AN EXPERIMENTAL INVESTIGATION ON CONFINED HYBRID GEO-POLYMER CONCRETE

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Abstract

Composite columns have been utilized in construction for a few decades. Where in concrete encased column construction steel have been the commonly used has confinement. However it has been expensive for low cost housing and steel is faced through problems like corrosion particularly while used in corrosive environment. Where Unplasticised Poly Vinyl Chloride (UPVC) tubes can be utilized for low cost housing because of their low self weight and economy. UPVC pipes are locally available for piping work; is future to be studied for its effectiveness can be utilized as columns. This form of columns is normally referred to as Concrete Filled UPVC Tube (CFUPVC).Where other different confinement materials like GFRP and Jute fiber have become a popular in retrofit technique, It has been compared with unconfined specimen. However, unconfined Geopolymer concrete (UGPC) exhibits much higher levels of brittleness compared to OPC concrete. Ductility of geopolymer concrete (GPC) can be increased by lateral confinement. Geopolymer concrete (GPC) without fibers and with fibers (GPCF) has been used to fill GPC in UPVC, GFRP and jute fiber specimens, The UPVC specimen had outer diameters of 160 mm, 110 mm and 90 mm and length of 300mm constant, all the specimens were subjected to axial compressive loads, therefore as to calculate the outcome of confinement on the axial load carrying capacity and the failure modes were discussed thoroughly. The results show superior performance by UPVC -GPC, GFRP-GPC as well as jute FRP-GPC confined specimens as compared to UGPC and flexural test was performed specimen had dimension of 110mm diameter and 600mm length. Results showed that Confined geopolymer concrete (CGPC) is effective in confining concrete, while in all cases fcc/fco>1. The Confined strength values increased between 1.26 to 3.39 times the unconfined strength values (UGPC). There is enormous potential of UPVC tubes for use in composite systems as illustrated by this research. The resultant is a cheap, more economical type of column for light weight construction. GFRP and Jute fiber GPC and GPCF demonstrated the same flexural behaviour while UPVC-GPCF attained even higher ultimate flexural load than the unconfined specimen. The study shows more preponderant potentiality of plastics as concrete confinement construction materials of future.

Keywords: *UPVC, Geopolymer Concrete, GFRP, Jute Fiber and Confined Specimen.*

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1. INTRODUCTION

Geopolymer cement is an innovative materials and the authentic choice to conventional Portland cement. Geopolymer is a type of inorganic polymer that can be composed at room temperature by utilizing industrial waste or by-products as source materials to compose a solid binder that looks like and performs as function to OPC. Instead, the base material such as fly ash, that is rich in silica (si) and aluminium (Al) is activated by alkaline solution to produce the binder. Where geopolymer paste binds the materials like coarse aggregates, fine aggregates and other un-reacted materials as one to compose the Geopolymer concrete (GPC).

Fly ash reacts with alkaline liquid comprising a coalescence of sodium silicate (NA2SIO3) solution and sodium hydroxide (NOAH) solution form binder. Ground-granulated blast-furnace slag (GGBS or GGBFS) is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. GGBS is comprise of silicates and aluminates of calcium and different bases often utilized as ingredient of Geopolymer Concrete. Slag once grind to less than 45 micron will contain a particular surface of around 400 to 600 m^2 /kg. GGBS has assuredly the same particle size as cement. GGBS which is mixed conventionally with Portland cement as low cost filler which improves concrete durability, density, workability and resistance to alkali-silica reaction. Glass and Steel fibers are without restraint and commercially available .These fibers are impervious to the majority of the chemicals and it would be cementations matrixes would break down first under destructive chemical attack.

