Studies on Glass Fibre Reinforced Geo Polymer Concretes withFly Ash and GGBS

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Abstract - In the present study, it is aimed to use fly ash and GGBS as full replacement to cement. They contain high amount of silica and alumina , which can be activated with the help of alkaline solution(i.e.,NaoH & Na_2Sio_3) to produce geo-polymer concrete(GPC). In the present work investigations are carried out to find strength properties of fly ash and GGBS based geo-polymer concrete i.e. (G 40) with the addition of glass fiber by using various combinations of fly ash(FA) and GGBS(i.e FA 100%+ GGB 0% , FA 80% + GGBS 20% , FA 60% + GGBS 40%) with constant molarities (i.e.8M), including addition of glass fiber in various percentages (0.5%, 1.00%, & 1.5%).The specimens prepared with above specification are cured in ambient conditions. Specimens are tested for compressive strength and splitting tensile strength at various ages (i.e 7 days,28 days,56 days) in order to find out effective combination of fly ash and GGBS based geo-polymer concrete mix with optimum dosage of glass fiber which can give desired strength properties.

Key words: Fly ash, GGBS, NaoH, Na_2Sio_3 , polymerisation, molarity, ambient curing.

I. INTRODUCTION:

Use of Industrial wastes

Increased awareness regarding the ill-effects of the over exploitation on natural resources, eco-friendly technologies are to be developed for effective management of these resources. Construction industry is one of the major users of the natural resources like cement, sand rocks, clays and other soils. The increasing unit cost of the usual ingredients of concrete has forced the construction engineer to think of ways and means of reducing the unit cost of its production. At the same time, increased industrial activity in the core sectors like energy, steel and transportation has been responsible for the production of large amounts of wastes like fly ash, blast furnace slag, silica fume and quarry dust with consequent disposal and pollution problem.

Need for geopolymer concrete (GPC):

The Geopolymer technology was first introduced by Davidovits in 1978 along with the geopolymer binders. His work considerably shows that the adoption of the geopolymer technology could reduce the CO_2. emission caused by cement industries. Geopolymers are members of the family of inorganic polymers. The utilization of concrete is increasing manifold due to developments and subsequent demand for infrastructure and construction activities. Ordinary protland cement (OPC) is conventionally used as the primary binder to produce concrete. The environmental issues associated with the production of OPC are well known. The amount of the carbon dioxide released during the manufacture of OPC due to calcination of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced.

Utilisation of fly ash and GGBS

Fly ash, which is considered as an industrial waste, if utilized to its maximum capacity in the construction industry , provides the benefits of reducing the conventional cement generated carbon dioxide as well as saving precious land from becoming a landfill site. Hence fly ash based geopolymer concretes have been gaining popularity as an eco friendly construction material and studies are being conducted on its suitability as an alternative to the much popular portland cement concrete. Ground granulated blast furnace slag(GGBS) is derived from the waste slag of steel factories. It is pozzolonic in nature and it is a very suitable mineral admixture that can be used along with fly ash in geo polymer concrete(GPC) replacing OPC completely.

Use of glass fibers in concrete

Fiber reinforced concrete is a relatively a new composite material in which fibres are introduced in the matrix as micro reinforcement, so as to improve the strengths like compressive strength, cracking strength and other properties of concrete. Some types of fibres produce greater impact, abrasion, and shatter resistance in concrete. Glass fiber reinforced concrete is a type of another reinforced concrete which is mainly used in exterior parts of buildings from architectural point of view. In the structural applications, fiber reinforced concrete possess many advantages compared to the traditional structural concrete.

