ISSN: 2348 9510
International Journal Of Core Engineering & Management (IJCEM)
Volume 3, Issue 3, June 2016

"EXPERIMENTAL INVESTIGATION ON ALKALI ACTIVATED CONCRETE"

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ABSTRACT

The project report entitled "Experimental investigation on alkali activated concrete" describes the detailed experimental work carried out on Alkali Activated Alumina-silicate concrete [Provis and Deventer, 2009]. The fly ash-Ground Granulated Blast Furnace Slag(GGBFS) based Alkali Activated Alumina-silicate concrete cured at ambient temperature was prepared by using different molarities of Alkali Activated solution namely 8M, 12M and 16M. The properties of concrete such as workability, compressive strength, Pull-out test/bond test and split tensile strength have been studied. The study on result of various combination of percentage of fly ash and GGBFS by mass of concrete has been carried out.

1. INTRODUCTION

1.1 Portland Cement (P-C) based Concretes

Cement concrete is often considered as an artificial stone which is made by mixing Portland cement (P-C), water, sand, and crushed stone aggregate to produce a mouldable mixture. This concrete, during the last century, has developed into the most important building material in the world; the beginning was made by August Perret, in 1902, by designing and building an apartment building in Paris employing "a system for reinforced concrete" (columns, beams, and slabs, but without using any load-bearing walls) Concrete is, now, an essential product used in a variety of constructions including infrastructure and industrial sectors. This is partly due to the fact that concrete is produced from natural materials available in all parts of the globe, and partly due to the fact that concrete is a versatile material, giving architectural freedom. More than a ton of concrete is produced every year for each human on the planet earth, making concrete as the second most widely consumed substance on earth after water [Sara Hart, 2008]. But, the environmental aspects of concrete are now being discussed with a view to develop an eco-friendly material for construction.

1.2 Geopolymer as Alternate to P-C

A new binder material, known as 'Geo-polymer' was first introduced by Davidovits in 1978 to describe a family of mineral binders with chemical composition similar to zeolites but with an amorphous microstructure [Davidovits, 1994]. He utilised silica (SiO_2) and alumina (Al_2O_3) available in the specially processed clay (metakaolin) to get inorganic polymeric system of alumino-silicates. Unlike Ordinary Portland Cement, geopolymers do not need calcium-silicate-hydrate (C-S-H) gel for matrix formation and strength, but utilise the polycondensation of silica and alumina precursors to achieve required mechanical strength level. Two main constituents of geopolymer (GP) are geopolymer source materials (GSMs) and alkaline activator liquids.The GSMs should be alumino-silicate based and rich in both silicon (Si) and aluminium (Al) and thus, by-product materials such as fly ash, silica fume, slag, rice-husk ash, red mud, etc can form GSMs. Recently, Rangan and Hardijto [2005] exploited silica and alumina of fly ash to produce three-dimensional polymeric chain and ring structure consisting of Si-O-Al. Geopolymers are unique in comparison to other aluminosilicate materials (e.g. aluminosilicate gels, glasses, and zeolites).The concentration of solids during geopolymerisation reactions is higher than that in aluminosilicate gel or zeolite synthesis [Rajamane, 2011a, Sindhunata, 2006]. Al-O bonds of geopolymeric binder are useful to prepare structural grade concretes. From above, it is now clear that any of the minerals containing reactive oxides of silicon and aluminium can be activated by suitably formulated highly alkaline liquid to obtain inorganic polymeric binding material [Sindhunata, 2006].Preliminary studies in this regard, were carried out at CSIR-SERC, Chennai, India, in early 2000s, using both fly ash and Ground Granulated Blast Furnace Slag (GGBS), to produce geopolymer concretes (GPCs) with sufficient strength levels [Rajamane and Sabitha, 2005d]. It was observed that the activation of FA and GGBS involved use of hydroxides and silicates of alkali (such as sodium, potassium) which are commonly available in India; the processing conditions for GPCs are almost similar to Conventional Concretes (CCs) except that during mixing operations of GPCs, instead of water, a premixed alkaline solution, known as 'Alkaline Activator Solution' (AAS), is added. Following materials were used to produce GPCs [Rajamane, 2009a, 2009b]:

(i) Fly ash,

(ii) Ground Granulated Blast Furnace Slag (GGBS),

(iii) Fine aggregates (in the form of river sand),

(iv) Coarse aggregates (in the form of crushed granite stone),

(v) Alkaline Activator Solution (AAS) - a mixture of alkali silicates and hydroxides, besides distilled water.

