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Literature Review on Steel Fibre Reinforced GEO-POLYMER Concrete

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Abstract: **-- The Geo-polymer concrete (GPC) is representing the most promising green and eco-friendly substitute to Ordinary Portland cement (OPC). One of the most important ingredients in the conventional concrete is the Portland cement. The production of cement in the factory emits the enormous amount of carbon- dioxide which pollutes the environment. Therefore, low calcium fly ash based geopolymer concrete is provided because this concrete uses no Portland cement. The geo-polymer cement (which is obtained from the reaction of low calcium fly ash with the alkaline solution (i.e.) sodium hydroxide and sodium silicate) does not pollute the environment and so it is eco-friendly. SFRMGPC consisting of fly ash, GGBS, Alkali-activated solution, fine aggregate, coarse aggregate and steel fiber. GGBS is obtained as a by-product i.e. waste from iron and steel industry from the blast furnace to produce a glassy, granular product which is then dried and crushed into a fine powder. It Increases the long-term strength, durability, and resistance to attack in peaty/acidic environments. To enhance the curing ground granulated blast furnace slag is added. Steel fibers increase the durability of geo-polymer concrete and it is proposed to determine and compare the differences in properties of geo-polymer concrete with GGBS and steel fiber. The investigation will consist 0f several tests which include workability test, compression test, split tensile strength and flexural strength. The fiber content varied from 0 to 1 % by weight of geo-polymer binder (Fly ash + GGBFS), also try to use of best molarity alkali solution. Concrete cube of 150mm x 150mm x 150mm will be considered for compression strength. Concrete cylindrical cube of internal diameter 15omm and height of 300mm will be considered for split tensile strength. Beams of 150mm x 150mm x 700 mm will be considered for the flexural strength. In this paper, an attempt is made to study steel fiber reinforced geo-polymer concrete by various aspects.**

I. INTRODUCTION

The demand for cement is increasing with the increase in infrastructure development. The process of producing cement is not only highly internal energy intensive but is also responsible for large emissions of carbon dioxide (CO2) which is around 80% to the air which is created by cement and aggregate industries and this is a greenhouse gas causing global warming. Geo-polymer cement concrete applies the innovation as an option for binder in Portland concrete and cement industry. Geo-polymerization is a methodology in which the source material (rich in silicon and aluminum) responds with high alkaline solution for produce binding material. GGBS, Fly ash can be in part substituted for OPC. Geo-polymer Concretes (GPC) is cement less concrete which utilize byproduct materials like fly ash, GGBS in the presence of alkaline solution to produce binders. These concretes are obtained by alkali activation of industrial waste materials such as fly ash in the presence of sodium hydroxide and sodium silicate solution, which is a polymerization process that differs widely from Portland cement hydration.

Promoting the use of fly ash as building material are done by many countries by granting carbon credit, which will not only reduces emission of carbon Dioxide by less production of cement but also promotes the consumption of the waste material fly ash which poses a major problem for disposal world over. In India most of all the states have thermal power plants and abundant availability of fly ash. The alkaline liquids are from soluble alkali metals that are usually sodium or potassium based. The combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate (Na2SiO3) or potassium silicate (K2SiO3) are alkaline liquid solution which is mostly used in geo-polymerization. The alkaline solution sodium hydroxide and sodium silicates are cheap and locally available. Geo polymer consists of silicon and aluminum atoms bonded via oxygen into a polymer network. In Geo-polymer it utilizes the poly condensation of silica and alumina precursors to attain structural strength by forming Al-O-Si bond but in Ordinary Portland/pozzolanic cements form Calcium-silicate-hydrates (CSH) for matrix formation and strength. Two main constituents of geo-polymer are: source materials and alkaline liquids. Any material that is rich in Si and Al in amorphous form such as fly ash, RHA, GGBS, Silica fume etc. can be a possible source material for geo-polymer binder. Fly ash is considered to be

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advantageous due to its high reactivity that comes from its finer particle size than slag. Moreover, low calcium fly ash is more desirable than slag for geo-polymer source material. Geo polymerization involves the chemical reaction of alumino-silicate oxides with alkali poly-silicates yielding polymeric Si – O – Al bonds. Water is expelled from the mixture during the curing process. In Geo-polymer concrete water is provided only to improve workability and does not become a part of the resulting geo-polymer structure. Concrete exhibits brittle behavior due to its low tensile strength. The addition of fibers, either short or continuous, changes its brittle behavior to ductile with significant improvement in tensile strength, tensile strain, toughness and energy absorption capacities. Earlier studies show that addition of different types of fibers improves the mechanical properties of geo-polymer concrete. Research efforts will be made to substitute the cement based binder in concrete recently by fiber reinforced cement concrete with ‘‘geo-polymeric’’ binder resulting in Fiber Reinforced Geo-polymer Composites (FRGCs), which is greener than the former one.