Polymerization:

The Polymerization process involves a substantially fast chemical reaction under alkaline conditions on Si-Al minerals, resulting in a three-dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds. The formed gel product contains alkaline captions which compensate for the deficit charges associated with the aluminium-for-silicon substitution. An intermediate, aluminium -rich phase is first formed which then gives way to a more stable, silicon rich three-dimensional get product of form Q4(nil), which is dependent upon curing condition and activator type. The slow growth of crystalline structures become evident as the nuclei of the polymerized gel reaches critical size. The matrix crystalinity is relative to the rate by which precipitation occurs: fast reactions between alkali and ash do not allow time for growth of a wells structured crystalline environment (respective of typical zealots). Therefore , most hardened geopolymer concretes are referred to as zeolitic precursors rather than actual zeolite. The final products geopolymerization is an amorphous, semi-crystalline cementitions material.

Details of present experimental investigation:

In the present experimental investigation, GGBS is tried as replacement to fly ash in various percentages. The molarity of the alkali sodium hydroxide (NaoH) is kept constant at 8. Crimped steel fibres were added to the GPC mix in percentages varying from 0.0 to 1.5 by volume. The specimens of GPC were cured at ambient temperature over various curing periods ranging from 7 days to 56 days. By testing the fibrous GPC specimens, conclusions are drawn on the optimum combinations of fly ash and GGBS.

II. REVIEW OF LITERATURE:

[1] Davidovits etal(1) studied the environmental effects including temperature on geopolymer concrete.
[2] Ferria etal.(2) reported that the presence of glass fibre in GPC improves the properties of strain hardening and crack arresting mechanism.
[3] 3. Hondjits etal (3 and 4) tested and gave mechanical properties of geopolymer cement and concretes. The results are good
[4] Lloyd etal(5) have studied the durability properties of GPC and reported better results.
[5] Polomo,A etal(6) studied the properties of alkali-activated fly ashes.
[6] Wallah,S.E etal(7) reported the results on the long term properties of geopolymer(fly ash based) concrete.
[7] Vijay.k etal studied the properties of glass fiber reinforced GPC and reported the strength results.

III. EXPERIMENTAL INVESTIGATION

Materials of GPC

Fly ash:

Fly ash is the alumino silicate source material used for teh synthesis of geo-polymer binder. Low calcium class fly ash was obtained from APARNA RMC plant located at Miyapur. The percentage of fly ash passing through 45µm is Seive was found to be 95%.

Ground granulated blast furnace slag:

Ground granulalted blast furnace slag(GGBS) is a by product of the steel industry. Blast furnace slag is defined as "the non-metallic product consisting essentially of calcium silicate and other bases that is developed in a molten condition simultaneously with iron in a blast furnace". The GGBS is used as a replacement to flyash by 0, 20 and 40 percents.

Aggregates:

The fine aggregates used in the study was river sand and coarse aggregates are crushed angular granite stone passing 12.5mm sieve. The results are found to satisfy the specifications.

Sodium Hydroxide:

Solution of 8 molar was prepared by mixing the pellets with distilled water. The mass of NaoH solids in a solution varied depending on the concentration of the solution expressed in terms of molar (M). Amount of sodium hydroxide solids are added to certain amount of water(in pellet form) to make up the solution upto 1 litre and mixed well 24 hrs prior to usage.

Sodium Silicate:

Sodium silicate solution of 8 molar was prepared by mixing the mass of Na_2sio_3 with diluted water. Concentration of the solution expressed in terms of molar m and sodium silicate solution was 24 hrs prior to usage. By combining NaoH with Na_2sio_3 the polymerization reaction is activated.

Water :

This is the least expensive but most important ingridient in concrete. The water, which is used for making concrete, should be clean and free from harmful impurities such as oil, alkali, acid etc. in general, the water which is fit for drinking was used for making concrete. Distilled water was preferred in the present investigation.

Super Plasticizer:

Super Plasticizersare capable of reducing water content by about 30% .However it is to be noted that full efficiency of super plasticizer can be obtained when it is added to a mix that has as initial slump of 20 to 30 mm. Depending on the solid content of the mix, dosage of 1 to 2 % by weight is recommend. For the present investigation , a super plasticizer namely CONPLASTSP 430 has been used for obtaining workable concrete. In addition to the above, super plasticizer and extra water are added to maintain the workabilty of the GPC mix

Glass Fiber :

Glass fiber is made of silicon oxide with addition of a small amount of oxide. Glass fibre is characteristic for high strength , good temperature resistance and corrosion resistance and is available at low price. Alkali resistant glass fibre of 12mm length & 14 microns nominal diameter having density of 2700 kg/m^3 was used. Its aspect rations is 857.14

Mix design for geo polymer concrete(gpc 40)

The mix design procedure is adopted from the literature and based on trial as per the following steps.

