Experimental Studies On Strength and Durability Characteristics of 8M GeoPolymer Mortar Based On Fly Ash and GGBS

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ABSTRACT: Ordinary Portland cement (OPC) is one of the most misfortune cover measurable in the structure business. It is evaluated that the production of OPC, discharges the enormous measure of Carbon-di-oxide (CO₂) gas which makes the 65% of a global warming which leads to global weather imbalance. For the manufacture of one ton of OPC transmits roughly 0.8 ton of CO₂ in the worldwide gases, along these lines the cement industry produces 7% of all (CO₂) ecological contaminating gases. The properties of the mortar have been calculated according to Indian and ASTM standard requirements, specific gravity, compressive and split tensile strength. The ratio of "Na₂SiO₃ to NaOH" is 2.5, and the ratio of "alkaline solvent to binder" is equal to 0.4, 0.45, 0.5, 0.55 in the cases of binder components are calculated with each ratio. Like in this research we calculated with each fluid/binder ratio with different mix proportions 1:15, 1:2, 1:2.5, 1:3 in this research using only two materials fly ash then GGBS, using the different ratios of fly residue and GGBS with identical molarity and IS specified normal sand sieve sizes. Once prepared with the "alkaline liquid to binder" ratio, it creates higher strength to the geopolymer mortar. It can be inferred that the results in terms of intensity by ambient curing are strong relative to outdated mortar.

Key Word : Geopolymer Mortar, Fly Ash, GGBS, Sodium Hydroxide, Sodium Silicate.

I. INTRODUCTION
Production of cement causes a huge volume of carbon dioxide CO₂ announcement causing temperature rise, a dangerous atmospheric deviation. It is assessed that one ton of concrete roughly needs around 2 tons of raw resources (Limestone also Shale) also discharge about 0.87 ton of CO₂ and around 3 kg of nitrogen oxide. Production of cement causes huge impact in grievance causing changes in land-use patterns and nearby water defilement just as air contamination. Criminal CO₂ emissions additionally
present tremendous danger to nature. The cement industry doesn't fit in feasible improvement because of raw materials utilized for the production doesn't reuse and are non-renewable. The waste material or side-effect from the business which can be used for reduction of carbon dioxide CO₂ outflow. Accentuation on energy preservation and nature protection has been expanded as of late which have prompted the examination of options in contrast to standard building materials and technological advances. In this manner, the material or through consequence of an industry could be utilized in cement production subsequently reducing carbon footprint. Inorganic polymer or natural polymer composites have the possibility to frame a generous component to form an environment friendly and feasible constructional building material which produces lower greenhouse footprint when contrasted with the customary cement.

In 1978, Joseph Davidovits created Inorganic polymeric resources & authored the period "Geopolymer" for it (1991). Geopolymer can possibly supplant usual Portland cement & yield fly ash based geo polymer plaster with brilliant corporeal & motorised possessions. So as to create geopolymer, low-calcium fly ash should be enacted through an alkaline explanation to crop polymeric Si-O-Al bonds. Geo polymer can possibly lessen greenhouse outflows by 80%.

NEED OF GEOPOLYMER MORTAR
To provide natural inviting solid, we have to supersede the solid with some various folios which should not have any horrendous effect on condition. The use of current reactions as spreads can diminish the issue. Right now, new advancement geo-polymer concrete is a promising system. To the extent reducing an Earth-wide temperature help, the geo-polymer advancement could diminish the CO₂ transmission to the air realized by cement and intentions actions by about 80% (Davidovits, 1994c). Also, besides the most ideal use of current wastes can decrease the issue of arranging the waste things into nature. geopolymer capitals, OPC is expatriate over waste incomes, meant at example, fly ash or slag concrete composed over a chemical activator. Notwithstanding the reduction in OPC and the utilization of waste items, geopolymer materials require less water for restoring and are seemed to have expanded protection from chemical attack.

