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Investigation on Mechanical Properties of Geopolymer Concrete

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ABSTRACT: Cement manufacturing causes significant pollution. To reduce such pollution, investigation into alternative materials for concrete production is an important research topic. Geo-polymers are potentially effective substitutes for cement in concrete production. Through a polymerisation reaction with Fly Ash and Alkaline solution, the geo-polymer concrete matches that of the conventional concrete in mechanical properties as well as in durability characteristics. Fly ash is one of the bi product which is used in the preparation of the geo polymer concrete by mixing with alkaline solution and cured under 60 deg in hot air oven to undergo polymerisation. In this paper an attempt has made for mechanical properties of geo polymer concrete with GGBS and Hybrid fibers. Ground granulated blast furnace slag is replaced with fly ash in ratios 20%, 40%, 60% and 80%. Hybrid fibers added are the combination of the steel fiber and glass fiber. Three trials are conducted for each mechanical property test. The specimens are cured for 7, 14 and 28 days and the tests are conducted at the corresponding days of the curing. The results are compared with the Geo polymer concrete with GGBS and Hybrid fibers v/s Geo polymer concrete with GGBS and without hybrid fibers.

I. INTRODUCTION:

The term polymer refers to organic molecules with large repeating units. Geopolymeric materials are obtained from the polycondensation of aluminosilicate solids, activated by a concentrated aqueous solution of alkali hydroxide or silicate. Such reactions produce poly-silico aluminates or simply polysialates, these materials generally called "geopolymers", or inorganic polymers. The PBC has become recognized in the market as the ideal for industrial paving andrepair of highways material as it hardened quickly and gained a compressive strength of 20 MPa, after 4 hours of its moulding at room temperature. Several applications of high technology and added value for geopolymers have emerged since then, among which worth noting are cements with low CO_2 emissions. These materials can be made by using aluminium silicon sources like fly ash, which replace the minerals or other natural materials. The mechanical properties are superior to Portland cement in general, but are influenced by the content of the liquid phase in the mixture, the curing temperature and the final porosity of the body. They have high fire resistance (can withstand temperatures of 1000-1200 °C without losing functional characteristics), high chemical stability and inertia, which gives them excellent durability. They have low thermal conductivity values ranging from 0.24 to 0.3 W/MK. The energy required to produce geopolymer cement concrete (GCC) is considerably lower than that required for concrete mixes of Portland (CPC) cement, resulting in up to 90% reduction in carbon emissions. The primary curing time (25 MPa compression) varies from 4-48 hours; studies indicate that geopolymers acquire about 70% of the compressive strength in 4 hours. Full curing occurs around 28 days, which may result in a geopolymer compressive strength of 100 MPa. A compositionused in the literature provides a mixture by weight of 57% fly ash and 15% calcined kaolin (metakaolin) and alkali as a binder, 3.5% sodium silicate, 20% water and 4% potassium or sodium hydroxide.

1.2 GEOPOLYMER TECHNOLOGY

1.2.1 Geopolymers

The production of Portland cement exhausts the resources and also it is an energy intensive process that releases large amounts of the green house gas CO_2 into the atmosphere Approximately 2.8 tons of raw materials, which include fuel and other material, are required to manufacture 1 ton of Portland cement (Nugteren et

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al 2005) It has now become mandatory mixing pozzolonic material like fly ash to cement to partially replace Portland cement Recently, another cementitious material, manufactured from an alumino-silicate precursor activated in a high alkali solution has been developed and this cementitious material is termed as Geopolymer Geopolymer has recently emerged as a novel engineering binder material with environmentally sustainable properties (Palomo etal 2004). It is also well known that alkali activation of alumino-silicates can produce X- ray amorphous alumino- silicate gels, or Geopolymers, with excellent mechanical and chemical properties These gels can be used to bind aggregate, such as sand or natural rock, to produce mortars and concretes. Geopolymers are inorganic binders that function as the Portland cements. Geopolymer represents a new binding material that can be produced from the activation of aluminosilicate material with alkaline solutions . Thus, geopolymer binders were proposed as an effective solution to fully or partially replace the use of cement. It is estimated by Davidovits that only 0.15 to 0.20 tons of cement are produced from each ton of geopolymer, significantly lower than when using cement alone. This shows the effective potential of replacing cement with geopolymers as an environmentally friendly alternative. Geopolymers have been considered a sustainable solution and eco-friendly disposal of industrial by-product materials such as ground granulated blast furnace slag (GGBS) , fly ash , metakaolin , bottom ash , and rice husk ash.

