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A Study on Mechanical Properties of High Strength Geopolymer Concrete

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ABSTRACT

Finding means of utilizing waste products is very important in field of research at this moment. Efforts are urgently underway all over the world to develop environment friendly construction materials which help to reduce greenhouse gas emissions from Cement industries. In this connection, Geopolymer concretes (GPCs) are new class of building materials that have emerged as an alternative to Ordinary Portland Cement Concrete (OPCC) and possess the potential to revolutionize the building construction industry.Researchers have critically examined the various aspects of their viability as binder system. GPCs were produced from fly ash mixing with alkaline activators of sodium hydroxide and also sodium silicate solutions of some molar concentration. High range water reducing admixtures are used to develop sufficient workability. The objective of the present work is to study the effect of SCMs in fly ash based Geopolymer concrete at ambient room temperature curing.

The present work deals with a development of Ground Granulated blast furnace slag (GGBS) based GPC. Trial mixes are carried out and results are compared. Workability properties of fresh state are measured and flexural strength properties are assessed at 7 and 28 days.The Reinforced GPC and OPC beams were designed considering a balanced section for the expected characteristic strength. Beams of length 1.15 m are laid to have a clear span of a one-meter length beam and a cross section of 100*150 mm is chosen. Flexural behaviours of reinforced beams are assessed in UTM using 0.01 mm least count deflectometers. Load-Deflection characteristics are obtained and study has been carried out simultaneously.

Keywords: GGBS, Silica fume, Superplasticizer, Compressive strength, Split Tensile strength, Flexural Strength.

I. Introduction

Concrete is generally utilized as construction material. Portland cement is the principle part utilized for making concrete. The concrete business is in charge of CO_2 discharge, in light of the fact that the creation of one ton Portland bond frees around one ton CO_2 into air which is not ecofriendly. Davidovits begat the term ‘Geopolymer’ to typify these binders.

The Geopolymer innovation expresses that an option cover can substitute the Portland cement in concrete industry. Fly ash, silica fume, ground granulated blast furnace slag, rice husk ash and metakaolin can be utilized as an option fastener rather than concrete. Geopolymer cement is a high quality and lightweight inorganic polymer solid that can be utilized as a part of place of ordinary cement. It is made by blending diverse mixes of solidifying materials, for example, silica fume, rice husk ash, metakaolin, ground granulated blast furnace slag (GGBS) and Fly ash alongside fine aggregate, coarse aggregate and alkaline solution. Geopolymer concrete has picked up its fame as the interest for a green and maintainable building material.

Around 75%-80% of the mass is made of coarse and fine aggregates. Nowadays the advancement of option materials to Portland cement concrete has turned out to be vital. The outline of Geopolymer cement gives an option answer for creation of ordinary cement. Normally, Geopolymers are blended from two-section blend, comprising of a basic arrangement (regularly solvent silicate) and strong aluminosilicate materials.

Geopolymers are delivered by buildup of tetrahedral aluminosilicate units, with alkali metal particles proportionate to the charge related of tetrahedral Al. The Geopolymer cement is made by initiating source materials with soluble fluids. The fly ash and GGBS are the general source materials used to deliver the Geopolymer concrete as 1.6 ton of crude materials are required to create one ton of cement and the term to shape the limestone is any longer than the rate at which people utilize it. To create ecofriendly concrete the cement is supplanted with fly ash, GGBS and Sodium hydroxide and sodium silicate are utilized as soluble arrangements. Geopolymerization is the way toward joining little atoms known as oligomers into a covalently bonded network. High quality geopolymer cement is a solid blend which has high toughness and high quality when contrasted with ordinary cement. This concrete contains at least one cementitious material, for example, fly ash, silica fume or ground granulated blast furnace slag as ordinarily a superplasticizer. The term high quality is to some degree self-important on the grounds that the fundamental fates of this solid is that its fixings and extents are particularly picked in order to have especially fitting properties for the normal utilization of structure, for example, high quality and low porousness.

Henceforth high-quality cement is not an exceptional kind of concrete, it includes same materials as that of the ordinary cement concrete. The utilization of some mineral and substance admixtures like silica smoke and superplasticiser improves the quality, durability and workability qualities to a high degree. The utilization of high-quality cement in development improves the administration life of the structure and the structure endures less harm which would lessen general cost.

Because of the high early quality Geopolymer Concrete should be successfully utilized as a part of the precast enterprises, so that immense creation is conceivable in brief span and the breakage amid transportation might likewise be limited. The Geopolymer Concrete might be successfully utilized for the shaft segment intersection of a fortified concrete structure.Geopolymer Concrete might likewise be utilized as a part of the infrastructure works. Strengthened geopolymer cement ought to be used for composite materials in development of streets, extensions, building and other common frameworks. The interest for the material is required to increment in future attributable to ascent of framework needs in many creating and mechanical nations. An experimentation procedure, combined with involvement and judgment, was utilized to build up the high-quality GPCs. The present work manages the improvement of

(i) GGBS based GPC of high strength
(ii) GGBS-GPC with sodium hydroxide of low molarity and sodium silicate and
(iii) Ambient curing.