II MATERIALS
A. Fly Ash
As designated by ASTM C-618, Two important programs of fly ash remain professed. These 2 programs are recognized through the kind of firewood expended and are allocated course F and class C in the mainstream of the contemporary symbols. Class F fly ash remains usually elated done irresistible anthracite or bituminous coal though class C fly ash remainders for the supreme helping become through overriding sub bituminous or lignite coal. The significant qualities of these two kinds of ashes remain talks about beneath. Current class F fly ash is gathered from Ramagundam thermal power place. Class F fly ash remains through calcium oxide (Cao) contented under 6%, assigned as small calcium cinder, are not self-setting but rather for the most part show pozzolanic belongings. These leftovers cover over 2% unburned carbon dictated through loss happening ignition. Quartz, mullite and hematite are major crystalline stages recognized fly ashes, got from bituminous coal. Fundamentally, all fly ash in existing and cement is accomplished class F fly ash displacing 80% of cover through weight. At the point when class F fly ash is utilization of class F fly ash as a rule lessens water request just as heat of hydration. The concrete completed through class F fly ash additionally shows enhanced protection from sulphate assault and chloride particle enteance. The test material is taken as of National Thermal Corporation (NTPC), Ramagundam. By and large, the material is gathered from the hypothetical information it is very surely known that it has a place with period F(ASTM C618).
Table I: Properties of fly ash

| Properties   | Values                      |
|--------------|----------------------------|
| Colour       | Light grey                 |
| Specific gravity | 2.9                       |
| Bulk density | 1100 kg/m$^3$ - 1200 kg/m$^3$ |
| Fineness     | >350 m$^2$/kg              |

B.  **GGBS**
GGBS (Ground Granulated Blast furnace Slag) is a cementitious physical whose fundamental use remains in existing and is a side-effect as of the influence heaters second-hand to brand iron. Impact radiators exertion on temperatures of about 1,500°C & are taken care of through a purposely measured blend of iron metallic, coke & limestone. The iron metallic stands summary to media besides the respite of the resources structure a slag that skims happening the iron. This slag is intermittently appointed off as a liquid watery & on the off accidental that it is to be exploited meant recycled for the production of GGBS it requirement be quickly satisfied in enormous volumes of water. The satisfying improves the cementations possessions & harvests granules like a coarse sand. This 'granulated' slag is then dry out & ground to a acceptable powder.

Table I: properties of GGBS

| Properties   | Values                      |
|--------------|----------------------------|
| Colour       | Off – white                |
| Specific gravity | 2.9                       |
| Bulk density | 1000 – 1100 kg/m$^3$ (loose) |
|              | 1200 – 1300 kg/m$^3$ (vibrated) |
| Fineness     | >350 m$^2$/kg              |

C.  **Fine Aggregate**:
The nearby obtainable river sand transitory finished IS 4.75mm sieve is reused zone II through way of per IS 383-1987. The possessions of powder remained assumed in Table I.

Table I: Properties of Fine aggregate

| Properties   | Values |
|--------------|--------|
| Specific Gravity | 2.65   |
| Fineness Modulus | 2.25   |

D.  **Sodium Hydroxide**
Through and large the sodium hydroxides remain reachable in strong state as Pellets & pieces as seemed in Figure The expenditure of the sodium hydroxide remains mostly changed by the immaculateness of the material. Since our geopolymer mortar is homogenous substantial & its important technique to indorse the sodium silicate it is prescribed to exploit the maximum negligible expenditure i.e., up to 94% near 96% virtue. Right now sodium hydroxide pellets in 8 molar fixations are utilized. The manufacturers’ information identified with physical and substance properties are given in Tables.
Physical properties of Sodium hydroxide

| Colour                  | Colourless |
|-------------------------|------------|
| Specific Gravity        | 1.47       |
| pH                      | 14         |

E. Sodium Silicate:
Sodium silicate (Na$_2$SiO$_3$) are typically charity as alkaline activators in geopolymerization procedure in this study, alkaline melted are act as binding agent to harvest a geopolymer mortar. The alkaline liquid that been recycled is the mixture of sodium hydroxide NaOH and Na$_2$SiO$_3$. Sodium-silicate which is known as fluid gas is accessible in fluid sort gel. In present research sodium-silicate 2.0 is utilized, according to fabricate, silicates were provided to the material industry as holding operator.

III. MIX DESIGN
In this experiment, we consider the different fluid binder ratio 0.4, 0.45, 0.50, 0.55. For this fluid binder ratios we take the different mix ratios 1:15, 1:2, 1:2.5, 1:3.