CHEMICAL ADMIXTURE

- **ALKALINE SOLUTION**

Alkaline solution plays most important role in geo-polymerization process. The alkaline liquid used is a combination of sodium silicate and sodium hydroxide solution. The molarity used for mixing of NaOH is 12M. It means 12 part of NaOH pellets is to be added in 1 liter distilled water. When mixed and stirred gradually an exothermic reaction takes place and extreme amount of heat is evolved. Hence for safety hand gloves are used. The mix solution is left for settling down for 24 hours. The NaOH solution and sodium silicate solution require preparing separately and mixed together at the time of casting. The Na_2SiO_3 solution had 34.64% SiO_2, 16.27% Na_2O, and 49.09% water.

Figure 3: Sodium Hydroxide flakes, Sodium silicate solution

- **SUPER PLASTICIZER**

In order to achieve the desired workability, a naphthalene based super plasticizer is used as the water reducer. In this project Conplast SP-430 is used as super plasticizer. The dosage of super plasticizer used was 2% of fly ash. It is brown in colour

Figure 5: Conplast SP-430

MINERAL ADMIXTURE:

- **FLY ASH**

    a) Low calcium Class F type fly ash obtained from thermal power station and it is generally analyzed as per IS:3812- 1981. Having specific gravity of 2.21.

    b) Fly ash consists primarily of oxides of silicon, aluminum iron and calcium. Magnesium, potassium, sodium, titanium, and sulfur are also present to a lesser degree. Chemical composition of Class C and Class F fly ash are defines by American Association of State Highway Transportation Officials (AASHTO) M 295 [American Society for Testing and Materials (ASTM) Specification C 618]. When used as a mineral admixture in concrete, fly ash is classified as either Class C or Class F ash based on its chemical composition.

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c) Class C ash consists of more than 20 percent CaO which is referred as high calcium fly ash. It typically derived from sub-bituminous coals and it consists of calcium alumino-sulfate glass, quartz, tricalcium aluminate & free lime (CaO).

d) Class F ashes has less than 10 percent CaO which is typically resulting from bituminous and anthracite coals & it consists of alumino-silicate glass, with quartz, mullite & magnetite.

Table 1-3: Sample oxide analyses of ash and portland cement

Compounds	Fly Ash Class F	Fly Ash Class C	Portland Cement
SiO_2	55	40	23
Al203	26	17	4
Fe_2O_3	7	6	2
CaO (Lime)	9	24	64
MgO	2	5	2
SO_3	1	3	2

Color: Color of fly ash is generally of tan to dark gray which is depend on its chemical & mineral constituents. Tan and light colors are due to high lime content. A brownish color is due to iron content. Elevated unburned carbon content gives a dark gray to black color. Fly ash color is usually very common or regular for each power plant and coal source.

- **GGBS**

It is glassy, granular product obtained by extinguishing molten iron & steel slag (a by-product from a blast furnace of iron and steel-industry) in water or steam, and ground into a fine powder after the dried. Concrete made with GGBS cement takes more time to sets than concrete made with ordinary Portland cement which is depending on the amount of GGBS contains, but in production conditions it continues to gain strength over a longer period. This results lower temperature rises because of lower heat of hydration, and avoiding cold joints easier, but it may also affect the construction schedules where quick setting is required. By using of GGBS, the risk of damages caused by alkali–silica reaction (ASR) considerably minimize and it provide higher resistance to chloride ingress — reducing the risk of reinforcement corrosion and provides higher resistance to attacks by sulfate and other chemicals. GGBS is used as a direct substitute for Portland cement, on the basis by weight. Replacement levels for GGBS ranging from 30% to up to 85%. Typically 40 to 50% is used in most instances for good result. Different laboratory tests were conducted on GGBS to determine Fineness, Specific Gravity. The specific gravity is 3.21 and fineness 2.78.The results conforms to the IS recommendations.

- **AGGREGATE(FINE & COARSE)**

The coarse aggregate is chosen by shape as per IS 2386 (Part I) 1963, surface texture characteristics of aggregate is classified as in IS 383 – 1970. Coarse aggregates comprising of different sizes 20mm, 12mm, 6mm having generally fineness modulus of 8.04, bulk density of 1578 kg/m^3 and specific gravity of 2.74 are used.

