Experimental Investigation On Geopolymer Concrete Using Concrete Demolition Waste

G. Purusothaman [1], A. Subramani [1], S. Ashok Manikandan [2]

[1]UG Student, Department of Civil Engineering, P.S.R.Engineering College, Sivakasi.
[2]Assistant Professor, Department of Civil Engineering, P.S.R.Engineering College, Sivakasi.

Abstract – *Very large quantities of aggregate are used in concrete production and in construction. The use of recycled aggregates from construction and demolition wastes is showing prospectivd application in construction as alternative to primary(natural) aggregates. The recycling of demolished construction waste in to aggregates to be used in new engineering application provides a promising solution problems. It conserves natural resources and reduces the space required for the landfill disposal. In this work the usability demolished waste as coarse aggregates in new concrete is attempted. This experimental investigation involves evaluating the properties of the constituents of geopolymer concrete including the demoslished concrete wastes which shall be used as coarse aggregates in new concrete with the aim of producing a green concrete.*

Keywords — ***Geopolymer Concrete, Demolition Waste, Green Concrete.***

I. Introduction

Geopolymer is a type of amorphous alumino-silicate product that exhibits the ideal Properties of rock-forming elements, i.e., hardness, chemical stability and longevity. The properties of geopolymer include high early strength, low shrinkage, freeze-thaw resistance, sulphate resistance and corrosion resistance. Ordinary Portland Cement (OPC) becomes an important material in the production of concrete which act as its binder to bind all the aggregate together. However, the utilization of cement causes pollution to the environment and reduction of raw material (limestone). The manufacturing of OPC requires the burning of large quantities of fuel and decomposition of limestone, resulting in significant emissions of carbon dioxide As such, geopolymer concrete had been introduced to reduce the above problem.

Davidovits (1988; 1994) 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 and rice husk ash to produce binders. Because the chemical reaction that takes place in this case is a polymerization process, he coined the term 'Geopolymer' to represent these binders. Geopolymers are members of the family of inorganic polymers. The chemical composition of the geopolymer material is similar to natural zeolitic materials, but the microstructure is amorphous. The polymerization process involves a substantially fast chemical reaction under alkaline condition on Si-Al minerals that result in a three-dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds (Davidovits, 1994). The schematic formation of geopolymer material can be shown as described by Equations (1) and (2) (Davidovits, 1994; van Jaarsveld et al., 1997)

$$n(Si_2O_5,Al_2O_2) + nSi_2 + nH_2O \xrightarrow{NaOH,KOH} n(OH)_3 - Si - O - \underset{\underset{(OH)_2}{\downarrow}}{\overset{-}{Al}} - O - Si - (OH)_3 \qquad (A)$$

$$n(OH)_3 - Si - O - \underset{\underset{(OH)_2}{\downarrow}}{\overset{-}{Al}} - O - Si - (OH)_2$$

$$\xrightarrow{NaOH,KOH} (Na^+,K^+) - (\underset{O}{\overset{|}{Si}} - O - \underset{O}{\overset{|}{Al}} - O - \underset{O}{\overset{|}{Si}} - O-) + nH_2O$$

The last term in Equation (2) reveals that water is released during the chemical reaction that occurs in the formation of geopolymers. This water, expelled from the geopolymer matrix during the curing and further drying periods, leaves behind discontinuous nana-pores in the matrix, which provide benefits to the performance of geopolymers. The water in a geopolymer mixture, therefore, plays no role in the chemical reaction that takes place; it merely provides the workability to the mixture during handling. This is in contrast to the chemical reaction of water in a Portland cement concrete mixture during the hydration process.

Construction is one of the fast growing fields worldwide. As per the present world statistics, every year around 260,00,00,000 Tons of Cement is required. This quantity will be increased by 25% within a span of another 10 years. Since the Lime stone is the main source material for the ordinary Portland cement an acute shortage of limestone may come after 25 to 50 years. More over while producing one ton of cement, approximately one ton of carbon di oxide will be emitted to the atmosphere, which is a major threat for the environment. In addition to the above huge quantity of energy is also required for the production of cement. Hence it is most essential to find an alternative binder.

