A Review on the Mechanical Properties of the Green Concrete

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Abstract. In the 1950s, Viktor Glukovsky of Kiev, U.S.S.R., developed concrete materials that were originally known as "soil silicate concretes" and "soil cements," however since Joseph Davidovits coined the geopolymer theory, the terms and meanings of "geopolymer" have become more complex and often more frequent. As the production of Ordinary Portland Cement produces substantial CO2 emissions, Geopolymer Concrete will be of considerable cure to global warming related to the construction industry. At the same time, GPC substitutes OPC by industrial waste products for instance Fly Ash, Ground Granulated Blast Furnace Slag (GGBS), Silica Fume, Rice-Husk Ash, Metakaolinite or Red Mud (RM) utterly or almost 80%.

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1. Introduction
Cement production is energy-intensive and subsidises to the pollution of the environment. While the manufacturing cement CO2 is emitted about 7%, which is hazardous. Polymer concrete can be represented as “GREEN CONCRETE” and as “ECO-FRIENDLY CONCRETE” as it reduces the CO2 emission during production. The concept of polymer concrete is to protect the environment is from the CO2 emissions and to create a sustainable concrete. [1]

Polymer concrete normally consists of normally thermosetting polymer. For geopolymer, the selection of the materials mainly depends on their availability and cost, the specific demand of the users, and the type of application. [2]. Different materials contribute to the enhancement of various parameters when added in concrete.

The workability of polymer concrete is comparatively less when compared to that of conventional concrete. The raw materials for geopolymers customarily encompass aluminum in Amorphous form, silica, from natural materials or by-products (Fly ash, silica fume, slag, red mud, rice-husk ash, etc.). Fly ash Polymer concrete delivers impressive attributes that make them applicable materials for structural solicitation. The two major roles of polymerization process NaOH with Na2SiO3 and KOH with K2SiO3. [8]

Polymer concrete has enhanced durability properties, as it resists from sulfate attack. Moreover, the concrete has good immunity to avoid acid attacks and undergoes very little creep and drying shrinkage. Polymer technology has long been recognized to provide the potential for immobilization of hazardous waste. [14]
The mechanical strength of Polymer mortar increases when water glass (Na$_2$SiO$_3$) is supplemented to NaOH, paralleled with using only NaOH. The substitution of water glass increases the Si/Al and Na/Al ratios, consequential in the enhanced creation of N-A-S-H, which designates better strength.

2. Mix Percentage of the Geopolymer Concrete

The collaborating of materials aimed at polymer concrete is the equivalent as OPC conventional concrete. Mingling of all the constituents can be performed in the laboratory at room temperature. Moreover, the fly ash and the aggregate can be variegated in a concrete pan mixture. The mingling of the constituents is permitted to endure for about 3 to 4 minutes. The totalling of Alkaline solutions resembling Sodium Hydroxide can be used to stimulate the binding nature among the concrete composite. [7]

| Constituent | Unit | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
|-------------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Fly ash     | Kg/m3| 428 | 444 | 428 | 428 | 428 | 428 | 428 | 428 | 428 |
| C. A        | Kg/m3| 630 | 630 | 630 | 630 | 630 | 630 | 630 | 630 | 630 |
| Na2SiO3     | Kg/m3| 1170| 1170| 1170| 1170| 1170| 1170| 1170| 1170| 1170| 1170|
| NaOH        | Kg/m3| 1170| 1170| 1170| 1170| 1170| 1170| 1170| 1170| 1170| 1170|
| Superplasticizer | Kg/m3 | 8.5 | 8.5 | 8.5 | 8.5 | 13  | 17  | 8.5 | 8.5 |
| Molarity    |       | 14  | 14  | 14  | 14  | 14  | 14  | 14  | 14  | 14  | 14  |
| Extra water | Kg/m3 | 43  | 43  | 43  | 43  | 43  | 43  | 43  | 43  | 43  | 43  |
| Curing temp | °C   | 75  | 75  | 75  | 75  | 75  | 75  | 75  | 75  | 75  | 75  |
| Curing period | Hours | 24  | 24  | 24  | 24  | 48  | 48  | 48  | 48  | 48  | 48  |

Mixes of various proportions were tested for mechanical as well as workability properties. Mix corresponding to the optimum mechanical properties was normally considered for practical applications.

3. Strength due to the Compressive force in the Geopolymer Concrete

Strength due to the compression is a dynamic attribute for all that concrete. Compressive strength, be determined by, time and temperature of the curing. While there is upsurge in curing time and temperature, the compressive strength surges. The array of curing temperature of 60 to 90°C, with the span of time 24 to 72 h, the strength in compression of polymer concrete can extended about 400 to 500 kg/cm$^2$ [3]. The content of fly ash gives more compressive strength of polymer concrete (smaller than 43 μm). [9]. The reason for the increase in strength was found to be greater surface area contact. Hence the dominant factors for Polymer concrete with respect to compressive strength are the nature of alkali activation reaction and the concentration of the activators. [6]