The composite columns are awarding a lot of acceptance for seismic resistance in recent times. So as to obviate shear failure of RC column resulting in storey collapse of building, it is all-important to accomplish ductility of columns larger. Concrete filled tubular columns have been gradually more utilized in many modern structures, for example, dwelling houses, tall buildings. There has been important research conducted on the investigation of behaviour and performance of Concrete Filled Steel Tubes (CFST) under axial loading and combined axial and bending. The compressive behaviour of FRP-confined concrete has been studied extensively. Few authors tested to-collapse concrete columns wrapped using carbon and fiberglass sheets. Where as a little work has been done on concrete filled unplasticised poly vinyl chloride tube as columns. UPVC pipes are commercially available and tubes are corrosion resistant and are economical as compared to the steel and FRPs. The strength, ductility and energy absorption capacity of recent concrete columns may be increased by providing external confinement by using UPVC tubes. These tubes can be utilized as formwork during construction and thereafter as an integral part of the column. Plastics have exceptional properties that build these materials enticing for various structural applications. A number of these properties enclose high resistance to severe environmental attacks, electromagnetic transparency and high strength to weight ratios. Due to these properties, there is nice demand for structures like pile, poles, highway overhead signs and bridge substructures to be made from materials that are more durable in comparison to traditional materials and systems. The objectives are briefly summarized below:

1. Study the mechanical properties of the chosen concrete.
2. To investigate the confinement of geopolymer concrete.
3. To determine the effect of concrete strength, specimen diameter and height on the strength and ductility of the composite stub columns.
4. To determine the effectiveness of UPVC tube, FRP and Jute fiber wrapping confinement on the concrete specimens.
5. To determinesthe ultimate1load capacity enhancement on the composite specimen.

Project Outcome

1. Compressivesstrength: The presence of fibers and cementitious materials may improve the compressivesstrength.
2. Flexure: The flexural strength might increase due to the presence of fibers.
3. Splitting Tensile Strength: The presence of fibers might increase the tensile strength.
4. A possible outcome from this study can be the advantage of using UPVC, GFRP and Jute fibers for retrofitting, Load carrying1capacity of the structure increases with the use of UPVC tube, GFRP and jute wrapping.

2. EXPERIMENTAL INVESTIGATION

2.1 Procurement of Materials

The materials used are Fly ash, GGBS as binders and sand, aggregates, Cem-FIL® glass fibers, UPVC pipes, Glass fibers (GFRP -artificial fiber), Jute fiber(natural fiber) and epoxy which have been used for confinement purpose. Sodium1silicate and Sodium1hydroxide were used to make the alkaline solution. The fly1ash and GGBS were procured from MH Promoters and Builders (Bangalore). Commercially available sodium1hydroxide and sodium1silicate and locally available sand, aggregates, Cem-FIL® glass fibers, UPVC pipes, Glass fibers(GFRP), Jute fiber and epoxy are used. The materials were stored in air tight containers. The following materials are used in the research

- Fly1ash
- Ground1Granulated1Blast1Furnace1Slag (GGBS)
- Fine aggregate
- Corse aggregate
- Materials used for Confinement purpose.

2.2 Mix Design of Geopolymer Concrete.

The quantity of materials required for $1m^3$ of Geopolymer concrete is as shown in

Table -1: Geopolymer concrete mix design

Specimen	Geopolymer Mortar
Volume	$1m^3$
GGBS	277.2kg
Fly ash	118.8kg
Sand	644kg
Coarse aggregate	1202.28kg
Sodium Hydroxide Solution of 8-molarity	45.06kg
Sodium silicate	112.66kg
Extra Water	40kg

2.3 Preparation of Concrete

The binder, fine aggregates and coarse aggregates are weighed and taken as per the mix proportions and are mixed in dry condition in a tray. Then the water/ activator solution is mixed and stirred continuously to ensure uniform distribution as shown in Fig 2.1. To determine the optimum ratio of GGBS to fly ash proportion, various trial mixes were performed. The concrete is checked for workability using slump test and later filled in moulds and by tamping in 3 layers than finally two types of concrete mixes were finalized, Mix 1 add plan geopolymer concrete and Mix 2 add geopolymer concrete with adding glass fiber of 1% total volume of GGBS and flyash (used in mix) thoroughly mixed and concrete was prepared.

Fig 2.1: Preparation of concrete

2.4 Mechanical Characterization of UPVC, GFRP and Jute Composite

(a)-UPVC

(b)-GFRP

(c)-Jute

Fig 2.2: (a)-UPVC, (b)-GFRP and (c)-Jute sample.