II. OBJECTIVE

To investigation on geopolymer concrete by Replacing coarse aggregate by concrete demolition waste and find Flexural strength and Tensile strength of the geopolymer concrete.

III. LITERATURE REVIEW

Several authors have reported the use of Fly ash in Geopolymer Concrete for various Civil engineering applications.

Alexander Vásquez, et al., proposed that the present study, the synthesis of geopolymers based on alkaline activation. The highest compressive strength was obtained in systems activated with sodium silicate, which enabled geopolymer synthesis at room temperature. The results obtained in the present study demonstrate the feasibility of using concrete demolition wastes as precursors to obtain geopolymer cements.

A. Allahverdi & E. Najafi Kani(2012) Proposed that geopolymerization can transform a wide range of waste alumino silicate materials into building materials with excellent chemical and physical properties such as fire and acid resistance. In this research work, geopolymerization of construction waste materials with different alkali-activators based on combinations of Na2SiO3 and NaOH has been investigated.The results obtained reveal that construction wastes can be activated using a proportioned mixture of Na2SiO3 and NaOH resulting in the formation of a geopolymer cement system exhibiting suitable workability and acceptable setting time and compressive strength.

Ganesh Kumar S, et al., (Dec-2015) suggested that the demand of concrete is increasing day by day and cement is used for satisfying the need of development of infrastructure facilities, 1 tone cement production generates 1 tone CO2, which adversely affect the environment. Geopolymer concrete uses fly ash and alkaline solution as their Binding Materials. Geopolymer requires oven curing in the varying range of 60°C to 100°C for a period of 24 to 96 hours. Replacement of Fly ash by GGBS increases the Strength gradually without Oven curing provision.

Rafael Andres Robayo – Salazar (2016) Proposed that the synthesis of geopolymers based on alkaline activation of concrete demolition waste (CDW) was investigated using sodium hydroxide and sodium silicate as alkaline activators. To produce hybrid and binary geopolymers, Portland cement and metakaolin were added at levels up to 30% by weight with respect to the CDW. The effect on the compressive strength of Na_2O/SiO_2 and SiO_2/Al_2O_3 molar ratios and type of curing (room temperature and thermal curing) was evaluated. To characterize the morphology and structure of the geopolymer pastes, techniques such as X-ray diffraction, infrared spectroscopy, and scanning electron microscopy were used. The highest compressive strength was obtained in systems activated with sodium silicate, which enabled geopolymer synthesis at room temperature. The simple geopolymer, based on 100% CDW, reached a maximum compressive strength of 25 MPa, and the hybrid geopolymer CDW + 30% OPC reached 33 MPa at 28 days with curing at room temperature. In the case of the binary geopolymer CDW + 10% MK, a significant increase in compressive strength was observed, reaching 46.4 MPa at 28 days of curing without applying thermal curing. The results obtained in the present study demonstrate the feasibility of using concrete demolition wastes as precursors to obtain geopolymer cements.

Shankar H. Sanni & Khadiranaikar, R. B (2012) suggested that the grades choosen for the investigation were M-30, M-40, M-50 and M-60, the mixes were designed for molarity of 8M and 12M. The alkaline solution used for present study is the combination of sodium silicate and sodium hydroxide solution with the ratio of 2.50 and 3.50.The test specimens were 150x150x150 mm cubes, 100x200 mm cylinders heat-cured at 60°C in an oven. The test results indicate that the heat-cured fly ash-based geopolymer concrete has an excellent resistance to acid and sulphate attack when compared to conventional concrete. Thus we can say that the production of geopolymers have a relative higher strength, excellent volume stability and better durability

IV. STUDY OF MATERIALS

4.1 FLY ASH

The aim of this research is to study the use of fly ash by completely replacing cement and to reduce the pollution effects of fly ash. Composition of Fly ash

