

Effect of Geopolymer (Hypo sludge) on Concrete: A Review

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Abstract- Next to water, Concrete is the world's most versatile, durable and reliable construction material. The production of ordinary Portland cement contributes 5-7% of total greenhouse gas emission. Hence it is essential to find the alternative to cement. The use of Geopolymer concrete as an alternative material over Portland cement concrete to reduce the adverse effects on the environment is investigated in this paper. Geopolymer is a material resulting from the reaction of a source material that is rich in silica and alumina with alkaline solution. Hypo sludge is the by product that can use in place of cement this is also rich in silica and alumina. In Geopolymer hypo sludge and silica fume acts as binder and alkaline solution acts as an activator. Alkaline solution used for present study is Sodium Hydroxide (NaOH). The mixes were designed for molarity of 5M, 10M and 15M. The tests were carried out to evaluate the mechanical properties like slump test, compressive strength, and flexural test and split tensile strength after 7 and 28 days.

Key words: Geopolymer concrete, Hypo sludge, silica fume, alkaline solution, admixture, slump, strength.

I INTRODUCTION

The name Geo polymer was found by a French professor Davidovits in 1978. As we know cement is the main constituent for construction and it is produced from natural resources which are non-renewable in nature. We must find the alternatives to reduce the use of cement, so to reduce the production of it. We can use the wastes in place of cement. As we know the manufacturing of ordinary Portland cement (OPC) which is the main ingredient of concrete but it releases large amount of greenhouse gases specially CO₂ [1]. Portland cement is responsible for 7-9% of CO₂ emission. It has been stated that every ton of Portland cement releases 1 ton of CO₂ emissions [2]. Dumping of wastes produced from industries cause a major problem to environmental issues. Geopolymer concrete utilises the waste materials like fly ash, rice husk ash, GGBS, Hypo sludge, red mud, metakolin etc. [3]. In Geopolymer concrete, cement as concrete binder can be replaced by industrial by products (fly ash) mixed with an activator. Due to low proportion of cement in its composition, Geopolymer concrete is an eco-friendly concrete [4]. The reutilizations of waste materials are really important as it decreases the pollution and prevent the greenhouse effect and also save the energy by recycling process. Using Hypo sludge waste as a replacement to cement reduces degradation of environment [5].

Hypo sludge is one of the waste materials produced from paper industry having almost similar properties as that of cement. Hypo sludge behaves like cement because of silica and magnesium properties [6]. To add the workability factor in this messy replacement of constituent materials by supplementary materials and to retain some amount of strength factor and durability of concrete, we have taken silica fume to replace cement. One of the beneficial uses for silica fume is in concrete because of its chemical and physical properties, it is highly reactive pozzolana. Silica fume present in concrete have very high strength and can be durable [7]. Silica fume is by product in the production of ferrosilicon industry and also a silicon metal. The microstructure of concrete improves due to the presence of high percentage of silica. Silica fume increases the strength of concrete and reduces the capillary pores [8]. The alkaline liquid is soluble alkali metals usually sodium or potassium based. Sodium based liquid is easily soluble and has more reactivity. Sodium hydroxide and sodium silicate solution was chosen as alkaline liquid.

II Necessity of Geopolymer concrete

As we know construction is fast growing nowadays around 260, 00, 00,000 tons of cement is required every year. For another 10 year span the quantity of cement will be increased by 25% [9]. Cement is very expensive and is not ecofriendly. Using of geopolymer concrete in place of standard concrete means that eighty percent less greenhouse gases are produced which is big difference. By using these by products we can not only reduce the cost of construction but also helps in saving our earth's natural resources and help in preventing other natural hazards such as disposal of the used wastes and pollution caused due to the extracting earth materials such as limestone which is the chief material in production of cement and the shortage of limestone may come after 25 to 50 years [9]. The major threat for environment is producing one ton of cement because approximately one ton of carbon dioxide will be emitted to the atmosphere. The paper waste which is dumped on earth occupies large area [10]. By producing geopolymer concrete all the issues shall be solved by using them in place of cement and also minimize the emission of carbon dioxide.

