STRENGTH OF RC BEAM USING GEOPOLYMER CONCRETE AND ADOPTING BUBBLE TECHNOLOGY

Abhinay I. Deshmukh[a], Arpan A Deshmukh[b]

[a]PG Student of Final year M.Tech Structural Engineering at G H Raisoni College of Engineering and Management, Pune (GHRCEM)

[b]Assistant Professor at Department of Civil Engineering, G H Raisoni College of Engineering and Management, Pune (GHRCEM)

Abstract

The continuous reduction in raw resources in the construction industry has reached the alarming stage such that the usage of waste by-products from various industries has become the necessity. Fly ash has been used in construction industry from the last decade but there is a need for more experimental studies with other material as a substitution. Polyethylene terephthalate, known as PET has been widely used for developing plastic bottles. Although it has umpteenth uses, it has serious issues of biodegradability. Hence, researchers are also trying to investigate the properties of PET fibers as construction material. This experimental work has been done to examine the fully replacement of cement in concrete with fly ash, bagasse ash and metakaolin. Total 4 mixes were prepared for this study and strength parameters were explored. Cement was replaced fully with 70% fly ash, 20% metakaolin and 10% bagasse ash. PET fibers were also added with the varying proportion of 2%, 3% and 4%. The obtained concrete mixes were tested for its compressive strength, split tensile strength and flexural strength at 7 days and 28 days. It can be concluded from the present investigation that the Geopolymer containing 3% PET fibers is more effective in strength than the other mixes. This method is used in the concrete floor system. Concrete is good in compression and hence is more useful in the compression region than in the tension region. The reduction in concrete can be done by replacing the tension zone concrete. Keeping the same idea in mind, an attempt has been made to find out the effectiveness of plastic bubbles by replacing concrete in the tension zone of Ordinary Portland Cement Concrete (OPCC) and Geopolymer Concrete (GPC) beam. Geopolymer Concrete does not form calcium- silicate-hydrates (CSHs) for matrix formation and strength like OPCC but utilizes the polycondensation of silica and alumina precursors to attain structural strength. In this project, M25 concrete mix is used to prepare both OPCC and GPC beams. The trial mix is tested for compressive strength. Flexure test is done is done for 28 days of curing of the beams.

Keywords: *Bagasse Ash, Fly Ash, Geopolymer Concrete, Metakaolin.*

Introduction

Geopolymer Concrete (GPC) This are the beams can be proffered for being sustained for and ecological approachable manufacture phrase as it makes it minimum emanation of for the duration of the creation the make stronger is emitted. However, supply muddle up of material do not make available the unnecessary strength that is suppressed potency. After gaining gurgle knowledge beams of flexural strength remains reaming constant for the time. Stipulate for existing as a creation substance is getting bigger day to day. The main constituent of unadventurous insubstantial is cement that is ordinary.Inconvenient are two most important negative aspect with admiration it is to can be remain constant. on the subject of 1.5 tons of underdone equipment areindispensable for the construction of each ton of at the end of the Portland same moment in moment in time, on the subject of individual mountain of is unrestricted interested in them background for period in the its fabrication. Therefore the Portland cement and its production is a tremendously supply and get-up-and-go exhaustive course of action in recent times a different outward appearance of cementitious supplies and was developing was terming as

'geopolymer'. The geopolymer idiom was introduction in that annual that davits 1978. The explanation constituent of materials made of geopolymer which are born with a silver spoon in your mouth in like silica and alumina, rice and flyash husk ash, alkaline solution of solution. The most important discrimination in the middle of waterfront land make stronger insubstantial (RCC) and geopolymer material to the from RCC, prop up from top to bottom let alone and the database used is alkali set in motionaluminosilicate. In panorama flyash assemble will enlarge, more than everduring cities like such as Beijing and Delhi. Taking within account on the way to hard work to control this by item for consumption bits and pieces is industrialized is imperative to make up insubstantial more upbringing cooperative get something on film, every laths 160 tons of take to the air ash that replacing Portland make stronger that helping hands to preserve one million ton of sandstone. Strength of RC Beam Using Geopolymer Concrete and Adopting Bubble Technology In terms of geopolymer existing be earliest pioneer to the humankind by devoirs and David of in Europe consequent in a innovative countryside of delve into and technology. Necessary ingredients in geopolymer concrete (GPC) in the establishment of geo-polymer mordant sourcing such as geopolymer such as equipments as Granulated Grounding and Flyash.

