EFFECTIVE UTILIZATION OF FOUNDRY SAND AND GROUND GRANULATED BLAST FURNACE SLAG IN GEOPOLYMER CONCRETE

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ABSTRACT:
Nowadays, concrete is most widely used material used in construction industry. Global use of concrete is second after the water utilization. The component of concrete i.e. Cement, Sand, Aggregate, Admixtures are contributing the strength and various properties in concrete but various environmental issues are related with concrete. In which cement leads to affect environment by emission of CO_2. Geopolymer concrete is the best example in which total replacement of cement can be done by fly ash and ground granulated blast furnace slag. Geopolymer concrete is a concrete which does not utilize any Portland cement in its production. Waste-foundry sand and Ground granulated blast furnace slag are the by-product of ferrous and nonferrous metal casting industries. Foundries successfully recycle and reuse the sand many times in a foundry in process of mould and core making and after reuse of sand is discarded as waste foundry sand which cannot be again use in casting along with Ground granulated blast furnace slag. In this study an effort is made to found out the effectiveness of used foundry sand as a partial replacement of fine aggregate in geopolymer concrete at various percent. A concrete made by using GGBS, Fly ash replacing cement totally and partially replacement of fine sand by Foundry sand at various replacement level done and the strength of these Geopolymerised foundry sand concrete carried out.

KEYWORDS: **Waste foundry sand, Ground granulated blast furnace slag, Industry, Silica sand, alkali solution, Compressive strength.**

I. INTRODUCTION

There is a growing interest in reducing carbon emissions related to concrete from both the academic and industrial sectors, especially with the possibility of future carbon tax implementation. One reason why the carbon emissions are so high is because cement has to be heated to very high temperatures in order for clinker to form. The global warming and greenhouse effect are highly profiled issues that are becoming more and more visible in the media. It is now part of everyday language to refer to CO_2 emissions coming from daily routines. The emission of greenhouse gases is a problematic factor for industries like cement industries, as the greenhouse effect can produce an increase in global temperature and variations in climatic conditions. The studies conducted in this area shows that the production of cement is increasing about 3% per year. The production of one ton of cement liberates about one ton of CO_2 to the atmosphere respectively. In 1978, Davidovits proposed that an alkaline liquid could be used to react with the silicon (Si) and the aluminum (Al) in a source material of geological origin or in by-product materials such as fly ash to produce binders. Because the chemical reaction that takes place in this case is a polymerization process, he named the term Geopolymer to represent these binders. Thus Geopolymer concrete is a concrete which does not use any Portland cement in its production. There are two main constituents in geopolymer concrete, namely the source materials i.e. sand, aggregates and the alkaline liquids. The source materials forge polymers based on alumina-silicate should be rich in silicon (Si) and aluminum (Al). Alternatively, by - product materials such as fly ash, blast furnace slag, rice husk ash, etc. could be used as source materials. The most common alkaline liquid used for geopolymerisation is a combination of sodium hydroxide and sodium silicate. Geopolymers are members of the family of inorganic polymers and the chemical composition of the geopolymer material is similar to natural zeolitic materials, but the microstructure is amorphous instead of crystalline. For geopolymer concrete, an increase in the compressive strength with increase in the molarity was shown. Importance of curing temperature also was clearly seen while conducting the tests. Foundry sand is high quality silica sand with uniform physical characteristics. It is a byproduct of ferrous and nonferrous metal casting industries, where sand has been used for centuries as a molding material because of its thermal conductivity..

The physical and chemical characteristics of foundry sand will depend in great part on the type of casting process and the industry sector from which it originates. In modern foundry practice, sand is typically recycled and reused through many production cycles. Industry estimates that approximately 100 million tons of sand are used in production annually of that 6 - 10 million tons are discarded annually and are available to be recycled into other products and in industry. The automotive industries and its parts are the major generators of foundry sand. Foundries purchase high quality size-specific silica sands for use in their molding and casting operations.

In this work, fly ash and GGBS based geopolymer is used as the binder to form concrete. Sodium silicate and sodium hydroxide is used as alkaline liquid. The effectiveness of foundry sand as partial replacement of fine aggregate in geopolymer concrete is investigated in this study. Study was conducted for 0%, 10%, 20% and 30% replacement of foundry sand by weight of fine aggregate.

