DEVELOPMENT OF STEEL FIBRE REINFORCED GEOPOLYMER CONCRETE.

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ABSTRACT

Efforts will be earnestly in progress all over the world todevelopconstruction materials, which make least utility of quick decreasing common assets and help to decrease greenhouse gas emanationsGeopolymers are indicating extraordinary potential and a few scientists have basically analyzed the different perspectives of their feasibility as binder framework. Geopolymer concretes (GPCs) are new class of building materials that have risen as an elective to Ordinary Portland cement concrete (OPCC) and have the potential to change the building development industry. Significant research has been done on improvement of Geopolymer 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 fibrereinforcedgeopolymerconcrete.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.The deflections at diverse stages including service load and peak load stage were higher for GPC beams.

Keywords: Geopolymer, Steel Fibre, Flyash , GGBS, Load Deflection

I.INTRODUCTION

Davidovits proposed geopolymer cement and cement industry applies this innovation as an option for binder in portland concrete. The Carbondioxide emanation in the climate is around 80% to the air which is created by cement and aggregate industries. Geopolymerisation is a methodology in which the source material (rich in silicon and aluminum) responds with high alkaline solution for produce binding material. Investigation of common asset , utilization of high energy and outflow of green house gasses are connected with generation of ordinaryportland cement. GGBS, Flyash can be in part substituted for OPC. GPC's commitment to ecoefficiency of the worldwide economy is noteworthy. Alkaline cements acquired through alkaline initiation and geopolymerisation methodology and result of distinctive industries can be substituted for OPC. ALkali activator is utilized to initiate a reaction or arrangement of reaction with alkali cements which delivers alkali activated slag cement. The different natural advantages of alkali activated concrete is as per the following , industry by-product use , utilization of low energy and low discharge of green house gas. Since 1940's the standards of alkali activation of slag is known. Since 1960's these binders is connected in development industry in Ukraine. Mortars and cement has been alkali activated in colombia for research purpose including GGBS as just binder. Magnificent mechanical and strength properties have been attained to. The drawbacks distinguished is found to endure drying shrinkage. Slag microstructure, fineness, alkaliactivator, nature,concentration and curing condition will impact drying shrinkage in concrete. The shrinkage control of brittle matrices and mechanical performance have been enhanced just through the expansion of fibres. The fracture toughness gave by fiber bridging over on main crack plane before crack extension increments. The bridging action is controlled by debonding , sliding and pulling out of fibres. The bridging action of fiber controls the opening and development of cracks toward the start of macrocracking. The demand of energy for the crack to propogate is expanded. In low volumetric fiberportion , the straight elastic behaviour of matrix couldn't have the capacity to influence altogether. At the point when the durability , strength and toughness of material is increased , the post cracking behaviour can be changed. This paper reports the impact of incorporation of steel fiber on flexural properties of alkali actuated concrete at early age of time of curing. This paper concentrate on perspective to identify their execution and potential application as building material. Particularly in those system reinforced with fibres that oblige enhanced crack behaviour and stability.

II.LITERATURE REVIEW

Susan.A.Bernal.et.al (June 2013) focuses on gel nanostructure in alkali-activated binders based on slag and flyash and effects of accelerated carbonation. Binders formed through alkali-activation of slags and fly ashes, including ‘fly ash geopolymers’, provide appealing properties as binders for low-emissions concrete production. However, the changes in pH and pore solution chemistry induced during accelerated carbonation testing provide unrealistically low predictions of in-service carbonation resistance. The aluminosilicate gel remaining in alkali-activated slag system after accelerated carbonation is highly polymerised, consistent with a decalcification mechanism an, while fly ash-based binders mainly carbonate through precipitation of alkali salts (bicarbonates at elevated CO2 concentrations, or carbonates under natural exposure) from the pore solution, with little change in the binder gel identifiable by nuclear magnetic resonance spectroscopy. In activated fly ash/slag blends, two distinct gels (C–A–S–H and N–A–S–H) are formed; under accelerated carbonation, the N–A–S–H gel behaves comparably to fly ash-based systems, while the C–A–S–H gel is decalcified similarly to alkali-activated slag. This provides new scope for durability optimisation, and for developing appropriate testing methodologies.