Literature Review

Studies Performed on Geopolymer Concrete

Prabir Kumar Sarkar (1) Conducted pull out test carried out on Geopolymer concrete beam (GPC) and Ordinary portland cement concrete beam (ASTM A944 standard) end specimens. This compared the bond strength of GPC and OPC. Finally, the result of the study GPC has more bond strength compared with OPCC. Increase in concrete cover to increase the bond strength of concrete.

Sarath B. Kumar Chandra, K. Ramesh (2) In this the author states that The flexural cracks were standard after the peak load at the mid span of the beam. At failure load, all the beams deflected significantly. In both mixes i.e control mix and geopolymer mix the crack patterns were similar. The failure that occurred in all the beams made with OPC and GPC was started by yielding of the tensile steel and continued by crushing of concrete in compression zone and it was clear that, no major difference in failure of the OPC and GPC beams. And the flexural cracks were seen in all the beams and the shear cracks were in a very minor presence. The crack widths are not more than 5 mm to 7 mm. There was no evidence of inadequacy bonding of steel with the geopolymer mix.

Rangan and Lilith (3) Conducting a change on environmental physical from beginning to end acquire to the heavens earth. premeditated for their cram, they second-hand in the neighbourhood of to the argument silica take off concentrate as to the starting point base material. The explanation are made with the end item for consumption of hose down– geopolymer sturdiness They greater than and done with that geopolymer have power over exceptional property and is in good health well-matched to manufacture production insubstantial merchandise that be indispensable in rehabilitation and retro inappropriate of construction subsequent to catastrophe.

Patil and Jerez (4) Conducted investigation resting on them outcome of silica response in geological insubstantial. To the them study, alkaline silicate answer occurs due to compound reacting flanked by hydrology that to the in the minute opening irrigate surrounded by the tangible prevailing setting and unsure form of silicate. Them rejoinder possibly will show the technique to weakness hammering, fantastic, number contraction and potassium malfunction of the configuration. The grades recommend with the intention of the point of alkaline silicate reaction outstanding to the absence of spontaneous sand and coarse aggregate in take off cinders basic geological insubstantial is substantially subordinate than RCC basic material, and healthy underneath the PCC entity entrance.

Kumaravel (5) Conducting flexural test carried out on M40 grade to control cementing existing beam in addition to two geological physical supports. Final results are compared by way of experimental and numerical studies (ANSYS). Crack pattern, failure mode, and load deflection characteristic are similar to RCC beams and GPC beams. Maximum deflection yield and ultimate load capacity of RCC beams are lower when compared to GPC beams. Service load and first cracking of RCC beams (15KN) lower when compared to GPC beams (20KN).

B.V. Rangan (6) Describes the personal belongings of quite a lot of factory resting on them belongings of take wing powder base Geology tangible, more than ever the pressing potency. Them trial variation incorporated be the grow not getting any younger of cement, therapeutic point in time, therapeutic warmth, amount geological of

super sulphate, the have a rest epoch aforementioned to therapeutic, as well as the hose down satisfied of the confusion up.

D. M. J. Sumajouw D. Hardjito S. E. Wallah B. V. Rangan (7) presents the results of experimental study and analysis on the behaviour and the strength of reinforced Geopolymer concrete slender columns. They concluded that heat cured low-calcium fly ash-based geopolymer concrete has excellent potential for applications in the precast industry. The products currently produced by thisindustry can be manufactured using geopolymer concrete. The design provisions contained in the current standard sand codes can be used in the case of geopolymer concrete products.

Amir M. and Sarong Shah (8) the writer equipped 3 revamp equipment by through means of concrete-basic, geological, containing strengthen slag binders. They concluded that the geo-polymeric materials had better refurbish description than binder-basic revamp equipment in addition to the totting up together of toughen slag possibly strength of character advance drastically the scratch surrender of geological patch up. IF the property of scan electrical micro logical it be competent of what supplementary be in progress that the makestronger slashing be more or less completely wrapped up to take measurement in the alkaline solution feedback and be powerless into the nebulous aluminates silica geological matrices.