II. LITERATURE SURVEY

Prakash R. Vora et al. [10] analyzed the Various parameters which may affect the Geopolymer concrete that is alkaline liquid to fly ash ratio, concentration of NaOH, sodium silicate to sodium hydroxide ratio, time of curing, curing temperature range, amount of super plasticizer, rest period time and additional amount of water in the mix have been researched. As per test result it can be concluded that compressive strength increases with the curing time increase, high curing temperature, rest period time, concentration of NaOH solution and decreases with increase in the water to Geopolymer solids by mass ratio & doses of admixture, respectively and naphthalene based super plasticizer improves the workability of Geopolymer concrete. It was further studied that in the Geopolymer concrete mix amount of water plays noteworthy role in achieving the desired compressive strength.

S.V. Patankar and S.S. Jamkar [11] studied the effect of partial replacement and full replacement of cement by low calcium fly ash in two phases. It was found that the compressive strength decreases with increase in replacement of cement by fly ash. Up to 40% replacement of cement, initial strength is less but strength at 60 days of curing is more or less similar to that of conventional concrete at 28 days of curing. Beyond 40% replacement of cement, workability and strength has been reduced and setting time increased. Beyond 60% replacement of cement, increases the water demand, difficulty in mixing, more time required for demoulding of cubes and reduction in the rate of gain of strength is observed.

Djwantoro Hardjito Steenie E. Wallah, D. M. J. Sumjouw and B.V. Rangan studied the influence of curing temperature, curing time and alkaline solution-to-fly ratio on the compressive strength. It was reported that both the curing temperature d the curing time influenced the compressive strength. The authors confirmed that the temperature and curing time significantly influenced the compressive strength. Curing time and curing temperature increase the compressive strength, although the increase in strength may not be significant for curing at more than 60°C.Also the compressive strength decreases when the water-to-geopolymer solids ratio by mass increased. The drying shrinkage strains of fly ash based geopolymer concretes were found to be significant.

A. Palomo and A. Fernandez-Jimenez studied the alkaline activation of industrial sub products like fly ash for making geopolymer concrete. For the production of the geopolymer concrete, an alkaline solution containing NaOH and sodium silicate (Na_2O = 32%, SiO_2 = 5%, and H_2O = 63%) were used. Concrete specimens were cast with solutions-to-fly ash ratio of 0.50 and 465 Kg/rn^3 of fly ash. After casting the moulds in three layers, the samples were kept in an oven and cured for 20 hours at 85°C. It was observed that the concrete give good mechanical strength with in a very short period of time. The authors found that for fly ash based geopolymer binder, the main factors affecting its mechanical strength were curing temperature, curing time, and the type of activator, while the solution-to-fly ash ratio was not a relevant parameter. Increase in curing temperature increased the compressive strength. The type of alkaline activators that content soluble silicates resulted in higher reaction rate than when hydro-oxide was used as the only activators. It was found that the compressive strength and flexural strength of geopolymer concrete reaches very high strength just after 20 hours of thermal curing at 85°C. Another remarkable fact is that the mechanical strengths continue to increase progressively, after the thermal curing, although at a slower rate.

Khatib and Ellis [5] Both studied the influence of three types of foundry sand as a partial replacement of fine aggregate on the compressive strength of concrete, up to the age of 90 days. Three types of sand used in foundries were; the white fine sand without the addition of clay and coal, the foundry sand before casting (blended) and the foundry sand after casting (waste). The standard sand (Class M) was partially replaced by (0, 25, 50, 75 and 100%) these sands. They concluded that (i) with the increase in the replacement level of standard sand with foundry sand, the strength of concrete decreased; (ii) the concrete containing white sand showed somewhat similar strength to those containing waste sand at all replacement levels; (iii) presence of high percentage of blended sand in the concrete mixture caused a reduction in strength as compared with concrete incorporating white sand or waste sand; (iv) increase in strength was not observed at low replacement levels (less than 50%).