Sanjay Kumar etal (September 2009) studied the use of GGBFS in altering the behaviour of flyash. The effect of varying amount (5% -50%) of GGBFS on the reaction kinetics has been studied using isothermal conduction calorimetry. It has been observed that at 27ºC the reaction is dominated by GGBFS but at 60ºC the reaction is due to combined interaction of flyash and GGBFS. The characteristics of reaction product of geopolymerisation are determined by X-ray analysis and SEM analysis. A-S-H and Ca-S-H are the main reaction products formed and its co-existence shows the interaction of flyash and GGBFS on geoploymerisation. From this study it was also concluded that geopolymerisation is along process of dissolution, precipitation, restructing, and polycondensation. Dissolution and precipitation occurs at early stages and polycondensation occurs at higher temperatures. At 27ºC, typical dissolution and precipitation of C-S-H takes place due to alkali activation of GGBFS. The increase in compressive strength due to the addition of slag may be due to the presence of A-S-H and Ca-S-H gel phases and compactness of microstructure.

C.K.Yipetal(October 2004) discussesthe coexistence of geopolymeric gel and calcium silicate hydrate the early stage of alkaline activation.Scanning electron microscopy was used to study the effects of the addition of ground granulated blast furnace slag (GGBFS) on the microstructure and mechanical properties of metakaolin(MK) based geopolymers. It was found that it is possible to have geopolymeric gel and calcium silicate hydrate (CSH) gel forming simultaneously within a single binder. The coexistence of these two phases is dependent on the alkalinity of the alkali activator and the MK/GGBFS mass ratio. It has been found that the formation of CSH gel together with the geopolymeric gel occurs only in a system at low alkalinity. In the presence of high concentrations of NaOH (N7.5 M), the geopolymeric gel is the predominant phase formed with small calcium precipitates scattered within the binder. The coexistence of the two phases is not observed unless a substantial amount of a reactive calcium source is present initially. It is thought that voids and pores within the geopolymeric binder become filled with the CSH gel. This helps to bridge the gaps between the different hydrated phases and unreacted particles; thereby resulting in the observed increase in mechanical strength for these binders.

P. De Silva. et.al (January 2007) discusses the early stage reaction kinetics of Metakaoline/sodium hydroxide/sodium silicate geopolymer system. The early strength development characteristics and associated mineral and micro structural phase development of mixtures containing varying ratios of SiO_2/Al_2O_3 cured at 40°C for 72 hours is studied. It has been observed that setting time is being controlled by the amount of alumina content. Setting time can be increased by increasing the amount of SiO_2/Al_2O_3 ratio in the initial mixture. The ratio of SiO_2/Al_2O_3 is found to be responsible for increase in strength at later stages. An increase in alumina content leads to reduction of strength accompanied by microstructures with increased amounts of Na-Al-Si containing massive grains. In general, inorganic geopolymer can be synthesized by alkali activation of SiO_2 and Al_2O_3. It was concluded from the studies that amount of available Si has dominant effect in controlling setting time. It was also shown that increasing the molar ratios up to 3.4-3.8 is highly responsible for strength development. The properties of geopolymer can be significantly altered by minor changes in Al and Si concentrations.

SravantiPuligillaetal (October 2012) discusses the microstructural development and hardening rate of flyash slag geopolymers. In this work , the activator solution used is the combination of potassium silicate and potassium hydroxide. Microstructural development was investigated using ultrasonic wave reflection (UWR), proctor penetration method, semi-adiabatic calorimetry and SEM imaging with EDS. Both UWR and Proctor penetration methods capture changes in hardening rate due to changes in the reaction mechanism. It was observed from the experiments that an increase in addition of slag increased the rate of hardening. It was also observed that calcium dissolving from the slagis important for both early and late age properties. Slow reaction rate and low strength development has been confirmed when flyash with low calcium content is activated with low concentration alkali and curved without any heat treatment.

Tiang Sing Ng etal (June 2013) studied the shear strength characteristics of fibre reinforced geopolymer concrete beams. Shear tests were conducted on five sets of 120mm × 250mm beams spanning 2250mm. The beams does not contain any stirrups. Instead the beam is reinforced by hooked and straight steel fibre of various dosages which vary between 0% - 1.5%. The results showed that the shear strength asa well as the crack behaviour improved on addition of fibres. Also, 100mm×100mm×500mm beams and 100mm×200mm cylinder were cast to determine the mechanical properties. The results of the test were compared with the fib Model Code 2010 alternative model for shear strength of steel-fibre reinforced concrete in combination with the variable engagement model for the determination of the tensile strength of steel-fibre-reinforced concrete. It was concluded from the studies that the beams without FRP, arching action is important in determining the failure load and failure mode. Ultimate strength and cracking load increased with increase in fibre volume

