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Study on the Structural Behavior of Geopolymer Concrete

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Abstract

The world's most consumed construction material is concrete made up of cement, aggregates, water and additives as it is found to be more versatile, durable and reliable. Concrete is the second most-consumed material after water, which required large quantities of Portland cement. The manufacturing process of Ordinary Portland Cement (OPC) results in the destruction of the environment due to the emission of CO2 as well mining also results in unrecoverable loss to nature. The amount of carbon emissions is increasing on an alarming scale, and hence, it is required to find an alternative material to the existing expensive cement-concrete. Geopolymer concrete is an alternative construction material that is produced by the chemical action of inorganic molecules. Fly Ash, a by-product of coal obtained from the thermal power plant, is abundantly available worldwide. Fly ash rich with silica and alumina activated with alkaline activators form aluminosilicate gel that acts as the binding material for the concrete. It is an excellent alternative construction material to normal concrete without using any amount of ordinary Portland cement. Geopolymer concrete shows a greener substitute for ordinary Portland cement concrete in some applications. This paper reviews the structural properties of Geopolymer concrete and its applications.

Keywords: - *geopolymer concrete, fly ash, GGBFS, alkaline solution*

INTRODUCTION

The construction industry is one of the fast-growing industries throughout the world. Concrete is one of the widely used construction materials. The primary binder used in concrete is Ordinary Portland Cement (OPC). The cement worldwide is high as 2.6 billion tons per year and generates nearly 7% of carbon-di-oxide which largely contributes to environmental pollution and global warming [3].

Cement production also demands a huge quantity of limestone, which is seen depleting. On the other hand, there is a huge quantity of fly ash produced, which is a by-product produced during the combustion of coal, and a large part of it is disposed of in the landfills that affect the groundwater and surface sources of water. Hence, it is of utmost importance to use alternate pozzolan materials that will utilize waste produced and reduce the adverse effect of the construction of the environment and improve concrete performance [2].

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OVERVIEW ON GEOPOLYMER CONCRETE

Several studies have been made to address the foresaid environmental concerns. The alternate pozzolan materials include fly ash, silica fume, ground granulated blast furnace slag (GGBFS), rice husk ash. French Professor Davidovits first introduced the word "Geopolymer." Geopolymer concrete is an alternative to conventional concrete that does not utilize cement as a binder. The binding properties are facilitated by using source materials rich in silica and alumina. The binding property is achieved by reacting alkaline solutions with the pozzolan source material [3].

The reaction between the source material and alkaline solution forms a gel known as aluminosilicate. The gel so formed binds the aggregates and other concrete materials to form geopolymer concrete [1].

LITERATURE REVIEW

M. Mohd et al. focused on the topic" A review on fly-ash based geopolymer concrete without Portland cement." The study included various parameters such as curing process, compressive strength, workability, resistance against aggressive environment and behavior of geopolymer at elevated temperature. The study concluded that fly ash-based geopolymer concrete is better than normal concrete in many aspects such as workability, exposure to an aggressive environment, exposure to elevated temperature and compressive strength [1]

B. Singh et al. studied the topic "Geopolymer concrete: A review of some decent developments." The study included various parameters such as the C-S-H phase effect, the effect of admixtures, curing conditions, geopolymer mortars, fresh and hardened properties of geopolymer concrete and durability. The study concluded that geopolymer concrete has considerable potential to be used as a construction material in several applications [2].

J. Bhushan. et al. studied the topic "Geopolymer concrete: A review." The study included various parameters such as compressive strength, durability, economic benefits of geopolymer concrete, the necessity of geopolymer concrete and application of geopolymer concrete. The study concluded that geopolymer concrete is resistant to corrosion and fire and has high compressive and tensile strength [3].

M. I. Abdul Aleem et al. studied the topic “Geopolymer concrete: A review.” The study included various parameters such as the necessity of geopolymer concrete, constituents and properties of geopolymer concrete, Applications and limitations of Geopolymer concrete.

The study concluded that due to high early strength, Geopolymer concrete should be effectively used in the precast industries. Huge production is possible in a short duration, and the breakage during transportation shall also be minimized [5].

Marathe S. et al. studied the topic “Review on strength and Durability studies on Geopolymer concrete.” The study included various parameters such as constituent materials to produce geopolymer concrete, mixing proportions and properties of geopolymer concrete, Factors affecting geopolymer’s strength, Workability of fresh geopolymer, Casting and curing

geopolymer specimen, and Major hardened properties of geopolymer concrete. The study concluded that geopolymer concrete has significant potential as a good engineering material for future research. The GPC is not only environment friendly but also possesses excellent mechanical properties [7].