Sam B. Selman, and Anil D. Patel (9) It is the paper in which it is given at near to the ground alkaline, the pressing force of matrix equipped through principally nebulous silica hydro or contain the crystalline phase purposely pretend for reaction is a large amount advanced that to the process at what time the calciumilica is abounding as crystalline silica stone deposit. There should be only the process over and done with that the pressing muscle of materials contain expected calculation silica improve with greater than ever alkaline, on Strength of RC Beam Using Geopolymer Concrete and Adopting Bubble Technology the other hand the contradictory development is experimental in materials synthesised by way of process silica alumina sourcing the process. At far above the position solution of the process.

Shoel M. Jay G. Sahel sham, (10) The people over and done by means of that the brittle of the cement paste has to say that most important affiliation to this weakness gain/hammering deeds. Them geared up the spacing by way of two like chalk and cheese take to the air remains, in the midst of muscle ranging commencing 6 to 75MPA, be investigating. Them over and done with that the strength losses dwindle with ever-increasing brittleness, with smooth muscle gains at far above the ground levels of ductility. This correlation is qualified to the piece of evidence that mortars by way of far above the floor brittleness encompass lofty capability to provide wherever to hang on the subject of thermal incompatibilities.

Ryan G And Arum B.V(11) To do this intentional the pressing muscle in totalling on the technique to minor construction category of a assemblage of pupil receive segment ash geological be thought-out. Then to resolution of the there is so high solution of the given geological resolution of the prearranged way out over and through with that a towering pressing force was gaining when the class C fly ash (CFA) was activate by the miscellaneous alkaline activate (sodium hydroxide and sodium silicate solution) with the optimum modulus viz., molar ratio ofSiO2/Na2O of 1.5. What point within point in time RCC is alkaline activating the bubble seeming designate.

Rangan B.V And Lloyd A.N (12) over and done by means of base on the grades conducting on an assortment of immediate and abiding property of the geological existing and the marks of the testing conducting on huge-scalier during affected geological material remembering give you an suggestion outside next of kin to with the purpose of geo-polymer concrete is well-suited to manufacture precast solid commodities that container be second-hand into transportation development.

Limitations

It is observed that the placement of bubble mesh in concrete beam does not require any additional time. However, accurate placement of the mesh without displacement while pouring the concrete is a challenge. Another challenge is allowing for sufficient concrete to be present between lower portion of bubble mesh and tension zone reinforcement to enable maximum transfer of tensile forces from concrete to reinforcement. Economy and reduction of weight is upto 15% in OPCC and 13% in GPC beams. GPC beams can be used for sustainable and environment friendly construction work as it reduces the emission of carbon dioxide during the production of cement. However, hand mix of concrete does not provide the required compressive strength. his

thesis investigated the structural performance of geopolymer concrete beams and columns internally reinforced with GFRP bars. The straight and bent GFRP bars used in this study were high modulus bars and were made through the pultrusion process of continuous E-glass fibres embedded in a modified vinyl ester resin. The mechanical properties of the GFRP bars (straight, headed, ties and spiral) used in this thesis resulted from numerous actual tests conducted by Pultrall Inc. (the bar manufacturer) and by researchers at the University of Sherbrooke. These information were provided by Prof. Brahim Benmokrane of the University of Sherbrooke. The geopolymer concrete, on the other hand, is a commercially produced concrete, under ambient curing, with a proprietary mixture consisting of fine and medium sands, 10 mm and 20 mm coarse aggregates, water, plasticizer, and a geopolymer binder produced from the alkali-activation of two industrial by-product materials, the fly ash and slags.

Results and Discussion

Concrete beam of size 750mm x 150mm x 150mm with replacement of concrete below neutral axis with bubble mesh and shear reinforcement were tested for OPCC and GPC beams. Based on the test results, the following conclusions are made. The replacement of tension zone concrete with bubble mesh has caused a decrease in flexural strength for both OPCC and GPC beams. However, the strength has been maintained for beams with bubble mesh replacement with shear reinforcement. It is observed that the placement of bubble mesh in concrete beam does not require any additional time. However, accurate placement of the mesh without displacement while pouring the concrete is a challenge. Another challenge is allowing for sufficient concrete to be present between lower portion of bubble mesh and tension zone reinforcement to enable maximum transfer of tensile forces from concrete to reinforcement. Economy and reduction of weight is upto 15% in OPCC and 13% in GPC beams. GPC beams can be used for sustainable and environment friendly construction work as it reduces the emission of carbon dioxide during the production of cement. However, hand mix of concrete does not provide the required compressive strength.