II. MATERIAL INVESTIGATION

2.1 Fly ash

Fly ash is an inorganic, non-combustible by product of coal burning power plants As coal is burnt at high temperatures, carbon is burnt off and most of the mineral impurities are carried away by the flue gas in the form of fly ash. Fly ash is a pozzolanic material possesses no cementitious value but which will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide with calcium ions to form calcium silicate hydrates. In today's construction world there is an increased pressure to use higher levels of fly ash in concrete is due to three main aspects. Fly ash is the finest of coal ash particles. It is called fly ash because it is transported from the combustion chamber by exhaust gases. Fly ash is the fine powder formed from the mineral matter in coal, consisting of the noncombustible matter in coal and a small amount of carbon that remains from incomplete combustion. Fly ash is generally light

Fig 1 : Fly ash

tan in color and consists mostly of silt-sized and clay-sized glassy spheres. Properties of fly ash vary significantly with coal composition and plant operating conditions.

Table 1 : Composition of Fly ash

Chemical properties % by mass	**Fly ash MTPP**
SiO2+A1203+Fe20,	90.5% max
SiO2	58%max
CaO	3.6%min
SO3	1.8%min
Na_2 O	2%max
LOI	2%min

2.2 Fine Aggregate

Locally available river sand passing through 4.75 mm sieve and retained on 150μ sieve was used for experimental investigation. The grading of sand used Conforms to zone- II of 1.S.383-1970 Fine aggregates generally consist of natural and or crushed stone with most particles passing through a 9.5mm sieve. Fine aggregates generally consist of natural sand or crushed stone with most particles 3/8-inch sieve Fine aggregate is natural sand which has been washed and sieved to remove particles larger than 5 mm The code tobe referred to understand the specification for fine aggregates IS 38F 1970 The criteria to classify fine aggregates are If they are Natural/ Man-made According to their size According to the IS specification Fine aggregate may be described more clearly according to their availability as Natural Sand-it is the aggregate resulting from the natural disintegration of rock and which has been deposited by streams or glacial agencies Crushed Stone Sand-it is the fine aggregate produced by crushing hard stone Crushed Gravel Sand-it is the fine aggregate produced by crushing natural gravel According to size the fine aggregate may be described as coarse

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sand, medium sand and fine sand. IS specifications classify the fine aggregate into four types according to its grading as fine aggregate of grading Zone-1 to grading Zone-4. The four grading zones become progressively finer from grading Zone-1 to grading Zone-4. 90% to 100% of the fine aggregate passes 4.75 mm IS sieve and 0 to 15% passes 150 micron IS sieve depending upon its grading zone.

2.3 Alkaline Liquid

Generally alkaline liquids are prepared by the mixing of sodium hydroxide solution to sodium silicate at room temperature. When the solution is mixed together both solutions start to react. It liberates large amount of heat so it is recommended to leave it for about 24 hours thus the alkaline liquid is get ready binding agent sodium-based solutions were chosen because they were cheaper than Potassium- based solutions. The sodium hydroxide solids were either a technical grade in flakes form of 3mm with a specific gravity of 2.130 with 98% purity, the sodium hydroxide solution was prepared by dissolving either the flakes or the pellets in the water. The mass of NaOH solids in a solution varied depending on the concentration of the solution expressed in terms of molar, M. For instance, NaOH solids per litre of the solution, where 40 is the molecular weight of NaoH.

2.4 Sodium Hydroxide

Generally, the sodium hydroxides are available in solid state in the form of pellets or flakes. The cost of the sodium hydroxide is mainly varied according to the purity of the substance. Since our geo polymer concrete is a homogenous material and its main process is to activate the sodium silicate it is recommended to use the lowest cost. In this investigation sodium hydroxide flakes of 10 molar concentrations are used.

Fig 2 : Sodium hydroxide

2.5 SODIUM SILICATE

Sodium silicate is the common name for a compound sodium meta silicate, Na2sio3,also water glass or liquid glass. It is available in aqueous solution and in solid forms and is used in cements, passive fire protections, refractions, textiles and lumber processing and automobiles. Sodium carbonate and silicon dioxide react when molten to form sodium silicate and carbon dioxide. In present investigation sodium silicate solution is used. As per the manufacturers, silicates were supplied to the detergent company and textile industry as bonding agent. Same sodium silicate is used for the making of geo polymer concrete.

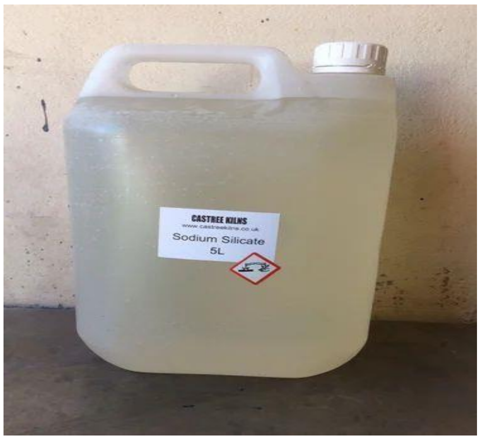

Fig 3 Sodium Silicate solution

Chemical formula	Na_2 OX Sio
Na_2 O	15.90%
Sio_2	31.40%
H_2 O	52.70%
Appearance	Liquid gel)
Colour	Light yellow
Boiling point	102°C for 40%aqueous solution
Molecular weight	184.04
Specific gravity	1.6

Table 2 Chemical and physical properties of sodium silicate.