Table 2.1: (a), (b) & (c) Specimen details of different composites

Details of UPVC Tubes					
Sl. No	Length (L) mm	Diameter (D) (mm)	Thickness(t) (mm)	L/D ratio	D/t ratio
1	300	90	3.2	3.33	28.13
2	300	110	3.6	2.73	30.56
3	300	160	4.5	1.88	35.56
4	600	110	3.6	5.45	30.56

(a)

Details of Glass FRP (Artificial fiber)						
Sl. No	Length(L) mm	Diameter (D) (mm)	Thickness(t) (mm)	L/D ratio	D/t ratio	no of layers
1	300	90	1.4	3.33	64.29	one
2	300	110	1.4	2.73	78.57	
3	300	160	1.4	1.88	114.29	
4	600	110	1.4	5.45	78.57	

(b)

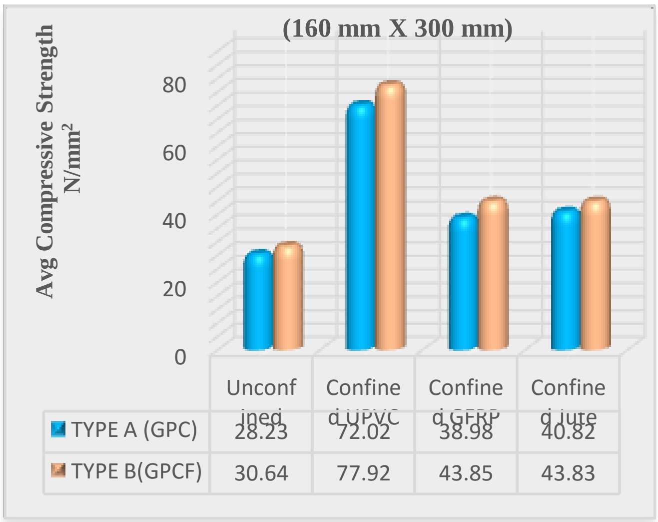
Details of JUTE (Natural fiber)						
Sl. No	Length(L) mm	Diameter (D) (mm)	Thickness(t) (mm)	L/D ratio	D/t ratio	no of layers
1	300	90	3.65	3.33	24.66	one
2	300	110	3.65	2.73	30.14	
3	300	160	3.65	1.88	43.84	
4	600	110	3.65	5.45	30.14	

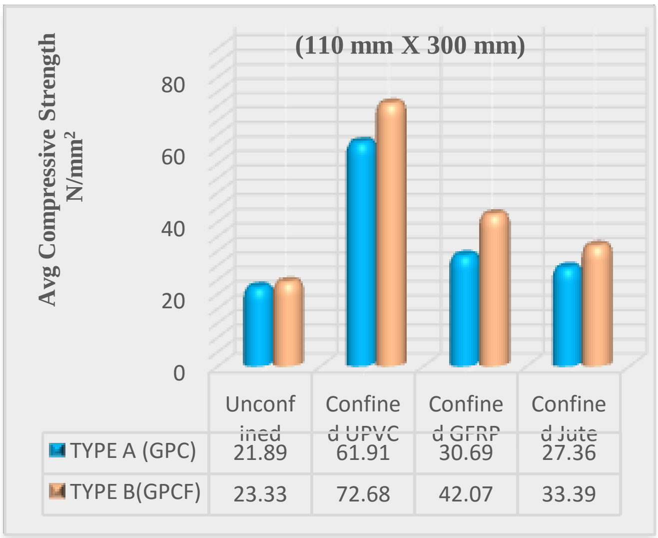
(c)

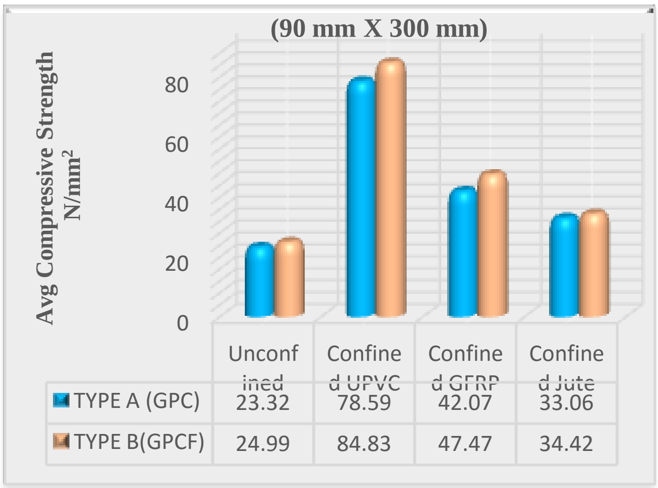
3. RESULTS AND DISCUSSIONS

3.1 Avg Compressive Strength

Graph 3.1 showing the results and values of Avg compression test.