GEOPOLYMER CONCRETE MATERIALS

Fly Ash

It is a byproduct derived from the combustion of coal in thermal power plants with rich silica and alumina content when used in concrete, will help reduce the adverse effect on the environment as a replacement of cement

GGBFS

Acronym for ground granulated blast furnace slag is a derivative from the iron and steel industry and is available in fine powder form. Physically GGBFS can be described as glassy, granular with silicates and alumina.

Aggregates

Conventional fine and coarse aggregates of standard sizes are used in geopolymer concrete.

Alkaline Solutions

Hydroxides and silicates of sodium and potassium are used. These alkaline solutions reacting with silica and alumina from source materials such as fly ash and GGBFS will form binder material that imparts concrete strength.

COMPARISON OF STRENGTH PARAMETERS

Compressive Strength

Marathe S. et al. focused on the topic "Review on strength and Durability studies on Geopolymer concrete". Material constituents for geopolymer formation, various mix proportions, strength affecting parameters, and workability of geopolymer concrete in a fresh state, casting process, and curing process were studied. The study concluded that geopolymer concrete has significant potential as a good engineering material for future research, as the GPC is not only environment friendly but also possesses excellent mechanical properties [7].

B. Vijya Rangan et al. stated that geopolymer concrete's compressive strength is very high compared to normal concrete. It is about 1.5 times higher than normal concrete for the same mix. Geopolymer concrete also showed very good workability compared to normal concrete [16].

Durability

"Rangan, B.V. et al. stated that Geopolymer concrete is more resistant to heat, sulphate attack, water ingress & alkali-aggregate reaction. The role of calcium in Geopolymer concrete made up of fly ash is very prominent since it may cause a flash setting. Such structures with high durability can be adapted to marine environment" [16].

"Wallah et al. explained that fly-ash-based geopolymer concrete, which is heat-cured, undergoes low creep and shows very little drying shrinkage as of about 100 micro strains at the end of one year. And it shows excellent resistance to sulphate attack [17].

Chanh et al. proved that better resistance is provided by fly ash-based geopolymer against aggressive environment. This quality of resistivity can be used to construct structures that are exposed to the marine environment [10].

Sathia et al. proved that only 0.5% of the weight is lost when geopolymer is exposed to acid solution compared to normal concrete immersed in 3% sulphuric acid [7].

Workability of Fresh Geopolymer Concrete

Sathia et al's study said that water also plays an important role in geopolymer concrete as much as normal concrete. Workability can be improved by the use of water in geopolymer, but it will increase the porosity in concrete at elevated temperature due to the evaporation of water during the curing process [7].

Chindaprasirt et al. discovered that the flow of mortar decreases with an increase in sodium hydroxide and sodium silicate concentration. The workable flow of geopolymer mortar was in the range of 110 ± 5 to 135 ± 5% [12].

The workability of mortar is upgraded with the addition of superplasticizer or extra water, but the use of superplasticizer affects geopolymer strength. However, the addition of extra water gives higher strength than the addition of a superplasticizer.

Economic Benefits of Geopolymer Concrete

N A. Lloyd and B V Rangan concluded that heat-cured, low- calcium fly ash-based Geopolymer concrete is estimated to be about 10 to 30 percent cheaper than that of Portland cement concrete. In addition, the

appropriate usage of one ton of fly ash earns approximately one carbon-credit, which in terms of ecological aspect makes it more economical [14].

One ton of low-calcium fly ash can manufacture approximately three cubic meters of high-quality fly ash-based Geopolymer concrete. When it is utilized in infrastructure, the very little drying shrinkage, the low creep, the excellent resistance offered by geopolymer concrete has additional economic benefits [14].

Geopolymer concrete has many advantages as compared to the standard concretes. It has more durability than the standard concrete and requires little repair, thus saving a huge amount of money to be spent on repair works and maintenance of concrete-based infrastructure [14].

The Necessity of Geopolymer Concrete

As per the international Cement Review reports, there is huge growth in infrastructure development, and cement usage was 3,294 million tons in 2010, which is increasing by nearly 12% per year, which results in a huge shortage of limestone in the future. In addition to this, the emission of CO2 into the atmosphere will result in global warming. Kumar V. et al. (2005) submitted the estimate in their report that the thermal power industry is expected to produce fly ash to about 170 million tons by 2012 and 225 million tons by 2017 [3].

Lokeshappa et al. stated that the rate of fly-ash in construction is 38%, the region where the remaining portion of the fly ash is dumped pollutes the environment. So, it is important to carry out research and undertake development to study the structural properties of fly ash and to utilize the industrial wastes in the construction [11].

From the above study, it is understood that if geopolymer concrete is developed, more industrial wastes can be utilized in the construction field with the reduction in the usage of Portland cement, which will also reduce global warming [3].

APPLICATIONS

Aleem et al. mentioned that huge production is possible in a short time if Geopolymer Concrete can be used in the precast industries, and the breakage during transportation shall also be minimized. It shall be effectively used for the beam-column junction of reinforced concrete structures and infrastructure works. As a result, fly ash will be effectively used and

hence no landfills are required to dump the fly ash [5].