The fine and coarse aggregates are the same as utilized as a part of ordinary cement. Standard and solid strategies for blend outline of geopolymer cements are still in the advancement organize.

II.LITERATURE REVIEW

M. Al-Majidi, A. Lampropoulos, A. Cundy(2016)[9]Their study investigated the fresh and hardened properties of slag and fly ash based geopolymer mortar. Setting time and workability tests were conducted to evaluate the characteristics of fresh geopolymer mortars while compressive strength tests were conducted for the mechanical performance of the hardened mortar. The results are summarized as Relative slump and setting time were increased as the initial water and superplasticizer contents were increased, while at the same time the compressive strength were reduced. Alkaline activator (potassium silicate) content was found to be a crucial parameter for the compressive strength as High Potassium silicate content (up to 12% of binder weight) was found to improve geopolymerization process leading to a more compact structure and strength development. The accelerated geopolymerization reaction is attributed to the presence of slag in the mix. As the slag to binder ratio was increased from 15% to 50%, the 28 days mean compressive strength was increased from 22 MPa to 49 MPa.

Mr. Ahmed Mohmed Ahmed Blash Dr. T.V. S. Vara Lakshmi(2016) [13]In their study, the physical properties of Ground Granulated Blast furnace Slag (GGBS) in geopolymer concrete were discussed. Compressive strength for ggbs cubes and geopolymer cubes and **Permeability test,** ISAT (Initial surface absorption test) are been conducted out. The incorporation of GGBS in the Geopolymer concrete mixes resulted in finer pore structure thus produce low permeability concrete. The longer curing durations reduce permeability and result in finer pore structure. They also observed that high performance concrete may be used in term of high strength and durability is significant to special structured such as marine structures.

C. Sreenivasulu, A. Ramakrishnaiah and J. Guru Jawahar(2015) [2] investigated the study of mechanical properties of geopolymer concrete (GPC) using granite slurry (GS) as sand replacement. GS has been replaced at different replacement levels (0%, 20%, 40% and 60%). Fly ash and ground granulated blast furnace slag (GGBS) were used at 50:50 ratio as geopolymer binders. Combination of sodium hydroxide (8M) and sodium silicate solution is used as an alkaline activator. Compressive strength and splitting tensile strength properties were studied after 7, 28 and 90 days of curing at ambient room temperature. Results reported as the mechanical properties were increased with the increasing replacement level of GS up to 40% and decreasing trend of these properties were observed at 60% replacement level and concluded that optimum replacement level (40%) of GS can be used in place of sand and can save the natural resources.

Seethalakshmi T, Sakthieswaran N (2015)[23]studies carried out on development of strength for various grades of Geopolymer concrete with varying Molarity.Different molarities of sodium hydroxide solution (8M,10M and 12M) are taken to prepare different mixtures and specimens are oven cured at 75ºC for first 24 hours and tested for mechanical properties. Results reported as GPC mix formulations with compressive strength ranging from 12.33 to 82.10MPa have been developed. They summarized that the combination of fly ash and ground granulated furnace slag (GGBS) can be used for development of Geopolymer concrete.

Maneeshkumar C S et al.(2015)[11]The GGBS and Fly ash based Geopolymer concrete gained strength with earlier time period at ambient temperature. Molarity of Sodium Hydroxide 10 M is taken to prepare different mixes. The specimen are tested at the age of 7, 14 and 28 days, the test includes compressive strength, split tensile strength and flexure strength. The necessity of heat curing of concrete was eliminated by incorporating GGBS and fly ash in a concrete mix. The strength of Geopolymer concrete was increased with increased percentage of GGBS in a mix. It was observed that the mix Id GC1 gave maximum compressive strength of 74.67Mpa. GGBS and Fly ash-based Geopolymer concrete has excellent compressive strength and is suitable for structural applications.

M.K.Thangamani Bindhu, Dr.D.S.Ramachandra Murthy(2015)[10] The load deflection characteristics for the reinforced cement concrete beams and reinforced geopolymer concrete beams are investigated.The cracking load, The ultimate load carrying capacity of reinforced geopolymer concrete beams is higher when compared to reinforced cement concrete beams.The crack width under load is within the permissible limit for the reinforced geopolymer concrete beams and reinforced cement concrete beams and for 30% replacement of Recycled Coarse Aggregates in normal concrete and GPC was above than the permissible limit. The experimental Values are higher when compared with theoretical values for all the beams almost similar for 0% and 10% replacement of RCA.

III.EXPERIMENTAL PROGRAMME

Cement

The properties of the cement to be determined are Fineness, Consistency, Initial & Final Setting time, Soundness, Compressive strength and Specific Gravity. These tests ought to affirm to Indian standards code IS12269.

