Experimental Investigation on Strength Properties of Lignite Fly ash Geo polymer Concrete

G. Harikumar, S. Harishankar

Abstract: ***The demand for Portland Cement is growing demand day by day. The main reasons for facing these challenges are limited reserves of lime stone and high increase in carbon taxes.This paper presents the strength properties of high calcium based geo polymer concrete. The high calcium fly ash was activated with sodium hydroxide (NaOH) and sodium silicate solution cured at ambient temperature. The optimum sodium silicate to sodium hydroxide ratio for optimum strength geopolymer was 1.5 and the concentration of NaOH was 14M. Different mixes were proportioned by varying the percentage of aggregates in the density of concrete. The proportions were 60%, 65%, 70%, 75% and 80%. Strength tests such as compression test, split tensile test and bond strength test were carryout on specimens and the results were obtained. The mix proportion with 70% of aggregates in the density of concrete manifested good strength in compression, tension and bond strength.***

Index Terms: Geo polymer, High calcium fly ash, ambient curing, split tensile strength, compressive strength, bond strength.

I. INTRODUCTION

Fly ash, a waste by product from thermal power plant is more reactive similar to ordinary cement. Utilization of waste materials such as fly ash in construction industry reduces the environmental problems [1]. Geo polymers are formed by reaction of alkaline liquids with silicon and aluminum in materials like fly ash. The increase in demand for cement in India is mainly due to the increase in infrastructural activities and concrete is one of the material which is predominantly used in almost all construction activities. Cement is the main component for making concrete and hence demand for Portland cement automatically increases with the increase in demand for concrete. Global warming a major problem and also major concern during the last one and half decade. Green-house gases such as CO2 by human activities is one of the major cause. The cement industry emits 6% of all CO2 emissions, this is because, the Portland cement production emits equal amount of CO2 into atmosphere. Although the use of cement cannot be avoided in future but many efforts are being made to reduce the use of Portland cement. One such effort to overcome the shortfall is to develop the alternative binders to Portland cement which aim to reduce environmental impact of construction and also use of higher proportion of waste in any form which will also improve the performance of concrete, these efforts also include the use of supplementary cementing materials like fly ash, meta-kaolin, rice-husk ash and slag. In the recent years, geo-polymer has attracted attention to use as binder as an alternative to the Portland cement because of its favourable properties like good chemical resistance , low permeability and excellent fire resistance behaviour.

Revised Manuscript Received on June 05, 2019

G. Harikumar, School of civil engineering, Sastra Deemed University, Tanjore, India.

S. Harishankar, School of civil engineering, Sastra Deemed University, Tanjore, India.

II. RESEARCH SIGNIFICANCE

Most of the researches were published on the behaviour of geopolymer concrete. There is no relationship available in the literature for the geopolymer concrete cured at ambient temperature. The present study deals with the strength properties such as compressive strength, split tensile strength and bond strength of Class C based geopolymer concrete for the age of 28 days.

III. MATERIALS AND METHODOLOGY

A. Materials for Concrete

The various materials used to prepare concrete for the test specimens are mentioned below.

A.1 Fly ash

Flyash used in this experimental work was obtained from Neyveli Lignite Corporation (NLC Ltd), Neyveli, India. The specific gravity, fineness modulus, specific surface area and density of flyash are 2.80, 2.7%, 310 m2/kg and 2293 kg/m3 respectively.

Table 1: Materials for each percentage of aggregates

Material	Percentage of aggregates (%)				
	60	**65**	**70**	**75**	**80**
Fly ash (Kg/m^3)	640	560	480	400	320
Coarse Aggregate (Kg/m^3)	1008	1014	1092	1080	960
Fine Aggregate (Kg/m^3)	432	546	588	720	960
Sodium silicate (Kg/m^3)	213.33	186.66	160	133.33	106.67

Sodium hydroxide (Kg/m³)	106.6	93.3	80	66.67	53.33
Water (Kg/m³)	320	280	240	200	160

A.2 Coarse Aggregate

The maximum size of coarse aggregate used in the project is 20mm. The specific gravity of coarse aggregate is experimentally determined as 2.5.

A.3 Fine Aggregate

M-Sand passing through 4.75mm Indian standard sieve is used as fine aggregate. The specific gravity of fine aggregate is found experimentally as 2.59. The grading zone of fine aggregate was zone II as per Indian standard specification IS 383.

A.4 Water

Potable water which is free from acids, oils, alkalis and other organic impurities is used to prepare the concrete mix.