1.3 Scope of Work

The experimental work involved conduct of long-term tests on low-calcium fly ash based Geo-polymer concrete. The tests currently available for Portland cement concrete were used. In the experimental work, only one source of dry low-calcium fly ash (ASTM Class F) from a local power station was used. Analytical methods available for Portland cement concrete were used to predict the test results.The research utilized low-calcium (ASTM Class F) fly ash as the base material formaking geo-polymer concrete. As far as possible, the technology and the equipment currently used to manufacture O.P.C concrete were used to make the geo-polymer concrete.The concrete properties studied included the compressive and split tensile strengths,pull out strength,slump cone test, the elastic constants, the stress-strain relationship in compression, and the Workability of fresh concrete under oven temperature is studied now is going to be studied under ambient condition.

ISSN: 2348 9510
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Volume 3, Issue 3, June 2016

2. MATERIALS AND PROPERTIES

The various materials used in the preparation of Alkali Activated Alumina-silicate concrete are as follows: -

- Fly ash –class F (C_{aO}<10%)
- GGBSF
- Fine aggregate
- Coarse aggregate
- Alkaline solution – Mixture of sodium silicate and sodium hydroxide solution
- Super plasticiser
- Water

Table: 1. Properties of Class F Fly Ash (physical and chemical)

Content	Range
Specific Gravity	**2.4**
Fineness (m^2/kg)	**1134.1**
LOI	**0.90**
Al2O3	**31.23**
Fe2O3	**1.50**
SiO2	**61.12**
MgO	**0.75**
SO3	**0.53**
Na2O	**1.35**
Chlorides	**0.06**
CaO	**3.2**

ISSN: 2348 9510
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Table: 2. Properties of GGBFS (physical and chemical)

Content	Range
Specific Gravity	**2.9**
Fineness	**416.0**
LOI	**0.19**
Al2O3	**13.24**
Fe2O3	**0.65**
SiO2	**37.21**
MgO	**8.46**
SO3	**2.23**
Na2O	**---**
Chlorides	**0.003**
CaO	**37.2**

Table:3. Properties of Normal Weight Aggregates for Concretes

Source	River Sand	Crushed Granite Aggregate
Type	**Fine Aggregate**	**Coarse Aggregate**
Specific Gravity	**2.61**	**2.72**
Fineness Modulus	**2.73**	**6.68**
Bulk density kg/m^3	**1540**	**1720**
Water absorption (%)	**0.83**	**1.2**
Flakiness index	**NA**	**18.72**
Elongation Index	**NA**	**36.27**
MSA, mm	**4.75**	**20**

Table 4. Properties of Super plasticisers

Chemical base	Sulphonated Naphthalene Formaldehyde Condensate (SNFC)
Density	1206 kg/m^3
Colour	Brownish
Nature	Free flowing liquid
Recommended dosage	0.1 – 1.5 kg/100 kg cement.
Type of surfactant	Anionic
pH	8.027

Alkaline Activator Solution (AAS)

The AAS consists usually a mixture of hydroxides and silicates of alkali. The fly ash/AAS ratio in GPC mix can vary in the range of 0.25-0.40 [Palomo, 1999; andHadjito, 2002]. The AAS has to be formulated such that the geo-polymerization can take place in steps: (i) the dissolution of alumino-silicate oxide in MOH solution (M=Na or K); (ii) the diffusion of dissolved Al and Si complexes, from particle surfaces of GSMs to the interparticle space; (3) the formation of a gel phase resulting from the polymerization between an added silicate solution and Al and Si complexes; (4) hardening of the gel phase by the exclusion of spare water to form geo-polymeric product [Xu, 2001].It is observed that geo-polymers contain non-reacted solid aluminosilicate source in the final matrix, depending upon the composition of AAS. However, there is no definitive and accurate method for quantitatively determining the amount of unreacted GSMs. Hence, formulations of AAS must be carefully done to achieve higher mechanical strength in the GPCs.

ISSN: 2348 9510
International Journal Of Core Engineering & Management (IJCEM)
Volume 3, Issue 3, June 2016

Fig.1 Sodium hydroxide (NaOH) white flakes used to prepare AAS.