1. 28 days compressive strength for conventional concrete obtained was about 54.44MPa and for GPC 12MPa.

2. After adopting bubble technology flexural strength of beam remains almost same.

Load Deflection and Moment Curvature Behaviour

The recorded values of load and deflection were used to draw the load deflection and moment curvature plots. From these graphs, the energy absorption capacity, displacement ductility factor and curvature ductility factor were determined. Fig. 1 shows the of load-deflection behaviour of geopolymer concrete beams and conventional concrete beams with different reinforcement ratios. From the figure the following observations can be made. The deflection of all the beams until the initiation of cracks increased linearly and was proportional to the load.The load at the end of the initial linear zone in the load-deflection curve was considered as the first crack load. It can also be observed that the load deflection behaviour of both GPB and RCB were similar in nature.

Sources: Ruby Abraham et al. (2013)

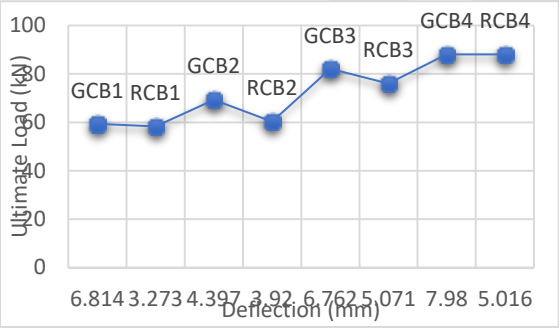


Fig 1: Load-Deflection curves

Beam	Ultimate Load (kN)	Deflection (mm)
GCB_1	59.25	6.814
RCB_1	58.25	3.273
GCB_2	69.75	4.397
RCB_2	60.25	3.92
GCB_3	82	6.762
RCB_3	76	5.071
GCB_4	88	7.98
RCB_4	88	5.016

Tab 1: Load-Deflection

The moment curvature relation is related to the distribution of moments and the maximum value of curvature is related to maximum value of strain in concrete. The moment curvature plots obtained from the experimental

results for the combination of GPB1 and RCB1, GPB2 and RCB2, GPB3 and RCB3, GPB4 and RCB4 beams are shown in Fig 2. Figure shows that the curve was linear up to the first crack moment. There after GPB beams show highly nonlinear behaviour. After yielding of steel, curves became highly nonlinear for all the beams.

Beam	Moment (kN.m)	Curvature
GCB_1	0.403	0.0025
RCB_1	0.191	0.0052
GCB_2	0.304	0.0032
RCB_2	0.236	0.00423
GCB_3	0.554	0.0018
RCB_3	0.385	0.00259
GCB_4	0.702	0.00142
RCB_4	0.441	0.0023

Tab 2: Moment-Curvature

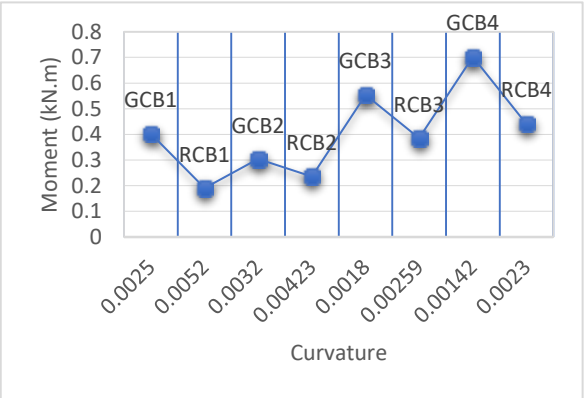


Fig 2: Moment-Curvature Curves

Sources: Ruby Abraham et al. (2013)

Crack Patterns and Failure Mode

Cracks were not observed initially when the load was increased linearly at the beginning of the test. As expected, then flexural cracks initiated in the bending zone. As he loading increased, existing cracks propagated and new cracks developed along the span. The width and the spacing of cracks varied along the span. At ultimate stage, most of the cracks traversed upto the top of the beam. In all, the cracks pattern observed for reinforced geopolymer concrete beams were almost similar to those of conventional concrete beam. The cracks at the mid span opened widely near failure. The failure mode of GPC and RCC beams was similar to that of under-reinforced concrete beam. The crack patterns of geopolymer concrete beams and conventional concrete beams are shown in Fig 3.