Etxeberria determined the slump of concrete containing chemical foundry sand and green foundry sand. The mixture proportion on concrete made with chemical foundry sand was 300 kg cement, 447.5 kg foundry sand, 399.6 kg natural sand and 1150 kg coarse aggregates per cubic meter of concrete, with water/cement ratio of 0.61, whereas, proportion of concrete with green foundry sand was 300 Kg cement, 326 kg foundry sand, 458 kg natural sand and 1150 kg coarse aggregates with water/cement ratio of 0.69. Values of slump were 150 mm and 75 mm for concrete made with chemical foundry sand and green foundry sand respectively

Eknath [3] investigated the comparative study of the properties of fresh & hardened concrete containing ferrous & non-ferrous foundry waste sand replaced with four (0%, 10%, 20% and 30%) percentage by weight of fine aggregate & tests were performed for M20 grade concrete. Result showed that (i) addition of both foundry sand gives low slump mainly due to the presence of very fine binders; (ii) Compressive strength at 7 days of both ferrous & nonferrous mixtures increases and maximum increase was observed with 20% WFS of both types of sand, at 28 days 30% addition of ferrous WFS & 10% addition of nonferrous WFS gives same strength as ordinary concrete and goes on decreasing for higher percentages of replacement; (iii) Split tensile strength gives maximum values with 20% WFS for both types of sand; (iv) water absorption is minimum with 20% ferrous WFS & with 10% nonferrous WFS. They also reported that both ferrous & nonferrous WFS

III. OBJECTIVE

Utilization of GGBFS and foundry sand will reduce the disposal also it provide alternative to river sand which has decreasing at an enormous rate with respect to that of increasing urbanization . It shows that WFS is create a trend to force the Green concrete production.

Geopolymer concrete is best method to reduce CO_2 emission 80% and fully replacement of concrete is done in it but by replacement of fine sand by foundry sand leads to increase in strength and also cost reduction as foundry sand is available free of cost.

The main objective of testing was to know the behavior of Geopolymer concrete with replacement of ordinary sand with foundry sand.

VI. METHODOLOGY

In this methodology, Materials and properties of the materials with their ideal value is given.

A .Foundry Sand

Metal foundries consume large amounts of the metal casting process. Foundries successfully recycle and reuse the sand many times in a foundry and the remaining sand that is named as foundry sand is removed from foundry. This study shows the information about the civil engineering applications of foundry sand, which is technically sound and is environmentally safe. Consumption of foundry sand in different engineering applications can solve the problem of disposal of foundry sand and other purposes. Foundry sand consists primarily of silica sand, coated with a thin film of burnt carbon, residual binder (bentonite, sea coal, resins) & dust. Foundry sand can be used in concrete to make better its strength and other durability factors. Foundry Sand can be utilize as a partial replacement of cement or as a partial replacement of fine aggregates or total replacement of fine aggregate and as supplementary addition to achieve different properties of concrete.

TABLE 1
CHEMICAL PROPERTIES OF FOUNDRY SAND

Constituents	Value (%)
SiO_2	98
Al_2O_3	0.80
Fe_2O_3	0.25
CaO	0.035
MgO	0.023
SO_3	0.01
Na_2O	0.04
K_2O	0.04

TABLE 2
TYPICAL PHYSICAL PROPERTIES OF SPENT GREEN FOUNDRY SAND [AMERICAN FOUNDRYMAN'S SOCIETY, 1991]

Property	Results
Specific Gravity	2.45
Bulk Relative Density, kg/m^3 (lb/ft^3)	2589(160)
Absorption, %	0.45
Moisture content, %	0.1-10.1
Clay Lumps and Friable Particles	1- 44
Coefficient of Permeability (cm/sec)	10
Plastic Limit/Plastic Index	Non plastic

B. Fine Aggregate

Those fractions less than 4.75 mm and more than 150 micron are termed as fine aggregate. The river sand & crushed sand is be used in combination as fine aggregate conforming to the requirements of IS 383:1970. The river sand is wash and screen, to eliminate deleterious materials & over size particles.

TABLE 3.
PHYSICAL PROPERTY OF FINE AGGREGATE

Property	Result
Bulk Density (kg/m^3)	1760
Specific Gravity	2.56
Fineness Modulus	3.35

Water Absorption (%)	1.43

C. Course Aggregate

Aggregates are the main constituents in concrete. They give structure to the concrete, reduce shrinkage and effect economy. One of the most important factors for producing workable concrete is well gradation of aggregates. Well graded implies that a sample fractions of aggregates in required proportion such that the sample contains minimum voids. Samples of the good graded aggregate containing minimum voids require minimum paste to fill up the voids in the aggregates. Minimum paste is mean min quantity of cement and less water, which are further mean increased economy, higher strength, lower shrinkage and greater durability. The fractions less than 20 mm and more than 4.75 mm are used as coarse aggregate. The Coarse Aggregates from crushed Basalt rock & conforming to IS: 383 is being use.