Fineness of cement

The fineness of cement is a measure of the size of cement. It is necessary to check the best possible pounding of concrete; it has an impact on the conduct of bond.

Normal consistency of cement:

Normal consistency is characterized as that rate of water required to create a concrete glue of standard consistency. Vicat device is utilized for discovering consistency of cement. The standard consistency of common Portland bond is 30 to 35% by weight of concrete

Ground Granulated Blast furnace Slag (GGBS)

Ground Granulated Blast Furnace slag (GGBS) is the granular material shaped when liquid iron blast furnace slag (a by-result of iron and steel making) is quickly chilled (extinguished) by inundation in water. It is a granular item, very Cementitious in nature and, ground to concrete fineness, hydrates like Portland bond. Ground granulated impact heater slag (GGBS) is a by-item from the impact heaters while making iron. GGBS is one of the "greenest" of development materials and in addition the natural advantage of using a by-item, GGBS replaces something that is created by an exceptionally vitality serious process. By correlation with Portland cement, fabricate of GGBS requires not as much as a fifth the vitality and creates not as much as a fifteenth of the carbon dioxide discharges. GGBS which is locally accessible in gadivemula, close to Kurnool area from JSW cement production line.

Silica fume

Silica fume, otherwise called microsilica, (is an undefined (non-crystalline) polymorph of silicon dioxide. It is a ultrafine powder gathered as a by-result of the silicon and ferrosilicon composite creation and comprises of round particles with a normal molecule distance across of 150 nm. The principle field of utilization is as pozzolanic material for elite cement concrete. Silica fume is added to Portland cement to enhance its properties, specifically its compressive quality, bond quality, and abrasion resistance.

Superplasticizers:

These are later and more viable kind of water diminishing admixtures otherwise called high range water reducer. The primary advantages of super plasticizers can be condensed as takes after: Increased smoothness: Flowing Self-leveling Self-compacting solid Penetration and compaction round thick support

Aggregates

The physical properties of fine and coarse aggregates have much impact on quality of cement in new and solidified state. Tests for physical properties like bulk density, specific gravity, water absorption, fineness modulus, grading of coarse aggregate are studied briefly for the purpose of mix design and to determine the amounts of materials.

Fine aggregates

Fine aggregate was secured from nearby crusher situated in Kurnool. The test comes about for physical properties of fine totals have been directed according to IS 383-1970 and are exhibited in table 5. The test comes about for research centre examination for physical properties of fine aggregates are introduced.

Experimental Test Methods

I. Compressive Strength Test

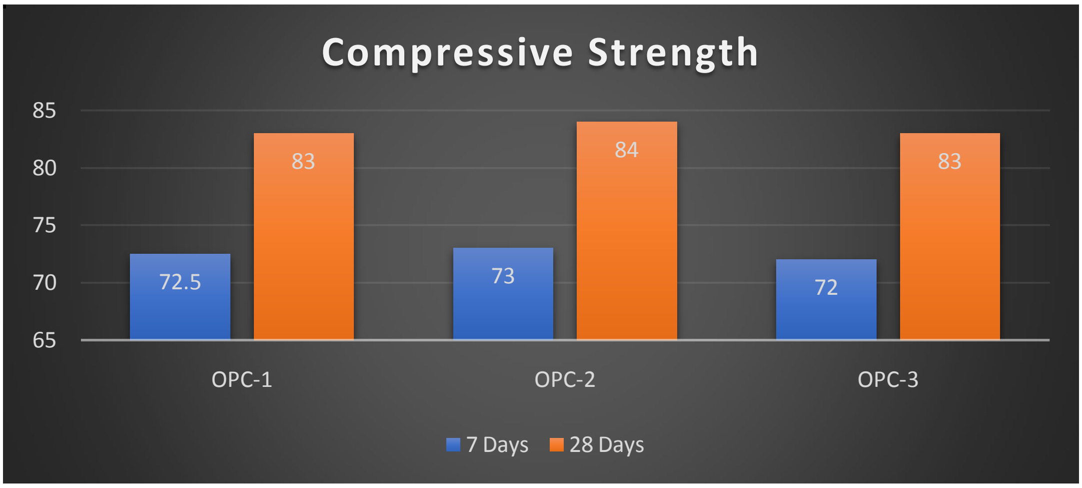
Mix A-OPC

(a) 7-days compressive strength

S.No	Specimen Identification (cubes 100X100X100 mm)	Weight of specimen (kg)	Load @ failure (KN)	Compressive strength (MPa)	Mean Compressive strength(MPa)
1.	OPC-1	2.664	725	72.5	72.5
2.	OPC-2	2.646	730	73.0	
3.	OPC-3	2.722	720	72.0	

(b) 28-days compressive strength

S.No	Specimen Identification (cubes 100X100X100 mm)	Weight of specimen (kg)	Load @ failure (KN)	Compressive strength (MPa)	Mean Compressive strength (MPa)
1.	OPC-1	2.676	830	83.0	83.5
2.	OPC-2	2.695	840	84.0	
3.	OPC-3	2.715	830	83.0	