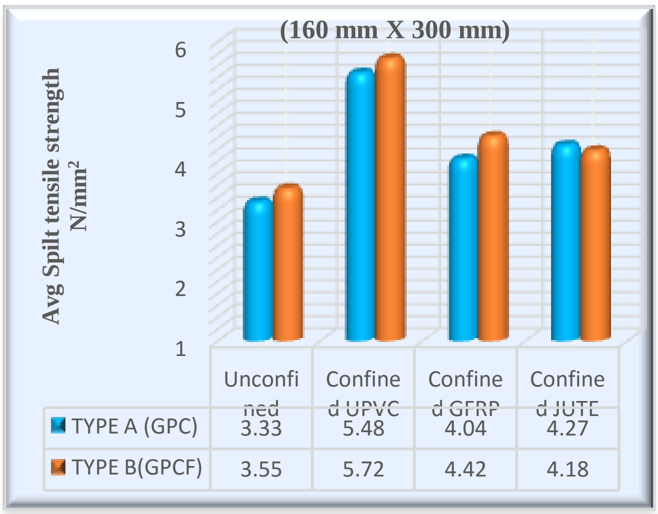


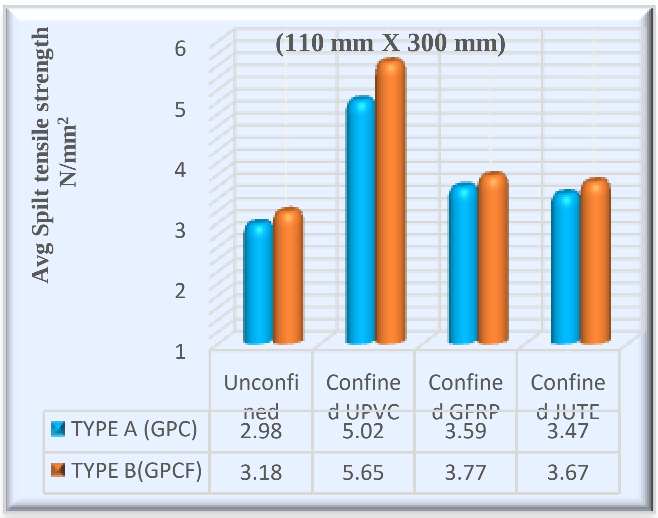


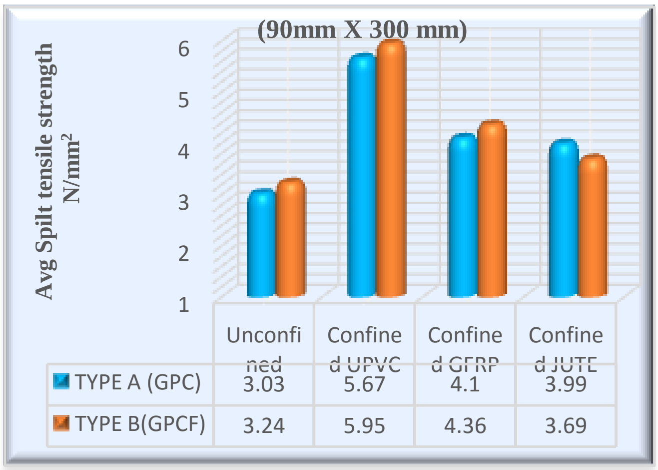
Graph 3.1: Results of Avg compression strength.

3.2 Avg Split Tensile Strength

Graph 3.2 showing the results and values of avg split tensile strength.







Graph 3.2: Results of Avg Spilt tensile strength test.