[1] In 1 cubic mete of concrete (mass=2400 kg), total aggregate is adopted at 78% .Out of this 30% is taken as fine aggregate (River sand). The coarse aggregate consists of 60% of 20mm size and 40% of 10 to 12mm size.
[2] In the remaining mass, the alkaline solution is 40% of the mass binder(fly ash)
[3] Out of the alkaline liquid NaoH solution and Na_2Sio_3 solutions are mixed in the ratio of 1:25.
[4] Solids of Na in the NaoH solution are 25.5% for molarity '8'. In the Na_2Sio_3 solution the water content is 55.9%.
[5] From the above the total solid chemicals and water are worked out.
[6] Hence finally the proportions of various constituents are worked out. Quantities required for 1 cubic meter of concrete are also shown in table 1.

Table 1: Materials required for GPC(40)

S l no	Details	Binder Fly ash	Sand	Coarse aggregate	NaoH Solution	Na_2Sio_3
1	Ratios	**1.0**	**1.49**	**3.47**	0.114	0.286
2	masses for 1 cubic meter of GPC	**377.14**	**561.16**	**1310.40**	43.102	107.75

Mix combinations tried in the present investigation

Three basic combinations between fly ash and GGBS were tried. The combinations were obtained by replacing fly ash with GGBS by 0%, 20%, 40% . These combinations of GPC were tested for compressive and split tensile strengths. Further, glass fibres were mixed at 0.5 ,1.0 and 1.5 volume percentages. In total there were 12 combinations tried for strength testing.

Mixing and Casting

The various materials of GPC like fly ash, GGBS, Coarse aggregate, fine aggregate , super plasticizer have been weighted accurately as per the mix proportions. The alkaline solution(NaoH + Na_2Sio_3) is made ready by one day earlier to mixing. A dry mix with all the ingredients is prepared in the pan mixer. The alkaline solution is added and mixed. Super plasticizer is added to maintain workability . Sufficient number of cube and cylinder specimens were cast for testing for compressive and split tensile strengths .

Curing of GPC specimens.

In the present investigation, curing at ambient temperature was adopted for GPC specimens. Demoulding of specimens was carried out two days after the casting and the specimens were subjected to curing at room temperature. Specimens were tested at the ages of 7,28 and 56 days.

Testing of specimens:

Specimens of respective ages were tested for compressive and split tension. Standared procedures were followed for testing. Average strengths are used for plotting. The variations in the compressive and split tensile strengths are shown by bar charts in fig 1 and 2. The variations of split tensile strength for different fiber percentages are shown in fig 3 to 5.

IV. DISCUSSION OF THE RESUTLS.

The results of the experimental investigations are discussed here in.

Mix Proportions of GPC

In the present experimental investigations, the alkaline solution is taken as 40 % of the binder (fly ash and GGBS). In the alkaline solutin NaoH of molarity 8 was taken as 28.5% of the total. The remaining is Na_2Sio_3. .The ratio of water to binder (fly ash and GGBS) is 0.21 with these proportions GPC equivalent to Grade 40 is evolved.

Design strength of GPC

It can be seen from the results(fig 1 and 2) that the compressive strength increases with age of the specimens. The GPC specimens have exhibited almost the design strength at the age of 28 days. This validates the design method used in the present investigation. The compressive strength increases with age and the highest in reached at 56 days showing an increase of nearly 12 to 15%. This may be due to the flyash binder which reacts slowly. Replacement of fly ash with GGBS has yielded more strength with 40% replacement giving highest strength.

