Incremental effect of saccharum officinarum addition on strength characteristics of geopolymer composite specimens

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Abstract. This paper reports the development of geopolymer concrete by adopting saccharum officinarum molasses and naphthalene sulphonate formaldehyde as admixtures. The behavioural effect of these admixtures on geopolymer is investigated. In the first stage, geopolymer concrete based on ordinary fly ash was prepared. In the second stage, by varying the percentages of cement (0 to 8%) with equal percentages of admixtures, three more geopolymer concrete mixes were prepared. Fresh and hardened properties of geopolymer concrete specimens were obtained by performing different tests. In addition, the concrete specimens were tested for ultrasonic pulse velocity, drying shrinkage and standard consistency. The findings of this study concluded that: the incremental addition of saccharum officinarum molasses improved the workability, boosted the durability and also enhanced the strength of geopolymer concrete. Further with the addition of cement in the range of 4 to 8% at a constant admixture content of 1.2%, strength and durability of geo-polymer concrete improved.

Keywords: green concrete Fly ash, saccharum officinarum plasticity, strength

1. Introduction
Environmental pollution is one of the fast growing serious challenges world over. A major part of the environmental pollution comes from the construction industry, mainly from the concrete production. The production of cement leads to over 5% of the carbon-dioxide that threatens the global warming seriously. Therefore, many researchers in the past have attempted to look for viable alternatives for cement replacement including the development of organic polymer, also known as geopolymer concrete [1-9]. Geopolymer concrete performs satisfactorily in terms of strength and workability characteristics compared to conventional concrete. It also possesses adequate resistance to corrosion as well as fire, and acquires early strength rapidly with lower shrinkage features [10]. The combination of admixtures with fly-ash based geopolymer concrete, NaOH and Na₂SiO₃ develops a gel that has binding effect between the aggregates. Furthermore, the molarity of sodium hydroxide has a direct relation with the compressive resistance of the geo-polymer concrete [11]. The suitable features of geo-polymer concrete can be effectively adopted for the development of precast concrete elements, required for retrofitting/rehabilitation of structures [12]. The quantity of molasses added decides its action on the concrete mix. At lower doses, it behaves as an accelerating agent, while as it behaves opposite at higher dozes. Moreover, it acts as a water reducing agent also, and can reduce the water content by up-to 12% [13]. Addition of molasses as admixtures improves the workability, compressive strength, prolongs the setting time, reduces the chances of segregation and also decreases water-to-binder ratio [14].

This paper presents the development of geopolymer concrete by adopting saccharum officinarum molasses and naphthalene sulphonate formaldehyde as admixtures. The behavioural effect of these admixtures on geopolymer is investigated. In the first stage, geopolymer concrete based on ordinary fly ash was prepared. In the second stage, by varying the percentages of cement (0 to 8%) with equal percentages of admixtures, three more geopolymer concrete mixes were developed. Fresh and
2. Materials used

The mix design of the geo-polymer concrete is shown in Table 1. Following constituents were used in the preparation of this type of concrete.

2.1. Fly Ash
Fly ash of class F obtained from the Kota Thermal Power plant, conforming to IS 3812-2003[15] was adopted from alumina silicate source.

2.2. Fine aggregates
Fine aggregates conforming to IS 383-1970 [16], Zone II, were used for the geo-polymer concrete preparation.

2.3. Coarse aggregates
Coarse aggregates conforming to IS: 383-1970 [16], of 10 to 20mm nominal sizes were used for the geo-polymer concrete preparation.

2.4. Cement
Ordinary Portland Cement under trade name Ambuja cement (grade 43) with normal consistency of 30.65%, conforming to BIS: 8112-1989 [17] was used for the geo-polymer concrete preparation.

2.5. Alkaline Solution
The solution prepared by the combination of NaOH and Na$_2$SiO$_3$ was used as an alkaline activator. NaOH of 98% purity in pellet form was used to prepare the NaOH solution of 16M. The ratio of activator:binder was taken as 0.5. Higher molarity of NaOH solutions produces geo-polymer concrete of higher compressive strength. The ratio of Na$_2$SiO$_3$/NaOH adopted was 2.5.

