CHARACTERISATION STUDY ON CLAY BASED GEOPOLYMER CONCRETE

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Abstract

In general geo polymer concrete is produced using industrial waste by products such as fly ash , slags and metakaolin and many published research papers are available. But very few papers are available an utilization of clay for geo polymer concrete. In this paper four types of raw clays collected from varies places of Tamilnadu and used for making geo polymer concrete. Clays are used as obtained from the source and also the same four clays after heat treatment up to 900°c for one hour in a muffle furnace. Chemical analysis, physical and mechanical strength parameters are studied and the result are presented.

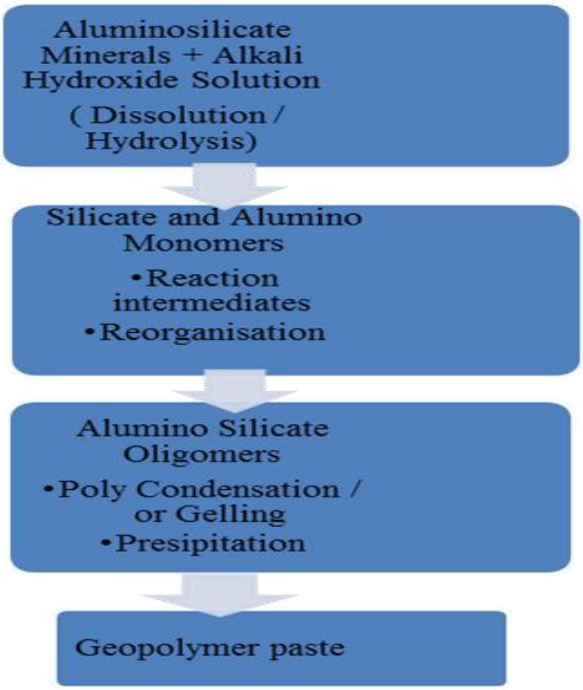
Keywords:Clay,Geopolymer,SilicateModulus,aluminosilicate,crystalisation,sialate.

I. INTRODUCTION

It is very important to develop a newer material from a country's natural resources and waste material to convert into a useful material will lead to a greater growth of Industrialization of a nation. Country like India has abundant quantity of clay deposits an earth crest. At present these clays are utilized for producing burnt clay bricks for building industry. Clays available in lakes and ponds are of poor quality and composed of many decayed vegetation and other organic matters [1]. These impurities can be removed by burning the raw clay in the furnace. This heat or thermal treatment also helps to opening new phases of silicates as well as makes the siO_2 phases from crystalline phase to amorphous which is essential the chemical bonding.

Making geo polymer concrete with clay presents may advantages compared to concrete mate with ordinary Portland cement (OPC). Geo polymer possess fast setting and hardening, excellent bond strengths, long term durability and better fire and acid resistance[2,3]. And therefore it has many industrial applications also [4]. Apart from these, the geo polymer concretes are produced by low energy consumption and low emission of Co_2 [5, 6] which certainly makes the product as a 'Green Material' [7,8]. Variety of aluminosilicate minerals are examined by many researchers to establish such alumino silicate materials as potential material for producing geo polymer [3] .It has been established that calcined minerals provide a potential source for making geo polymer.[9] it has ever proved that the calcined clay provides best results due to change of phase from crystalline to amorphous [10] proof of record for Indian clays are missing. The activator alkaline solution is sodium silicate with sodium hydroxide solution. Composition variation of this alkaline solution, usually control setting and hardening process of geopolymer. higher content of sodium silicate and sodium hydroxide provide the higher mechanical strength.[1] it is also found that very high p^H or alkalinity of the solution affect the geo polymer properties adversely [13,14]. It has been suggested [15] that the molar ratio of (Na_2O / Al_2O_3) must be unity. Presence of Na_2O, Al_2O_3 and SiO_2 plays a major role for the transformation of phases from crystalline to amorphous [15]. Increase in Fe_2O_3 in clay cause darkness of the raw clay. Higher content of Fe_2O_3 will be dark grey and low Fe_2O_3 will present lighter or white clay. Therefore , in this research work, raw clay as obtained from the natural sources are treated in muffle furnace to heat it to 900°c for one hour used for making geo polymer concrete. The curing temperature of the geo polymer concrete also plays a major role for development of strengths [1, 16, 17]

Conceptual Formulation of Geopolymerisation [18].