Split tensile strength results:

The results of split tensile strength follow the same pattern as the compressive strength. The strength increases with age. Presence of GGBS has contributed to increase in the split tensile strength.

Influence of fibres on split tensile strength:

Glass fibres were added to GPC mixes at volume percentages of 0.5 ,1.0 and 1.5. The results (Fig 3 & 5) show that the presence of alkali resistant glass fibre has contributed to increase in the split tensile strength. The increases are nearly 25 to 30% in the case of basic GPC mix with fibre percentages of 0.5 to 1.5 . With GGBS in the mix the same trend can be seen. With 40 % GGBS in the binder, there is an increase of nearly 50 % increase with 1.5 % fibre. This shows that even glass fibre contributes to substantial increase in the split tensile strength of GPC.

Presence of GGBS in the GPC mix.

The result (fig 1 and2) clearly show that the replacement of fly ash with GGBS in various percentages as binder in the GPC mix has contributed to strength increase. In the present investigation, the maximum increase was recorded with 40% replacement.

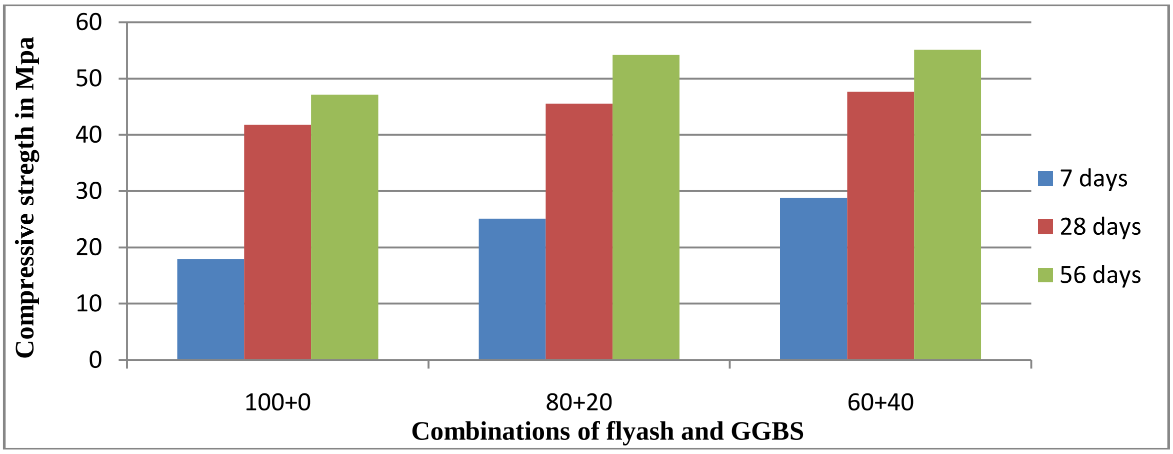

fiG1 The variation of compressive strength with age for different combinations of flyash and GGBS

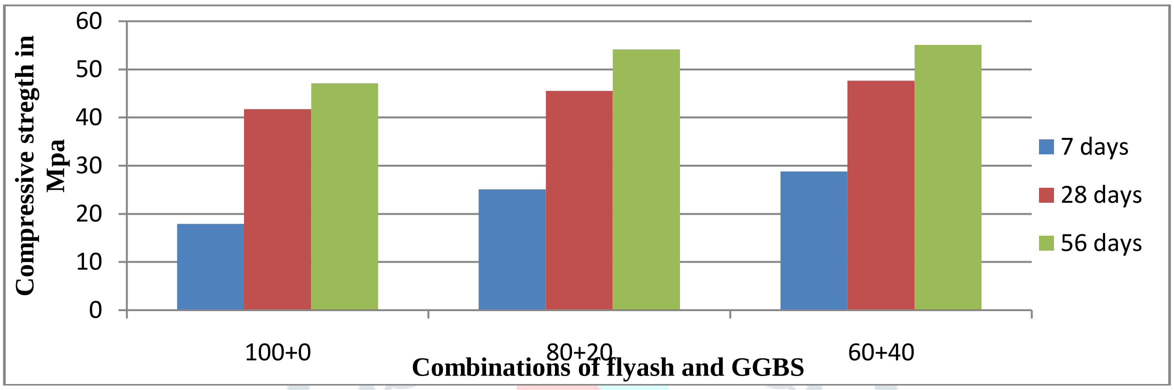

FIG 2 The variation of Split tensile strength with age for different combinations of flyash and GGBS