III Types of Geopolymer materials [11]

1. Fly ash
2. Palm oil fuel ash (POFA)
3. Metakaolin
4. Kaolin
5. Dolomite
6. Hypo sludge
7. Ground Granulated Blast- Furnace Slag (GGBS).

IV Properties of Geopolymer concrete [12]

1. Geopolymer has higher resistance to heat and resist all inorganic solvents.
2. It sets at room temperature.
3. It has long working life before stiffening.
4. Non-toxic and bleed free.
5. Impermeable.
6. Geopolymer concrete possess very high acidic resistance when tested under exposure to 2% and 10% sulphuric acids.
7. Drying shrinkage is less than that of cement concrete.
8. Higher compressive strength.

V Geopolymer Concrete Constituent Materials and Casting Technique

5.1 Materials

5.1.1 Portland cement [13]

Ordinary Portland cement OPC of grade 43 and 53 can be used, having specific gravity 3.14. Portland pozzalona cement PPC shall not exceed 20% conforming.

5.1.2 Properties of fine aggregates [14]

Specific gravity = 2.61.

Water absorption < 1.5%.

Fine modulus should be 2.2 – 2.6 (zone II)

5.1.3 Properties of coarse aggregates [14]

Specific gravity = 2.73

Crushing value < 45% for non-wearing surfaces and < 30% for wearing surfaces.

Abrasion value shall not exceed 30%.

Impact value shall not exceed 30%.

5.1.4 Hypo sludge

It is a by-product produced from paper industry and can be replaced as a cementitious material because of silica and magnesium which are ingredients of cement. We can save the disposal problems of industry by using Hypo sludge [15].

Ingredients	% in Hypo sludge
Moisture	54.9
CaO	48.2
MgO	3.4
SiO ₂	8.8
R ₂ O ₃	3.8
Igneous	28

Table 1. Chemical properties of Hypo sludge

5.1.5 Silica fume

It is a by-product of producing silicon metals or ferrosilicon alloys. It also plays an important role in concrete because it is very reactive pozzolan. Silica fume particles are very small with more than 95% particles being less than 1µm particle [15].

Ingredients	% of Silica fume
SiO ₂	90
Al ₂ O ₃	2.18
Fe ₂ O ₃	2.2
CaO	1.52
MgO	0.9
SO ₃	1.2
Alkalies (K ₂ O, Na ₂ O)	2

Table 2. Chemical properties of silica fume

5.1.6 Alkaline solution

Binding solution used in geopolymerization process is an alkaline solution comprising of mixture NaOH and Na₂SiO₃ in varying proportions. Addition of Na₂SiO₃ to NaOH solution as the alkaline liquid improved the reaction between source material and solution. Various mixes of different molarities of sodium hydroxide such as 8M, 10M, and 12M are examined for the strength of geopolymer concrete [16].

Required molarity	Weight of sodium hydroxide in gms
8M	320
10M	400
12M	480

Table 3. Weight of sodium hydroxide pellets

5.1.7 Admixtures

To improve the workability of fresh concrete different types of super plasticisers are used without increasing the water. The utilization of viscosity modifying admixture gives more possibilities of controlling segregation and homogeneity of the mix by using (PCE) polycarboxylate ether [17].

5.2 Mixing of Geopolymer concrete [18]

Mixing process of geopolymer concrete can be divided into two stages, dry mixing and wet mixing. Alkaline solution (Sodium hydroxide and sodium silicate) is prepared 24 hours before casting in order to get desired solution.

