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A Comparison of Geopolymer Concrete Blended with Steel Slag under Sunlight and Ambient Curing

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ABSTRACT

In the present context, global warming is one of the greatest environmental issues. The production of one ton of PC emits approximately one ton of CO_2 into the atmosphere. Geopolymer concrete is an innovative concrete and is produced by totally replacing PC. This study seeks to optimize the benefits of using steel slag in Geopolymer concrete. Steel slag is used in different percentages such as 2%, 2.5%, 3%, and 3.5%. Alkaline solution to fly ash at a ratio of 0.5 is used. The casted cubes were cured in ambient curing and sunlight curing. The cube specimens were tested at 7, 14 and 28 days. The results were analyzed. The compressive strength was compared in two different mediums of curing for different percentage of addition of steel slag in concrete. The conclusions are drawn on the effect of steel slag in the Geopolymer concrete. The results obtained shows improved compressive strength by addition of steel slag and that the sunlight curing increases compressive strength of the concrete compared to ambient curing.

Keywords: Fly ash, Geopolymer concrete, Alkaline solution and Steel slag.

1. INTRODUCTION

Concrete is the most widely used material in the world after water because of its versatile application. In the present context, global warming is one of the greatest environmental issues. Global warming is caused by the emission of greenhouse gases like CO_2 to the atmosphere. It has been reported that the worldwide cement industry contributes around 1.65 billion tons of the greenhouse gas emissions annually (Malhotra, 2002; McCaffrey, 2002; Hardjito et al., 2004). The production of one ton of PC emits approximately one ton of CO_2 into the atmosphere (Davidovits, 1994c; McCaffrey, 2002). Due to the production of PC, it is estimated that by the year 2020, emissions will rise by about 50% from the current levels (Naik, 2005; Salloum, 2007).

In order to reduce the environmental impact due to cement production, it is necessary to develop a new type of binder. In this respect, the geopolymer technology proposed by Davidovits (1978) is one of the revolutionary developments resulting in a low-cost and greener substitute for PC.

Geopolymer concrete is an innovative binder material and is produced by totally replacing PC. It is an alkali-activated binder produced by a polymeric reaction of alkaline liquids with the silicon and the aluminium oxides in source materials of geological origin like metakaolinite (calcined kaolinite) or by-product materials such as fly ash and rice husk ash (Davidovits, 1999). Therefore, it not only helps to generate less CO2 than PC but also reuses industrial waste and or by-products of alumino-silicate composition to produce added-value construction material products (Malhotra, 2002; Davidovits, 2005). Use of fly ash in concrete production not only reduces greenhouse gas emissions but also the water requirement for mix design, the energy needed to produce concrete and it creates longer-lasting, more durable products that do not have to be replaced frequently. Thus, the proper utilization preserves hundreds of thousands of acres currently used for the disposal of coal combustion products, as

well as protects aquifers and surface bodies of fresh water via the elimination of fly ash disposal sites while at the same time conserving natural resources for other purposes.

2. LITERATURE REVIEW

Pratap Kishanraoet al. (2013) discussed the mixture of fly ash and ground granulated blast furnace slag in equal proportions and used as binding material in complete replacement of conventional Portland cement to prepare Geopolymer concrete mixes.

Vijaya Rangan et al (2010) produced Low-calcium fly ash (Class F) based Geopolymer concrete which has excellent compressive strength and is suitable for structural applications.

Milind V. Mohod (2015) has done different test on concrete for different conditions like control curing & irregular condition, from this it has been seen that for the irregular condition initially have more compressive strength than control curing condition but as the days advances it loses its strength or do not give satisfactory strength as compare to curing condition.

ShankarH.Sanniet.al, (2013) has discussed the result for any grade of GPC, as ratio of alkaline solution increases, the workability of mix goes on increasing. The study showed that the strength of geopolymer concrete can be improved by decreasing the water / binding and aggregate / binding ratios. It was observed that water influences the geopolymerization process and the hardening of concrete. Inclusion of increased binder content enhances the geoplymerization and affects the final strength. The optimum dosage for alkaline solution, which is used a geopolymerbindercanbeconsideredas2.5, because for this ratio, the GPC specimens of any grade produced maximum strength results with compression and tension.

