Effect on addition of Polypropylene fibers in wood ash-fly ash based geopolymer concrete

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Abstract: In this study, optimization of wood ash and fly ash by varying 0-100% of both in GPC were carried out by testing the concrete for compressive strength. From the previous literatures it could be noted that, GPC had a less brittleness and energy absorbent. To improve the brittleness and energy absorption capacity polypropylene fibre were added by 0, 0.5, 1, 1.5, and 2 % of volume fraction. Further, effects on addition of polypropylene of the optimized wood ash-fly ash based Geopolymer were studied. In this study, the mechanical properties such as compressive strength, tensile strength, flexural strength of geopolymer concrete were investigated. The results showed that, 30% replacement of wood ash increased the compressive strength by 12.2% than the conventional mix. Further, addition of 1% of PP fibre had also increased the compressive strength, tensile strength, flexural strength by 3.7%, 15.6% and 5.13% respectively.

1. INTRODUCTION

Concrete and Cement manufacturing have an effect of climate change which leads 5 to 8 percent of total green house gas emission [1]. After water cement is the major product which consumed by the people worldwide. Moreover, cement is the second major factor of green house gas emission. In the year 2020, the GHG emission by cement industry could reach to 10 to 15 percent of total emission in worldwide [2]. This environmental impact and disruption of ozone layer by cement production gives an important target to the researchers to find and use eco friendly materials for construction [3]. Geopolymer is an eco-friendly material which has a more durable than normal OPC and can be used as an alternative for cement in the construction industry. The research in the area of geopolymer is acquiring strength and performance of geopolymer concrete in mechanical and durability aspects are much better when compared with ordinary Portland cement [4]. The various aluminosilicate source materials such as fly ash, Ground Granulated Blast furnace Slag, Metakaolin, Rice Husk Ash, Pulverized Fly ash, Palm Oil fuel ash and Wood ash are used for the production of geopolymer [5]. Most of the researchers concentrated only on the geopolymer made with fly ash. Utilization of Fly ash and demand of fly ash was enhanced day by day in the construction industry [6]. In order to counteract the aforementioned problem, alternative solution for source material has to be developed. Meanwhile, amount of alkaline solution present in the geopolymer gives the improvement in strength. The strength parameters such as compressive strength and split tensile strength are increased by increasing the molarity of alkaline solution [7]. (2018). The flexural strength is increased by increasing the molarity of NaOH from 4M to 18M. However, too much amount of NaOH leads to disruption of geopolimerisation process [8]. Hence, the limiting the amount of alkaline solution is much important in the later age strength development aspect. To counteract the alternate alunino silicate source material problem and reducing the requirement of alkaline solution, the source material with alunino silicate sources and alkaline content can be a good alternative for the fly ash in
geopolymer concrete. Based on that, wood ash has a composition of act as aluminosilicate source material and also has a composition of potassium oxide (K2O) which can helps in reducing the alkaline solution will be used in this study.

Generally, geopolymer has a disadvantage of brittle and less energy absorption capacity [9,17]. In order to improve the brittleness and crack resistance behavior, low modulus fibers will be added. Addition of polypropylene in flyash based geopolymer concrete helps in reducing the environmental pollution, shrinkage limiting and improving the brittle behavior [10,13]. Incorporation of polypropylene fibres helps in limiting the propagation of cracks and also increases the crack resistance behavior of geopolymer concrete [11,13]. This confirms that, the strength aspects of geopolymer concrete are enhanced by the addition of PP fibre.

Hence in this study, the optimization of wood ash with fly ash, optimization of molarity of alkaline solution, optimization of solution binder ratio will be studied. Further, effects on addition of polypropylene fibre in wood ash-fly ash based geopolymer concrete will also be studied.

2. MATERIALS AND ITS PROPERTIES

Fly ash is a by-product collected from tutucorin thermal power plant station. The calcium oxide confirms that, fly ash is categorized as a Class-F type fly ash. Wood ash is a waste residue collected from locally available hotels. The physical properties of wood ash and fly ash are listed in Table 1. The chemical compositions are confirmed through Energy Dispersive X-Ray diffraction and mentioned in Figure 1. Alkaline solutions such as sodium silicate and sodium hydroxide having specific gravity of 1.60 and 1.47 are used in this study. Fine aggregate of size below 1.18mm with fineness modulus of 2.42 and specific gravity of 2.62 is used. Coarse aggregate of size 10mm with fineness modulus of 7.6 and specific gravity of 2.91 is used. Further Polypropylene fibre of length 20mm and dia of 0.1mm is added in this study. Wood ash is replaced for fly ash by varying 0-100% at 10 percent increment. Polypropylene fibre is added by varying 0.5, 1, 1.5 and 2% of volume fraction.