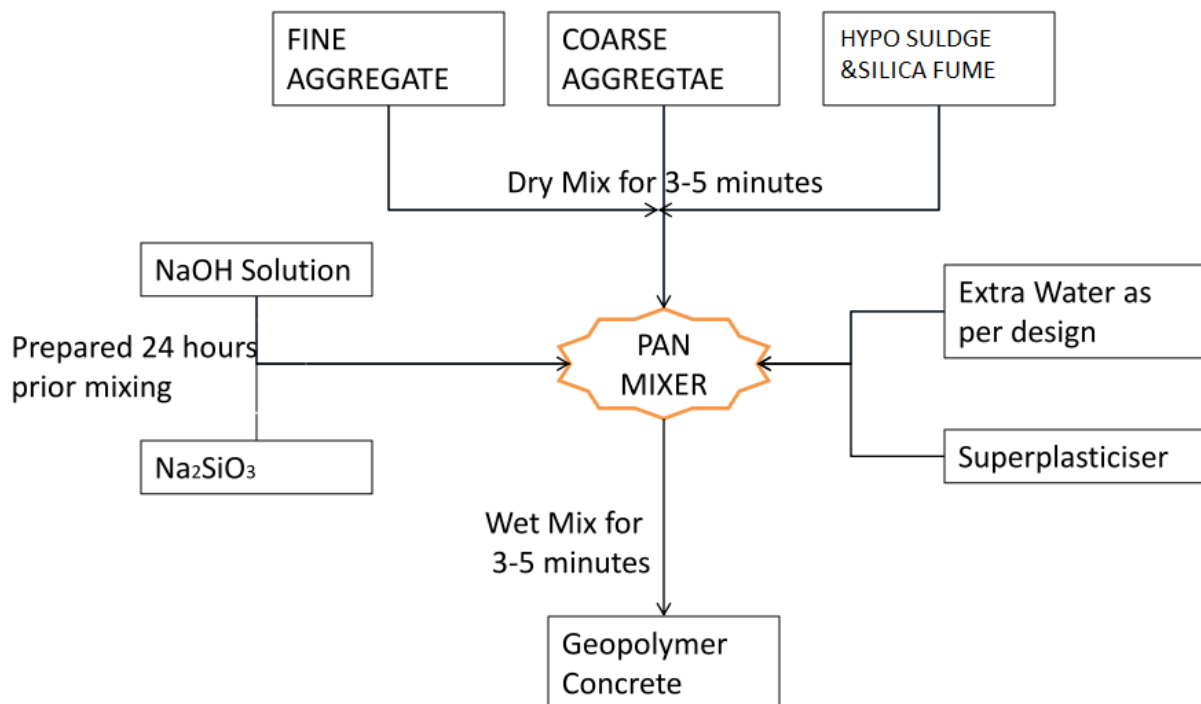


Fig1. Mixing of Geopolymer concrete

5.3 Tests and Results

5.3.1 Tests on fresh concrete

1. Workability test (slump cone test)

5.3.2 Tests on hardened concrete

1. Compressive strength test.
2. Flexural strength test.
3. Split tensile test.
4. Durability test.

VI Effect of compressive strength on Geopolymer concrete

Compressive strength test is one of the most important properties of concrete. Compressive strength test were carried out after 28 days with reference to M30 grade of concrete. By using 10% Hypo sludge compressive strength increases but decreases after increasing in percentage of hypo sludge. However mixes of Hypo sludge and metakaolin shows good performance than mixes of Hypo sludge and fly ash [5]. Compressive strength of Grade M60, with replacement of silica fume was increased up to 5% and then decreases after adding Hypo sludge. The compressive strength is 62.1MPa and 60.3MPa on 20% and 25% replacement of cement respectively. Cement was replaced with Hypo sludge at 5%, 10%, 15% and 20% in concrete and concluded that compressive strength of concrete increases by 10% at 10% of Hypo sludge [19].