Alkaline activation of aluminosilicate materials is a complex process. It results, first of all in a breakdown of Si -O-Si structure results substantial feature of this reaction, and forms aluminosilicate gels (zeolite precursors). Their composition can be characterized by the following formula:

$M_n [-(Si-O)_z -Al-O]_n.wH_2O$

The C-S-H and C-A-H phase may also form according to the composition of the precursor material and the reaction condition.

Poly (sialate)
Si: Al = 1(Si-O-Al-O)

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     o     o
     |     |
  o- Si-o-Al-o
     |     |
     o     o
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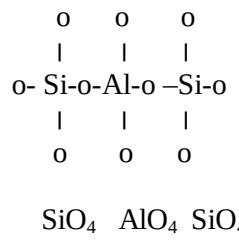
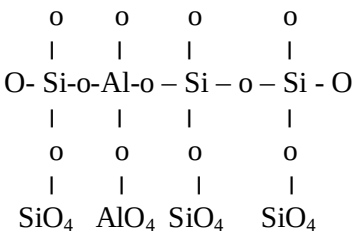
SiO_4 AlO_4

Poly (sialate – siloxo)
Si : Al =2 (-Si-O-Al-O-Si-O)



Poly (sialate – disloxo)
Si : Al =3(-Si-O-Al-O-Si-O-Si-O)



Therefore geo polymer does not possess any monolithic structure of poly – sialate – siloxo type. It is characterized by random three dimensional arrangements. This structure represents a porous body with pore size ranging from nanometers to micrometers and the pores are filled with water and gel. The process of geo polymerization is completely different from the process of hydration of inorganic binders or cements (OPC).

MATERIALS USED:

Raw clay samples (aluminosilicate materials) were collected from the lakes of Sivaganga and Pudukkottai districts of Tamilnadu India. All the collected samples are dried in hot sun atmosphere until all moisture evaporation. Then the clay samples are powdered and sieved using 300 micron sieve. Clay powder passing through the sieve were collected and stored separately. River sand was purchased and after washing and drying the sand thoroughly, it was stored in a container. Sodium silicate of commercial grade was procured from Coimbatore. The density of Na_2SO_3 was 1.53 g/cc, the alkaline modulus was 2.00 (Na_2O =14.7%, SiO_2 = 29.4%) AM = (SiO_2 / Na_2O). Crushed granite stone aggregates are procured locally and washed, dried thoroughly and then sieved to get it passed from 6mm and 10mm size sieves and stored separately. Tap water was used for preparing activator solution.

The raw clays obtained from sources sieved and passed through 300 micron sieve were heated in a muffle furnace to 900°c with a soaking period of one hour. The colours of the clays were changed to red as shown in Fig 1 because of the presence of Fe_2O_3.