Material requirement for mix ratio 1:2 for geopolymer mortar

| Unit weight of geopolymer mortar | =2200 kg/m$^3$ |
| Binder to aggregate             | =1:2          |
| Mass of binder (fly ash)        | = (1/3)*2200 = 733 kg/m$^3$ |
| Mass of fine aggregate          | =2200-733 = 1467 kg/m$^3$  |
| Assume, alkaline liquid / binder ratio | = 0.40     |
| Mass of alkaline liquid         | =0.40*733 =293.2 kg/m$^3$  |
| Assume, the sodium silicate / sodium hydroxide | =2.50     |
| Liquid mass of sodium hydroxide | =293.2*(1/3.5) =83.77 kg/m$^3$  |
| For 8 molar sodium hydroxide solid | =26.23% *83.77     |
| Water                           | =83.77-21.972 =62.40 kg/m$^3$  |
| Liquid mass of sodium silicate  | =293.2-83.71 =209.43 kg/m$^3$  |
Mass of sodium silicate gel 44.1% of 209.43 $= 92.358 \text{ kg/m}^3$

Mass of water $= 209.43 - 92.358 = 117.071 \text{ kg/m}^3$

Volume of cube $= 0.0706 \text{ m}^3$

Mass of a binder (fly ash) for one cube $= 0.0706 \times 1467 = 102.699 \text{ gm}$

Mass of a fine aggregate for one cube $= 0.0706 \times 1467 = 102.699 \text{ gm}$

Mass of a sodium hydroxide (solids) for one cube $= 0.0706 \times 62.407 = 4.434 \text{ gm}$

Water required for sodium hydroxide $= 0.0706 \times 21.9579 = 1.521 \text{ gm}$

Mass of sodium silicate gel for one cube $= 0.0706 \times 92.358 = 6.526 \text{ gm}$

Water required for mixing for one cube $= 0.0706 \times 41.958 = 2.937 \text{ gm}$

For 12 cubes

Mass of binder (fly ash) $= 310 \times 12 = 3720 \text{ gm}$

But 20% is required by GGBS

Mass of binder (GGBS) $= 930 \text{ gm}$

Mass of NaOH (solids) $= 21.957 \times 12 = 263.484 \text{ gm}$

Water required for mixing NaOH $= 26.094 \times 12 = 313.128 \text{ gm}$

Mass of a sodium silicate gel $= 32.4916 \times 12 = 389.899 \text{ gm}$

Water required for mixing of Na$_2$SiO$_3$ $= 41.958 \times 12 = 503.496 \text{ gm}$

**IV METHODOLOGY**

The sodium hydroxide (NaOH) solids remained smashed depressed trendy water to type the solution. The figure of NaOH solids popular a solution fluctuated trusting upon the junction of the solution connected as far as 8 molar, M. For instance, NaOH prearrangement through a convergence of according to calculations of NaOH solids (in piece or pellet form) per liter of the solution, where 40 is the sub-atonic load of NaOH. The sodium silicate arrangement & the sodium hydroxide solution were mutual at any rate 1 day before utilize to usual up the elementary fluid. The soluble fluid was combined with the extra water (assuming any) to set up the fluid share of the mixture. After 24 hours solution get cool then we can use to prepare the geopolymer mortar by mixing with fly ash GGBS and fine aggregate as per the calculations after that cast the cubes.

Mix proportion $1:1.5$, $1:2$, $1:2.5$, $1:3$ with representing the Fluid binder(f/b) ratios of 0.4 as ‘A’, 0.45 is ‘B’, 0.5 is ‘C’ and 0.55 is ‘D’ for each f/b ratio there is four mix proportions and there are represented as like $A_{1.5}, A_2, A_{2.5}, A_3$.

**Preparation of alkaline liquid and examples**

- Sodium hydroxide (8M) pellets are used to prepare alkaline liquid.
- In this research 8 Molar NaOH concentration solution were used which consists of $8 \times 40 = 320$ gm of NaOH pellets per liter of water, where 40 is the molar weight of NaOH.
- Once the pills get dissolved sodium silicate result of 2.5 times of NaOH solution is mixed to prepare the alkaline liquid.
- It stays to be well-known that the answer is ready at smallest 24 hours before to casting, because the concentration of NaOH is gets to react as a binder.
- Cubes also cylinders specimens were casted to training the compressive asset and torn separately tensile asset.
- Cube size of 70.6 mm x 70.6 mm x 70.6 mm.
- Cylinder sizes of 50mm dia x 100mm.
Ambient curing of geopolymer mortar

Ambient remedial of fly ash and GGBS constructed geo polymer mortar is normally curing substantially supports the chemical response that occur in the geo polymer glue both curing temperature effect the compressive strength of enhanced the polymerization procedure resulting in complex compressive strength. The rate of surge in asset was rapid active to 24 hours of remedial time and outside 24 hours, the gain in asset was solitary moderate. Higher curing temperature of geo polymer existing resulted in advanced compressive strength. Ambient cutting is strange but weather cutting i.e. area infection.