2.6. Admixture
Saccharum officinarum and Sulphonated naphthalene formaldehyde were adopted in the dosage of 0.8% and 0.4% respectively by the weight of binder material.

2.7. Water
The potable water was used for mixing and curing of concrete specimens.

3. Mix Design

In the present study, M35 mix of geo-polymer concrete was prepared and tested in fresh and hardened state as per international specifications and guidelines.

| Material content (kg/m$^3$) | P0 | P1 | P2 | P3 |
|-----------------------------|----|----|----|----|
| Fly Ash (%)                 | 270| 270| 270| 270|
| (kg/m$^3$)                  | 0  | 0  | 4  | 8  |
| Cement                      |    |    |    |    |
| NaOH                        | 27 | 27 | 27 | 27 |
| Na$_2$SiO$_3$                | 67 | 67 | 67 | 67 |
| Coarse agg (kg/m$^3$)       | 454| 454| 454| 454|
| 10mm                        |    |    |    |    |
| 20mm                        | 632| 632| 632| 632|
| Fine aggregate (kg/m$^3$)   | 840| 840| 840| 840|
| Water content (l/m$^3$)     | 147| 147| 147| 147|
| Chemical admixture (%)      | 0  | 1.2| 1.2| 1.2|
| (kg/m$^3$)                  | 0  | 4.36| 4.36| 4.36|
4. Results and Discussion

The tests conducted on geo-polymer concrete in plastic and hardened stage are given in the sections as under:

4.1. Workability

For determining the workability of geo-polymer concrete, Slump Cone Apparatus was used as per the recommendation of IS 1199-1959. The variation in slump for various mixes is shown in Fig. 1. On the addition of admixtures, the workability improved from P0 to P1 mix, but later decreased from P2 to P3.

![Figure 1. Variation in slump](image)

4.2. Drying Shrinkage

For conducting drying shrinkage test on different mixes of geo-polymer concrete, prism specimens were casted for the same, and the test results show an increasing trend from P0 to P3 mix as shown in Fig. 2.

![Figure 2. Variation in drying shrinkage](image)

4.3. Plastic Density

Soon after the batching, the tests on plastic density of fresh geo-polymer concrete were conducted, and the test results as seen in Fig.3. The results show an increasing trend from P0 to P3 mix.

![Figure 3. Variation in plastic density](image)

4.4. Compressive Strength

Fig.4 show the variation in compressive strength for various geo-polymer mixes. On the addition of cement and admixtures, the compressive strength of the geo-polymer concrete specimens improved,
particularly the 28 days strength.

**Figure 4.** Variation in compressive strength

4.5. **Flexural Strength**

Fig. 5 shows the variation in flexural strength for various geo-polymer mixes. On the addition of cement and admixtures, the flexural strength of the geo-polymer concrete did not change much in the beginning. However, it showed appreciable improvement between P1 to P2 mix, particularly the 28 days strength.

**Figure 5.** Variation in flexural strength

4.6. **Split tensile Strength**

Fig. 6 shows the variation in split tensile strength for various geo-polymer mixes. On the addition of cement and admixtures, the split tensile strength of the geo-polymer concrete improved, particularly the 7 days strength.

**Figure 6.** Variation in split tensile strength
4.7. Ultrasonic pulse velocity

The testing procedure in ASTM C 597-02 [18] was followed for the quantification of pulse velocity through concrete, and the test results are shown in Fig. 7.

5. Conclusions

A study on the investigation of the influence of saccharum officinarum molasses on the characteristics of geo-polymer concrete was carried out. The industrial waste (fly-ash) was used as a binding material. Due to the large availability of fly ash, it can sustainably replace cement as a binding material, partially. This would lead to green and economic construction, with less environmental pollution. The incremental addition of saccharum officinarum molasses improved the workability, boosted the durability and also increases the strength of geo-polymer concrete. The strength and durability characteristics of geo-polymer concrete improved with the addition of cement in the range of 4-8% at a constant admixture content of 1.2%. More studies need to be carried out to explore other alternatives to NaOH and Na2SiO3, so as to make concrete construction more economical and environment friendly.

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