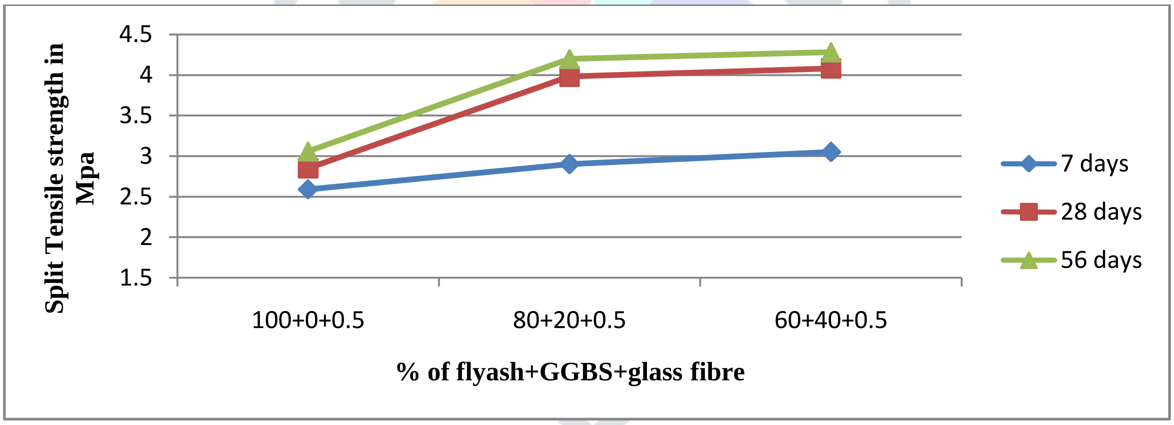

FIG 3 Variation of split tensile strength with 0.5% glass fibre for various combinations

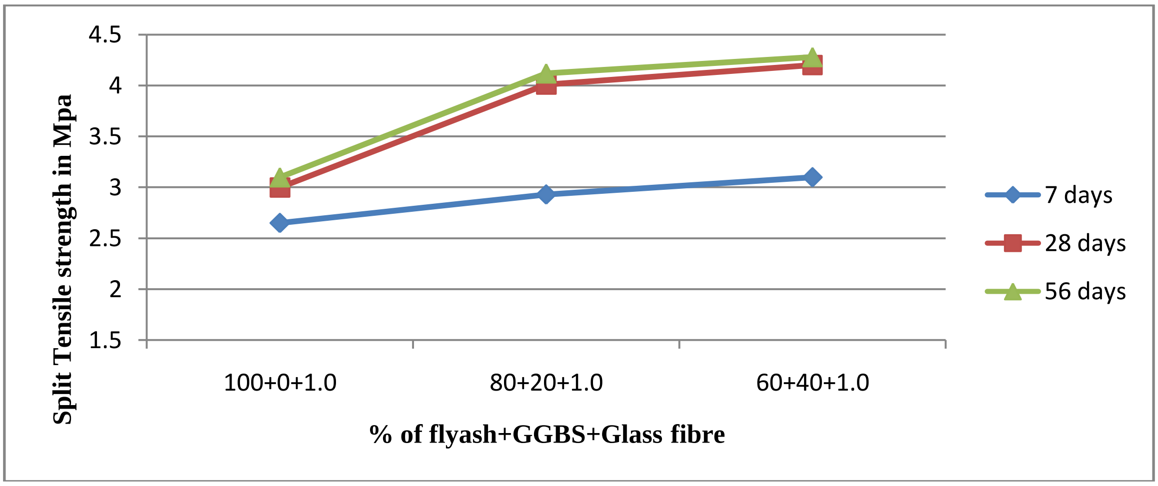

FIG 4 Variation of split tensile strength with 1.0% glass fibre for various combinations