| Properties          | Fly ash | Wood ash |
|---------------------|---------|----------|
| Specific Gravity    | 2.3     | 1.7      |
| Fineness            | 6%      | 9%       |
| Consistency         | 38%     | 58%      |
| Initial Setting Time| 18 hours| 36 hours |
| Final Setting Time  | 2.30 hours| 3 hours  |

Table 1. Physical Properties of Fly ash and Wood ash
3. MIX PROPORTIONING

The mix proportions will be designed based on the modified guidelines for the geopolymer concrete as per Indian standards [12]. The mix design is calculated as 1:1.05:1.57 with alkaline solution ratio of 0.61. The quantity of materials obtained based on the above mix design was mentioned in the Table 2.

In a pan mix, dried coarse aggregate and fine aggregate are mixed with the aluminosilicate source materials such as fly ash and wood ash. The NaOH solution is prepared before 1 day of casting by mixing the sodium hydroxide pellets and water. Then the alkaline solutions (mixture of NaOH solution and Na2SiO3) are added in the pan mixer. The mix will be mixed until it attains the stage of solid gel structure.

| Mix id | % of FA | % of WA | Fly ash (gm) | Wood ash (gm) | NaOH (gm) | Na2SiO3 (gm) | Sand (gm) | CA (gm) |
|--------|---------|---------|---------------|---------------|-----------|--------------|-----------|--------|
| GC     | 100     | 0       | 550           | 0             | 110.2     | 275.59       | 666.58    | 993.7  |
| GCW10  | 90      | 10      | 495           | 32.1          | 110.2     | 275.59       | 666.58    | 993.7  |
| GCW20  | 80      | 20      | 440           | 64.2          | 110.2     | 275.59       | 666.58    | 993.7  |
| GCW30  | 70      | 30      | 385           | 96.3          | 110.2     | 275.59       | 666.58    | 993.7  |
| GCW40  | 60      | 40      | 330           | 128.4         | 110.2     | 275.59       | 666.58    | 993.7  |
| GCW50  | 50      | 50      | 275           | 160.5         | 110.2     | 275.59       | 666.58    | 993.7  |
| GCW60  | 40      | 60      | 220           | 192.6         | 110.2     | 275.59       | 666.58    | 993.7  |
| GCW70  | 30      | 70      | 165           | 224.7         | 110.2     | 275.59       | 666.58    | 993.7  |
| GCW80  | 20      | 80      | 110           | 256.8         | 110.2     | 275.59       | 666.58    | 993.7  |
| GCW90  | 10      | 90      | 55            | 288.9         | 110.2     | 275.59       | 666.58    | 993.7  |
| GCW100 | 0       | 100     | 0             | 321           | 110.2     | 275.59       | 666.58    | 993.7  |

Figure 1. EDX analysis of Fly ash and Wood ash
4. EXPERIMENTAL PROGRAM

4.1. Compressive Strength Test
The compressive strength test is carried out as per ASTM-D695 standards [14]. 100mm x 100mm x 100 mm size cubes are casted and tested in the Universal Testing Machine to find the compressive strength of geopolymer concrete. At the age of 3, 7 and 28 days, the cubes are tested. Figure 2 shows the compressive strength test of cube.

![Compressive test of cube](image)

Figure 2. Compressive test of cube

4.2. Split tensile Strength Test
The split tensile strength test is carried out as per ASTM-C496 standards [15]. The cylinder of size 100mm x 200mm is tested in the Universal Testing Machine to find the split tensile strength of geopolymer concrete with addition of PP fibre. At the age of 3, 7 and 28 days, the cylinders are tested. Figure 3 shows the testing of cylinder.

![Split tensile test of cylinder](image)

Figure 3. Split tensile test of cylinder

4.3. Flexural Strength Test
The flexural strength test is carried out as per ASTM-C78 standards [16]. The prism of size 500mm x 100mm x 100mm is tested in the Universal Testing Machine to find the flexural strength of geopolymer concrete with addition of PP fibre. At the age of 3, 7 and 28 days, the flexural strength are measured. Figure 4 shows the testing of prism for its flexural strength.
5. RESULT AND DISCUSSION

5.1. Optimization of wood ash in fly ash based geopolymer concrete
The wood ash optimization is carried out with the help of testing the cubes at the age of 3, 7 and 28 days for its compressive strength by varying the wood ash replacement percentage from 0 to 100 at 10 percent increment. The graphical representation of results is shown in figure 5. From the figure it confirms that, increasing the wood ash replacement beyond 30% results in reducing the strength. Up to 30% replacement of wood ash with fly ash, the strength will be increased. Hence 30% replacement of wood ash given the maximum result and it will be chosen as an optimum.