Table: 4.1 Composition

Chemical properties % by mass	Fly ash MTPP
SiO_2+Al2O_3+Fe2O_3	90.5%max
SiO_2	58%max
CaO	3.6%min
SO_3	1.8%min
Na_2O	2%max
L.O.I	2%min

MgO	1.91%min

4.2 Fine Aggregate

Good quality locally available river sand passing through 2.36 rnm sieve was used for all experimental investigations and the product considered. The grading of sand used conforms to Zone-Il of 1.S: 383 -1970 and it also conforms to the stipulations in ACI 549 1 R - 93 and Ferro cement Modal Code (FMC).

4.3 Coarse Aggregate

The coarse aggregate particles passing through 20mm and retained on 12.5 mm I.S Sieve used as the natural aggregate which met the grading requirement of IS 383-1970.

4.4 Alkaline Liquid

4.4.1 Sodium hydroxide

In this investigation the sodium hydroxide pellets in 12 molar concentrations are used. The manufacturers data related to physical and chemical properties are given in Tables 4.2 and 4.3.

Table: 4.2 Physical properties of Sodium hydroxide

Colour	Colour less
Specific Gravity	1.47
Ph	14

Table: 4.3Chemical properties of Sodium hydroxide

Chemical formula	Colour less
Assay	97%
Carbonate ($Na2CO_3$)	2%
Chloride (Cl)	0.02%
Sulphate (SO_4)	0.01%
Lead (Pb)	0.002%
Iron (Fe)	0.005%
Potassium (K)	0.1%
Zinc (Zn)	0.02

4.4.2 SODIUM SILICATE

As per the manufacturer, silicates were supplied to the detergent company and textile industry as bonding agent. Same Sodium silicate is used for the making of geopolymer concrete.

Table: 4.4 Properties

Chemical formula	Na_2O x SiO_2Colour less
Na_2O	15.9%
SiO_2	31.4%
H_2O	52.7%
Appearance	Liquid (Gel)
Colour	Light yellow Liquid (gel)
Boiling Point	102 C for 40% aqueous solution
Molecular Weight	184.04
Specific Gravity	1.6

Super Platizers

Conplast SP430 has been used where a high degree of workability and its retention are likely or when high ambient temperatures cause rapid slump loss. It facilitates production of high quality concrete.

V MIX DESIGN

Ratio of M_{30} = 1 :1 :1.5

5.1 Geopolymer Mix:

Sodium Hydroxide Concentration = 12 Molarity

Sodium Hydroxide / Sodium Silicate Ratio = 1:1

Alkaline Activator /fly ash Ratio = 0.4

Curing Type = Oven Curing

Curing Period = 24 hours @ 80^{o}C

VI CASTING & TESTING

6.1 Casting on Geopolymer concrete

The geopolymer concrete used in this study is composed of low calcium fly ash and alkaline solution composed NaOH and sodium silicate combination. NaOH is mixed with deionized water at a concentration of 12 molarity and in the ratio of Alkaline Activator and Fly ash is 0.4. It kept for at least 24 hours prior to casting. All the geopolymer concrete were made with sand -to- fly ash ratio by equal proportion. The hydroxide to silicate ratio is kept constant as 1:1. The fly ash, fine aggregates and coarse aggregates were dry mixed together in mixer machine for 5 min, followed by the addition of activator solution containing hydroxide and silicate to the mixture, and mixed for another 10 min. The mixing was carried out in a room temperature of approximately 25-30^{o}c.

6.2 Curing on Geopolymer concrete

The geopolymer concrete was cured under heated 80^{o}C for 24 hours, used in heat chamber.

Fig.6.1 Curing of geopolymer concrete

6.3 Testing on geopolymer concrete

The mould could be easily separated from cast elements after its initial setting. The contact surface of the mould were greased before casting the specimens to ease the demoulding process. The geopolymer concrete was cured under heated 80^{o}C for 24 hours.