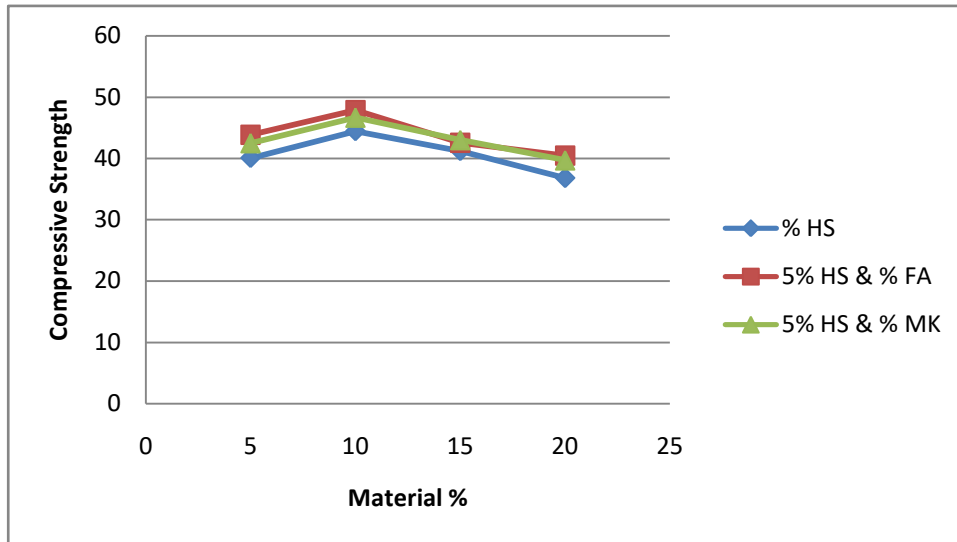


Fig2. Compressive strength of M30 Grade of concrete

VII Flexural strength test

Flexural strength is the stress in a material just before it yields in flexural test. Flexural strength tests were carried out after 28 days. By using 10%, 20% and 30% of Hypo sludge. When replacement of cement by Hypo sludge is 10% Flexural strength of concrete increases up to 10% but decreases on increasing in the percentage of Hypo sludge [20]. In rigid pavement roads when 10% - 40% Hypo sludge were used at 10% of Hypo sludge flexural strength is good but beyond that it decreases.

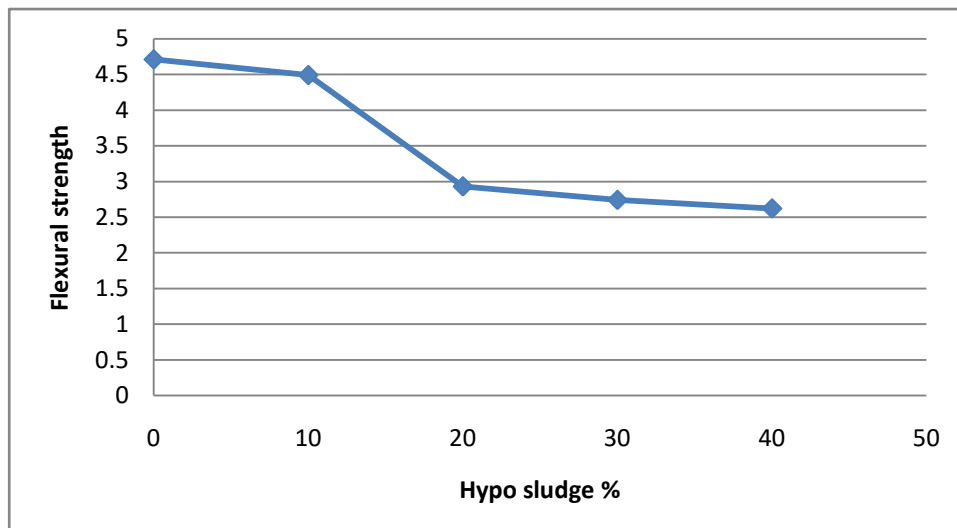


Fig3. Flexural strength of concrete

VIII SPLIT TENSILE STRENGTH

This test with hypo sludge and fly ash is more than mixes of hypo sludge and metakaolin [15]. Replacement of cement with silica fume the split tensile strength of concrete at 28 days increased gradually up to the optimum replacement level of 5% but after that decreases with in increasing in the percentage of silica fume [21]. The split tensile strength of concrete was carried out on cylinders using CTM of 2000 KN. The split tensile strength of concrete with hypo sludge shows good performance as compared to normal concrete.