The paramount compressive strength was expanded by using the solution of sodium silicate as an activator (n = 1.5; 10% Na2O). The seemliest alkaline activator is Sodium silicate, for the reason that it comprises partially polymerized silicon that dissolves and retorts effortlessly, incorporates into the reaction products and considerably contributes to cultivating the mortar characteristics [11]. The compressive strength of polymer concrete achieved up to 45Mpa, with the gravel size ranging from 12.5 to 25 mm offered maximum compressive strength and the specimens were healed at ambient temperature and 600 °C in the oven. Capacity of natural concrete or standard 10Mpa to 60Mpa compressive strength.[5]
Table 2. Compressive Strength of Polymer concrete at various days with various mixes [3][10]

| Age (days) | Sample 1 (Mpa) | Sample 2(Mpa) | Sample 3(Mpa) | Sample 4(Mpa) | OPC(Mpa) |
|------------|----------------|--------------|---------------|--------------|----------|
| 7          | 27             | 31           | 44            | 29           | 36       |
| 28         | 40             | 47           | 45            | 54           | 48       |
| 96         | 47             | 56           | 52            | 68           | 62       |
| 58         | 49             | 59           | 50            | 63           | 56       |
| 180        | 45             | 509          | 54            | 70           | 55       |

4. Tensile Strength of the Geopolymer Concrete
The standard concrete exhibits a tensile strength of about 30Mpa and 19Mpa when cured between 600 °C and 800 °C. Tensile strength of 51Mpa and 40Mpa were achieved by polymer concrete by curing the mixture at the same temperature.[3]. After testing all samples, the polymer concrete has 32.7% more than OPC.[10]

Table 3. Comparative Tensile Properties of Polymer concrete [5][9]

| MIX          | Tensile strength (Mpa) |
|--------------|------------------------|
| Conventional | 2.06                   |
| SFRC         | 5.40                   |
| Polymer      | 12.06                  |
| SFRPIC       | 15.50                  |

Tensile properties of polymer concrete were enhanced when steel fibers are used up to 12% addition. The test results revealed that the when compared to the conventional concrete the tensile properties of the polymer concrete were significantly higher about 75% increase in the tensile strength. The tests were done by casting both cylinder models and dog bone specimens

5. Strength due to Flexural in the Geopolymer Concrete
The strength due to flexure for polymer concrete was carried out by casting beam specimens. Related to the results due to the compression and tensile strength, Polymer concrete exhibited advanced flexural strength at several ages. By using polymer concrete flexural strength can be enhanced up to 67% increases when compared to the conventional concrete.[12].

Table 4. Flexural Strength of Polymer concrete [7][8]

| Samples | Flexural strength MPa (7 days) | Flexural strength MPa (28 days) |
|---------|-------------------------------|--------------------------------|
| Sample 1| 4.8                           | 5.02                           |
| Sample 2| 5.3                           | 5.51                           |
| Sample 3| 5.72                          | 6                              |
| Sample 4| 6.1                           | 6.28                           |

The flexural strength is gracious than the ordinary concrete, shows the higher performance in various ages. The maximum strength of Green concrete or geopolymer concrete is 29.02MPa and the minimum strength is 1.4Mpa.

6. Durability features of the Geopolymer Concrete
In the circumstance of geopolymer concrete using 20% silica fume, compressive strength losses remained insignificant in the company of 2% H2SO4 and 5% NaCl solution. Geopolymer concrete ensured exceptional enduring durability properties proficient of counterattacking chemical attacks in the presence of 20 percent silica fume. [2]. Some of the foremost difficulties connected with OPC
concrete is enduring durability, which has constantly been an concern with the climate, and geopolymer concrete helps a lot to overcome. [8]

The strength of green concrete has been improved by 20-25 percent since adding polyester resin. Maintaining the mortar mixture of geopolymer concrete is normal, so the crack formation is lower compared to conventional concrete.

Portland lime cement produced by the IMERYS group supplied by Lafarga cement provides a maximum polymer admixture composition of 100% above a minimum of 20 to 20% below.

7. Effects of Acid and Sulphate attacks on the Geopolymer Concrete

7.1 Acid Attacks
The acid resistance of the geopolymer paste or the concrete degradation extension depends on the acid solution concentration and exposure time. Davidvits etal suggested that metaoalin-based geopolymer paste displayed just 7 percent mass loss when the specimen was submerged for 30 days in 5 percent H$_2$SO$_4$ Fly ash based on geopolymer paste or concrete has also been documented to maintain a dense micro-structure after 3 months of HNO$_3$ exposure. Thus showing a significant resistance for acid attacks. Soaking in 2% H$_2$SO$_4$ solution, resistance damage was 11% compared to 36.2% OPC concrete. [14].

7.2 Sulphate Attacks
Fly ash based on geopolymer paste or concrete has not substantially deteriorated and the effect of water and sodium sulphate has not deteriorated the strength properties of the concrete. [12]. The flexural strength fluctuation was observed between 7 days and 3 months of exposure. The smallest difference in intensity was observed in the 5% Na$_2$SO$_4$ and MgSO$_4$ solution.

8. Conclusion
Finally, GGBFS-modified fly ash-based geopolymer is found to be an efficient binder for low to medium strength concrete production at ambient healing as it eliminates the need for heat healing. [1] Replacing 10% of OPC fly ash in GPC mix removes the two disadvantages of Geopolymer Concrete (GPC mix) such as time delay and the need for heat to improve the strength of the Geopolymer Concrete Composite (GPCC mix). Increased GGBFS in a mixture of geopolymers based on fly ash reduces workability and time setting. [11]

Decrease in the flow of concrete and mortar occurs, with a rise in slag. Workability and time setting improved with lower compressive strength as alkaline fluid content augmented. Mixtures of sodium silicate alkaline activator solution at a sodium hydroxide ratio of 2.5 showed less slumps and time setting than 1.5 and 2.0. [4] Accumulation of slag up to 30 per cent of the overall binder reached a concrete compressive strength of up to 55 MPa and a mortar strength of up to 63 MPa at 28 days. Compressive intensity reduced from 35 to 45% of the overall binder with an increase in the quality of the alkaline solution. [3]
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