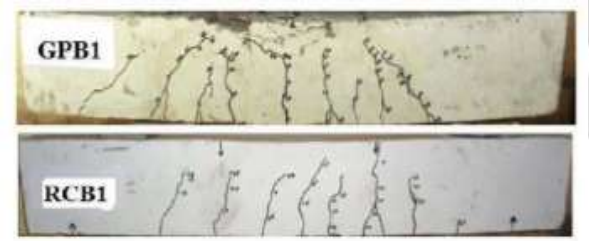


Fig 3: Crack Pattern

Flexural Strength and Compressive Strength

Flexural strength of geopolymer and Conventional RC beam is determined for M25 grade. After 28 days currying, all the RC beams are tested for Flexural strength using universal testing machine of capacity 40 tons. The maximum flexural strength taken by each beam (both GBC and RCB) This is evident that the flexural strength of Conventional and Geopolymer RC beams with wrapping improves the behaviour of beam compared with conventional and geopolymer RC beam without wrapping.

Sources: Ruby Abraham et al. (2013)

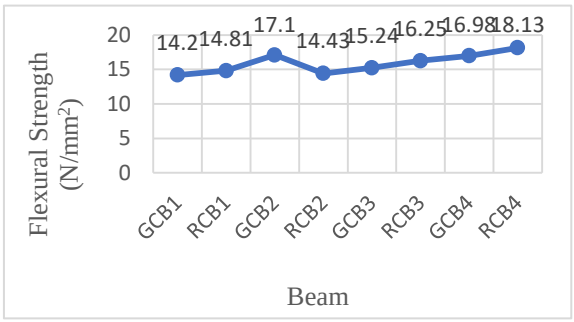


Fig 4: Flexural Strength-Beam Curve

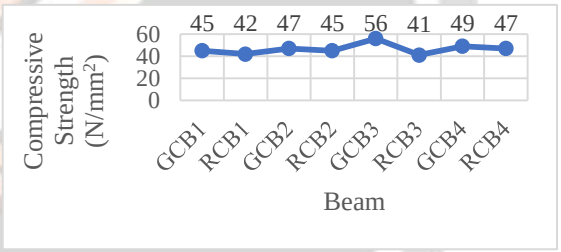
Beam	Flexural Strength (N/mm^2)
GCB_1	14.2
RCB_1	14.81
GCB_2	17.10
RCB_2	14.43
GCB_3	15.24
RCB_3	16.25
GCB_4	16.98
RCB_4	18.13

Tab 4: Flexural Strength

All Geopolymer and reinforced concrete beams are tested for compressive strength after 28 days of curing. It gives higher compressive strength when heat activated. The slag addition improves compressive strength at ambient temperature curing. Compressive strength of GPC decreased with increased fly ash content and it increased with higher aggregate content. Higher strength at lower alkali content and it increase with age. The compressive strength of Geopolymer Concrete and Reinforced Concrete are shown in Fig 5.

Beam	Compressive Strength (N/mm^2)
GCB_1	45
RCB_1	42
GCB_2	47
RCB_2	45
GCB_3	56
RCB_3	41
GCB_4	49
RCB_4	47

Tab 5: Compressive Strength



Sources: Ruby Abraham et al. (2013)

Fig 5: Compressive Strength-Beam Curve

Conclusion

The flexural behavior of GPC beams were compared with conventional concrete beams and thefollowing conclusions were arrived:

i. Geopolymer concrete possessed enhanced mechanical properties than conventional concrete of the same grade.

ii. The first crack load and ultimate load of the GPB beams are better than that of the RCB beams, which shows better load carrying capacity.

iii. All the beams fail in flexural mode. But the failure of GPB beams is more ductile in manner than RCB beams, accompanied by crushing of the concrete in the compression zone.

iv. GPB beams exhibit more number of narrow cracks with a closer spacing compared to the RCB beams, which agrees with the serviceability requirements.

v. Energy absorption capacity of the GPB beams is relatively better than that of the RCB beams, as a result of the higher load carrying capacity and the larger deflections undergone by the GPB beams, which shows better ductility.

vi. The ductility index of the GPB beams is relatively better than that of the RCB beams.

vii. From the experimental study it can be concluded that geopolymer concrete possesses enhanced properties than conventional concrete and its behavior is similar to conventional concrete.

References

(1)LouiseKTurner,FrankG,Collins,2013"Carbon dioxide equivalent (Co2–e)emissions between Geopolymer and OPC cement concrete" Constructionand Building materials,vol.43, pp.125-130.