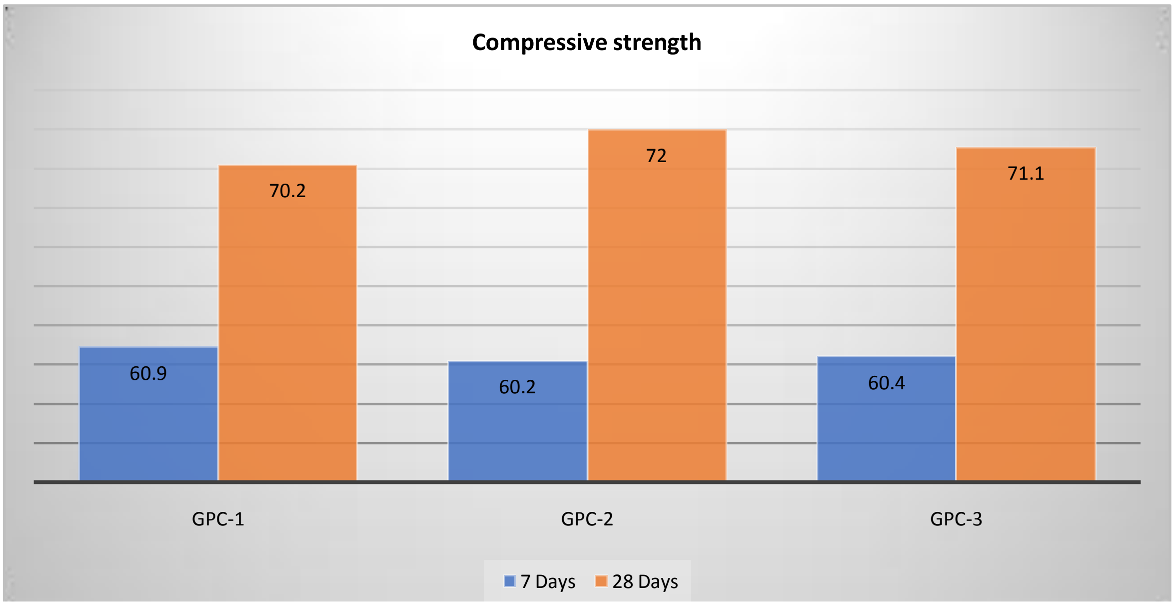
Mix B-GPC

(a) 7-days compressive strength

S.No	Specimen Identification (cubes 150X150X150 mm)	Weight of specimen (kg)	Load @ failure (KN)	Compressive strength (MPa)	Mean Compressive strength(MPa)
1.	GPC-1	8.837	1370	60.9	60.5
2.	GPC-2	8.562	1355	60.2	
3.	GPC-3	8.871	1360	60.4	

28-days compressive strength

S.No	Specimen Identification (cubes 150X150X150 mm)	Weight of specimen (kg)	Load @ failure (KN)	Compressive strength (MPa)	Mean Compressive strength(MPa)
1.	GPC-1	9.126	1580	70.2	71.1
2.	GPC-2	9.042	1620	72.0	
3.	GPC-3	9.071	1600	71.1	



