International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8, Issue-1C, May 2019

Influence of Molarity on Fracture Behaviour in Geopolymer Concrete Beams

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Abstract: In this present study an effort was made to know the fracture behavior of Geopolymer concrete beams with different molarities. The beams which were made of geopolymer concrete with notch were subjected to three point bending test and load vs. deflection curves for all the members were obtained. From the obtained data fracture properties such as fracture energy, fracture toughness and nominal stress were determined. The test showed increasing trend in fracture property such as fracture toughness, fracture energy and nominal tress in molarity range from 12M to 14M after which it showed decreasing trending in the molatity range of 14M to 16M..

Index Terms: Geopolymer- geopolymer; fracture behaviour ;three point bending test.

I. INTRODUCTION

In 1978, Joseph Davidovits developed a binder called geopolymer. Geopolymer is amorphous to semi-crystalline equivalent of certain zeolitic materials with excellent properties such as high fire and erosion resistances and high strength materials. There are two main constituents of geopolymer and they are namely source materials and the alkaline liquids. The source materials for geopolymer based on alumina-silicate should be rich in silicon (Si) and aluminum (Al) such as natural minerals like kaolinite, clays, etc. Alternatively, by-product materials such as fly ash, silica fume, rice-husk ash, slag, red mud, etc. can also be used as source materials. The choice of source materials for making geopolymer depends on the factors such as cost, availability, type of application and specific demand. The alkaline liquids used in the geopolymer are usually sodium or potassium based.

The most common type of alkaline liquid used in the geopolymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH). and sodium silicate or potassium silicate. Their mechanical properties are influenced by factors including raw materials, alkaline to fly ash ratio, activator type and curing conditions. These alkaline liquids are generally used depending upon the molarity of NaOH solution such as 10M, 12M, 14M etc.

Revised Manuscript Received on May 20, 2019.

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Fracture mechanics is the study of material behaviour in the existence of cracks and crack like defects and provides comfortable methods to measure the fracture strength and toughness of the material. In quasi brittle materials like concrete large fracture zone is formed which usually consumes more energy than failure. This provides the concrete.
Uneven post peak response. The fracture behaviour is commanded by fracture parameters such as fractured energy, critical4stress intensity factor and crack mouth opening displacement. Three point bending test of notched beams is used to determine fracture properties.

II. LITERATURE REVIEW

In the studies done by Deepa raj S the fracture properties of fibre reinforced geopolymer concrete were studied. The materials used were fly ash, coarse aggregate, fine aggregate, ordinary Portland cement, alkaline solution and super plasticizer. Three specimens each for GPC and PCC were casted the beam size were 100x100x500 mm. During the tests Crack mouth opening displacement (CMOD) was noted using LVDT and central deflections were noted using the dial gauges. The different behaviors were noted. In load to deformation behavior the mid span behavior were noted with help of dil gauges at 100N intervals. From the load deflection curves of GPC and PCC were plotted, from the results of the tests it was observed that the GPC had more load carrying capacity compared to that of PCC. When the fibre content increased load carrying capacity also increased. They observed that the ultimate load and first crack load of GPC were 10-20% and 60-70% respectively more than that of PCC and also increase in the fibre content by 0-0.75% increased the ultimate load of GPC by 1.78-2.8 times. And the fracture energy of GPC was 80% more than that of PCC, increase in the fibre content increased the fracture energy In both GPC and PCC. They also found that GPC exhibited 10-40% more fracture toughness than PCC.

In the studies done by N Ganesan, The fracture properties of geopolymer concrete were studied. For this study geopolymer concrete of grade M30 was developed and the results of this were compared with conventional concrete. For finding fracture properties 18 notched prisms of size 150x150x500 mm were prepared which were subjected to bending test. CMOD and load deflection for each prism were observed. From the test results it was seen that GPC exhibited higher strengths for hardened strengths, The load carrying capacity of

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GPC were observed to be more than PCC when notch depth was increased deflections and CMOD decreased, The fracture energy of GPC was twice than that of PCC and even the fracture toughness was 20-30% more than PCC.

