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# Fiber Reinforced Geopolymer Concrete with Replacement of Coarse Aggregate by Waste Paver Blocks

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**ABSTRACT:** Most of the countries are in search of various techniques to lessen greenhouse gas emissions since Global warming and climate changes are progressively essential problems. Cement production results up to 1T of CO<sub>2</sub> per each ton of cement, paralleling to approximately 3% of total global greenhouse emissions. Hence an alternate to ordinary concrete called Geopolymer Concrete is used in this research purpose which contains only 10% of Portland cement. It possesses the advantages of rapid strength gain, elimination of water curing, good mechanical and durability properties and are eco-friendly and sustainable. In this paper, geopolymer concrete made up of 45% Fly ash and 45% Ground Granulated Blast Furnace Slag (GGBS) is used as cementitious material along with 10% OPC. Also polypropylene fiber 0.4% of volume of cementitious material is mixed with this concrete. Sodium hydroxide (NaOH) of 12M and sodium silicate (Na<sub>2</sub>SiO<sub>3</sub>) are used in this study for the geopolymerization. The alkaline liquids help the cementitious particle and aggregates to bind and produce the concrete. The objective of this research is to determine the strength characteristics for polypropylene fiber reinforced geo-polymer concrete replaced with various percentages of waste paver block aggregates like 0%, 25%, 50%, 75% and 100% and to find the optimum percentage of waste paver block as coarse aggregate in geopolymer concrete.

**KEYWORDS:** Geo-polymer concrete, Flyash, GBS, Sodium Silicate solution, Sodium Hydroxide pellets.

## I. INTRODUCTION

### General

Cement is a main ingredient of concrete. It is the fine powder that, when mixed with water, sand, and gravel or crushed stone (fine and coarse aggregate), forms the rock-like mass known as concrete. Concrete's durability, strength and relatively low cost make it the backbone of buildings and infrastructure worldwide houses, schools and hospitals as well as airports, bridges, highways and rail systems. The concrete industry is one of two largest producers of Carbon dioxide (CO<sub>2</sub>), generating up to 5% of worldwide artificial emissions of this gas. The carbon dioxide CO<sub>2</sub> produced for the manufacture of structural concrete (using ~14% cement) is estimated at 410 kg/m<sup>3</sup> (~180 kg/Ton @ density of 2.3 g/cm<sup>3</sup>) (reduced to 290 kg/m<sup>3</sup> with 30% fly ash replacement of cement).

### Geopolymer Concrete

In 1978, geopolymer matrix was introduced by Davidovits and proposed that it can replace cement in concrete. Geopolymerization is an innovative technology that can transform several Alumino Silicate materials into useful products called geopolymers or inorganic polymers. Geopolymerization involves a heterogeneous chemical reaction between solid Alumino Silicate oxides and alkali metal silicate solutions at highly alkaline conditions and mild temperatures yielding amorphous to semi-crystalline polymeric structures, which consist of Si-O-Al and Si-O-Si bonds.

## II. NEED FOR STUDY

Global cement production is expected to increase from 3.27 billion metric tons in 2010 to 4.83 billion metric tons in 2030. In China, the cement production in 2015 amounted to some 2.31 billion tons. With nearly 455 Million Tons (MT) of cement production capacity, India is the second largest cement producer in the world. The cement production capacity is estimated to touch 550 MT by 2020. Cement production in India increased from 230.49 million Tons in 2011-12 to 297.56 Million Tons in 2017-18. It is estimated that one percent replacement of cement with fly ash represents a .7% reduction in energy consumption. With the proposed mixes in this paper, will help the world with considerable energy saving

## III. EXPERIMENTAL INVESTIGATIONS

### MATERIALS USED

#### **Cement:**

Portland cement is the basic ingredient of concrete, mortar, stucco and non-specially grout and it is the most common type of cement used all around the world. It was developed from other types of hydraulic lime in England in the mid-19th century. Portland cement consists essentially of compounds of lime (Calcium oxide, CaO) mixed with Silica (Silicon dioxide, SiO<sub>2</sub>) and Alumina (Aluminum oxide, Al<sub>2</sub>O<sub>3</sub>).

#### **Flyash (IS 3812-2003)**

The most extensively used source material for geopolymer concrete is Fly ash due to its ease of availability and appropriate composition. Fly ash is a spinoff product of the coal industry. It is a fine material produced from burning of coal and collected from the combustion system. The main composition of fly ash is Silica dioxide (SiO<sub>2</sub>), Ferric oxide (Fe<sub>2</sub>O<sub>3</sub>), Aluminum oxide (Al<sub>2</sub>O<sub>3</sub>), Calcium oxide (CaO). The specific gravity of flyash is found to be 2.3.