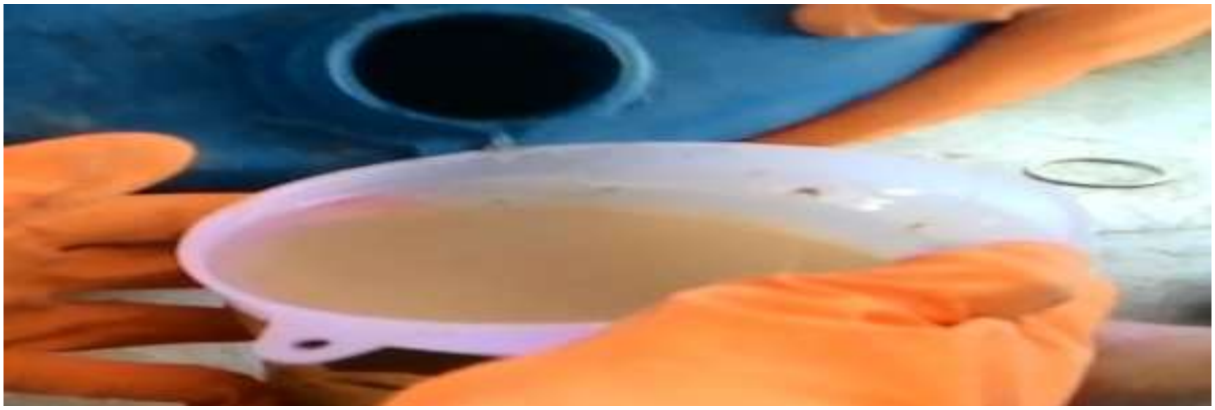

Fig.2 Sodium silicate solution usedto prepareAAS.

3. EXPERIMENTAL WORK

Mix design

- Low calcium (ASTM Class F) dry fly ash and GGBFS, Alkaline liquid

ISSN: 2348 9510
International Journal Of Core Engineering & Management (IJCEM)
Volume 3, Issue 3, June 2016

- Ratio of sodium silicate solution-to-sodium hydroxide solution, by mass, of 0.4 to 2.5. This ratio was fixed at 2.5 for most of the mixtures, because the sodium silicate solution is considerably cheaper than the sodium hydroxide solution.
- Molarity of sodium hydroxide (NaOH) solution in the range of 8M to 16M.
- Ratio of activator solution-to-(fly ash+GGBFS), by mass, in the range of 0.3 and 0.4.
- Coarse and fine aggregates, as given in Section 3.2.3, of approximately 75% to 80% of the entire mixture by mass. This value is similar to that used in OPC concrete.
- Super plasticiser, as given in Section 3.2.4, in the range of 0% to 3% of (fly Ash+GGBFS), by mass.
- Extra water, when added, in mass.

Quantity of Material as per Mix design

I. Coarse aggregate = 0.77 x 2400 = 1848 kg/m^3
   i. *20mm=776.4* kg/m^3
   ii. *10mm=517.6* kg/m^3
II. Fine aggregate = 0.3 x1848 = 554.4 kg/m^3
III. Binder = 408 kg/m^3
IV. Fly ash = 285.6 kg/m^3
V. GGBS = 122.4 kg/m^3
VI. NaOH solution = 41 kg/m^3
VII. Na_2SiO_3 solution = 103 kg/m^3
VIII. Extra water = 5% x 408 = 20.4 kg/m^3

4. RESULTS AND CONCLUSION

A)SPLIT TEST

Age of	M40	8M GPC	12M GPC	16M GPC	Percentage

ISSN: 2348 9510
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Specimen	Normal conc	Specimen in N/mm^2	Specimen in N/mm^2	Specimen in N/mm^2	increment
7 day	2.056	1.073	1.556	2.441	18%
28 day	4.640	2.901	4.222	5.047	8%

Table 5. Determination and comparison of average pullout bond strength test and Different molar alkali activated concrete with graphs and result.

Graph for Average split tensile strength of different molar concrete .

Comparision of split tensile strength using different molar solution viz.. M40 normal concrete, 8M, 12M&16M GPC at the age of 7 day,28 day .of ambient cured alkali activated concrete.