6.3.1 Split Tensile Testing

The specimen is then placed in the machine in such a manner that the load shall be applied by placing the specimen horizontal.

The maximum load at failure was taken and split tensile strength is calculated using the equation.

$$\text{Split tensile strength} = 2P/\pi dl$$

Where,
P = Maximum load at failure (N)
d = Diameter of cylindrical specimen (mm)
l = Length of cylindrical specimen (mm)

Fig.6.2 Tensile test on geopolymer concrete

6.3.2 Flexural Testing

The specimen is then placed in the machine in such a manner that the load shall be applied.The maximum load at failure was taken and flexural strength is calculated using the equation.

$$\text{Flexural strength} = M/Z$$

Where,
M = Moment (Nmm)
Z = Section modulus (mm^3)

Fig.6.3 Flexural test on geopolymer concrete

VII RESULT

7.1 GEOPOLYMER CYLINDER SPECIMEN

Table:7.1 Tensile Test result

		Load (Kn)	**Strength (N/mm^2)**	**Avg. Value**
Conventional concrete	Sample 1	370	5.23	5.4
	Sample 2	395	5.59	
	Sample 3	380	5.38	
CDW Concrete	Sample 1	235	3.32	3.41
	Sample 2	250	3.54	
	Sample 3	240	3.39	

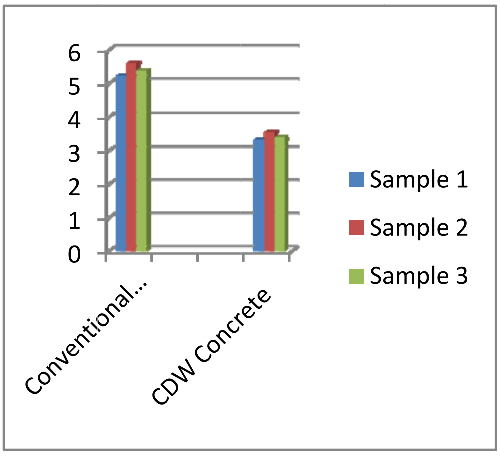

Fig.7.1 Chart for Tensile test

7.2 GEOPOLYMER PRISM SPECIMEN

Table : 7.2 Flexural Test result

		Load (Kn)	Strength (N/mm^2)	Avg. Value
Conventional Concrete	Sample 1	20.1	15.07	14.5
	Sample 2	18.3	13.72	
	Sample 3	19.7	14.7	
CDW Concrete	Sample 1	15	11.25	12.6
	Sample 2	17.4	13.05	
	Sample 3	18	13.5	

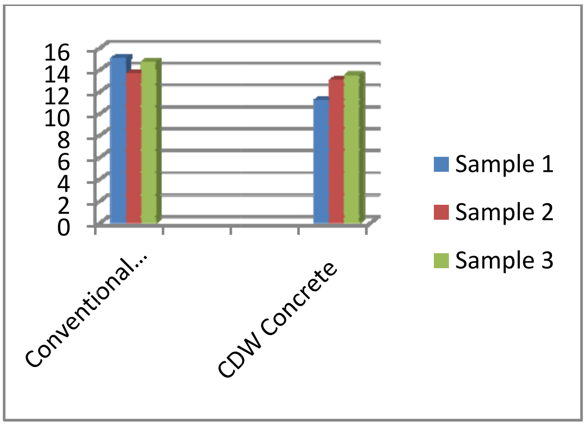

Fig. 7.2 Chart for Flexural test

VIII. CONCLUSION

Geopolymer Concrete by replacing Concrete Demolision Waste had shown a significant potential as a good engineering material for the future research, as the Geopolymer Concrete is not only environmental friendly but also it possesses excellent mechanical properties, both in short term and long term. The economic benefits and contributions of Geopolymer concrete to sustainable development are evident. Geopolymer concrete had very less curing time. Higher concentration of activated alkali solution results into achieve the optimum strengths.

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