#### **Ground Granulated Blast Furnace Slag (GGBS) (IS 12089:1987)**

Ground granulated blast furnace slag (GGBS) is a byproduct of iron industry. Iron ore, coke and limestone are fed into the furnace to produce iron, and the resulting flowing slag floats above the molten iron at a temperature of about 1500°C to 1600°C. The melted slag has content 30-40% silicon dioxide (SiO<sub>2</sub>) and approximately 40% calcium oxide (CaO), which is close to the chemical configuration of OPC. After the molten iron is tapped off, the remaining melted slag which mainly contains siliceous and aluminous residues is then quickly water- quenched. GGBS is prepared by molten iron slag quenched in water to yield a granulate slag glassy in nature. Rapid cooling or quenching is done to get glassy granular slag. This glassy granulated slag is dried and ground into a fine powder to produce ground granulated blast furnace slag. The specific gravity of GGBS is found to be 2.7.

#### **Fine Aggregates (IS 383-1970)**

Manufactured Sand falling within the grading Zone II as specified by IS:383 manufactured from the hard rock is suitable as fine aggregate in concrete and masonry mortars. Also, IS-2116 and IS 383 codes permit the use of crushed stone fine aggregate in masonry mortars and concrete. In this investigation manufactured sand conforming to zone II as per IS 383-1970 passing through 4.75 mm I.S. Sieve is used. The specific gravity of fine aggregates is found to be 2.72 .

#### **Coarse Aggregates (IS 383-1970)**

In this investigation Crushed granite metal from local sources conforming to zone II as per IS 383-1970 passing through 20 mm and retained on 12mm sieve is used as natural coarse aggregate. The specific gravity of fine aggregates is found to be 2.8.

#### **Paver Block**

Paver Block also known as brick paving is a commonly used decorative method of creating a pavement or hardstanding. The main benefit of this bricks over other materials is that individual bricks can later be lifted up and replaced. Concrete pavers are made by pouring a mixture of concrete and some type of coloring agent into a mold of some shape and allowing to set. In this waste paver block is crushed to smaller size aggregate passing through 20 mm and retained on 12mm sieve is used.

#### **Sodium Hydroxide Solution**

Sodium Hydroxide is in solid state commonly by means of pellets and flakes. The cost of the sodium hydroxide depends on its purity. It is recommended to use 94% to 96% purity. Sodium hydroxide solution is prepared by dissolving Sodium



Hydroxide pellets are taken and dissolved in the water at the rate of required molar concentrations. The concentration of Sodium hydroxide solution varies with respect to molarity. The mass of NaOH solids in a solution varies depending on the concentration of the solution. In this investigation 12M molar concentration is used.

**Sodium Silicate Solution**

Sodium silicate is 2.0 (ratio of Na<sub>2</sub>O and SiO<sub>2</sub>) is used. Sodium silicate from detergent and textile company is used in geopolymer concrete as bonding agent. The properties of solution are as follows: the density of solution is 52Be, the concentrations of Na<sub>2</sub>O is 13.50 %, and SiO<sub>2</sub> is 31.50%. The ratio of Na<sub>2</sub>O :SiO<sub>2</sub> is : 1: 2.30 and the total solid content is 47%.

**Polypropylene Fibers**

Polypropylene fibers are designed to provide reinforcement and crack control in construction materials such as concrete and asphalt. The fibers are manufactured from polypropylene materials. Polypropylene is the first stereo regular polymer to have achieved industrial importance. Their primary role is to modify the properties of the fresh concrete. They increase the homogeneity of the mix, stabilizing the movement of solid particles and blocking bleed water channels. This reduces the bleed capacity of the concrete and slows down the bleed rate, helping to reduce plastic settlement. The matrix of filaments also helps reduce plastic shrinkage cracking which can occur when the concrete surface is allowed to dry out rapidly. Polypropylene fibers have a limited effect on the properties of the hardened concrete. They do not provide any significant post first crack ductility.

**IV.MIX DESIGN FOR GEOPOLYMER CONCRETE**

The quantity of materials adopted are as under:

- (1) Solution to flyash ratio by mass: 0.35, (2) Sodium silicate to sodium hydroxide ratio by mass: 2.5, (3) Flyash: 465 kg/m<sup>3</sup>, (4) Sodium Hydroxide: 46.5 kg/m<sup>3</sup>, (5) Sodium Silicate: 116.25 kg/m<sup>3</sup>, (6) FA: 739.632 kg/m<sup>3</sup>, (7) CA: 1142.06 kg/m<sup>3</sup> and (8) Extra water: 13.95 kg/m<sup>3</sup>.

**1. Preparation of Samples**

Preparation of geopolymer concrete is similar to that of cement concrete. Two types of coarse aggregate that is nominal aggregate and waste paver block aggregate, M-sand, polypropylene fiber, GGBS and fly ash were mixed in dry state. Then prepared mixture solution of sodium hydroxide and sodium silicate was added along with extra water based on water-to- geopolymer binder ratio and mixed thoroughly for 3 to 4 minutes so as to give homogeneous mix. About 45 numbers of concrete cubes of size of 150 mm and 30 numbers of concrete cylinders of diameter 150mm and length 300mm were casted and tested for the compressive strength and split tensile strength. After 24 hours of casting, all specimens were removed from moulds and then cured at ambient temperature. The various mixes adopted in this investigation is tabulated in Table 3.1.