3.2.1 Failure Pattern of Compression Test and Split Tensile Test

(1)

(2)

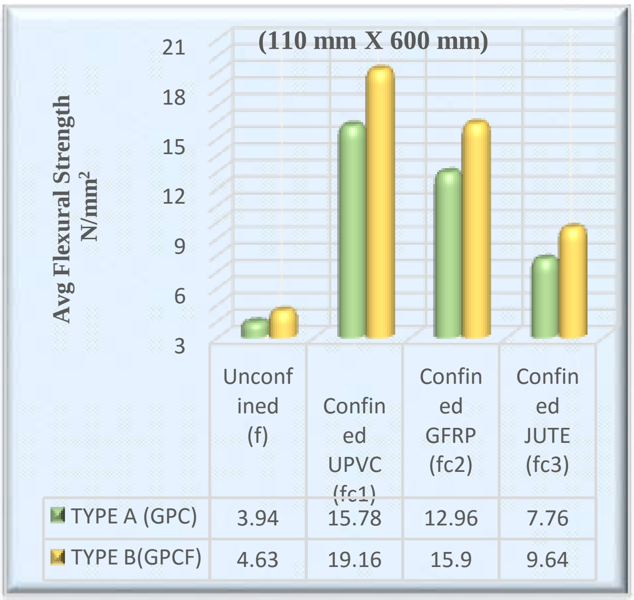
(3)

Fig 3.1: Failure of specimens subjected to axial compression and split tensile test {1, 2, 3}

The observed failure modes of all confined GPC and GPCF specimens are clearly presented in Fig. 3.1 for UGPC and UGPC, the ultimate failure was reached by excessive concrete cracks throughout the height of these specimens. It was observed that the confinement strength of GFRP fully confined specimen was 38.98N/mm^2 and came very close to jute confinement strength, which had a confinement strength value of 40.82N/mm^2. The highest confinement strength was displayed by UPVC confined specimens at 72.02 N/mm^2, and unconfined concrete specimens displayed strength of 28.23 N/mm^2.

3.3 Avg Flexural Strength

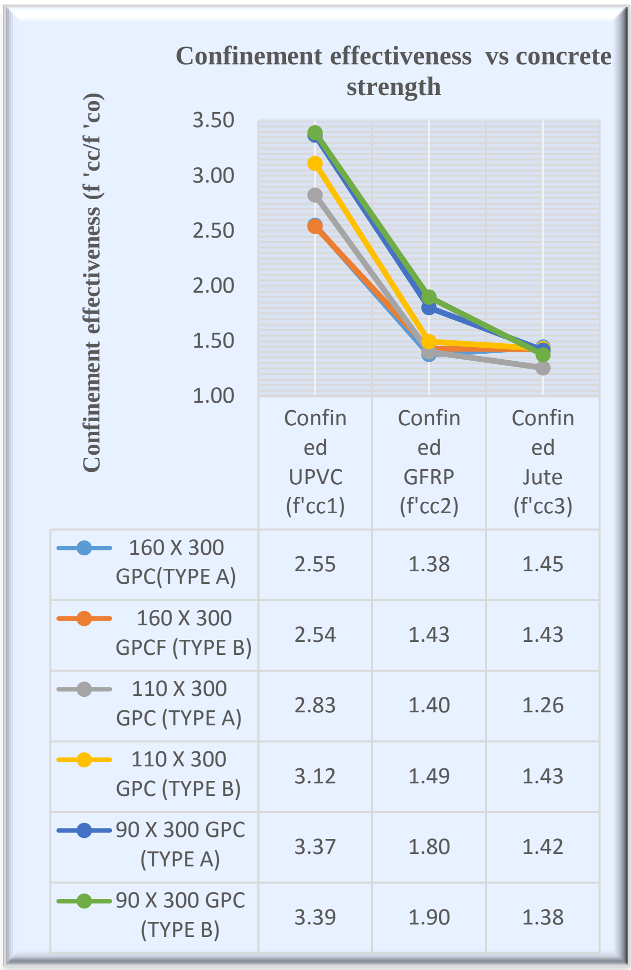
Graph 3.4 showing the results and values of Avg flexural strength test



	Unconfined (f)	Confined UPVC (fc1)	Confined GFRP (fc2)	Confined JUTE (fc3)
TYPE A (GPC)	3.94	15.78	12.96	7.76
TYPE B(GPCF)	4.63	19.16	15.9	9.64

