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Strength Studies on Geo-Polymer Concrete using Recycled Fine Aggregate

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Abstract

The production of Ordinary Portland Cement and the usage of normal river sand are increased due to the rising demand of concrete in Construction Industry. In order to account for this current demand, flyash activated with alkaline solutions is used for making concrete, termed as "Geo-polymer Concrete". So that the demand on cement is reduced along with emissions into atmosphere which are released by cement factories. In this paper, an attempt is made to study the Mechanical properties of Geo-polymer concrete produced with construction waste as replacement for fine aggregate. Class F flyash from Ennore Power Plant is used as binder material to make Geo-polymer concrete. Coarse aggregate of size between 10mm-4.75mm is used. The broken concrete cubes from the laboratory is crushed into fines of size less than 4.75mm using jaw crusher and is used for replacing the fine aggregate. The strength of Geo-polymer concrete such as Compressive Strength, Split Tensile strength, Flexural strength are studied. The experimental scheme includes Geo-polymer Concrete produced by varying the sodium hydroxide concentration from 8M to 10M and alkaline solution to flyash ratio between 0.6 and 0.7. The compressive strength of this concrete ranges from 31MPa to 52MPa.It is concluded from the experimental results that Geo-polymer concrete with recycled fine aggregate can be used in the construction industry for both in-situ and precast concrete applications.

Keywords:- Geo-polymer concrete, Flyash,Recycled fine aggregate,Alkaline solution, Compressive strength.

I. INTRODUCTION

The usage of concrete is second only to water. Concrete is one of the most widely used construction material and Ordinary Portland cement is the key ingredient of concrete. However, large amount of natural resources such as limestone, fossil fuels, electricity, and natural gas are required in Portland cement concrete production. High temperatures are required in the production of Portland Cement, and calcination of limestone has resulted in a larger amount of carbon dioxide (CO_2) emission into

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the atmosphere Therefore, the production of Portland Cement is extremely resource and energy intensive process. Several studies have been carried out to reduce the use of Portland cement in concrete to address the global warming issues. These include the utilization of supplementary cementing materials such as fly ash, silica fume, granulated blast furnace slag, rice-husk ash and metakaolin. These pozzolanic materials contain rich silicon (Si) and aluminium (Al) and can also be used to produce geo-binder when mixed with alkaline solutions. Geo-polymer concrete (GPC) proposed by Joseph Davidovits [1988; 1994] and it was an alternative binder system with source material to produce concrete eliminating cement. The most common alkaline liquid used in geopolymerization is a combination of sodium hydroxide or potassium hydroxide and sodium silicate or potassium silicate. Geo-polymer binders are used together with aggregates to produce geopolymer concretes which are ideal for building and repairing infrastructures and for pre-casting units.

On the other hand, production and utilization of concrete is rapidly increasing, which results in increased consumption of natural aggregate as the largest concrete component. A possible solution to these problems is to recycle demolished concrete and produce an alternative aggregate for structural concrete. Thus in recent years, the use of recycled concrete aggregate has gained tremendous momentum in constructional engineering. In this project demolished concrete is used as fine aggregate for making the geo-polymer concrete. It involves breaking, crushing and removing irrelevant and contaminated materials from existing concrete and then using it for making geopolymer concrete.

A.OBJECTIVE

The Objectives of the study are identified as under.

i. To produce geo-polymer concrete with recycled fine aggregate ,by varying the sodium hydroxide concentration and alkaline to flyash ratio.

ii. To select the optimum mix proportion for the geo-polymer concrete based on the compressive strength.

iii. Tostudy the mechanical properties such as compressive strength, flexural strength and split tensile strength for the selected optimum mix proportion of geo-polymer concrete.

II. LITERATURE REVIEW

1) B.V.Rangan (2014) made study on "Geopolymer Concrete for Environmental Protection". This paper deals with the study of properties of geo-polymer concrete and its mix proportion. The author has concluded geo-polymer concrete converts low calcium flyash and blast furnace slag into high value construction material for infrastructural development. The elastic properties of hardened geopolymer concrete is similar when compared to portland cement concrete leading to the usage of standards and codes of portland cement concrete for geopolymer concrete. Heat cured low calcium flyash based geopolymer

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shows resistance to sulphate attack, fire, acid resistance undergoes low creep less drying shrinkage.