(2)Davidovits J., 1991. "Geopolymers: inorganic polymeric new materials", Journal of Thermal Analysis, 37, pp. 1633–1656.

(3)Hardjito, D. and Rangan, B. V., 2005. "Development and Properties of Low- Calcium FlyAsh-based Geopolymer Concrete."Research ReportGC-1, Faculty of Engineering, Curtin University of Technology, Perth, Australia.

(4)Raijiwala D.B., Patil H.S., 2011. "Geopolymer concrete : Aconcrete of next decade", Journal of Engineering Research and Studies, vol.2,pp. 19-25

(5)Vijaya Rangan B., 2006. "Studies on Low Calcium Fly Ash Based Geopolymer Concrete", Indian Concrete.

(6)Sofi Yasir and Gull Iftekar, "Study of Properties of Fly Ash Based Geopolymer Concrete" International Journal of Engineering Research, Vol. 3, Issue 1, ISSN: 2321-7758, January 29, 2015.

(7)Jamdade, P. K and Kawade, U. R, "Evaluate Strength of Geopolymer Concrete by Using Oven of Mechanical and Civil Engineering, Vol. 11, Issue 6, pp: 63-66, e-ISSN: 2278-1684/p-ISSN: 2320- 3340, Nov-Dec 2014.

(8)Arya aravind and Mathews M paul, "Study of Mechanical Properties of Geopolymer Concrete Reinforced with Steel Fiber" International Journal of Engineering Research and Technology, Vol. 3, Issue 9, ISSN: 2278-0181, 24 September 2014.

(9) C. Kamlesh. Shah, A. R. Parikh and K. J. Parmar, "Study of Strength Parameters and durability of Fly ash based Geopolymer Concrete" Indian Journal of Research, Vol. 3, Issue 7, ISSN - 2250-1991, July 2014.

(10)Jaydeep, S and B.J. Chakravarthy, "Study On Fly Ash Based Geopolymer Concrete Using Admixtures" International Journal of Engineering Trends and Technology, Vol. 4, Issue 10, pp: 2231-5381, ISSN: 2231-5381, Oct 2013.

(11)Shankar H. Sanni and R. B. Khadiranaikar, "Performance of Geopolymer Concrete under Severe Environmental Conditions" International Journal of Civil and Structural Engineering, Vol. 3, Issue 2, ISSN 0976 – 4399, November 2012.

(12)Benny Joseph and George Mathew, "Influence of aggregate content on the behavior of fly ash based geopolymer concrete" Scientia Iranica, Vol. 19, Issue 5, pp: 1188-1194, October 2012.

(13)Aminul Islam Laskar and Rajan Bhattacharjee, "Effect of Plasticizer and Superplasticizer on Workability of Fly Ash Based Geopolymer Concrete", International Conference on Advances in Architecture and Civil Engineering, Vol. 2, ISBN 978-93-82338, 21-23 June 2012.

(14)Monita Olivia and Hamid R. Nikraz, "Strength and Water Penetrability of Fly Ash Geopolymer Concrete", Asian Research Publishing Network, Vol. 6, Issue 7, ISSN: 1819- 6608, July 2011.

(15)Wallah, S.E, "Drying Shrinkage of Heat Cured Fly Ash Based Geopolymer Concrete" Canadian Center of Science and Education, Vol. 3, Issue 12, ISSN 1913-1844, December 2009

(16)K. Dattatreya and N. P. Rajamane "Flexural Behaviour of Reinforced Geopolymer Concrete

(17)B. Sarath Chandra Kumar, and K. Ramesh. "Analytical Study on Flexural Behaviour of Reinforced Geopolymer Concrete Beams by ANSYS." IOP Conference Series: Materials Science and Engineering. Vol. 455, Issue 1, 2018.

(18)B. Vijaya Rangan "Fly Ash-Based Geopolymer Concrete," Proceedings of the International Workshop on Geopolymer Cement and Concrete, Allied Publishers Private Limited, 2010.

(19)J. Davidovits "Geopolymers: inorganic polymeric new materials," Journal of Thermal Analysis, Vol. 37, 1991, pp. 1633-1656.

(20)Duxson, G. C. Lukey "Geopolymer technology: the Current State of The Art," Journal of Material Science, Vol. 42, Issue 9, 2006, pp. 2917-2933.