5.2. Optimization of molarity
After the optimization of wood ash percentage as 30, molarity of sodium hydroxide will be optimized. The molarity optimization is carried out with the help of testing the cubes at the age of 3, 7 and 28 days for its compressive strength by varying the molarity from 8 to 14. The graphical representation of results is shown in figure 6. The obtained result reveals that, with increasing the molarity of NaOH up to 13M, the compressive strength is increased gradually. The optimum molarity which attains maximum compressive strength is 13 M. However, the target strength is achieved at the molarity of 10M itself. Increasing the molarity beyond 13 showed decrease in strength. Hence it confirms that, high amount of alkaline solution leads to the disruption of geopolymerisation and reduces the strength attainment which is already mentioned in the previous study [8]. The 10M of NaOH can also be fixed as a molarity which helps in reducing the amount alkaline solution by achieving the target mean strength.
5.3. **Optimization of Solution Binder Ratio**

By fixing the wood ash percentage as 30 and molarity of NaOH as 10M, the solution binder ratio will be optimized with the help of testing the cube at the age of 3, 7 and 28 days for its compressive strength. From the figure 7, it is observed that, solution binder ratio of 0.61 shows the optimum which has the maximum compressive strength at all ages. However at 0.45 itself, the target mean strength is achieved. Hence, 0.45 can be used as solution binder ratio to reduce the amount of alkaline solution.

5.4. **Effect of Polypropylene**

5.4.1. **Compressive Strength**

The effect of polypropylene on the compressive strength of wood ash-fly ash based geopolymer concrete is shown in figure 8. At all ages, there is an increasing in compressive strength due to the addition of 1% of PP fibre. Increasing the fibre content up to 1% resulted in enhancement of the compressive strength by 3.7% compared to control GPC. However, increasing the fibre content beyond 1% resulted in reducing the compressive strength.
5.4.2. Split tensile strength
The effect of polypropylene on the split tensile strength of wood ash-fly ash based geopolymer concrete is shown in figure 9. The test result shows that, addition of 1% of PP fibre increases the tensile strength at all ages of GPC. Increasing the fibre content up to 1% resulted in enhancement of the tensile strength by 15.6% compared to GPC without fibre. However, increasing the fibre content beyond 1% resulted in reducing the tensile strength [10,13].

5.4.3. Flexural strength
The effect of polypropylene on the flexural strength of wood ash-fly ash based geopolymer concrete is shown in figure 10. The test result shows that, addition of 1% of PP fibre increases the flexural strength of GPC at all ages. While the addition of PP fibre up to 1%, the flexural strength is enhanced by 5.13%. However, increasing the PP fibre content beyond 1% resulted in reducing the flexural strength [11,13].
6. CONCLUSION

The feasibility of utilizing wood ash as an alternative (partial replacement) for fly ash in the geopolymer concrete was studied. Optimum percentage of wood ash for the replacement of fly ash was found. Optimum molarity of alkaline solution and optimum ratio of solution to binder was also found in this study. Further, effects due to addition of polypropylene fibre on the mechanical properties of wood ash-fly ash based geopolymer concrete were also carried out. From this detailed study, it may be concluded that,

- Increasing the wood ash replacement beyond 30% resulted in reducing the strength. Upto 30% replacement of wood ash with fly ash, the strength shown increased. Hence 30% replacement of wood ash would be an optimum replacement level which gives the maximum strength.
- With increasing the molarity of NaOH up to 13M, the compressive strength was increased gradually. The optimum molarity which attains maximum compressive strength was 13 M. Increasing the molarity beyond 13 showed decrease in strength. However, the target strength was achieved at the molarity of 10M itself. Hence, the 10M of NaOH could also be fixed as a molarity which helps in reducing the amount alkaline solution.
- At all age of curing, the optimum value of solution binder ratio is 0.61 which has the maximum compressive strength. However, the target mean strength was achieved at 0.45 itself. Hence, 0.45 could be used as solution binder ratio to reduce the amount of alkaline solution.
- Increasing the addition of PP fibre up to 1% increases the strength when compared to GPC without fibre. Addition of fibre beyond 1% decreases the strength. Addition of 1% of polypropylene fiber increased the compressive strength, flexural strength and tensile strength by 3.7%, 5.13% and 15.6% respectively.

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