Curing of specimens

Compressive asset test

- To test the compressive asset of a mortar cube we use the compression testing machine of volume 2000KN.
- Weight rate is 2.5KN/sec as per IS: 516:1959 practical.
- Test performed on 7 and 28 days.
Split tensile strength test

- Articulated as the smallest tensile stress wanted to divided the physical apart.
- Load rate is 2 KN/sec.
- Test is performed on 7 and 28 days.

V RESULT AND CONCLUSION

Compressive Strength
Results for 0.4 fluid binder ratio of mix proportions

Compressive strength test result

| mix ratios   | compressive strength, N/mm² |
|--------------|----------------------------|
| A1.5 (1:1.5) | 25                         |
| A2 (1:2)     | 15                         |
| A2.5 (1:2.5) | 10                         |
| A3 (1:3)     | 20                         |

7 days 28 days
Results for 0.45 fluid binder ratio of mix proportions

Results for 0.5 fluid binder ratio of mix proportions

Results for 0.55 fluid binder ratio of mix proportions
**Split Tensile Strength**

Split tensile strength of 0.4 fluid binder ratio of mix proportion

![Split tensile strength test result](image)

| Mix Ratios       | Split Tensile Strength, N/mm² | 7 days | 28 days |
|------------------|-------------------------------|--------|--------|
| A1.5 (1:1.5)     | 3                             | 2.5    | 1.5    |
| A2 (1:2)         | 2                             | 1.5    | 1      |
| A2.5 (1:2.5)     | 1.5                           | 1      | 0.5    |
| A3 (1:3)         | 1                             | 0.5    | 0      |

Split tensile strength of 0.45 fluid binder ratio of mix proportion

![Split tensile strength test result](image)

| Mix Ratios       | Split Tensile Strength, N/mm² | 7 days | 28 days |
|------------------|-------------------------------|--------|--------|
| B1.5 (1:1.5)     | 2.5                           | 2      | 1.5    |
| B2 (1:2)         | 2                             | 1.5    | 1      |
| B2.5 (1:2.5)     | 1.5                           | 1      | 0.5    |
| B3 (1:3)         | 1                             | 0.5    | 0      |

Split tensile strength of 0.5 fluid binder ratio of mix proportion

![Split tensile strength test result](image)

| Mix Ratios       | Split Tensile Strength, N/mm² | 7 days | 28 days |
|------------------|-------------------------------|--------|--------|
| C1.5 (1:1.5)     | 1.5                           | 1      | 0.5    |
| C2 (1:2)         | 1                             | 0.5    | 0      |
| C2.5 (1:2.5)     | 0.5                           | 0      | 0      |
| C3 (1:3)         | 0                             | 0      | 0      |
CONCLUSIONS

- It is examined that geopolymer mortar in ambient-curing circumstances can attain good strength in 28-days.
- Compressive-strength of 1:1.5 mix proportion develops more in 0.45 and 0.55 fluid binder ratio from “7 to 28” days.
- Compressive-strength of “1:1.5” mix-proportion is high compared to “1:2”, “1:2.5 & 1:3”.
- Mostly 0.4 binder ratio is give the perfect results by comparing the compressive and split tensile strength but to getting more strength we use 12 molarity.
- Higher-concentration of “sodium hydroxide” i.e, explanation obtain greater strength in geo-polymer mortar.
- As percentage of FLY ASH content increases, the compressive strength of geo polymer mortar decreases.

FURTHER INVESTIGATIONS

- By reducing the cohesive property of the geo polymer mortar (i.e. more workable) it can be applied in the field conditions.
- Few other industrial waste products can be utilized in the making of geo-polymer mortar or concrete like, red mud, rice husk ash, etc.
- Ambient curing conditions can be refined by replacing the GGBS with other waste products such as burnt clay, etc.
- Red Soil is higher reactive with GGBS when in comparison with fly ash based geo polymer mortar/concrete.

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