II. Split tensile tests

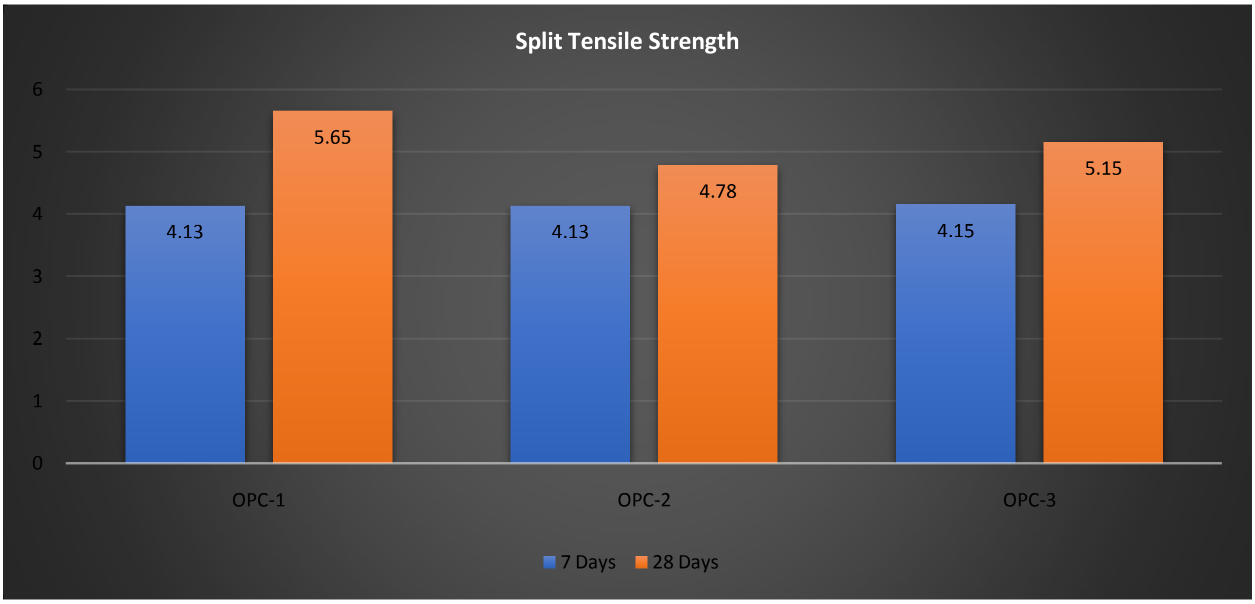
Mix A-OPC

(a): 7-days split tensile strength

S.No	Specimen Identification (cylinders 100X200 mm)	Weight of specimen (kg)	Load @ failure (KN)	Split tensile strength (MPa)	Mean Split tensile strength (MPa)
1.	OPC-1	4.150	130	4.13	4.14
2.	OPC-2	4.250	130	4.13	
3.	OPC-3	4.170	135	4.15	

(b) 28-days split tensile strength

S.No	Specimen Identification (cylinders 100X200 mm)	Load @ failure (KN)	Split tensile strength (MPa)	Mean Split tensile strength (MPa)
1.	OPC-1	175	5.65	5.19
2.	OPC-2	150	4.78	
3.	OPC-3	162	5.15	



Mix B-GPC

(a): 7-days split tensile strength

S.No	Specimen Identification (cylinders 150X300 mm)	Weight of specimen (kg)	Load @ failure (KN)	Split tensile strength (MPa)	Mean Split tensile strength (MPa)
1.	GPC-1	13.322	225	3.18	3.09
2.	GPC-2	13.530	200	3.00	
3.	GPC-3	13.500	215	3.15	

(b) 28-days split tensile strength

S.No	Specimen Identification (cylinders 150X300 mm)	Load @ failure (KN)	Split tensile strength (MPa)	Mean Split tensile strength (Mpa)
1.	GPC-1	275	3.89	4.06
2.	GPC-2	300	4.24	
3.	GPC-3	310	4.25	