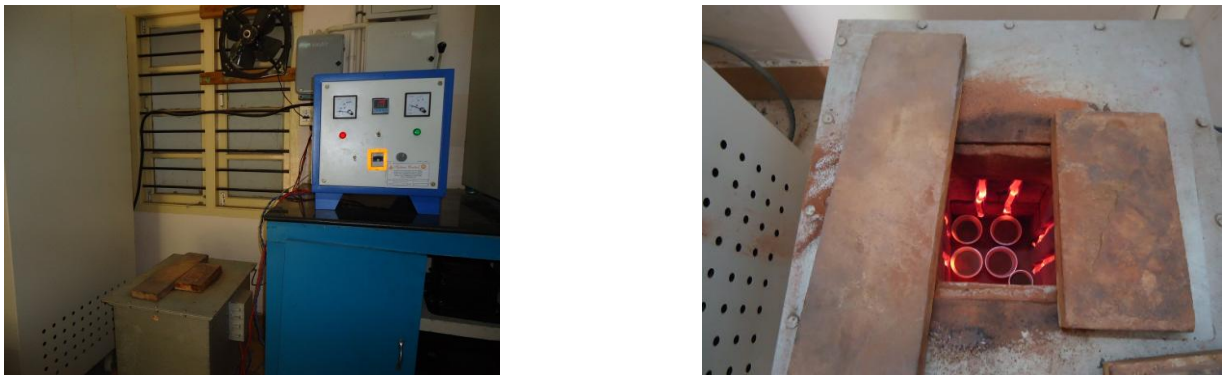


Fig :1 Thermal Treatment of Clay

EXPERIMENTAL:

Raw clays and thermally treated clays were subjected to chemical analysis to obtain percentage of oxides present by using X –Ray fluorescence technique (XRF) and the results are shown in table 1.

Table :1 Chemical Analysis of Clay (XRF analysis)

Oxides	Raw clays				Thermally treated clays			
	A	B	C	D	A	B	C	D
SiO_2	54.13	32.25	35.46	34.39	63.01	67.77	58.45	54.25
Al_2O_3	29.43	36.25	16.46	36.23	17.10	18.99	8.32	23.47
Fe_2O_3	10.32	12.94	27.85	17.14	5.03	4.94	18.34	13.32
Ca_2O	2.31	3.78	2.25	3.70	2.69	2.09	2.13	2.31
K_2O	2.23	13.44	15.89	7.22	1.79	0.49	3.94	0.89
TiO_2	1.14	0.67	1.48	0.84	0.31	0.52	0.86	0.99
MgO	1.12	1.68	1.78	1.92	0.19	0.22	0.39	0.9
Na_2O	1.39	0.88	0.99	0.97	0.92	0.43	0.49	0.24
LOI	5.03	2.76	7.16	2.86	-	-	-	-

In all the clay sample SiO_2 and Al_2O_3 are the predominant oxides. The formulation clay based geo polymer shown in table 2. The geo polymer specimens were cured in oven at 750°C for 48 hours continuously for the formation of in organic polymer chain as indicated earlier in this paper.

Table :2 Geo polymer Formulations

RAW CLAYS	Raw clays					
	Aggregate			Alkaline solution		
	sand	6mm	10mm	Na_2So_3	NaOH	water
A 430	780	345	695	53	56	140
B 430	780	345	695	53	56	140
C 430	780	345	695	53	56	140
D 430	780	345	695	53	56	140
Treated Clays						
A 430	780	345	695	53	56	140
B 430	780	345	695	53	56	140
C 430	780	345	695	53	56	140
D 430	780	345	695	53	56	140

Cylinder compression and split tensile test specimens of size 100 mm dia x 200mm height were cast and cured thermally. For flexural test , beam specimens of size 40 x 40 x 300 mm were cast. For each category test and for each clay samples triplicate specimens were cast and average values are noted in the table3.

Table: 3 Physical / Mechanical Properties

Physical/mechanical Properties	Raw clay based (28d)				Treated clay based(28)			
	A	B	C	D	A	B	C	D
Cylinder compressive strength (N/mm^2)	29.11	27.87	22.36	31.14	43.41	49.92	37.14	40.63
Split tensile strength (N/mm^2)	3.62	3.44	2.96	3.81	5.96	6.41	5.51	5.86
Flexural strength (N/mm^2)	4.96	4.82	4.54	4.99	6.84	8.32	7.03	7.61
Density (Kg/m^3)	2368	2360	2368	2359	2358	2358	2360	2350
Water absorption	3.62	3.83	4.11	3.21	3.21	3.62	3.73	3.14