In the experimental investigation carried out by T S Ng, T N S Hut, and S J Foster, Mode 1 and 2 fracture behavior of steel fibre reinforced high strength geopolymer concrete were tested.

The tests which were conducted were direct shear test and uniaxial tensile test. The test were conducted on a 10KN Instron universal testing machine LVDT were used to test displacement the specimens were loaded until the fibres were completely pulled out from the section or fractured, for mode 2 tests additional 2 LVDT's were used to measure the separation plane opening displacement. The conclusions which were obtained from the tests were for mode 1snubbing effect dominated the highly inclined fibres and negatively inclined fibres dominated in mode 2. Fibers at high inclination angles potentially fracture and sconsequently result in a brittle failure. The efficiency of the fibre pullout was dependent on the modulus of pullout medium and tensile strength of fibres it was found that pullout efficiency was lower on GPC because of lower elastic modulus.

III. AIM OF THE INVESTIGATION

The literature review clearly indicates the gap in literature of direct linking of molarity of alkaline solution and fracture behaviour in ambient cured geopolymer concrete. This motivated the proposed study wherein, the effects of molarity of alkaline solution on fracture behaviour will be explored.

IV METHODOLOGY

A. Materials Used:

The Following Are The Materials Used In This Investigation: Fine Aggregate (M Sand) Passing Through 4.75mm Is Sieve With A Specific Gravity Of 2.62 And Fineness Modulus Of 2.66 And Confirms To Grading Zone Ii As Per Is: 383-1970 (Reaffirmed 2007). Geopolymer Is Composed Of The Following Materials: Fly Ash, Fine Aggregate (M Sand), Activator Solution (Sodium Hydroxide And Sodium Silicate Solution).

B. Preparation of Geopolymer concrete.

Geopolymer concrete is prepared by mixing fly ash, ggbs, coarse and fine aggregates with alkaline solution containing naoh solution and sodium silicate solution. sodium hydroxide is mixed with distilled water and kept for at least 24 hours before casting.

C. Specimen Preparation

To find fracture properties three beams of size 1150 mm (length) x 150 mm (breadth) x 300 mm (depth) were casted for 12 molar, 14 molar and 16 molar respectively. For creating a notch at the bottom of the beam plastic sheet of depth 90mm was placed at the bottom of beam during the time of casting and concrete was poured into the mould. All these cubes, cylinders and beams were ambient cured for 48 days and then tested.

D. Three point bending test setup.

To determine the fracture properties such as load deflection behaviour, fracture energy and critical stress intensity factor, three point bending tests with deflection controlled equipment were done. The specimens were placed on the roller supports with the notch on the tension side and load was applied. The machine had a built in data procurement system which noted down load and deflections.

E. Microstructure analysis.

Field Emission Scanning Electron Microscopy (FESEM) analysis was done to observe the microscopic properties of geopolymer concrete with different molarities. Ambient cured geopolymer samples were taken for SEM analysis after 28th day testing. The samples were initially sputter coated with gold and then mounted on a platform for examination using carbon tape. Microstructure analysis helps to monitor the polymerization of NaOH solution and sodium silicate and also morphological properties of the concrete

V. RESULT AND DISCUSSION

A. Three Point Bending Test

Fig.1: Three point bending test setup.