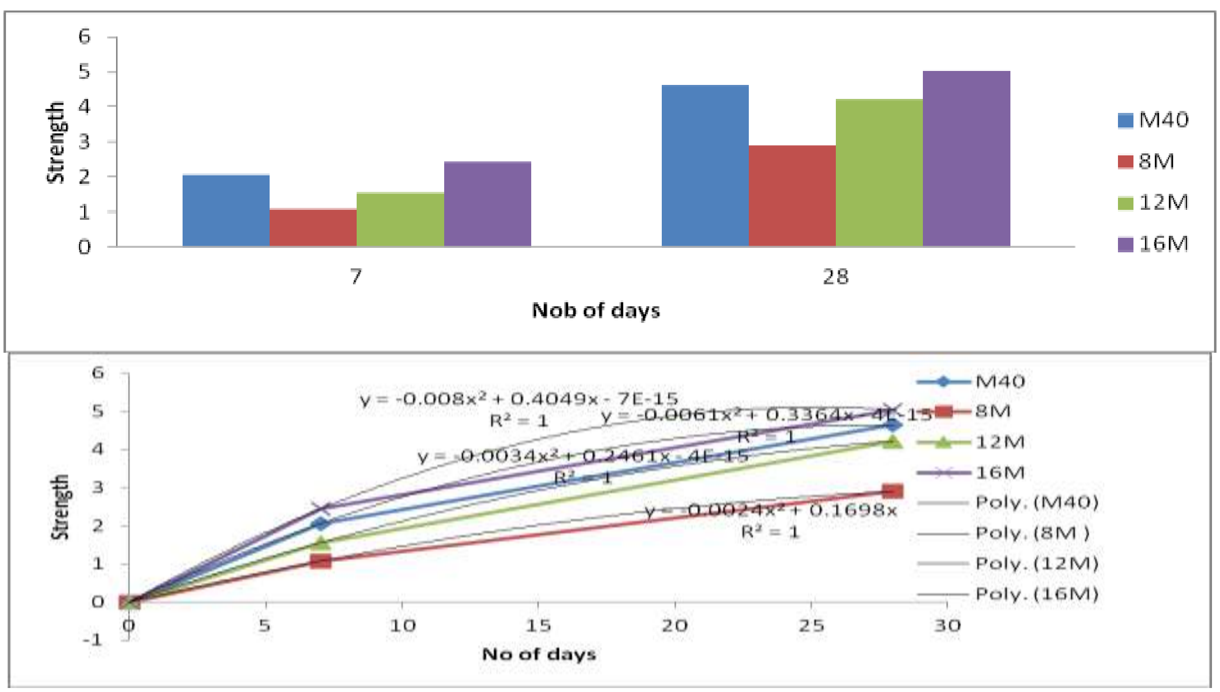

Fig 3 Bar Graph and Polynomial Graph Comparision of split tensile strength of different molar GPC and Conventional Concrete

ISSN: 2348 9510
International Journal Of Core Engineering & Management (IJCEM)
Volume 3, Issue 3, June 2016

❖ **Conclusion is drawn from the above graph and table**:-

1. Split tensile strength of alkali activated concrete increases marginally as compressive strength increases.
2. The relationship between compressive strength and tensile strength is similar to conventional concrete.
3. Highest tensile strength i.e., 5.047 N/mm^2 was observed for 28 days of 16M GPC .
4. Lowest tensile strength i.e., 2.901 N/mm^2 was observed for28 days of 8M GPC.
5. As the molarity of alkali activated solution for concrete increases, the split tensile strength of concrete increases.
6. As compare to conventional concrete of M40 grade, their is 18% increment in strength of 16M GPC in 7 days test and 8% increment of 16M GPC in 28 days test
7. Hence it is clear that 16M GPC maximum strength develop and maximum strength increment up to 18 % in 7 day as compare to conventional concrete of M40 grade
8. It is clear that 16M AAS is sufficient and economical for preparing high strength Geo-polymer concrete, as strength gains are same as 8M and 12M at all ages of gpc specimen, further cost reduces with less molar AAS.

A) PULLOUT BOND TEST

Age of Specimen	M40 Normal conc	8M GPC Specimen in N/mm^2	12M GPC Specimen in N/mm^2	16M GPC Specimen in N/mm^2	Percentage increment
7 day	6.890	2.768	5.484	8.297	20%
28 day	10.200	7.979	9.187	11.300	10%

Table 6. Determination and comparison of average pullout bond strength test and Different molar alkali activated concrete with graphs and result.