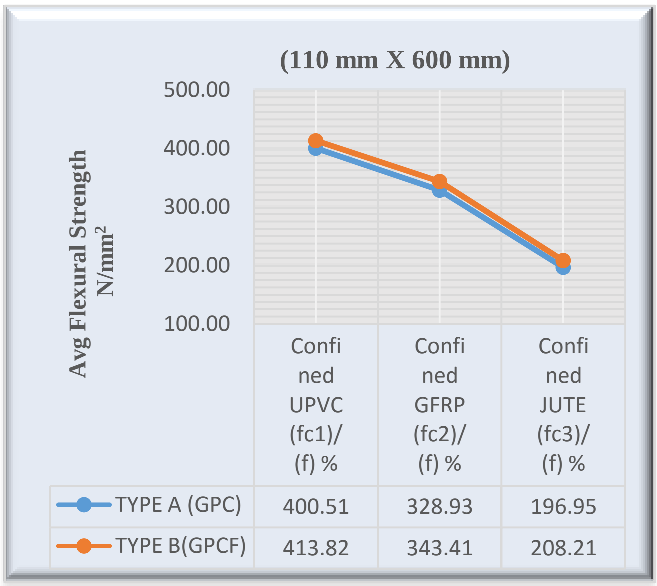
Graph 3.3: Results of Avg flexural strength test.

3.4 Confinement Effectiveness Vs Concrete Strength



	Confined UPVC (f'cc1)	Confined GFRP (f'cc2)	Confined Jute (f'cc3)
160 X 300 GPC(TYPE A)	2.55	1.38	1.45
160 X 300 GPCF (TYPE B)	2.54	1.43	1.43
110 X 300 GPC (TYPE A)	2.83	1.40	1.26
110 X 300 GPC (TYPE B)	3.12	1.49	1.43
90 X 300 GPC (TYPE A)	3.37	1.80	1.42
90 X 300 GPC (TYPE B)	3.39	1.90	1.38

Graph 3.4: Results of Confinement effectiveness vs. concrete strength.



	Confined UPVC (fc1)/ (f) %	Confined GFRP (fc2)/ (f) %	Confined JUTE (fc3)/ (f) %
TYPE A (GPC)	400.51	328.93	196.95
TYPE B(GPCF)	413.82	343.41	208.21

Graph 3.4.1: Results of Percentage increase in Flexural Strength

3.4.1 Discussions on Flexural Strength

Fig 3.2: Observed failure modes of the tested specimens.

It was observed that the average load for unconfined geopolymer concrete specimen is 10.5 kN (Two point load) and that for confined geopolymer concrete specimen likes UPVC, GFRP and Jute fiber are 42kN , 34.5kN and 21kN. By adding fibers to Geo polymer concrete specimen it showed increase in failure load of (19 % to 23 %). The observed failure mode in all CGPC was initiated by the rupture of the UPVC and GFRP tube fibers on the tension side followed by the crushing of concrete, and finally rupture of the fibers on the compression side. The observed failure mode in all of the CGPC was due to the rupture of the bottom fibers within the middle segment of the specimen.

4. CONCLUSION

1. The use of ground granular blast furnaces slag and flyash in place of ordinary Portland cement increases the compressive strength, flexural strength and split tensile strength of the specimen.
2. It was observed that the confinement strength of GFRP fully confined specimen was 38.98N/mm^2 and came very close to jute confinement strength, which had a confinement strength value of 40.82N/mm^2. The highest confinement strength was displayed by UPVC confined specimens at 72.02 N/mm^2, and unconfined concrete specimens displayed strength of 28.23 N/mm^2.
3. Geopolymer concrete (CGPC) specimens of UPVC tubes, GFRP and Jute fiber wrapping showed increases in compressive strength and confined geopolymer concrete with glass fiber (CGPCF) also showed increases of (6% to 8%) in compressive strength compared to GPC.
4. The enhancement in strength is dependent on the concrete strength and geometrical properties of the tubes.
5. Results showed that CGPC are effective in confining concrete, while in all cases *fcc*/*fco*>1. The Confined strength values increased between 1.26 to 3.39 times the unconfined strength values (UGPC).
6. Where local buckling is less due to UPVC confinement. There was decrease in length and also increase in diameter about 3.5 mm decrease in length and 2 mm increase in diameter.
7. It was observed that the failure of CGPC and CGPCF specimens can occur in any of the two ways like by crushing or shear failure.
8. It was observed that the average load for unconfined geopolymer concrete specimens are 10.5 kN (Two point load) and that for confined geopolymer concrete (CGPC) specimens like UPVC, GFRP and Jute fiber are 42kN , 34.5kN and 21kN . By adding fibers to Geo polymer concrete specimen it showed increase in failure load of (19 % to 23 %).
9. However UPVC confinement can be used and its better compare to GFRP and Jute fiber its expansive in technology