III. EXPERIMENTAL INVESTIGATIONS

3.1 Mix Proportions

The most common activator used for preparing GPC is a combination of NaSi2O3 and NaOH. The activators have a significant impact on the polymerization process. When the alkali activator dissolves Si and Al from the binding material to form the matrix, polymerization occurs to a high degree. The activator prepared using NaOH and Na2SiO3 enhances the reactivity of FA. Therefore, the amounts of alkaline activators should be carefully adjusted when designing the GPC mix [41,42]. The formulations with different alkali activator ratios used in the study are given in Table 2.

3.2 Mixing and Casting

As the NAOH was hand mixed with water. It was mixed a minimum of 24 hours prior point it intended time of usage in a mix. This waiting period allowed the solids to fully dissolve throughout the solutions as well as to enable inspection and detection of badly mixed solution prior to use. After casting the specimens, they were kept in moulds for a rest period of purdays and then they were demoulded, since the geopolymer concrete did not nimmediately at room temperature as in conventional concrete. The term rest indicates the time taken from the completion of casting of test specimens to the start of curing at an elevated temperature. Geopolymer concrete specimens pok a minimum of 3 days for complete setting without leaving an impression on the hardened surface. All the specimens were given an uniform rest period of fur days and at the end of the rest period, six cubes, four cylinder sand two prisms were kept under ambient conditions for curing at room temperature. Remaining by six cubes, thirty six cylinders and eighteen prisms were heat cured at 80°C hot air oven for 24 hours.

3.3 Testing Program

For the evaluation of compressive strength, all the cube specimens were selected to compressive load in a digital compression testing machine with a ding capacity of 2000 KN. Before subjected to the test, weight of each specimen added and density of each specimen was calculated by dividing the weight It the specimen by its volume. Specimens were placed in the machine in such a near that the load shall be applied to opposite sides of the cubes as cast, that is, A to the top and bottom. The load was applied without shock and increased continuously of approximately14N/mm2/min until there resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen was recorded and the compressive strength of the concrete was calculated using equation (3.1)

$$\int c = P/A$$

Where,∫c is the compressive strength,p is the maximum load applied to specimen and A is the area of the specimen.

	Mix	Days of exposure	Weight (kg)	Change inmass %	Compressive strength (N/mm^2)	Changein Compressive strength (%)	Concentration of Solution
Sulphate Resistance Test	GPC Mix-1	0	8.34	0.0	52.32	100.0	5%sodium sulphate solution
		28	8.51	2.04	50.65 (3.19%)	96.81	
Acid Resistance Test	GPC Mix-2	0	8.32	0.0	51.85	100.0	2%acidsolution
		28	8.48	1.92	49.15 (5.20%)	94.80	
Salt Resistance Test	GPC Mix-3	0	8.30	0.0	51.60	100.0	3.5% NaCl
		28	8.46	1.80	49.90 (3.29%)	96.71	

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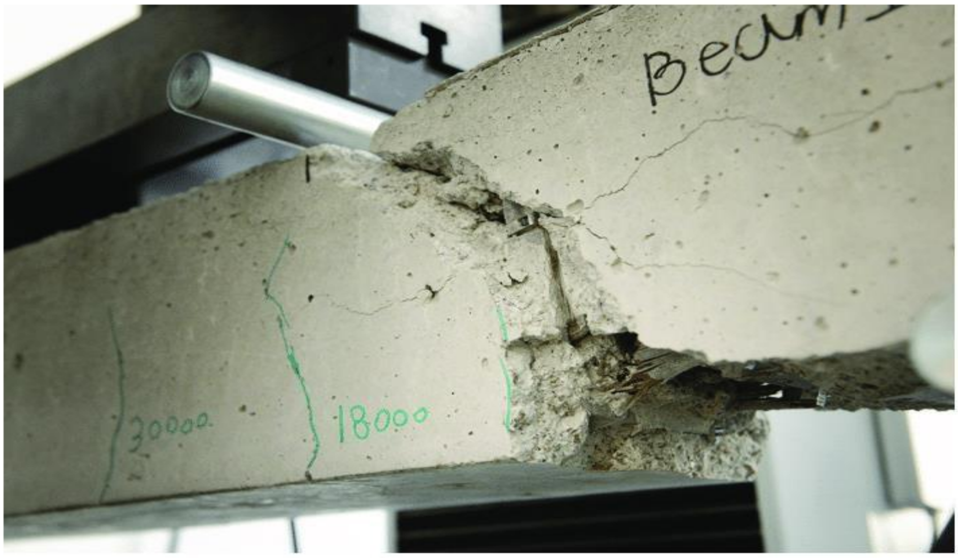
Table 3 : Durability Test Properties



IV. CONCLUSION & REFERENCES

The Flyash can be used as a cement replacement material and it gives opportunity to the construction industries to reduce their cost and thereby preserving the environmental quality. The concrete with replaced material of flyash for cement shows comparable strength to that of control cement in concrete.