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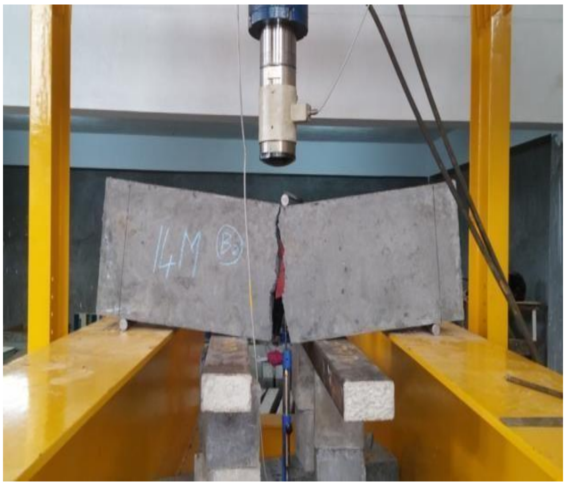

Fig 2: Test specimen after failure

The following were the test results obtained by testing notched geopolymer concrete beams under three point loading, maximum load required to break the member and its corresponding deflections are presented in table 4.4 and the plot of load Vs deflection is shown in figures 4.8- 4.10 for the molarityranges of 12M, 14M and 16M respectively.

Table 1: Maximum load and deflection.

Sl no.	Molarity.	Maximum load (KN)	Maximum deflection (mm)
1.	12	13.2015	0.71
2.	14	14.125	0.54
3.	16	9.519	0.59

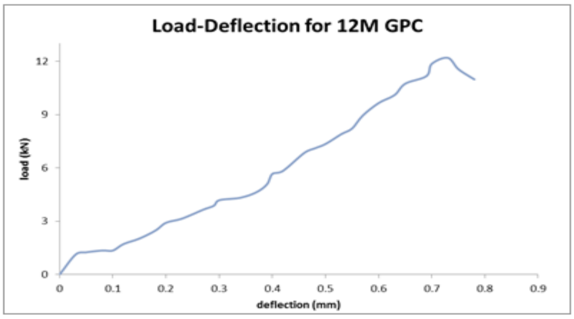

Fig.3: Graph showingLoad deflection behavior of 12M GPC.

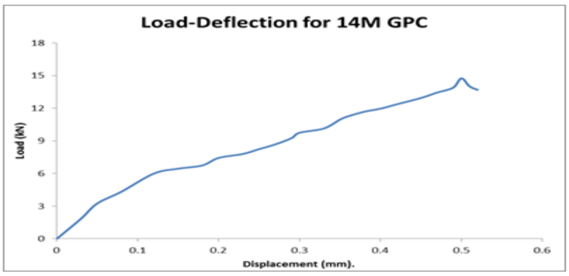

Fig 4: Graph showingLoad deflection behavior of 14M GPC.

Observation: The test results presented in table 1 and the load Vs deflection plot shown in figures 3-5 is utilized for evaluating fracture properties such as fracture energy, fracture toughness and nominal stress.

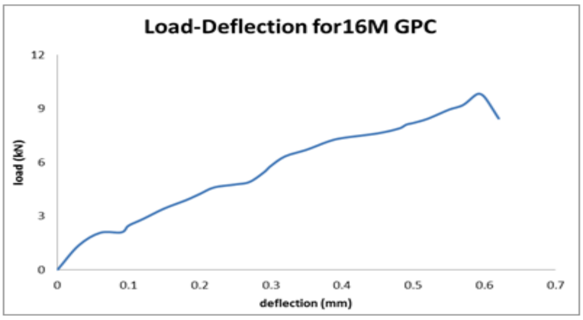

Fig.5: Graph showingLoad deflection behavior of 16M GPC.

B. Fracture energy.

Fracture energy is calculated by considering area under load deflection curve, maximum load and maximum displacement.