**Table 3.1 Mix Variations**

Mixes adopted	Flyash (%)	GGBS (%)	Cement (%)	Polypropylene Fiber (%)	Coarse Aggregate	
					Nominal Aggregate (%)	Waste Paver block Aggregate (%)
Control Mix	45	45	10	0.4	100	0
Mix 1	45	45	10	0.4	75	25
Mix 2	45	45	10	0.4	50	50
Mix 3	45	45	10	0.4	25	75
Mix 4	45	45	10	0.4	0	100

V. RESULTS AND DISCUSSIONS

1. Compressive Strength Test (IS:516-1959)

Compressive strength of concrete is important because the main properties of concrete, such as elastic modulus and tensile strength, are qualitatively and quantitatively related to this property. It is also important because in structural design, load-bearing capacity of structures is related to the concrete compressive strength. The average compressive strength of concrete cube specimens is shown in Figure 1.

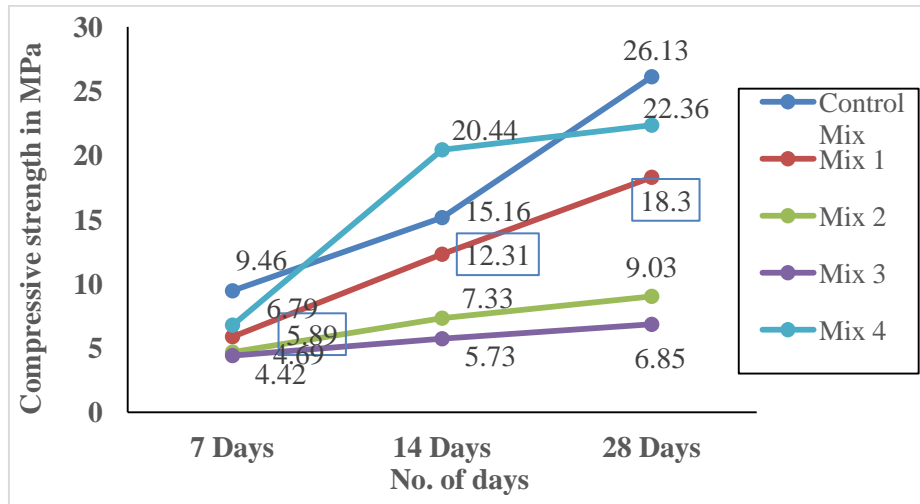


Fig 1 Average Compressive Strength of Concrete Cubes

2. Split Tensile Strength (IS 5816- 1999)

The concrete is weak in tension and strong in compression. Tensile strength is one of the basic and important properties of the concrete. Splitting tensile strength is generally greater than direct tensile strength and lower than flexural strength (modulus of rupture). Splitting tensile strength is used in the design of structural lightweight concrete members to evaluate the shear resistance provided by concrete and to determine the development length of reinforcement. The average split tensile strength of concrete cylinders found plotted in Figure 2.

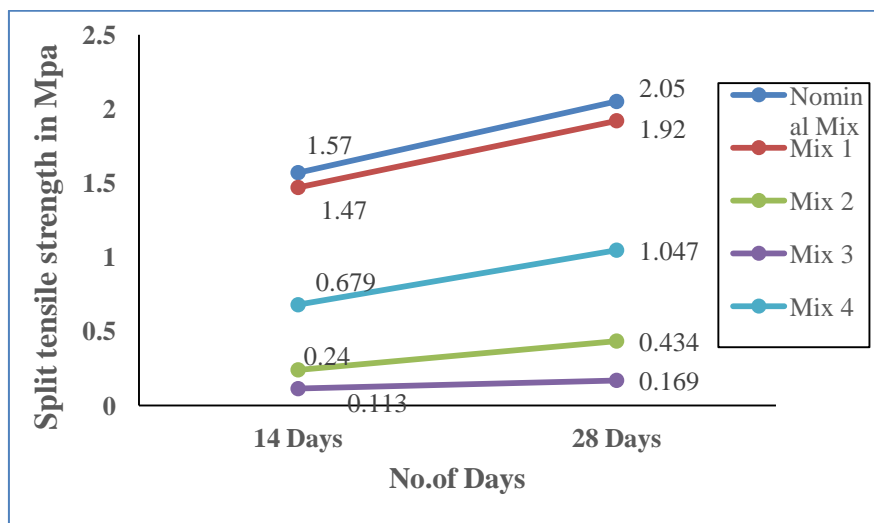


Fig 2 Average Split Tensile Strength of Concrete Cylinders

V. CONCLUSIONS

- Environmental safety is unveiled by Geopolymer concrete by means of reutilizing fly ash and slag waste from the industries, into a significant green building material needed for construction.

- The compressive strength and the split tensile strength of the nominal mix were found to be higher than the other mixes.
- Mix 4 that is mix with 100% waste paver block aggregate has higher compressive strength compared to other mixes with different percentages of paver block.
- The compressive strength of nominal mix is 14.42% higher than that of Mix 4.
- The split tensile strength of Mix 1 with 25% waste paver block aggregate is higher compared to other mixes with waste paver block aggregate.
- The split tensile strength of Mix 4 is found to be 45.5% less than Mix 1 and 48.9% less than the nominal mix.

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