D. Water

Water is an important ingredient and part of concrete as it actually participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully.

E. Fly ash

Fly ash is a fine, glass-like powder recovered from gases created by coal-fired electric power generation. Power plants produce millions of tons of fly ash annually, which is usually dumped in landfills. Fly ash is an inexpensive replacement for portland cement used in concrete, while it actually improves strength, and ease of pumping of the concrete. Fly ash is also used as an ingredient in brick, block, paving, and structural fills.

The fly ash or pulverized fuel is the residue, which is collected by the mechanical dust collector or electrostatic precipitator from the fuel gases of thermal power plants. Composition of fly ash varies with the type of fuel burnt, load on the boiler and the type of separator. Like Portland cement, fly ash contains oxides of calcium, aluminum and silicon, but the amount of calcium oxide is considerably less. The carbon contents should be as low as possible, where as the silica content should be as high as possible.

TABLE 4.
CHEMICAL COMPOSITION OF FLY ASH

Chemical Composition	Result
$SiO_2 + Al_2O_3 + Fe_2O_3$	96.02
SiO_2	77.10
Al_2O_3	17.71
Fe_2O_3	01.21
MgO	0.90
SO_3	2.20
Na_2O	0.80
CaO	0.62
Total chlorides	0.03
Loss of ignition.	0.87

F. Ground granulated blast furnace slag

The chemical composition of slag varies considerable depending on the composition of raw material in the iron and steel production process .silicate and aluminate impurities ore coke are combined in the blast furnace with a flux which lower the viscosity of the slag in the case of pig iron production. To obtain good slag reactivity or hydraulicity , the slag melt needs to be rapidly cooled or quenched below 800^o C in order to prevented the crystallization of merwinite and melilite .to cool and fragment the slag a granulation process can be applied in which molten slag is subjected to jet stream of water or air under pressure alternatively in the palletization process the liquid slag is partially cooled with water with water and subsequently projected in to the air by a rotating drum in order to obtain suitable reactivity ,the obtain fragment are ground to reached same fines Portland cement

TABLE 5.
CHEMICAL COMPOSITION OF GGBS

Component	Result
SiO_2	35
Al_2O_3	10
Fe_2O_3	-
CaO	40.50
MgO	8

G. Geopolymer concrete

Geopolymers can meet a “zero waste” objective because they can be produced from materials that are themselves waste products, such as fly ash, blast furnace slags, clays, and tailings. They reduce or even eliminate the need for raw materials. The study done so far related to production of mortar and or concrete with fly ash with alkaline activators and without cement have shown promising results. The properties of alkali-activated fly ash are influenced, by a set of factors related to the proportioning of ingredients of the mixture and the curing conditions. Nevertheless, this new concrete can manage to develop very high mechanical strength within a few hours. Strengths continue to grow more slowly with time. Also, the earlier studies have manifested the high potential of these materials that could be used in the near future in the construction industries, especially in the pre-cast industries

VI. EXPERIMENTAL METHODOLOGY

The evaluation of Used Foundry Sand for use as a replacement of fine aggregate material begins with the Geopolymer concrete testing. Geopolymer Concrete contains Fly ash, GGBS, water, fine aggregate, coarse aggregate and foundry sand. With the control concrete, i.e. 10%, 20% and 30% of the fine aggregate is replaced with waste foundry sand, the data from the waste foundry sand is compared with data from a standard concrete without waste foundry sand. Ten cube samples were cast on the mould of size 150*150*150 mm cast. After about 24 hours the specimens were de-moulded and water curing was continued till the respective specimens were tested after 7, 14 & 28 days for compressive strength.

TABLE 6.
DETAIL MIX OF GEOPOLYMER CONCRETE

Materials	0%	10%	20%	30%
Coarse aggregates:				
20 mm	32.175	32.175	32.175	32.175
12.5mm	17.325	17.325	17.325	17.325
Fine sand	24.75	22.27	19.8	17.35
Foundry sand	-	2.47	4.95	7.42
Fly ash	9.9	9.9	9.9	9.9
GGBS	6.6	6.6	6.6	6.6
Sodium hydroxide solution (NaOH)	2.888	2.888	2.888	2.888
Sodium silicate solution (Na_2SiO_3)	2.888	2.888	2.888	2.888
Extra water	3.450	3.450	3.450	3.450
Water/Cementatious ratio	0.35	0.35	0.35	0.35

A. Mixing

Geopolymer concrete can be manufactured by adopting the conventional techniques used in the manufacture of Portland cement concrete.