3. OBJECTIVE

Earlier researchers have investigated in making Geopolymer concrete more greener by adopting ambient curing for the development of strength in geo-polymer concrete. Some researchers [2,3,6] studied the effect of alkaline solution by varying the molarity of the sodium hydroxide solution and the ratio between sodium silicate solution and sodium hydroxide solution. In some research ratio between fly ash and alkaline solution is different. In this investigation we are attempting to make Geopolymer concrete of high strength by adding steel slag to it and also to compare the strength between ambient curing and sunlight curing of geopolymer concrete.

4. METHODOLOGY

In this study, Geopolymer concrete is made with a mixture of fly ash, fine aggregate, coarse aggregate, alkaline solution and steel slag. The properties of each of these materials should be studied. The casted specimens were of different percentage of steel slag blended with fly ash and the compressive strength of the specimen was tested for two different curing conditions (Ambient curing and sunlight curing)

4.1 Fly Ash

In this study classf fly ash taken from Neyveli used in concrete. Chemical composition of fly ash was tabulated

Table 2.Chemical properties of fly ash

Oxides	Percentage (%)
SiO_2	52.0
Al_2O_3	33.9
Fe_2O_3	4.0
CaO	1.2
K_2O	0.83
Na_2O	0.27
MgO	0.81
SO_3	0.28
LOI	6.23
SiO_2/Al_2O_3	1.5

4.2 Steel Slag

Steel slag can normally be obtained from slag processors who collect the slag from steel-making facilities. The steel slag used in this study is obtained from a steel plant in Trichy, India and is the final disposal product of a steel plant.

Table 1.Physical properties of Steel Slag

Properties	Value
Specific gravity	3.2-3.6
Unit weight, kg/m^3	1600-1920
Absorption of water	Up to 3%

Table 2.Chemical properties of steel slag

Constituent	Composition (%)
CaO	40 - 52
SiO_2	10 - 19
FeO	10 – 40
MnO	5 - 8
MgO	5 - 10
Al_2O_3	1 - 3
P_2O_5	0.5 - 1
S	< 0.1
Metallic Fe	0.5 - 10

4.3 Fine Aggregate

Specific gravity: 2.469

Fineness modulus of fine aggregate: 5.80

4.4 Coarse aggregate

Fineness modulus: 2.32

Specific gravity: 2.63

Percentage wear by Los Angeles abrasion test: 24.60%

4.5. Alkaline solution

Sodium Hydroxide

Sodium hydroxide is a strong base, which is a compound that splits apart in water to make many hydroxide (OH-) ions. When dissolved in water, sodium hydroxide has a very high pH and feels very slippery. Generally, sodium hydroxide is most corrosive when it is dissolved in water. It is an extremely important compound in our lives because it has so many uses. Chemical composition of NaOH is given in Table3.

Table 3. Chemical composition of alkaline solution

Constituents	Percentage
Na_2CO_3	2%
Cl	0.01%
SO_4	0.05%
Pb	0.001%
Fe	0.001%
K	0.1%
SiO_2	0.05%
Zn	0.02%

Sodium Silicate

Sodium silicate usually known as water glass or liquid glass is well known due to wide commercial and industrial application. The pure compositions are colourless or white, but commercial samples are often greenish or blue owing to the presence of iron containing impurities. It is commonly manufactured by using a reaction in liquid

phase or in solid phase. The chemical composition of Sodium silicate solution supplied by the manufacturer is as follows: 14.7% of Na2O, 29.4% of SiO2 and 55.9% of water by mass.

5. MIX DESIGN

Geopolymer concrete there is a standard guidelines. For this study mix design and alkaline solution ratio and fly ash alkaline ratio are adopted from literature.

5.1 Mix proportion of concrete

Mix proportion of 1:1.3:2.8 and alkaline solution to fly ash ratio of 0.4 for all percentage of slag is used. The ratio between alkaline solution ratio and fly ash alkaline ratio are adopted from literature.

GPC 1- control specimen

GPC 1 – Geopolymer concrete with 2% steel slag

GPC 2 – Geopolymer concrete with 2.5% steel slag

GPC 3– Geopolymer concrete with 3% steel slag

GPC 4 – Geopolymer concrete with 3.5% steel slag

Table 4.Mix proportion for different percentage of steel slag

6. RESULTS

STUDY 1

A.Compressive strength

The compressive strength of concrete is one of the most important and useful properties of concrete. In most structural applications concrete is employed primarily to resist compressive stresses.