2) A.M.Mustafa Al Bakri (2011),in this paper "The Effect Of Curing Temperature On Physical And Chemical Properties Of Geopolymers" has reported that the curing temperature was a reaction accelerator in fly ash based geo-polymers.The author suggested that heat curing was also required to produce a fast geo-polymerization process to achieve an acceptable strength within shortperiod. Based on the results of this paper concluded that the samples cured at 60^0C produced the maximum compressive strength.When the curing temperature was increased , the compressive strength increased ,also found that increasing curing temperature beyond 60^0C did not substantially increase the compressive strength.

3) A V Lăzărescu (2017) in his work "The Effect Of Alkaline Activator Ratio On The Compressive Strength Of Fly Ash-Based Geopolymer Paste" has briefed that the most common alkaline solution used to produce geopolymer concrete is a mixture of sodium silicate solution and sodium hydroxide solution.The alkaline solution ratio commonly used lies between the range 0.4-2.5.The author arrived at a conclusion stating that the effect of alkaline activator ratio on the compressive strength is one of the most important factors affecting the material.Increasing the alkaline solution ratio leads to more SiO2 species therefore more Si-O-Si bond are formed, creating a stronger material.

4) Namita Patiyal(2016) made study on"Experimental Study on Geopolymer Concrete with Partial Replacement of Fine Aggregate with Foundry Sand".In this paper Foundry sand is used as a partial replacement for fine aggregate. The author concluded that Partial replacement of fine aggregate with foundry sand increases the compressive , flexural and split tensile strengths of geopolymer concrete.Use of Foundry sand as partial replacement of fine aggregate is economical. Reuse of Foundry sand reduces environmental hazards.

5) Kamlesh .C.Shah (2014) from the paper,"Study of Strength Parameters and durability ofFly ash based Geopolymer Concrete" has concluded thatHigher compressive strength is observed for geo-polymer concrete as compared to that of concrete OPC. Compared to oven cure and ambient temperature cured, oven cured specimens gives higher compressive strength. Geo-polymer concrete show excellent sulphate and acid resistance properties. It can be said that the geo-polymer concrete is good alternative of construction material of from both strength and durability considerations.

6) R.C.Ravindrarajah and C.T.Tam (1987) in the work "Recycling concrete as Fine Aggregate in Concrete "has found out the effects of using recycled concrete as fine aggregate for concrete. Compressive strengths at early ages was marginally lower

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but with increasing age the difference in strength became negligible. The ratio of tensile strength or flexural strength to compressive strength was not affected. Modulus of elasticity of concrete at the age of 28 days was reduced by 15% to 20%. Drying shrinkage of concrete was increased by about 40%.

III MATERIAL PROPERTIES

A.FLYASH

Class F flyash collected from Ennore Thermal power plant is used as a source material to produce geo-polymer concrete. The specific gravity of flyash is given in Table 1

TABLE 1

SPECIFIC GRAVITY OF FLYASH

S.NO	Properties	Values
1.	Specific Gravity	2.33

B. FINE AGGREGATE

The broken concrete cubes from the laboratory is crushed manually for nominal size of 60 mm and is to be fed into the jaw crusher available at the laboratory. The particles will be crushed into fines of size less than 4.75 mm. This is termed as recycled fine aggregate (RFA). Properties of recycled fine aggregate is given in the Table 2.

TABLE 2

PROPERTIES OF FINE AGGREGATE

S.No	Properties	Values
1.	Specific Gravity	2.301
2.	Bulk Density	1460 kg/m^3
3.	Fineness Modulus	4.25
4.	Gradation	ZONE I

C.COARSE AGGREGATE

Coarse aggregate of size between 10mm-4.75mm is used as raw material to produce geo-polymer concrete. Properties of coarse aggregate is given in the Table 3.

TABLE 3

PROPERTIES OF COARSE AGGREGATE

S.No	Properties	Values
1.	Specific Gravity	2.72
2.	Bulk Density	1223.54 kg/m^3

D.ALKALINE SOLUTION

Alkaline solutions are used to induce the silicon and aluminium atoms in the source materials. In this experiment alkaline solution is prepared using flakes of sodium hydroxide and sodium silicate solution, is used as activators for the geo-polymerization process.