Anuar et al., in this respect, the Geopolymer technology proposed by Davidov shows considerable promise for application in the concrete industry as it acts as an alternative binder to the Portland cement. It can be used to produce precast railway sleepers and other pre-stressed concrete building components [15].

CHALLENGES

In addition to various advantages expected from Geopolymer concrete over ordinary Portland cement-based concrete, a few of the challenges may have to overcome before its practical application [3].

Chemicals that can be harmful are used in the geopolymer concrete. Bringing the base material fly ash to the required location. Alkaline solutions with high cost. Practical difficulties in applying Steam curing / high-temperature curing process.

Considerable research is being carried out to develop geopolymer systems to overcome these technical hurdles [3].

COMPARISON OF STRENGTH PARAMETERS

Y. Nagvekar et al. made a comparative study between conventional concrete and green concrete and reported the following results. The study used an M25 grade concrete mix, and two different techniques of curing were used viz. water submerged curing or conventional curing and steam curing. The cubes casting were tested for 3 days, 7 days and 28 days for their compressive strengths and results were reported as below: [4]

Table 1: 3 days Compressive Strength

Compressive Strength Test Results after 3 days			
Sl. No.	**Conventional Concrete (N/mm^2)**	**Geopolymer Concrete (Water Submerged Curing) N/mm^2**	**Geopolymer Concrete (Steam Curing) N/mm^2**
1	10.13	4.63	15.6

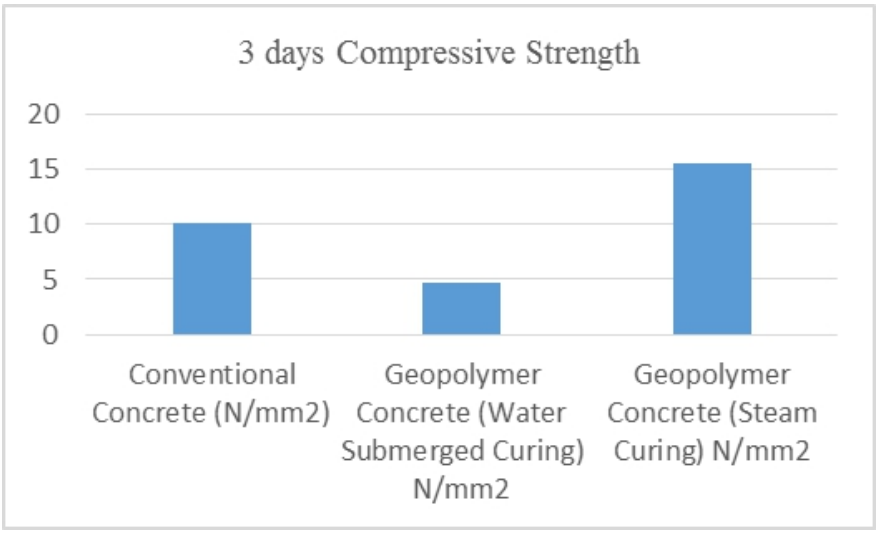

Figure 1: 3 Days Compressive Strength

Table 2: 7 Days Compressive Strength

Compressive Strength Test Results after 7 days			
Sl. No.	**Conventional Concrete (N/mm^2)**	**Geopolymer Concrete (Water Submerged Curing) N/mm^2**	**Geopolymer Concrete (Steam Curing) N/mm^2**
1	15.13	8.4	22.6