Fig 1. Geopolymer concrete in UTM

Table 5.Compresive strength of cube for different percentage of steel slag

Sl. No	SLAG	2 days	7 days	14days	28days
1.	2%	3.5kN	8.5kN	13.250kN	21.251kN
2.	2.5%	4.8kN	9.32kN	14.815kN	23.898kN
3.	3%	3.25kN	7.8kN	12.920kN	18.589kN
4.	3.5 %	3.6kN	7.2kN	11.897kN	16.578kN

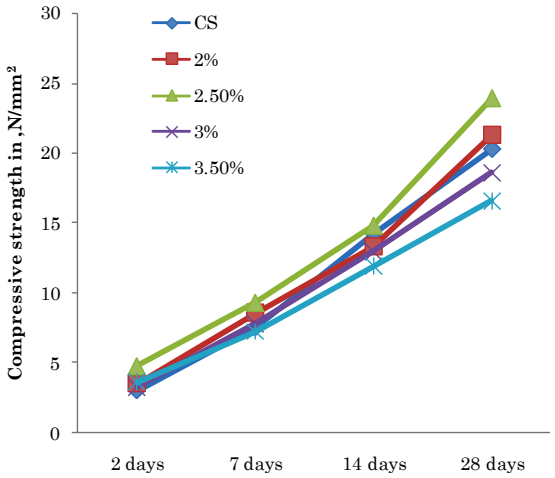

Fig 2. Compressive strength of Geopolymer concrete for different percentages of steel slag

Fig 3. Ambient curing of concrete

Fig 4. Sunlight curing of concrete

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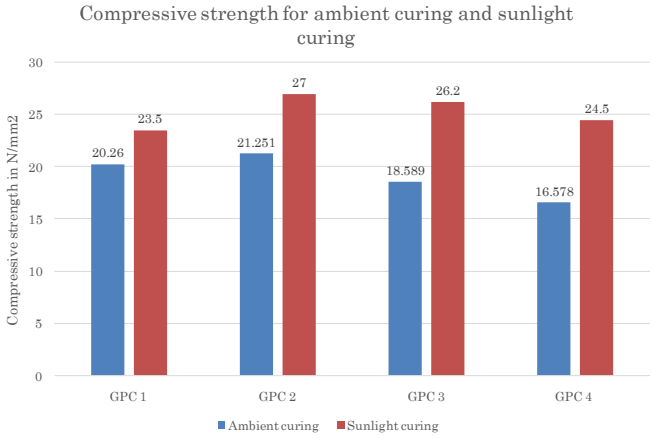

Fig 5. Column graph for different curing condition and their compressive strength

Above graph plotted for the comparison between ambient curing and sunlight curing for GPC mix. The graph clearly indicates that the specimen cured in sunlight has shown better results by attaining high strength on compared with specimen cured in ambient temperature. On reviewing all the results with the respect to the different percentages of steel slag varying from 0% to 5% by weight of fly ash it validates that sunlight curing increased the compressive strength.

7. SUMMARY

In the present study coal combustion product fly ash in concrete has fulfilled most of the objective of the research work. The below is the conclusion based on the research. Steel slag used as a crack arrester in concrete. Cracking of concrete is a random process, highly variable and influenced in many factors. However, one process is insured the longer the crack, the higher the stress concentrations induced by it. Due to the presence of a crack in a structure, the strength of the structure will decrease progressively with the increase of the crack size. As a result, the structure will be subject to failure when its strength becomes so low that fracture occurs under normal loading. Consequently, cracks in concrete structures should not be taken for granted, but on the contrary, they must be prevented which can be fulfilled by steel slag.

8. CONCLUSION

Based on the experimental investigation carried out, the following conclusions are drawn.

1. There is an increase in workability of the concrete with increase in alkaline solution to fly ash ratio. It can be observed that for the ratio of 0.4 medium, degree of workability is medium. It is suitable for normal reinforced concrete placed with vibration.
2. Geopolymer concrete cubes have a improve the strength than that of the conventional concrete. So fly ash can be used instead of cement in concrete.

3. By comparing the cost of Geopolymer concrete with conventional concrete, there is no big difference because price of fly ash is very less.
4. The alkaline solution contains sodium hydroxide and sodium silicate which enhance the polymerization in the Geopolymer concrete.
5. There is an increase in strength of the Geopolymer concrete with steel slag at different percentage of 0.5%, 0.75% and 1% when compared to the plain Geopolymer concrete.
6. The compressive strength of the concrete increased especially at 2.5% of slag after that it was decreased.
7. The compressive strength of the concrete cubes in sunlight curing is high when compared to ambient curing. Sunlight curing is practically possible. So there is no problem in sunlight curing.

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