength equal to normal concrete or even more was achieved on replacement of cement to the tune of 47% , 7% by lime and 40% by ferrochrome ash in various mix proportions such as{1:1.3:3},{1:1.5:3.5}, {1:1.5:3}, {1:1:2.5} &

{1:2.5:5} of concrete using OPC(43 grade).

Due to inclusion of 7% lime and 10% - 40% ferrochrome ash on cement replacement to concrete made with OPC, containing natural coarse aggregate, the flexural strength increased 15.78 – 10.52% at 7 days, 9.09 -4.54% at 28 days, 11.11 - 6.66% at 91 days, 15.55 - 6.66% at 180 days in comparison to normal concrete. Results showed high rise in short term strength, rise in 28 days strength and appreciable rise in long term strength.

• Flexural strength at highest replacement 47% of cement, 40% by ash &7% by lime, At the age of 7, 28, 91 and 180 days is 10.52, 4.54,6.66 and 6.66 % more than the control mix.

• The compressive strength of concrete made from OPC containing lime and ferrochrome ash increased with age.

• Due to inclusion of 7% lime and 10% - 40% ferrochrome ash on cement replacement to concrete made with OPC, containing ferrochrome slag coarse aggregate, the compressive strength increased 15.00 – 10.00% at 7 days, 8.69 -4.34% at 28 days,

16.66 -12.50% at 91 days, 18.36 -14.28% at 180 days in comparison to normal concrete.

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