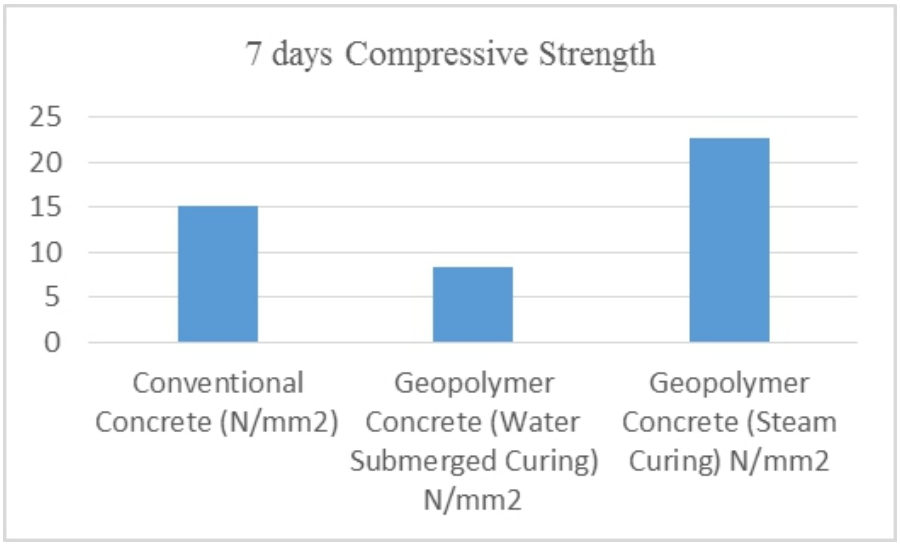

Figure 2: 7 Days Compressive Strength

Table 3: 28 days Compressive Strength			
Compressive Strength Test Results after 28 days			
Sl. No.	**Conventional Concrete (N/mm^2)**	**Geopolymer Concrete (Water Submerged Curing) N/mm^2**	**Geopolymer Concrete (Steam Curing) N/mm^2**
1	15.6	22.6	27.53

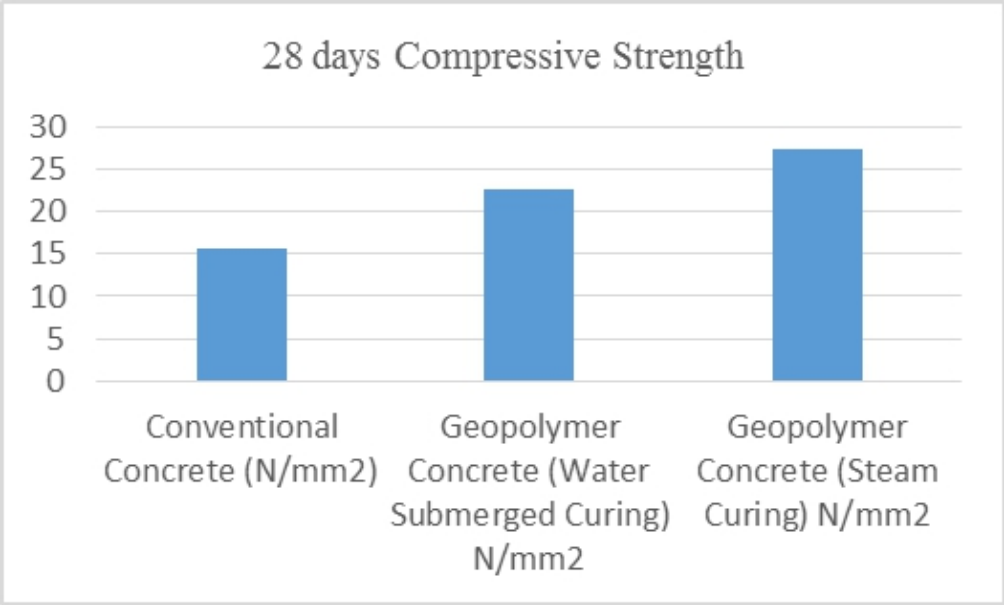

Figure 3: 28 days Compressive Strength

From the experimental results the author concluded that under water submerged curing, conventional concrete has better compressive strength when compared to geopoylmer concrete/green concrete.

However under steam curing process the strength of geopolymer concrete is 10% higher than conventional concrete. Hence for geopolymer concrete steam curing is a better alternative than water submerged curing.

CONCLUSIONS

From various studies conducted, it can be concluded that fly ash-based Geo polymer is preferred over normal concrete as it excels in many aspects such as compressive strength, exposure to aggressive environment, work-ability and exposure to high temperature. The study

shows that Geo polymer concrete is more resistant to corrosion and fire and has high compressive and tensile strengths. It also gains its full strength quickly (cures fully faster). The shrinkage is also less compared to standard concrete. Thus, considering these structural advantages, it may be concluded that Geopolymer concrete might find an effective alternative to standard cement concrete in the near future.

For the researchers' common conclusion of merits and demerits of geopolymer, concrete, detailed study and research are required.

Geopolymer concrete can be used easily under the same conditions which apply to ordinary Portland cement concrete. These geopolymer concrete constituents are capable of being mixed with low alkali activating solution and are curable in a short time under natural conditions. The production of this geopolymer concrete can be effectively mixed and hardened like Portland cement. Geopolymer concrete can be used for repair and renovation works.

Due to its property to attain high strength early, Geopolymer Concrete can be effectively used in the precast industries so that in a short duration, huge production can be accomplished, and the breakage during transportation shall also be minimized. The Geopolymer Concrete can be effectively used for the beam-column junction of a reinforced concrete structure. Also, geopolymer Concrete shall be efficiently used in the Infrastructure works. In addition to that, the Fly ash shall be effectively used and hence no landfills are required to dump the fly ash.

When steam cured than water submerged curing process, geopolymer concrete gains better strength. The strength gained is increased by 10% when steam is cured.

The government can take the necessary steps to extract sodium hydroxide and sodium silicate solution from the waste materials of chemical industries to reduce the cost of alkaline solutions required for its concrete.

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