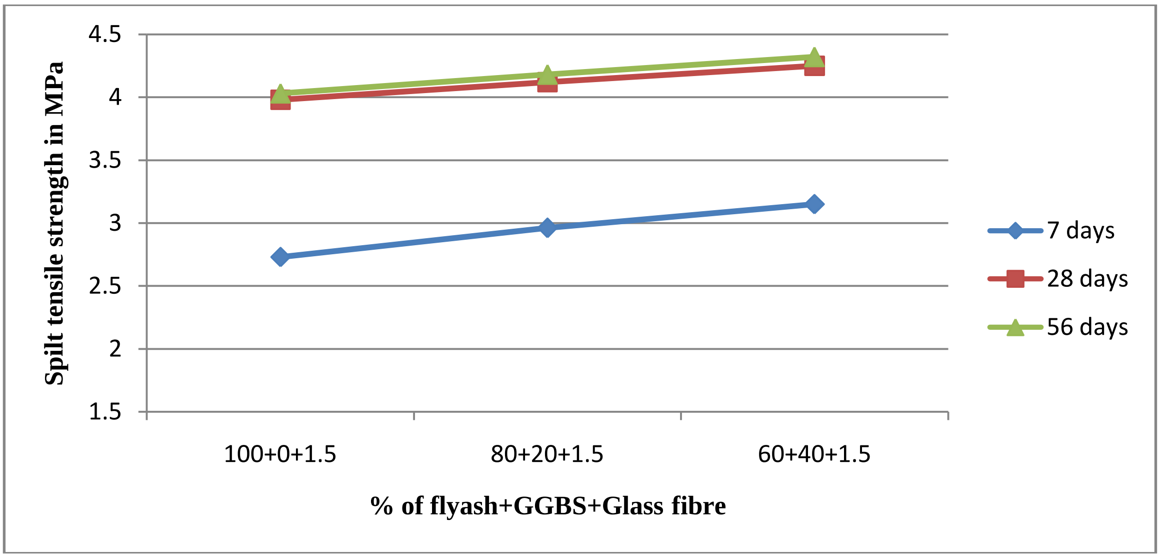

FIG 5 Variation of split tensile strength with 1.5 % glass fibre for various combinations

Influence of ambient curing

Ambient curing at room temperature instead of oven curing was adopted in the present investigation. Ambient curing over a period of 28 days has resulted in the design strength of GPC. It can be seen that by extending the period of ambient curing the 28 days strength has increased by nearly 15% at the age of 56 days for the basic GPC mix. Hence , it is clear that extended curing period contributes to increase in the strength because of the fly ash binder with slow reactivity.

Overall comments:

Optimum GPC mixes can be developed with binary mixes like fly ash and GGBS and by using alkali resistant glass fibres.

V. CONCLUSIONS:

Based on the experimented investigation, the following conclusions are drawn.

[1] By varying the relative properties of NaoH, of molarity 8 GPC (40) can be obtained with binder to chemical solution ratio of 0.21.
[2] The maintain workability of GPC the required percentage of super plasticizer may be added to the mix.
[3] By curing at ambient temperature over 28 days the required design strength can be obtained. Extended curing periods give increased strength.
[4] The replacement of fly ash by GGBS in various percentages yields higher strength. With 40% GGBS replacement, the 28 day strength is increased by nearly 15 percentage.
[5] The presence of glass fibre in GPC mix has contributed to increased split tensile strength. With a maximum percentage of 1.5 percentage glass fibre, the basic split tensile strength of GPC has increased by more than 50 percentage.
[6] Though the initial cost of GPC is high because of chemicals, there is saving in water curing. GPC is more impervious, chemical resistant and crack free. As such , geo polymer concrete works out to be economical

VI. ACKNOWLEDGMENTS:

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