The sand is used as fine aggregate and it is collected from nearby area. The sand has been sieved in 4.75 mm sieve having specific gravity of 2.62 and fineness of 3.14 is generally used. Tests are conformed to IS: 383-1970.

- **STEEL FIBRE**

Steel fibre having geometry of cylindrical with hooked ends are used. The length and diameter of fibres are 50 mm and 1mm respectively. The aspect ratio (l/d) of the steel fibre is 50. The tensile strength is about 1100 Mpa. Also round crimped steel fibres having diameter 0.45mm and length 25mm are used for the present study. The aspect ratio of the fibre was 55 and has a density of 7.2g/cc

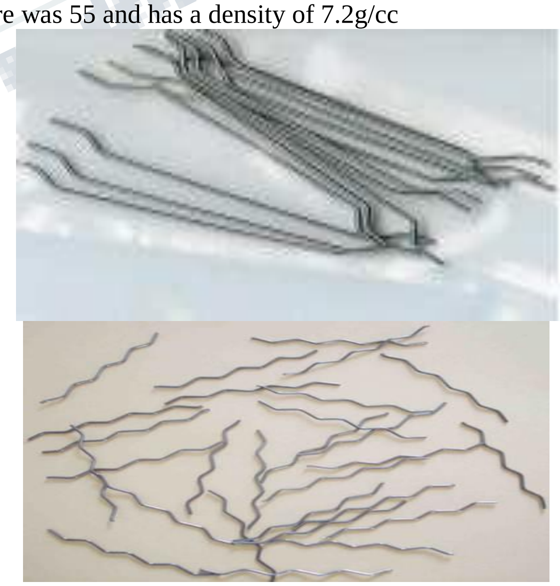

Figure 4: Cylindrical hooked end & Crimped steel fibres

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II. REVIEW OF LITERATURE

a. Ali A. Aliabdo, Abd El-moaty M, Hazem A. Salem b [(2016) [1] He studied properties of fly ash based GPC workability, compressive strength, splitting tensile strength, modulus of elasticity, absorption, and porosity. The results indicated that if we add water content, it increased workability but decreased other fly ash based GPC properties and the optimum additional water content was found to be 30 kg/m3 which has slight effect on geo-polymer properties. The increase of plasticizer content up to 10.5 kg/m3 had acceptable effects on GPC properties due to improved workability. The optimum molarity of sodium hydroxide solution was found to be 16 M. GPC properties was significantly affected by alkaline solution to fly ash ratio and 0.40 was expected to be the optimum ratio. Increasing sodium hydroxide solution to sodium silicate solution ratio reduces geo-polymer concrete properties; nevertheless, low ratio is not economic due to sodium silicate solution cost.

b. Faiz U.A and Anwar H ((2016) [3]

This paper evaluated the effects of different elevated temperatures on the residual mechanical properties such as compressive strength, indirect tensile strength and elastic modulus of steel fiber reinforced geo-polymer concretes containing sodium and potassium based alkali activators (SFRGC(Na) and SFRGC(K)) and comparison is also made with those of steel fiber reinforced OPC concrete (SFRC). Steel fiber reinforced geo-polymer concretes (SFRGC (Na) and SFRGC (K)) exhibited much higher residual compressive strength capacity at elevated temperatures compared to their original ambient temperature strengths than that of SFRC. Strong correlations of compressive strength with indirect tensile strength and elastic modulus of SFRC at elevated temperatures is observed. However, in the case of SFRGC (Na) and SFRGC (K) no such strong correlations are observed.

c. N.Ganesan, P.V. Indiraa and Anjanasantha kumar((2013) [7]

In this paper Engineering properties of geo-polymer concrete (GPC) and steel fiber reinforced geo-polymer concrete (SFRGPC) such as compressive strength, splitting tensile strength, modulus of rupture, modulus of elasticity and Poisson's ratio have been obtained from standard tests and compared. The increase was found to be nominal in the case of compressive strength (8.51%), significant in the case of splitting tensile strength (61.63%), modulus of rupture (24%), modulus of elasticity (64.92%) and Poisson's ratio (50%) at 1% volume fraction of fibers

d. Supriyaprakash, G. Senthilkumar (March 2015) [10]