II. Flexural Strength tests

Mix A-OPC

(a): 7-days split tensile strength

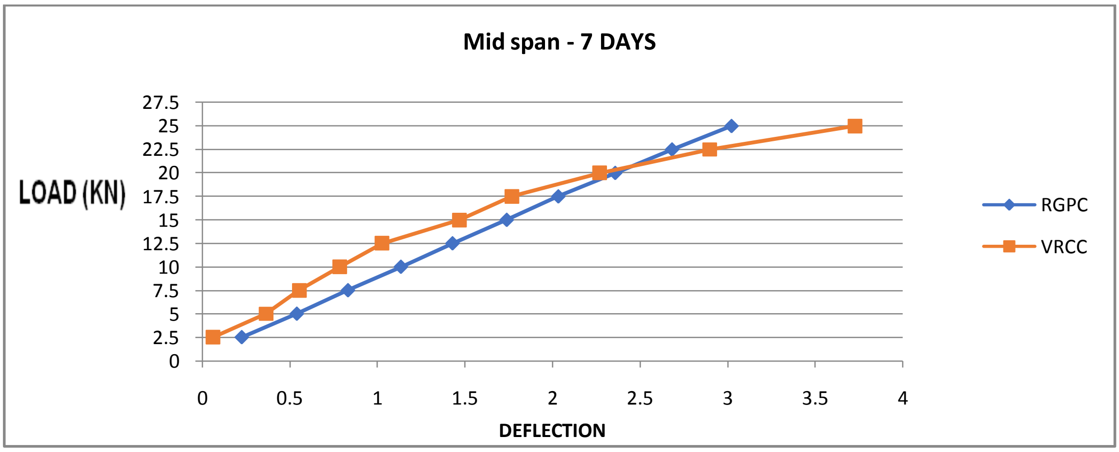


Figure 3: Load Deflection Curves At 7 Days @Mid Span

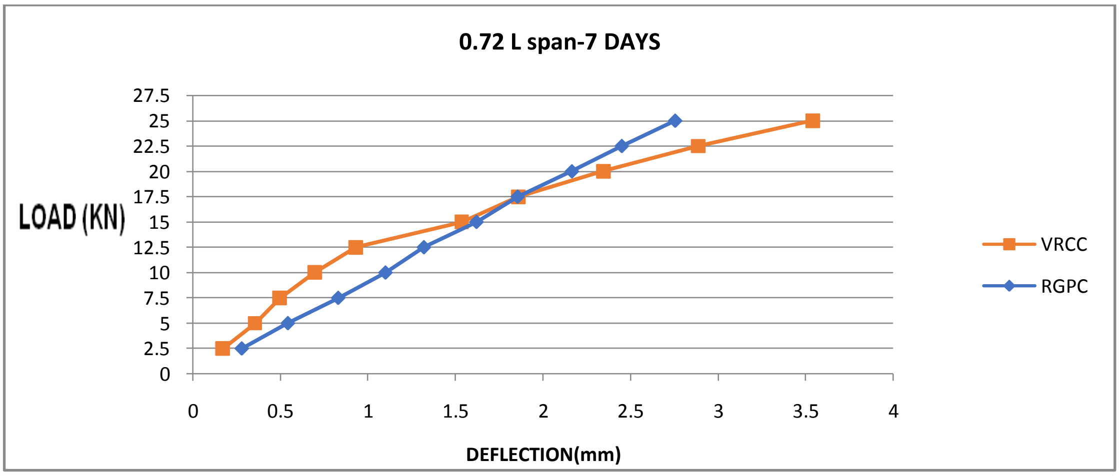


Figure 4: Load Deflection Curves At 7 Days @ 0.72 L

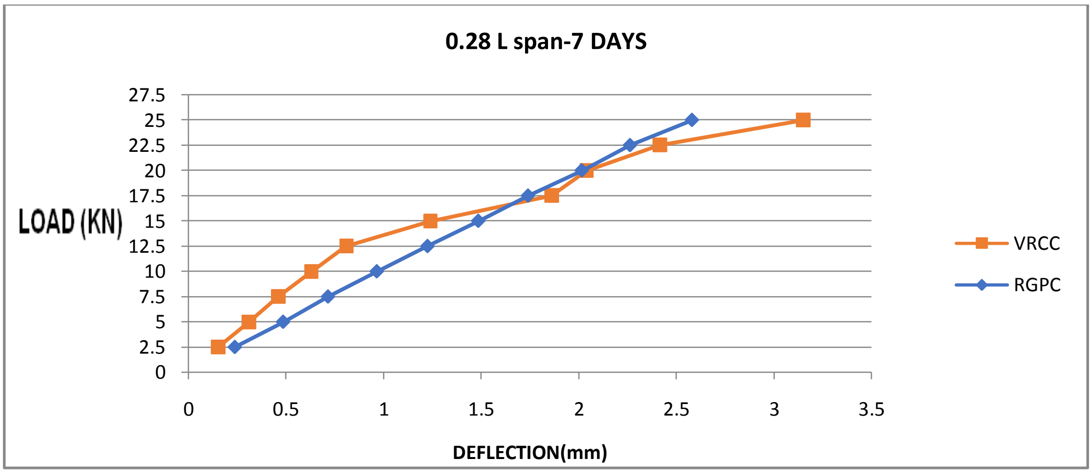


Figure 5: Load Deflection Curves At 7 Days @ 0.28 L

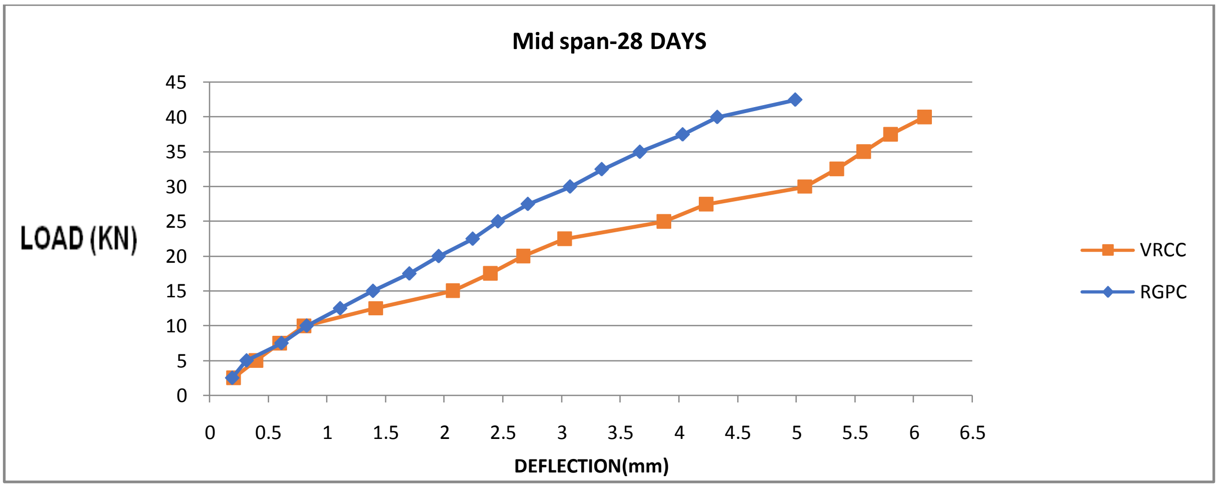


Figure 6: Load Deflection Curves At 28 Days @Mid Span

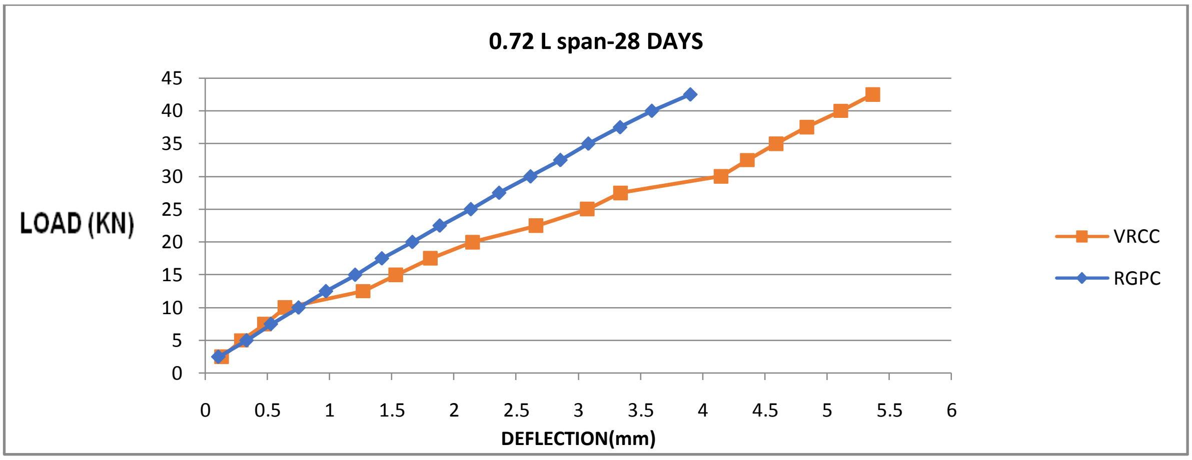


Figure 7: Load Deflection Curves At 28 Days @0.72 L

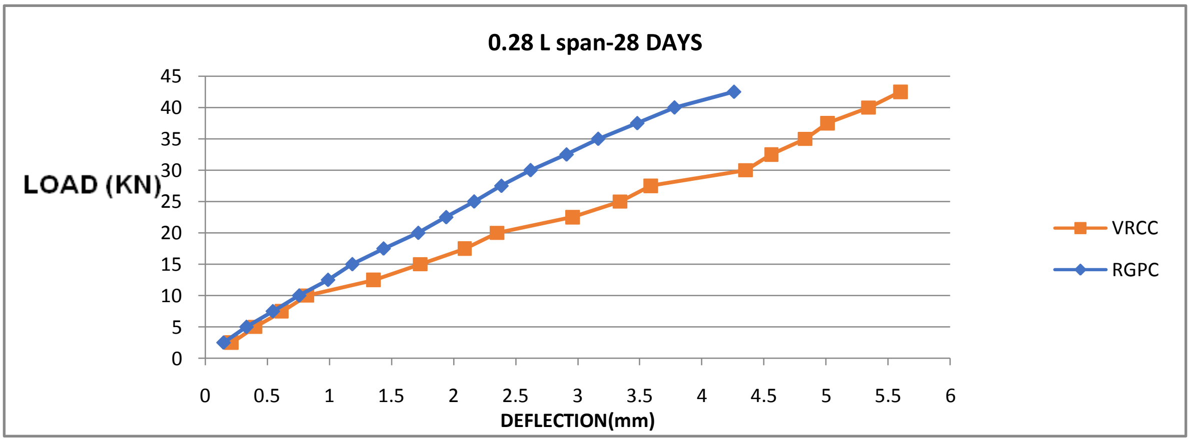


Figure 8: Load Deflection Curves At 28 Days @ 0.28l

IV.CONCLUSION

- Geopolymer concrete shows significant potential to be a material for the future; because it is environmentally friendly and possesses excellent mechanical properties.
- GPCs offer generally better protection to embedded steel from corrosion as compared to CC
- The ductility factor of GPCC beams could be marginally less than CC beams indicating higher stiffness of GPCC beams.
- Workability characteristics of GPC depend on mixing time of GPC that is workability of GPC is directly proportional to the mi xing time.

- Compressive Strength and Split Tensile Strengths at 7 days and 28 days are higher in OPC, when compared with plain GPC and OPC concrete.
- It is observed that deflections are smaller in RGPC when compared with RCC beams from the load vs deflection graphs.
- Diagonal cracks in flexure and shear are observed to be smaller in magnitude in the RGPC beam, when compared to RCC beam.
- Beams are seen to fail at first by pulverizing of concrete in the pressure zone as the area is an over fortified.
- It is observed that the crack patterns for reinforced geopolymer beams are equally similar to those in CC beams.
- Useful suggestions on utilization of geopolymer solid innovation in down to earth applications, for example, precast concrete items and waste exemplification should be created in Indian context
- In light of lower interior vitality (very nearly 20% to 30 % less) and bring down CO_2 emission of elements of geopolymer based composites contrasted with those of routine Portland cements, the new composites can be thought to be more eco-accommodating and consequently their utility in useful applications should be produced and encouraged.

