Enhancement of Properties of Geopolymer concrete with Crimped Steel Fibers

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Abstract: Geopolymer technology is nascent technology in the world of concrete. Indian standard code is not available for geopolymer concrete. However, at the initial stage, mix design of plain geopolymer concrete is done by testing various parameters. Calcium based, sodium based and potassium based solutions are available in the market. Sodium based alkaline solutions are used in the present research. Here, 100\% replacement of cement is done with fly ash. Fly ash used is Pozzocrete 63. Geopolymer concrete with addition of crimped steel fibers are used in the research. Molarity is finalized as 13M and ratio of Na\textsubscript{2}SiO\textsubscript{3}/NaOH is finalized as 2. Alkaline solution to fly ash ratio is taken in the research. Crimped steel fibers of aspect ratio 70 and 100 are added in geopolymer concrete. Results obtained shows that as aspect ratio of crimped steel fibers increases there is increase in compressive strength, flexural strength and split tensile strength of concrete. It is observed that as the aspect ratio of fibers increased up to some extent, its compressive strength is also increased.

1. Introduction
Pollution free environment protects the life. In today’s life apart from food, water and shelter, healthy environment is also important for everyone’s life. The cement industry which is responsible for about 7\% of CO\textsubscript{2} emissions of total CO\textsubscript{2} generation in environment, because for production of one ton of Portland cement it emits approximately one ton of CO\textsubscript{2} into the atmosphere, as heating of lime stone releases CO\textsubscript{2} directly. Among the total greenhouse gases, CO\textsubscript{2} contributes about 65\% of global warming. In Geopolymer technology, cement less concrete is possible by using any other base material which is rich in Silica and Alumina. GGBS, Rice husk ash, fly ash are the alternative materials to cement. Availability of fly ash is abundant as compared to these materials. In the present research, fly ash (pozzocrete63) is used as a base material to form geopolymer concrete. Disposal of fly ash is also a big problem. As per Ministry of Environment and Forest’s (MoEF’s) notification of 3rd November 2009, utilization of fly ash should be 100\%. But the highest utilization of fly ash is 62.60 \% and that is in the year 2009.

2. Literature Review
Jain A.K. Technical Advisor, Ultra Tech cement Ltd.Has focused on cement production and distribution cost of cement .According to author there is great pressure on financial viability of cement business.Wallah S. E. and Rangan B. V.performed investigation on low calcium fly ash based geopolymer concrete on long term properties. The work considered two mixtures as mixture 1 contained 8 molar NaOH concentration and no extra water was added. Mixture 2 contained 14 molar NaOH
concentration and with addition of extra water. Na2SiO3/NaOH ratio was 2.51 and Naphthalene superplastizser was used to achieve workability. Patankar S.V.et. al. (2015) studied on mix design procedure of fly ash based geopolymer concrete. Different parameters for selection of suitable ingredients of geopolymer concrete to achieve desire strength at required workability were studied.

3. Methodology

Here, molarity of NaOH is used as 13Molar and ratio of sodium silicate to sodium hydroxide is referred as 2. Steel crimped fibers having aspect ratios respectively 70 and 100 are added in geopolymer concrete. Fly ash, fine aggregates, coarse aggregates alkaline solution and water are ingredients of geopolymer concrete. Crimped steel fibers having aspect ratio 70 and 100 are added in geopolymer concrete. Fly ash is defined as fine, glass powder obtained from the gases of burning coal during the production of electricity. P63 pozzocrete is used in the present research procured from Dirk India Ltd., Nasik. As per the test results supplied from suppliers, fineness of fly ash is 435m²/kg. Locally available sand of fineness modulus 3.15 and specific gravity 2.65 is used. Coarse aggregates of size 20 mm and 12mm having sp. Gravity 2.84 and 2.79 respectively are used. Sodium hydroxide flakes are used for preparation of NaOH solution.

Quantity of materials obtained is as follows:

3.1. Selection of quantity of fly ash

Pozzocrete 63 is used in present research. As per the test results fineness of fly ash is 435m²/kg. Also, target mean strength of M30 grade of Concrete is 38.25 Mpa.