Paper presents results of an experimental program to find the mechanical properties of Fibre Reinforced Geo-polymer Concrete (FRGPC) such as compressive strength, split tensile strength, flexural strength. In FRGPC, it contains fly ash, alkaline liquids, fine aggregate, coarse aggregate and steel fibre. Alkaline liquid to fly ash ratio was maintained as 0.45 with 100% replacement of OPC. Ratio of sodium silicate to sodium hydroxide solution was fixed as 2.5 for alkaline liquid combination. Steel fibres were added to the mix in volume fractions of 0.5%, 1.0%, and 1.5% by volume of concrete in each of separate mix. Specimens had undergone 24 hours of Heat curing at 80°C in heat curing chamber. Based on the test results, optimum % were formulated and compared it with conventional Concrete. Compressive strength of 1% steel fiber geo-polymer concrete has found to be 5% increase in strength, when compared to that of conventional concrete. Split tensile strength of 1% steel fiber geo-polymer concrete has found to be 5% increase in strength, when compared to that of conventional concrete. Hence 1% concentration of steel fibers is found to be the optimum dosage for his project work

e. H TejaKiran Kumar((January 2017) [5]

In this paper it is shows the behavior of coir fiber as reinforcement in geo-polymer concrete by Analysis of fly ash having low-calcium is used for the making of geo-polymer concrete. The combination of Na2SiO3 solution & NaOH result was used for fly ash activation. Binding agent to fly ash ratio was 0.45.The molarity used was 12M (Molars). Ambient curing is followed for this work. By findings the various strength parameters were tested at various ages i.e.., 7, 14 and 28 days. Application of Coir fiber which is acting as reinforcement added to resist the micro cracks. So this can be applicable where the requirement to resist the micro cracks.

f. Nisha Khamar, Resmi V Kumar V ((2013) [8]

The manufacture of Portland cement releases carbon di-oxide. The environmental problems caused by cement production can be reduced by finding a substitute conventional concrete material. An environmental friendly concrete is developed by replacing cement by fly ash and GGBS and there by forming geo-polymer concrete. Evolution of geo-polymer concrete cured at ambient temperature broadens its suitability and applicability to concrete based structures. Different mixes prepared haing of different molarities of sodium hydroxide solution i.e. 8M, 10M and 12M and the compressive strength is calculated for each of the mix. From that optimum molarity was obtained and which is used for further studies. The 0, 0.25, 0.5, 0.75 and 1 are varying percentages of steel fibres which were added in the mix .After getting the optimum percentage of steel fibres, the polypropylene fibre is varied at 0, 10, 20, 30 and 40 percentages of steel fibre with optimum steel fibre remains constant. For curing, temperature was fixed at room temperature for 24 hours. after the ages of 28 and 56 days The specimens were tested. The tests were conducted for cement, chemical admixture, and coarse aggregate & fine aggregate. For mechanical properties of concrete, specimens were tested namely; cube compressive strength, splitting tensile strength, and flexural strength which shows improved properties than general concrete.

g. G. Ramkumar, S. Sundarkumar, A. Sivakumar (March 2015) [4]

Significant research has been done on improvement of Geo-polymer concretes (GPCs), which include ambient temperature curing and use of stainless steel fibre and mild steel fibre. In this paper an attempt is made to study steel fibrer reinforced geo-polymer concrete. Three GPC mixes of fly ash (50%) and GGBS (50%) in the binder stage were considered with control GPC mix, GPC mix with added stainless steel fibre and mild steel fibres. The studies showed that the load carrying capacity of most of the GPC mix was in most cases more than that of the conventional OPCC mix. There is no need of exposing geo-polymer concrete to higher temperature to achieve most extreme strength GPC diminished the workability of concrete mix with the addition of steel fibres. The necessity of water substance is reduced because of the addition of alkaline solution which helps in increasing the compressive strength of concrete. Use of steel fibre increase compressive strength by 2.25% (appx.). GPC mix with added steel fibres is approximately 20% more than GPC control mix in compression behavior. GPC mix with added stainless steel fibres is 57% more than control mix and GPC mix with added mild steel fibres is 75% more than control mix in split tensile strength behavior.82.3% of compressive strength was attained by control mix in only 7days and 70-73% of compressive strength was accomplished in just 7 days. Flexural strength of GPC with added fibres is approximately 24% more than control mix. The addition of fibres diminishes the crack propagation in concrete and can achieve higher peak value deflections at diverse stages including service load and peak load stage were higher for GPC beams.

h) A. Maria Rajesh, Dr.C. Selvamony, Dr.T.R. Sethuraman, M.ShajuPragash((February 2014) [02]