References

[1] **Aswathy Kurian, Mr. Binu M Issac, Mrs. Soumya Anand** An Experimental Study On Geopolymer Concrete With The Partial Replacement Of Coarse Aggregate With Laterite **ICSTM (**International Conferece on Science,Technology And Management)

[2] **C. Sreenivasulu, A. Ramakrishnaiah and J. Guru Jawahar** "Mechanical properties of geopolymer concrete using granite slurry as sand replacement" International Journal of Advances in Engineering & Technology, Apr., 2015. 83 Vol. 8, Issue 2, pp. 83-91

[3] **D. M. J. Sumajouw ,D. Hardjito S. E. Wallah B. V. Rangan** FlyAsh-Based Geopolymer Concrete: Study Of Slender Reinforced Columns Advances In Geopolymer Science & Technology J Mater Sci (2007) 42:3124–3130 DOI 10.1007/S10853-006-0523-8

[4] **D.V. Reddy J-B Edouard K. Sobhana A. Tipnis (2011)** Experimental Evaluation Of The Durability Of Fly Ash-Based Geopolymer Concrete In The Marine EnvironmentNinth LACCEI Latin American And Caribbean Conference (LACCEI'2011), Engineering For A Smart Planet, Innovation, Information Technology And Computational Tools For Sustainable Development, August 3-5, 2011, Medellín, Colombia.

[5] **Dr. I.R. MithanthayaDr. N. Bhavanishankar Rao**Effect of Glass Powder and GGBS on Strength of Fly Ash Based Geopolymer Concrete International Journal of Engineering Trends and Technology (IJETT) – Volume 19 Number 2 – Jan 2015 ISSN: 2231-5381.

[6] **Ganapati Naidu, A.S.S.N. Prasad, S. Adiseshu ,P.V.V.satayanaray** "A study on strength properties of Geopolymer Concrete with the addition of GGBS ",International Journal of Engineering Research and Development (IJERD),2012 ISSN: 2278-800, Page 19-28

[7] **Gaurang D. Bhavsar et.al**"workability properties of geopolymer concrete using accelerator and silica fume as an admixture"International Journal For Technological Research In Engineering Volume 1, Issue 8, April-2014

[8] **Gokulanatha Prasanna venkatesan Pazhani K.**C Effect of NaOH Concentration on Strength of GGBS and BRHA Based Geopolymer Concrete International Journal of Civil and Environmental Engineering, ISSN:1701-8285, Vol.35, Issue.2 1158 November 2013

[9] **M. Al-Majidi, A. Lampropoulos, A. Cundy** "Effect of Alkaline Activator, Water, Superplasticiser and Slag Contents on the Compressive Strength and Workability of Slag-Fly Ash Based Geopolymer Mortar Cured under Ambient Temperature"International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering Vol:10 No: 3, 2016

[10] M.K.ThangamanibindhuDr.D.S.Ramachandra Murthy Flexural Behaviour Of Reinforced Geopolymer Concrete Beams Partially Replaced With Recycled Coarse Aggregates International Journal of Civil Engineering and Technology (IJCIET) Volume 6, Issue 7, July (2015), pp. 12-21 Article Id: 20320150607003

[11] **Maneeshkumar C S et al**. An Experimental Investigation on GGBSandFlyash Based Geopolymer Concrete with Replacement of Sand by Quarry Dust. Int. Journal of Engineering Research and Applications www.ijera.com ISSN : 2248-9622, Vol. 5, Issue 5, (Part -1) May 2015, pp.91-95

[12] **Maria Rajesh, Dr.C. Selvamony, Dr.T.R. Sethuraman,M.Shaju Pragash** Behaviour Of Low Calcium Flyash Based Geopolymer Concrete Structural Elements With Ggbs& Steel Fibre International Journal of Scientific Research Engineering & Technology (IJSRET) Volume 2 Issue 11 pp 782-789 February 2014 ISSN 2278 – 0882.

[13] **Mr. Ahmed Mohmed Ahmed Blash** Studies on the Physical Properties of Ground Granulated Blast- Furnace Slag Incorporating in Geopolymer Concrete International Journal of Engineering Research & Technology (IJERT)ISSN: 2278-0181 Vol. 5 Issue 02, February-2016

[14] **Mr. Bennet Jose Mathew, Mr. M Sudhakar, Dr. C Natarajan,** "Strength, Economic and Sustainability Characteristics of Coal Ash – GGBS Based Geopolymer Concrete", International Journal Of Computational Engineering Research (ijceronline),ISSN 2250-3005 Vol. 3 Issue. 1,page 207-212.

[15] **Nisha Khamar, Resmi V Kumar** Properties of Hybrid Fibre Reinforced Geopolymer Concrete under Ambient Curing International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064 Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438 Volume 4 Issue 8, August 2015 www.ijsr.net