III. EXPERIMENTAL INVESTIGATION

3.1. Materials used

The GPC was acquired by blending distinctive mixes of Ground Granulated blast Furnace Slag (GGBS), Fly Ash (FA), fine aggregates, coarse aggregates and Alkaline activator solution(AAS). FA fitting in with grade 1 of IS 3812 and GGBS from Andhra cements, Vishakhapatnam conforming to IS 12089 were utilized. Stream sand available in Chennai was utilized as fine totals. They were tested according to IS 2386. In this investigation, generally accessible blue granite crushed stone aggregates of maximum size 12mm and down was utilized and characterization tests were done according to IS 2386.The properties of the materials utilized are indicated as a part of Tables 1. potable water was utilized for the GPC and distilledwater was utilized for the RGPCs.The alkaline activator solution (AAS) used in GPC mixes was a combination of sodium silicate solution (SiO2/Na2O=2.2), sodium hydroxide pellets and distilled water. The part of AAS is to break down Si and Al present in the reactive portion of source materials, for example, FA furthermore GGBS and give a high alkaline liquid medium for condensation polymerization reaction. The sodium hydroxide was taken as form of flakes of 3mm in size. The sodium hydroxide (NaOH) arrangement with obliged concentration was arranged by dissolving the processed measure of sodium hydroxide flakes in distilled water. The NaOH solution and sodium silicate solution were prepared independently and mixed at the time of casting. Since lot of heat is created when sodium hydroxide chips respond with water, the sodium hydroxide arrangement was prepared a day prior to casting. It ought to be noted here that it is crucial to attain to the desired level of workability of the GPC concrete. Notwithstanding, overabundance water can bring about development of pore system, which could be the source of low quality and low toughness.Experimental work is designed to study the effect of steel fibres on mechanical and elastic properties on geopolymer concrete. The materials used for making fly ash geopolymer concrete composite specimens are low-calcium fly ash, course and fine aggregates, steel fibres, alkaline solution, and water.

3.1.1 Fly Ash

Fly ash is the residue from the combustion of pulverized coal collected by mechanical or electrostatic separators from the flue gases of thermal power plants. The spherical shape of particle improves the flow ability and reduces the water demand. In this experimental work, the fly ash used is obtained from the silos of Ennore Thermal Power Station, Chennai, India, which is of low calcium, Class F. Low calcium fly ash makes substantial contributions to the workability, chemical resistance, and reduction in thermal cracking. Table 1 shows the chemical composition.

Table 1 : Chemical Composition of Fly Ash

Compound	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	TiO_2	Mn_2O_3	SO_3	P_2O_5
Fly Ash	49.45	29.61	10.72	3.47	1.3	0.31	0.54	1.76	0.17	0.27	0.53

3.1.2 Ground Granulated Blast Furnace Slag

GGBS is a by product from Iron smelting Industry, Chennai. Table 2 describes the composition of GGBS.

Table 2 : Chemical Composition of GGBS

Compound	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	TiO_2	Mn_2O_3	SO_3
GGBS	33.45	13.46	0.31	41.7	5.99	0.16	0.29	0.84	0.40	2.74

3.1.3 Sodium Hydroxide (NaOH)

The most common alkaline activator used in geopolymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate. The type and concentration of alkali solution affect the dissolution of fly ash. Leaching of Al^{3+} and Si^{4+} ions are generally high with sodium hydroxide solution compared to potassium hydroxide solution. Alkali concentration is a significant factor for controlling the leaching of alumina and silica from fly ash particles, geopolymerization process and mechanical properties of hardened geopolymer. Duchesneetal confirmed that in presence of NaOH in the alkaline activating solution, the reaction takes place more rapidly and the gel is less smooth.

3.1.4 Sodium Silicate Solution (Na_2SiO_3)

Sodium silicate is the common name for a compound sodium metasilicate, Na_2SiO_3, also known as water glass or liquid glass. It is available in both aqueous solution and solid form and is used in cements, passive fire protection, refractories, textile and lumber processing, and automobiles. Sodium carbonate and silicon dioxide react in molten state to form sodium silicate as well as carbon dioxide.

3.1.5 Alkaline Solution

Sodium hydroxide (NaOH) in the form of flakes and sodium silicate are used as alkaline activators to give a good binding solution for the geopolymeric mix.The alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NaOH) and sodium silicate as activators. Sodium silicate solution was purchased from a local supplier in bulk. The sodium hydroxide in flakes or pellets was purchased from a local supplier in bulk.

- Alkaline liquid is prepared by mixing sodium silicate solution and sodium hydroxide solution with proper proportion.
- Sodium-based solutions were selected because they were cheaper than potassium based solutions.
- The sodium hydroxide solids were a commercial grade in pellets form (3 mm).