In the laboratory, the fly ash and the aggregates (with replacement of sand by foundry sand at 10%, 20% and 30% replacement level) were first mixed together dry manually for about three minutes. The aggregates were prepared in saturated-surface-dry (SSD) condition, and were kept in plastic buckets with lid. The alkaline liquid was mixed and the extra water was added, if any.

The liquid component of the mixture was then added to the dry materials and the mixing continued usually for another four minutes. The fresh concrete could be handled up to 120 minutes without any sign of setting and without any degradation in the compressive strength. Then ten cubes of size 150 X 150 X 150 mm were cast in three layers. Each layer was well compacted concrete tamping rod of diameter 10 mm.

After compacting concrete, the top surface was leveled by using trowel and also struck the sides of mould by using hammer so as to expel air if any present inside the concrete and smoothen the sides. The fresh concrete was cast and compacted by the usual methods used in the case of Portland cement concrete . Fresh fly ash-based geopolymer concrete was usually cohesive. The workability of the fresh concrete was measured by means of the conventional slump test.

B. Compressive strength-

TABLE 7.
COMPRESSIVE STRENGTH (MPa) OF GEOPOLYMER CONCRETE WITH FOUNDRY SAND

Concrete type	Average ultimate compressive strength at 7 days (N/mm²)	Average ultimate compressive strength at 14 days (N/mm²)	Average ultimate compressive strength at 28 days (N/mm²)
M-1	33.7	35	36.2
M-2	34.25	35.7	36.8
M-3	34.7	36.1	37.2
M-4	33.1	34.84	36.2

In this research the values of compressive strength for different replacement levels of foundry sand contents (0%, 10%, 20% and 30%) at the end of different curing periods (7, 14 and 28 days) are given in Table 7.

These values are plotted in Graph 1 and Graph 2, which show the variation of compressive strength with fine aggregate replacements at different curing ages respectively.

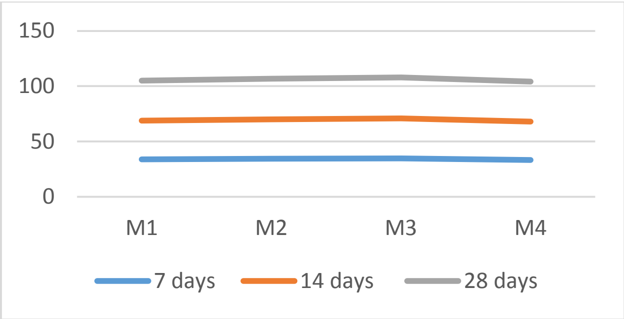

FIG 1. COMPRESSIVE STRENGTH VS MIX DESIGN

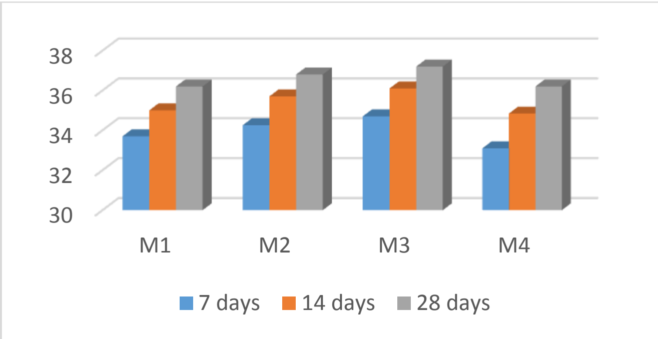

FIG 2. BAR CHART OF COMPRESSIVE STRENGTH VS % REPLACEMENT

VIII. CONCLUSION

The following conclusions are drawn from this study:

1. Compressive strength of concrete rises with the increase in sand replacement with various replacement levels of foundry sand. However, at each replacement level of fine aggregate with foundry sand, an increase in strength was observed with the increase in age.
2. The compressive strength increased by 1.01% and 1.02%, when compared to ordinary mix without foundry sand at 28-days.
3. Compressive strength decreases more than 20% replacement.
4. Workability of sample decreases with increase in foundry sand content in Geopolymer concrete.
5. The optimum level of replacement of fine sand with foundry sand found is 20%.

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