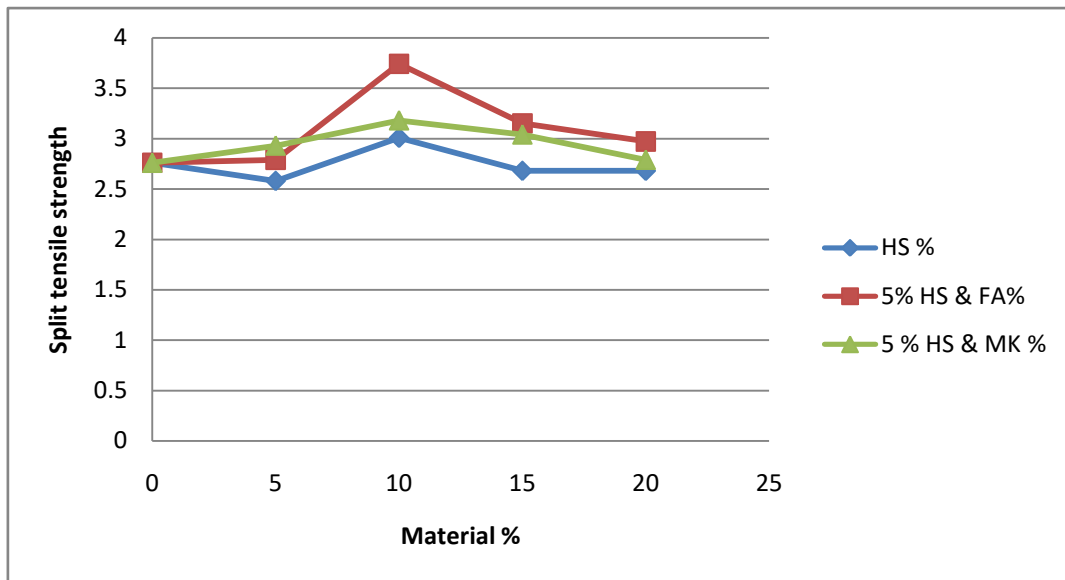


Fig4. Split tensile strength of concrete

IX DURABILITY ASPECTS OF GEOPOLYMER CONCRETE

Geopolymers are new materials which completely lack the long service and durability issues when compared to conventional concrete systems. Geopolymer concrete is suitable for tough environmental conditions and can be used for the blending of the geopolymer cement which can be useful in marine environments and on islands short on the fresh water [22].

The Geopolymers are resistant to the corrosion and do not exhibit any sign of deterioration for long periods of time when exposed to environmental of NaCl solution. Geopolymer concrete do not show any sign of sulfate attack or degradation in compressive strength [23]. The strength of Geopolymer concrete gradually decreases as the day of exposure to sulphuric acid increases [24].

X CONCLUSION

- All research papers and review papers show Geopolymer concrete is a best alternative construction material to replace the conventional concrete for reducing the carbon dioxide emission.
- Hypo sludge is useful for construction of rigid pavements in development of low cost because of its cementations properties.
- Due to presence of silica and magnesium the strength of concrete goes on increasing with replacement of hypo sludge up to certain percentage.
- Utilization Hypo sludge in concrete can save the paper industry's disposal costs and storage problems.
- Concrete mix with hypo sludge and metakaolin performed better with respect to strength properties when compared with hypo sludge and fly ash combination.

- At 10% replacement of cement by Hypo sludge in different grades (M20, M25 and M30) of concrete shows maximum strength among all percentage replacements of Hypo sludge.
- With the molarity of sodium hydroxide solution is 10M strength of Geopolymer concrete increases but decreases after increasing in the molarity
- Mixes of Hypo sludge and metakaolin shows more strength than mixes of Hypo sludge and fly ash.
- Silica fume with Hypo sludge also shows good performance up to (5% silica fume and 20% Hypo sludge) beyond 30% there is decrease in compressive strength.
- Geopolymer concrete beams develop crack at an early load stages if they are exposed to elevated temperatures.

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