3.1.6 Aggregates

Locally available river sand sieved through 4.75mm is used as fine aggregates and crushed stones of nominal size 10mm coarse aggregates is used.

3.1.7 Steel Fibres

Use of crimped steel fibres of aspect ratio (a/d) 60 is used.For the geopolymer mix we have used crimped stainless steel fibres and crimpes mild steel fibres. The use of fibres in concrete has the property to resisitance against cracking and crack propogation. The fibre composite pronounced post cracking ductility which is unheard of in ordinary concrete. The transformation from a brittle to a ductile type of material would increase substantially the energy absorption characteristics of the fibre composite and its ability to withstand repeatedly applied shock or impact loading. These fibres are short, discrete lengths having an aspect ratio in the range of 20-100, with any cross section that are sufficiently small to be randomly dispersed in an unhardened concrete mixture using usual mixing procedures.

3.2 Mix Proportion of GeopolymerMix

Fly ash, GGBS, coarse and fine aggregate and steel fibres are mixed thoroughly in a dry state and then alkaline solution is added to make the mix wet until it gains homogeneous state. Mix proportion and quantity of fibre content in each mix is explained below in table 3.

Table 3 :Geopolymer Mix Proportion

Mix	Fly Ash (kg)	GGBS (kg)	C.A. (kg)	F.A. (kg)	SH (kg)	SS (kg)	CSS (kg)	CMS (kg)	Water (kg)
CM	25.85	25.85	141.35	80.553	3	6	--------	--------	22.2
GP-1	25.85	25.85	141.35	80.553	3	6	7.471	--------	22.2
GP-2	25.85	25.85	141.35	80.553	3	6	--------	7.471	22.2

Table 4 : Mix Details

MATERIALS	**MIX 1**
MOLARITY (NaOH)	3.5M
NaoH/Na_2SiO_3 (Kg/m3)	1:2
FLY ASH (Kg/m3)	203.5
GGBS (Kg/m3)	203.5
Sodium hydroxide (Kg/m3)	23.62
Sodium silicate(Kg/m3)	47.24
Water (Kg/m3)	174.8
F.A (Kg/m3)	634.2
C.A (Kg/m3)	1112.9
DENSITY (Kg/m3)	2600

3.3 Collection of By Products

The materials used for the study like fly ash (Thermal power plant, Ennore); GGBS (Iron smelting industries, Chennai) ; fibres and alkaline solution (Local suppliers, Chennai).

3.4 Preparation of Geopolymer

3.5M molarity geopolymer are produced with alkali activator ratios of 1:2 and mixes for GP concrete with the following combinations are given :

- (Fly ash – 50%) + (GGBS -50 %) – Control mix
- (50 % Fly ash + 50 % GGBS) + (0.75% Crimped stainless steel fibres)
- (50% Fly ash + 50 % GGBS) + (0.75% Crimped mild steel fibres)

The mass of NaOHflates was taken depending on the concentration of the solution expressed in terms of molar, M. To get desired alkaline solution the sodium hydroxide solution which is prepared one day before is mixed with sodium silicate at the time geopolymer concrete preparation

IV.TEST SPECIMENS AND TESTING

4.1 Preparation of Specimens

Before casting, the inward walls of moulds were covered with greasing up oil to avoid adhesion with the solidifying concrete. GPC were mixed in a tilting drum mixer machine of 350kg limit for around 5-8 minutes. The concrete was put in the shape in three layers of equivalent thickness and every layer was vibrated until the concrete was completely compacted. Three no's of 100mm cubes were casted to focus the 28 day compressive strength.specimens were demoulded after 24 hrs.The split tension test were conducted on cylinder specimen after 28 days. The flexure test conducted on beam specimens showed higher results because of the addition of steel fibres and the high bondage strength. Table 4 briefly explains the test analysis values.

V. TEST RESULTS AND DISCUSSIONS:

Table 5 : Test Results on Compressive Strength.

Mix	Compressive Strength, MPa			SplitTensile Strength, MPa (28 days)	Flexure Strength Test, MPa (28 days)
	3rd day	7th day	28th day		
GPCM	21.21	32.37	44.16	3.372	6.61
GPCS	34.61	37.21	52.164	5.317	8.14
GPCMS	32.15	38.313	53.13	5.91	8.19