REFERENCES

[1] V. Bhikshma, M. Koti Reddy and T. Srinivas Rao, “An Experimental investigation on properties of Geopolymer concrete (no cement concrete)” Asian journal of civil engineering (Building and Housing) VOL. 13, NO. 6 (2012) Pages 841-853 received: 5 June 2011, Accepted: 10 December [2011].

[2] Hardjito, D. and Rangan B V- “Development and properties of low-calcium fly ash-based geopolymer concrete”, Research Report GC 1, [2005].

[3] P.balaguru,Stephen Kurtz, and Jon Rudolph, “Geopolymer for repair and rehabilitation of reinforced concrete beams” ,Rutgers The state university of New jersey Piscataway, USA,www.geopolymer.org.[1997]

[4] H. Gokulram and R. Anuradha,-“Strength Studies on Polypropylene Fiber Reinforced Geopolymer Concrete using M-Sand” Department of Civil Engineering, Sri Krishna College of Technology, Kovaipudur, Coimbatore, Tamil Nadu, India. [2013].

[5] Nisha Khamar and Resmi V Kumar,-“Properties of Hybrid Fiber Reinforced Geopolymer Concrete under Ambient Curing”, International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064,[2013]

[6] Kurt C. E, "Concrete filled structural plastic columns."*Journal of the Structural Division, Vol. 104,* No. 1, pp. 55-63,[1978].

[7] Marzouck M and Sennah K, Concrete-filled PVC tubes as compression members: Composite Materials in Concrete Construction. Proceedings of the international congress "challenges of concrete construction" pp. 31-38,[2002].

[8] Gupta,"Confinement of concrete columns with Unplasticized Poly-vinyl chloride tubes."International Journal of Advanced Structural Engineering, Available online at : http://www.advancedstructeng.com/content/5/1/19 [2013]

[9] Gathimba Naftary K, Oyawa Walter O and Mang'uriu Geoffrey N, "Compressive Strength Characteristics of Concrete- Filled Plastic Tubes Short Columns", International Journal of Science and Research (IJSR) ,ISSN (Online): 2319-7064 ,Impact Factor (2012): 3.358 Volume 3 Issue 9, September [2014]

[10] Kurt Lembo,Weena Lokuge and Warna Karunasena,"Geopolymer concrete with FRP confinement" in ST Smith (ed.), *23rd Australasian Conference on the Mechanics of Structures and Materials (ACMSM23)*, vol. I, Byron Bay, NSW, 9-December, Southern Cross University, Lismore, NSW, pp. 483-488. ISBN: 9780994152008, [2014].

[11] Qasim S. Khan, Josiah S. Strong, M. Neaz Sheikh and M N. S Hadi, "Flexural testing of concrete filled fiber reinforced polymer tubes (CFFT) with and without internal fiber reinforced polymer (FRP) reinforcement" Proceedings of the 27th Biennial National Conference of the Concrete Institute of Australia in conjunction with the 69th RILM Week (pp. 400-407). North Sydney, Australia: Concrete Institute of Australia, [2015]

[12] Tara Sen and Ashim Paul, "Confining concrete with sisal and jute FRP as alternatives for CFRP and GFRP", Gulf Organization for Research and Development International Journal of Sustainable Built Environment 4, 248–264, Science Direct, [2015]

[13] Usha C.M and Dr. H.Eramma , "Experimental study on concrete filled, unplasticised poly vinyl chloride (UPVC) tubes", International Journal of Advanced Technology in Engineering and Science www.ijates.com Volume No.02, Issue No. 07, July [2014]

[14] Dattatreya J K, Rajamane NP , Sabitha D, Ambily P S, Nataraja MC, "Flexural behaviour of reinforced Geopolymer concrete beams", International Journal Of Civil And Structural Engineering, Vol.2, No.1, pp 1,[2011]

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