A.5 Sodium hydroxide and sodium silicate

The sodium hydroxide solids were of commercial grade in pellet form with 97% purity. Sodium silicate solution (Vitrosol D - A53) has the chemical composition Na2O=14.7%, SiO2=29.4%, and water 55.9% by mass was purchased from local supplier. The alkaline activator solution with sodium hydroxide solution is mixed with sodium silicate solution to get the desired one day before making the geo polymer concrete.

B. Specimens for the Experiments

B.1 Standard Cube Specimens

Totally fifteen standard cube specimens of size 10cm x 10cm x 10cm were prepared to test the compressive strength of the concrete. Three mixes were proportioned by varying the percentage of aggregates in the density of concrete. The proportions were 60%, 65%, 70%, 75% and 80%.

B.2 Standard Cylinder Specimens

Fifteen cylinder specimens of diameter 100mm and height 200mm were prepared to test the split tensile strength of the high calcium based geo polymer concrete. That is three specimens per each fraction of replacement.

B.3 Standard cube Specimens

Three standard cube specimens per each fraction of replacement are prepared to test the bond strength of the concrete.

C. Tests on the Hardened Concrete

C.1 Compression Test

The prepared cube specimens were tested in a compression testing machine. Three specimens were tested for each mixes and average of the three results of each mixes is considered for the comparison of results.

C.2 Split Tensile Strength Test

Split tensile test of cylinder specimens is conducted to assess the tensile strength of the concrete. Average test result is found from three specimens for each mixes and is considered for the comparison.

C.3 Bond Strength Test

Cube specimens were tested for bond strength test. The average test results of mixes are obtained from the three specimens for each mixes and results are compared.

IV. RESULTS AND DISCUSSION

The test results of specimens for each proportions are tabulated in the Table 2.

Table 2: Summary of test results

Percentage of Aggregates (%)	Split tensile strength (N/mm²)	Bond strength (N/mm²)	Compressive tensile strength (N/mm²)
60	2.18	3.92	15.30
65	2.24	4.13	16.38
70	2.31	4.32	19.34
75	1.99	3.87	16.70
80	1.81	3.75	14.75

A.Compressive Strength

The compressive strength is increasing from 15.30 N/mm^2 to 16.38 N/mm^2 as the percentage of aggregate in the density of concrete varies from 60% to 65% respectively. Then it is increased to 19.34 N/mm^2 as it reaches 70% replacement of fine aggregate. The following table shows the average compressive strength with variation in aggregate composition in the density of concrete.

Table 3: Average compressive strength

Compressive strength (N/mm²)	Aggregate Composition (%)				
Specimen	60	65	70	75	80
1	15.6	16.7	18.9	17.4	14.6
2	15.3	16.3	19.3	16.1	14.4
3	14.9	16.1	19.7	16.5	15.2
Average	15.3	16.3	19.3	16.7	14.7

B.Split Tensile Strength

An increase in split tensile strength was observed from 3.063 N/mm^2 to 3.343 N/mm^2 as the percentage of aggregate in the density of concrete varies from 60% to 65% respectively. The following graph shows the variation compressive strength with increase in percentage of aggregate in the density of concrete.

Table 4: Average split tensile strength

Split tensile strength (N/mm²)	Aggregate Composition (%)				
Specimen	60	65	70	75	80
1	2.23	2.09	2.43	2.1	1.83
2	2.18	2.33	2.27	1.96	1.81
3	2.13	2.30	2.23	1.91	1.79
Average	2.18	2.24	2.31	1.99	1.81

Bond Strength

It was observed that the geo polymer concrete with 70% of aggregates in the density of concrete exhibits the maximum bond strength of 4.32N/mm^2.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Table 5: Average bond strength

Bond strength (N/mm²)	Aggregate Composition (%)				
Specimen	60	65	70	75	80
1	3.90	4.10	4.29	3.90	3.70
2	3.92	4.15	4.37	3.86	3.73
3	3.95	4.14	4.30	3.85	3.82
Average	3.92	4.13	4.32	3.87	3.75

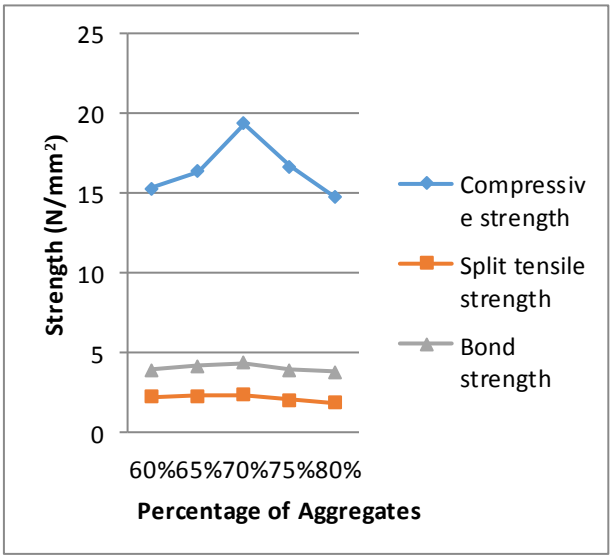

Fig 1: Average strength properties of various aggregate composition

V. CONCLUSION

Based on the above experimental work regarding high calcium based geo polymer concrete the following conclusions can be arrived as inference.