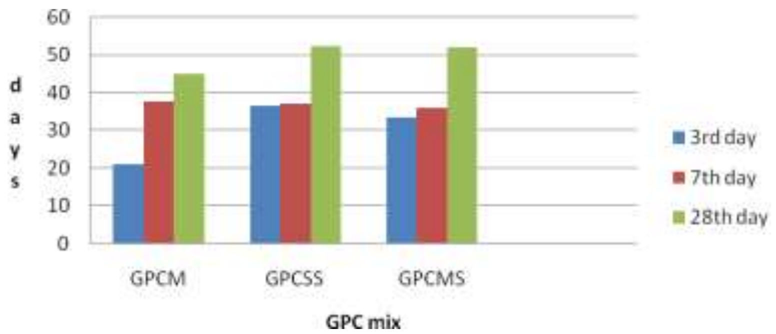
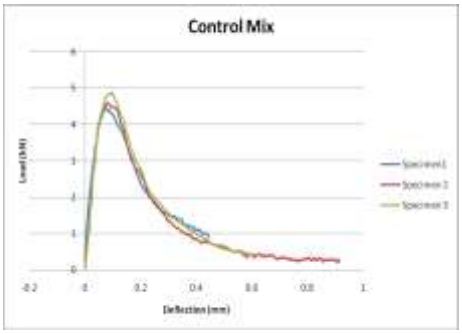
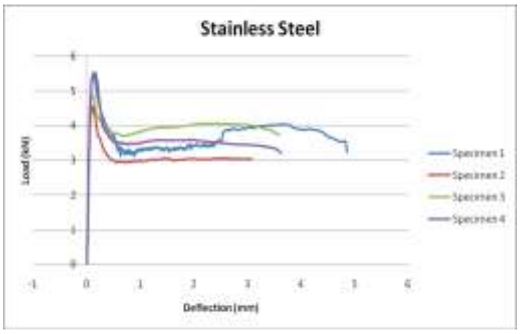


Chart 1 : Plot Between Geopolymer Mixes And Duration (Days).

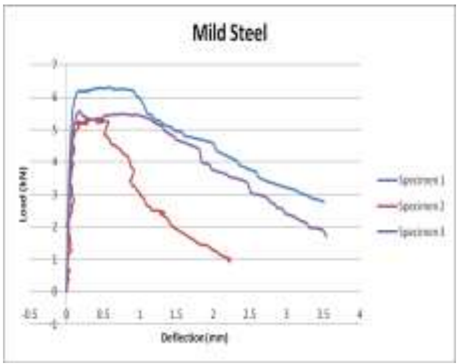
5.1 Load-Deflection Behavior

As the load was applied on the notched beam specimen (100*100*500mm) slowly no cracks were formed until the peak load was attained. A crack started to propogate at the end of the notched part faster in the ligament when the load reached its peak value. Failure started to propogate by opening a single crack in the geopolymer concrete specimens. The typical load–deflection diagrams of GPC concrete specimens are given. It is seen from these figures that the peak load of geopolymer concrete specimen was higher similar to its compressive strength. Figure 1: Load deflection curves for each batch





a)Load Deflection Curve For Control Mix **b) Load Deflection Curve For Steel Fibres Mix**



c) Load Deflection Curve for Steel Fibres Mix

5.2 Curing of Geopolymer Concrete

The Geopolymer samples were cured under ambient temperature. Water curing is not required. Geopolymer concrete attains its full strength only after 28 days.

VI. RESULTS AND DISCUSSIONS

Table demonstrates the compressive strength developed by different mixes at 3, 7 and 28 days of age. It might be seen that the mixes accomplished the normal level of 28 day strength. In spite of the fact that all in all it is required for geopolymer concrete to achieve strength at a speedier rate, in the present mixes. Consequently it can be normal there would be some unreacted flyash in the mix which could credit to further strength pick up with age. However the present goal was to attain to a workable mix with strength of around 30 MPa at 28 days with no extraordinary curing necessities, since the vast majority of the concrete utilized as a part of India are in this evaluation and are insitu made. Alkali activated slag based geopolymer concrete with ambient air curing with a compressive strength at 28 days in abundance of 30 MPa was attained to for all the mixes. From the perception all the mixes has sufficient retention period and it can be embraced for making of GGBS based geopolymer concrete. The most essential parameter of workability and slump maintenance for sufficient time was attained to in this mixes.

VII. CONCLUSION

Based on the experimental work the following conclusions are drawn

- There is no need of exposing geopolymer concrete to higher temperature to achieve most extreme strength
- With the addition of steel fibres in GPC diminished the workability of concrete mix.
- The necessity of water substance is reduced because of the addition of alkaline solution which helps in increasing the compressive strength of concrete.
- The compressive strength is increased by 2.25% (appx) when steel fibres are utilized .
- GPC mix with added steel fibres are approximately 20% more than GPC control mix in compression behaviour.
- 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 behaviour.
- 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 propogation in concrete and can achieve higher peak value.

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