Fig : 2 Cylinder Compression Test

Fig: 3 Split Tensile Test

Percentage of water absorption was calculated using the expression:

$$\text{Percentage of water Absorption (\%)} = \frac{Ws - Wd}{Wd} \times 100$$

Where
Ws = saturated weight of specimen
Wd = completely dried weight of specimen

The testing of cylinder compression at 20Kn/mm^2 per minute rating was kept. The fig 2 and fig 3 shows the cylinder compression test and split tensile test. the split tensile stress was computed using the formula

$$F_{sp} = \frac{2P}{\pi dl}$$

Where
F_{sp} = split tensile stress(n/ mm^2)
P = maximum load at failure (N)
d = diameter of the specimen (mm)
l = length of the specimen (mm)

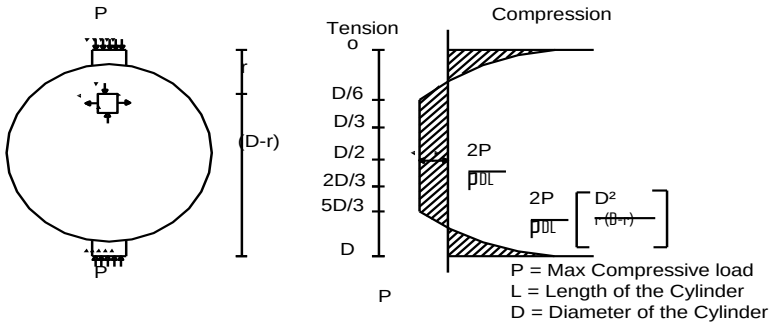


Fig :4 Schematics of the Split Tensile Test and the Stress Distribution Diagram

The fig 4 shows the schematics of the split tensile test and the stress distribution diagram. The flexural test was calculated in flexural stress or the modulus of rupture was formed from the basic principles. Three point loading frame was used for finding the flexural stress.

RESULT AND DISCUSSIONS:

The XRF analysis shows major oxide contents as SiO_2 and Al_2O_3 this indicates that the clays are aluminosilicate materials. Therefore these clays can be used for making geo polymer concrete. Upon heating all the four clays changed to red in colour, this indicates the presents of Fe_2O_3.

The cylinder strength was found significantly higher for thermally treated clay based geo polymers. This is due to opening up of SiO_2 phase and changing of crystalline phase to amorphous state. This can be seen from the table 3 the increase in SiO_2 components in all four clays. However reduction in Al_2O_3 is observed in all four clays this may be due oxidation of Al_2O_3 oxides. The reason for increase compressive strength can be attributed to the fact to the fact

there is an increase in ratio of SiO_2 / Al_2O_3 component and also SiO_2 / Fe_2O_3 component. The presence of calcium oxide does not play any role for increase or decrease in strength.

The split tensile strength and flexural strength are around 13% and 18% of cylinder strength respectively. Compare to split tensile strength the flexural strength is higher this is due to the action of micro fibers presents in the clay. The density of all the mixes either raw clay based geo polymers or thermally treated clay based geo polymer. The density varies 2350 to 2368 which is almost equal to the density of plain concrete based on Ordinary Portland Cement (OPC)

The percentage of water observation varies from 3.14% to 4.11%. These values are comparatively less than the values of normal OPC concrete. This is due to the fact the poly sialate chain formation and its crystallization.

CONCLUSION :

The raw and thermally treated clays are aluminosilicate materials.

The ratio of SiO_2 / Al_2O_3 and SiO_2 / Fe_2O_3 are increased on heating , which is responsible increase in mechanical strengths such as cylinder compressive strength, split tensile strength , flexural strength.

Geo polymer crystallization is highly dense and therefore reduced water absorption compare to many other OPC concrete.

The presents of calcium oxide (CaO) do not play any adverse role in formation of geo polymer.

Acknowledgment

The authors are thankful to the director, CSIR-CECRI for having granted permission to carry out the research in CECRI.

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