3.2. Alkaline Activators to Fly Ash Ratio:

Alkaline activator to fly ash ratio is fixed as 0.35. Mass of \((\text{Na}_2\text{SiO}_3 + \text{NaOH}) / \text{Fly Ash} = 0.35\). Mass of \((\text{Na}_2\text{SiO}_3 + \text{NaOH}) = 0.35 \times 420 = 147\text{kg/m}^3\). \(\text{Na}_2\text{SiO}_3/\text{NaOH} = 2\), \(\text{NaOH} = 49\text{kg/m}^3\), \(\text{Na}_2\text{SiO}_3 = 98\text{kg/m}^3\)

3.3 Solid content in Sodium Silicate solution:

It depends upon percentage of solids of Silicon Dioxide and Sodium Dioxide in Sodium Silicate solution. Here, \(\text{Na}_2\text{O} = 15.06\text{ and } \text{SiO}_2 = 34.01\text{Total Solid} = 49.07 \times 98 = 48.08\text{kg/m}^3\). Solid Content of Sodium Hydroxide in Sodium Hydroxide Solution: 18.33 kg/m3.

3.4 To find water content in alkaline Solution and additional quantity of water required

Water content in alkaline solution = (Mass of Sodium Silicate + Sodium Hydroxide) – (Total Solid Content in Alkaline Solution) m Water content in Alkaline Solution = 147 – 60.93 = 86.07 kg/m³, Additional quantity of water required = (Total quantity of water) – (Water content in Alkaline Solution)

From the figure 1, quantity of fly ash used is 420kg/m³.
If fineness of fly ash is in between 300 to 400 $m^2/kg$ then quantity of water required is 110 $kg/m^3$. Additional quantity of Water required = $110 – 86.07 = 23.93$ $kg/m^3$. For fineness of fly ash 435$m^2/kg$, density of concrete is obtained as: 2535 $kg/m^3$.

3.5. To find total aggregate content

To decide Fine to total aggregate Content in Percentage:

It depends upon fineness modulus of fine aggregate. Fineness modulus of sand is obtained 3.15.

![Figure 2. Fineness Modulus of aggregates](image)

Fine aggregate / Total aggregate = 34.5 % = (34.5 / 100) x 1944.07 = 670.70 $kg/m^3$

Coarse Aggregate required = Total Aggregate – Fine Aggregate = 1944.07 – 670.70 = 1273.37 $kg/m^3$

| Fly ash $kg/m^3$ | F A $kg/m^3$ | C A $m^3$ | NaOH $kg/m^3$ | Na$_2$SiO$_3$ $kg/m^3$ | Additional Water $kg/m^3$ |
|------------------|-------------|-----------|----------------|------------------------|---------------------------|
| 420              | 668.81      | 1269.77   | 49             | 98                     | 29.41                     |

![Figure 3. Compressive strength of GPC with Crimped Steel Fiber of aspect ratio 70](image)
3.6. Quantity of Separate Fibers used in Geopolymer Concrete:
Alkaline solution to fly ash ratio is taken as 0.40. Percentage of fibers used in cube specimen and cylinder specimen is used as 0.2%, 0.4%, 0.6%, 0.8% and 1% by mass of concrete. Mechanical properties of specimens are checked. Crimped Steel Fiber 70:As addition of volume fraction of fiber increases its strength is increases up to 0.8 % and after that it reduces as flocculation offibers at one place takes place.

**Figure 4.** Split Tensile strength of GPC with Crimped Steel Fiber of aspect ratio 70

**Figure 5.** Compressive strength of GPC with Crimped Steel Fiber of aspect ratio 100

**Figure 6.** Split Tensile strength of GPC with Crimped Steel Fiber of aspect ratio 100
4. Conclusion:
For crimped steel fibers of 70 aspect ratio, maximum compressive strength is obtained for addition of fibers of 0.8% volume fraction by mass of geopolymer concrete, whereas in case of 100 aspect ratio fibers, maximum compressive strength is obtained for addition of volume fraction of 0.6%. Split tensile strength is observed maximum for 70aspect ratio at 0.8% addition of fibers and for 100 aspect ratio; it is maximum at 1% addition of fibers.

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