International Journal of Core Engineering & Management

ISSN: 2348 9510

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Volume 3, Issue 3, June 2016

❖ **Graph for Average Pullout bond strength of different molar concrete**

Comparision of Pullout bond strength using different molar solution viz.. M40 normal concrete, 8M, 12M&16M GP

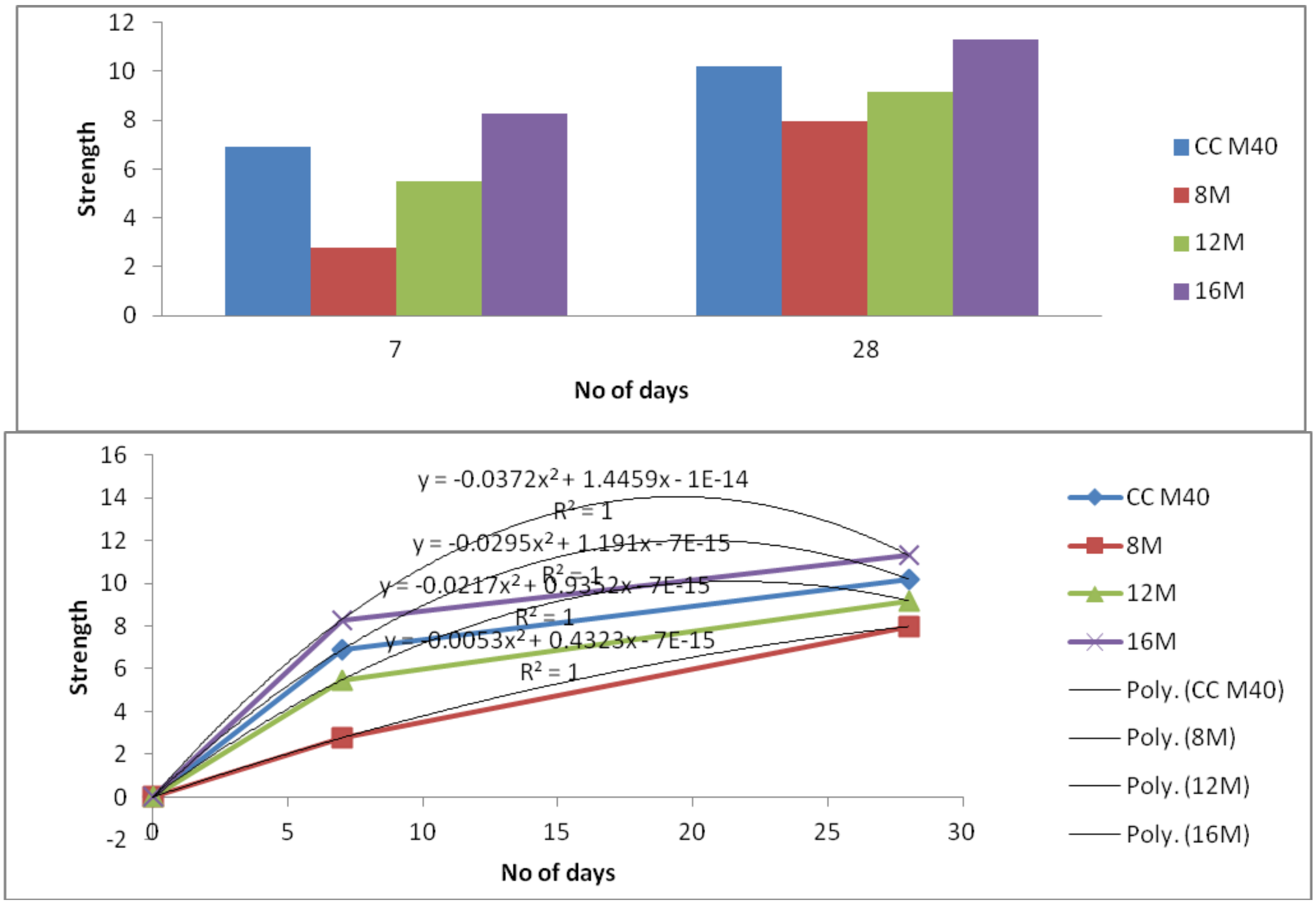

Fig 4 Bar Graph and Polynomial Graph Comparision of Pullout/Bond strength of different molar GPC and Conventional C

❖ **Conclusion is drawn from the above graph and table :-**

1. Pullout bond strength of alkali activated concrete increases marginally as compressive strength increases.
2. The relationship between compressive strength and Pullout bond strength is similar to conventional concrete.