1. The compressive strength of high calcium fly ash based geo polymer concrete cubes increases gradually up to 70% of aggregate in the density of concrete. Then it gradually decreases.
2. The tensile strength of high calcium fly ash based geo polymer concrete cylinders increases gradually up to 70% of aggregate in the density of concrete. Then it gradually decreases.
3. The bond strength of high calcium fly ash based geo polymer concrete cubes increases gradually up to 70% of aggregate in the density of concrete. Then it gradually decreases.
4. Since the strength results reaches maximum in geo polymer concrete with content of 70% by weight of aggregate in the density of concrete, this proportion is found to be optimum.
5. Hence cement is replaced with high calcium fly ash in geo polymer concrete cured under dry condition at room temperature. Further durability properties of high calcium based geo polymer concrete for the above mixes can be studied.

REFERENCES

1. J. Jegan, G. Lavanya. (2015), Evaluation of relationship between split tensile strength and compressive strength for geopolymer concrete of varying grades and molarity, International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 15 (2015)
2. T. Ch. Madhavi, L. Swamy Raju, Deepak Mathur. (2014), Durability and strength properties of high volume fly ash concrete, Cement and Concrete Research, 31, 1227–1231.
3. Xiaolu Guo, Huisheng Shi, Warren A. Dick. (2009), Compressive strength and microstructural characteristics of class c fly ash geopolymer, Cement & Concrete Composites 32(2010) 142-147.
4. Kolli Ramujee, M.Potharaju, (2014), Abrasion resistance of geopolymer composites, procedia materials science, 6, 1961–1966.
5. P. Chindaprasirt , T. Chareerat ,V.Sirivivatnanon .(2007), Workability and strength of coarse high calcium fly ash geopolymer, Cement & Concrete Composites 29(2007) 224-229.
6. Kolli.Ramujee, M.PothaRaju, (2017), Mechanical properties of geopolymer concrete composites,material today proceedings 4(2017) 2937-2945.
7. S. Detphan and P. Chindaprasirt (2009),Preparation of fly ash and rice husk ash geopolymer, International Journal of Minerals, Metallurgy and Materials Volume 16, Number 6, 2009, Page 720.
8. Satish H. Sathawane ,Vikrant S. Vairagade and Kavita S Kene (2013), Combine Effect of Rice Husk Ash and Fly Ash on Concrete by 30% Cement Replacement , Procedia Engineering 51 (2013) E– 44.
9. E. Muthu Kumar, K. Ramamurthy (2017), Influence of production on the strength, density and water absorption of aerated geopolymer paste and mortar using Class F fly ash, Construction and Building Materials 156 (2017) 1137–1149.
10. T. Venu Madhav , I.V. Ramana Reddy , Vaishali G. Ghorpade , S. Jyothirmai (2018),Compressive strength study of geopolymer mortar using quarry rock dust ,Materials Letters 231 (2018) 105–108.
11. Eslam Gomaa, Simon Sargon, Cedric Kashosi, Mohamed ElGawady (2017), Fresh properties and compressive strength of high calcium alkali activated fly ash mortar, Journal of King Saud University – Engineering Sciences 29 (2017) 356–364.
12. Rafat Siddique , Karambir Singh , Kunal , Malkit Singh, Valeria Corinaldesi, Anita Rajor (2016),Properties of bacterial rice husk ash concrete, Construction and Building Materials 121 (2016) 112–119.
13. Saengsuree Pangdaeng, Tanakorn Phoo-ngernkham, Vanchai Sata, Prinya Chindaprasirt(2014), Influence of curing conditions on properties of high calcium fly ash geopolymer containing Portland cement as additive , Materials and Design 53 (2014) 269–274.
14. J. Temuujin, R.P.Williams, A. van Riessen(2009), Effect of mechanical activation of fly ash on the propertieS of geopolymer cured at ambient temperature, Journal of Materials Processing Technology 209 (2009) 5276–5280.

AUTHORS PROFILE

G.Harikumar is pursuing his M.Tech integrated degree in structural engineering from SASTRA Deemed university, Thanjavur , India.He is currently reasearching about geopolymer concrete

S.Harishankar is Assistant professor in SASTRA Deemed University, Thanjavur, India. His area of interest in research work is geopolymer concrete and concrete materials.