E.MIX PROPORTION

The mix proportion available in the literature were implemented in the present study [6,7]. The details of mix proportion for 0.6 & 0.7 ratio are presented in Table 4 & 5.

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TABLE 4

MIX DESIGN FOR 0.6 RATIO

S.No	Materials	Density (kg/m^3)
1.	Coarse aggregate	1092.36
2	Fine aggregate	583.60
3.	Flyash	400
4.	Sodium hydroxide	68.75
5.	Sodium Silicate	171.42
6.	Super Plasticizer	8

TABLE 5

MIX DESIGN FOR 0.7 RATIO

S.No	Materials	Density (kg/m^3)
1.	Coarse aggregate	1045.94
2.	Fine aggregate	558.81
3.	Flyash	400.00
4.	Sodium Hydroxide	80.00
5.	Sodium Silicate	162.35
6.	Super Plasticizer	8

IV .RESULTS AND DISCUSSSION

A. COMPRESSIVE STRENGTH

Sufficient number of cubes were prepared by varying the sodium hydroxide concentration from 8M to 10M and alkaline solution to flyash ratio between 0.6 and 0.7. The compressive strength study has been carried on the cube specimens of size 100mm, oven cured for 6 hours at a temperature of 60^0C.Three test specimens were used to test the strength for each variation and average value was considered. Compressive strength of the cubes produced using river sand and recycled fine aggregate separately were compared and the results are shown Table 6 and Fig 1. From the values of compressive strength, an optimum mix proportion for the geo-polymer concrete that yields good strength was obtained by using 0.6 of alkaline solution to flyash ratio and 10M concentration of sodium hydroxide.

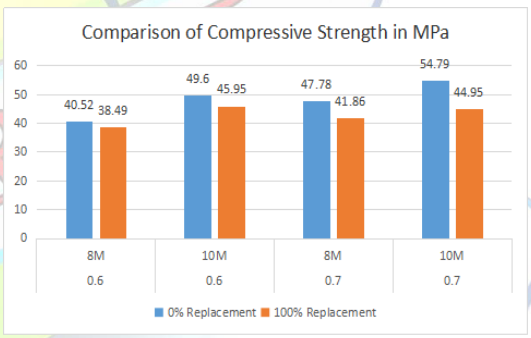

Fig 1: COMPARISON CHART

TABLE 6

COMPRESSIVE STRENGTH OF

GEO-POLYMER CONCRETE

Alkaline solution to Flyash ratio	Molarity	Compressive Strength (in MPa)	
		0 % Replacem	100 % Replacem

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		ent	ent
0.6	8M	40.52	38.49
	10M	49.60	45.95
0.7	8M	47.78	41.86
	10M	54.79	44.95

B. TENSILE STRENGTH AND FLEXURAL STRENGTH

The Tensile strength and Flexural Strength tests are conducted on the geo-polymer concrete using the optimum mix proportion (0.6,10M) obtained from the compressive strength tests. Flexural strength test was carried out on a beam specimen of size 100mm×100mm×500mm.Tensile strength tests was carried out on a cylindrical specimen of size 100mm Ø 200mm.Three specimens were tested and their average was taken as the Tensile strength.

TABLE 7

FLEXURAL AND TENSILE STRENGTH OF GEO-POLYMER CONCRETE WITH RECYCLED FINE AGGREGATE

S.No	Property	Values in (MPa)
1.	Flexural Strength	4.628
2.	Tensile Strength	1.58

V.CONCLUSIONS

From the experimental study, it is concluded that geo-ploymer concrete containing recycled fine aggregate yields a compressive strength of about 46 MPa at 0.6,10M and temperature. The flexural and tensile strength for the above geo-ploymer concrete are also found to be reasonable. Therefore, from study, it is understood that recycled fine aggregate can be used as a replacement for the river sand in the geo-polymer concrete. The Geo-polymer concrete becomes eco-friendlier than any other conventional concrete due to the complete replacement of river sand by recycle fine aggregate. It is concluded from the experimental results that geo-polymer concrete with recycled fine aggregate can be used in the construction industry for both in-situ and precast concrete applications.

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