Durability of geo-polymer concrete increases by steel fibre and to enhance the curing ground granulated blast furnace slag is added. It determines and compares the differences in properties of geo-polymer concrete with GGBS and steel fiber. The investigation are to be carried out using several tests which include workability test, impact value test , sieve analysis, specific gravity test, compression test, split tensional strength and flexural strength. The Optimum compressive strength of GPC specimens (40% of GGBS replacement by fly ash) was found to be 58.50Mpa for 28 days after hot curing compare with30%, 40%, 50%, 60% of GGBS. The Optimum Split tensile strength of GPC specimens (40% of GGBS replacement by fly ash) was found to be 11.50Mpa for 28 days after hot curing compare with 30%, 40%, 50%, 60% of GGBS. The Optimum Flexural strength of GPC specimens (40% of GGBS replacement by fly ash) was found to be 13.50Mpa for 28 days after hot curing compare with 30%, 40%, 50%, and 60% of GGBS. Geo-polymer concrete is more environmental friendly and has the potential to replace ordinary Portland cement concrete in many applications such as precast units. It is proposed to study the behavior of Steel fibre and GGBS in Geo-polymer Concrete. It is suggested that to cast and test the Structural elements with the Optimum mix proportional of above high performance GPC where made, this research work should be satisfied.

i) Mrs. S.N.Deshmukha, Prof.U.R.Kawade ((2016) [06]

Geo-polymer concrete is one such ecofriendly material which is used as alternative to ordinary Portland cement (OPC). GPC result from polymerization process of fly ash and GGBS as a binding material and alkaline liquid. Alkaline solution is sodium silicate Na 2SiO3 and Sodium Hydroxide NaOH. This paper presents data on the engineering properties of geo-polymer concrete with varying Molarity & different percentage of polypropylene fibers & steel fiber (0.2%, 0.4%, 0.6%, 0.8%, and 1%). Ratio of Na2SiO3 / NaOH is 2 & Na2O / SiO2 are 2.25. The paper demonstrates that this particular geo-polymer concrete complies with relevant performance requirement and thus provides engineer with viable alternative to Portland cement based concrete allowing greatly reduced the embodied energy and carbon dioxide footprint. Flexural strength increases with increase in Molarity of NaOH up to 13M. It gives percentage increase of 15.26%. Beyond 13MFlexural strength decrease .It gives percentage decrease of 8.12%. The increase in Flexural strength of steel fibre reinforced geo-polymer concrete was found to be increased as compared to geo-polymer concrete. The maximum Flexural strength is achieved with 0.8 % of mass of steel fibres by mass of geo-polymer concrete. It gives % strength increase of 16.40 %. Split tensile strength increases with increase in Molarity of NaOH up to 13M. It gives percentage increase of 9.70%. Beyond 13M Split tensile strength decrease .It gives percentage decrease of 4.61%. The increase in Split tensile strength of steel fibre reinforced geo-polymer concrete was found to be increased as compared to Geo-polymer concrete. The maximum Split tensile strength is achieved with 0.8 % of mass of steel fibres by mass of geo-polymer concrete. It gives % strength increase of 9.70 %

III. CONCLUSION ON LITERATURE RIVIEW

1. Industrial waste like fly ash & GGBS material can be used as a binder or a substitute of cement in concrete industry.
2. It can be used in multistory building & special types of structure as it produce high compressive strength concrete as well as high tensile strength.
3. The increase in Flexural strength of steel fibre reinforced geo-polymer concrete was found to be increased as compared to geo-polymer concrete. The maximum Flexural strength is achieved with 0.8 % of mass of steel fibres by mass of geo-polymer concrete. It gives % strength increase of 16.40 %.
4. Flexural strength increases with increase in Molarity of NaOH up to 13M. It gives percentage increase of 15.26%. Beyond 13MFlexural strength decrease .It gives percentage decrease of 8.12%.
5. The increase in Split tensile strength of steel fibre reinforced geo-polymer concrete was found to be increased as compared to Geo-polymer concrete. The maximum Split tensile strength is achieved with 0.8 % of mass of steel fibres by mass of geo-polymer concrete. It gives % strength increase of 9.70 %.
6. The Optimum compressive strength of GPC specimens (40% of GGBS replacement by fly ash) was found to be 58.50Mpa for 28 days after hot curing compare with30%, 40%, 50%, and 60% of GGBS.
7. With the addition of steel fibres in GPC diminished the workability of concrete mix.
8. The necessity of water substance is reduced because of the addition of alkaline solution which helps in increasing the compressive strength of concrete.
9. The compressive strength is increased by 2.25% (appx) when steel fibres are utilized.
10. GPC mix with added steel fibers is approximately 20% more than GPC control mix in compression behavior.
11. 82.3% of compressive strength was attained by control mix in only 7days and 70-73% of compressive strength was accomplished in just 7 days by ambient temperature curing.

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