ISSN: 2348 9510
International Journal Of Core Engineering & Management (IJCEM)
Volume 3, Issue 3, June 2016

3. Highest pullout bond strength i.e., 11.300 N/mm^2 was observed for 28 days of 16M GPC.
4. Lowest pullout bond strength i.e., 7.979 N/mm^2 was observed for 28 days of 8M GPC .
5. As the molarity of alkali activated solution for concrete increases, the split tensile strength of concrete increases.
6. As compare to conventional concrete of M40 grade, their is 20% increment in Pullout strength of 16M GPC in 7 days test and 10% increment of 16M GPC in 28 days test.
7. Hence it is clear that 16M GPC maximum strength develop and maximum strength increment up to 20% in 7days as compare to conventional concrete of M40 grade.
8. It is clear that 16M AAS is sufficient and economical for preparing high strength Geopolymer concrete, as strength gains are same as 8M and 12M at all ages of gpc specimen, further cost reduces with less molar AAS.

5. CONCLUSION

1. From The Above Two Conclusion Of Pull Out Bond Test And Split Tensile Test It Is Clear That Geo-Polymer Concrete Is Better Than Conventional Concrete.
2. Geo-Polymer Concrete Is Good For Normal Grade Concrete And Best For High Strength Concrete.
3. Geo-Polymer Concrete Being Eco-Friendly Concrete So It Can Be Used In All Type Of Conctructions
4. According to economic point of view the cost of both the concrete. (i.e Geopolymer Concrete and Conventional Concrete) is nearly equal.but geoplymer concrete is Eco-Friendly concrete so it should be preferred first.

REFERENCES

1. N. P. Rajaman“ Ambient Temperature Cured Fly Ash And Ggbs Based Geopolymer Concretes” (Retired Head, Advanced Materials Laboratory, Csir-SercChennai**)** Head, Centre For Advanced Concrete Research, Srm University, India

2. Hardjito, D. and Rangan, B.V. (2005). Development and Properties of low calcium fly ash based geopolymer concrete. *Research Report GC1, Curtin University of Technology, Australia.*
3. DjwantoroHardjito, Steenie E Wallah, Dody MJ Sumajouw and VijayaRangan, B. (2005). Fly ash based geopolymer concrete. *Australian Journal of Structural Engineering*, (6), No.1, 2005.
4. Duxson, P., Fernandez-Jimenez, A., Provis, J.L., Lukey, G.C., Palomo, A. and Van Deventer, J.S.J. (2007). Geopolymer technology: the current state of the art. *Journalof Material Sci.*, 42:2917-2933.
5. Hardjito D., and Rangan B. V., *Development and Properties of LowCalcium fly ash- based GeopolymerConcrete,* Research Report GC 1,Faculty of Engineering, Curtin University of Technology, Perth, Australia, 2009
6. Gajanan M. Sabnis, Kenneth Derucher and Kristin Cooper Carter. (2009). Concrete Construction and Sustainability. *CI Journal, October-December 2009.*
7. Laura E. Gordon,John L Provis, JannieS.J.Van Deventer, Non Tradational (Geopolymer) Cement And Concretes For Construction Oflarge Ccs Equipment Energy, Procedia 4 (2011) 2058–2065,Doi:10.1016/J.Egypro.2011.02.088 Elsevier, SciverseSciencedirect.
8. Benny Joseph A,∗, George Mathewb1 , Influence Of Aggregate Content On The Behavior Of Fly Ash Based Geopolymer Concrete , Scientia Iranica A (2012) 19 (5), 1188–1194 1026-3098 © 2012 Sharif University Of Technology. Production And Hosting By ElsevierB.VDoi:10.1016/J.Scient.2012.07.006Scientia Iranica
9. E. Arioza, O. Ariozb, O. Mete Kockara A*, Leaching Of F-Type Fly Ash Based Geopolymers Procedia Engineering , 42 (2012) 1114 – 1120, 1877-7058 © 2012 Published By Elsevier Ltd. Doi: 10.1016/J.Proeng.2012.07.503 Elsevier, ,SciverseSciencedirect