Table 2: Variation of fracture energy with molarity

Sl No	Molarity	Fracture energy(N/m).
1.	12	197.96
2.	14	205.02
3.	16	127.84

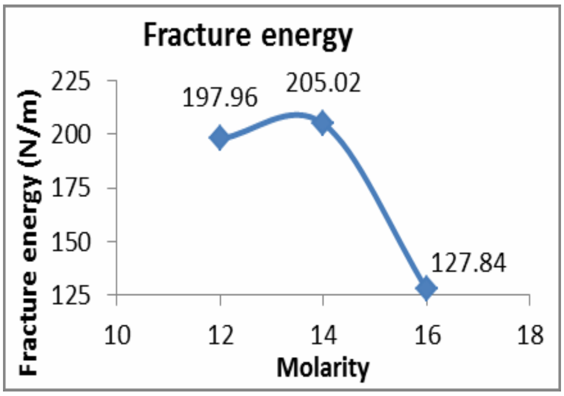

Fig 6: Graph showing fracture energy behavior for different molarities

Observation: From the above plot it is seen that as the molarity increases, the fracture energy shows increasing trend in molarity range from 12M to 14M by 3.44% after which it showed decreasing trend in the molarity range of 14M to 16M by 37.65% .

A. Fracture toughness.

Fracture toughness is calculated based on critical stress intensity factor.

Observation: From the above plot it is seen that as the molarity increases, the fracture toughness shows increasing trend in molarity range from 12M to 14M by 20.97% after which it showed decreasing trend in the molarity range of 14M to 16M by 33.4%.

Table 3: Variation of fracture toughness with molarity.

Sl No	Molarity.	Fracture toughness. X10^5 (N/m$^{3/2}$)
1.	12	7.52 46
2.	14	9.10 27
3.	16	6.05 44

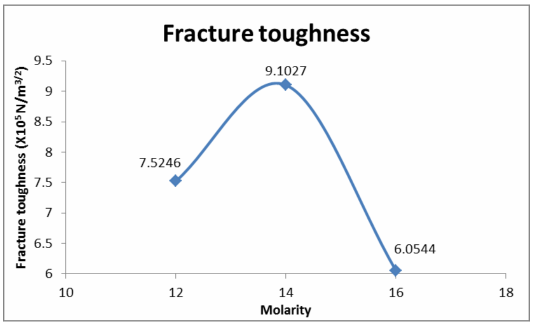

Fig 7: Graph showing fracture toughness behavior for different molarities

B. Nominal stress.

Nominal stress is calculated for the obtained maximum load.

Table.4 Variation of nominal stress with molarity.

Sl No	Molarity.	Nominal stress. (N/mm^2)
1.	12	1.56
2.	14	1.886
3.	16	1.25

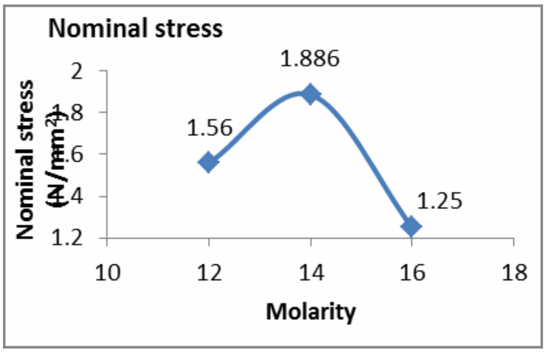

Fig 8: Graph showing nominal stress behavior for different molarities.

Observation: From the above plot it is seen that as the molarity increases, the normal stress shows increasing trend in molarity range from 12M to 14M by 20.9% after which it showed decreasing trend in the molarity range of 14M to 16M by 33.72%.

C. Microstructure analysis.(12M)

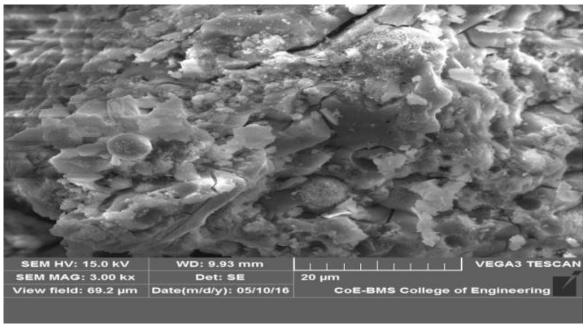

Fig 9: microstructure image of 12M GPC

Observation: The micro structure image shows that the mix is non-homogenous and unreacted fly ash particles are observed here and there. Many voids can be also being seen as shown.

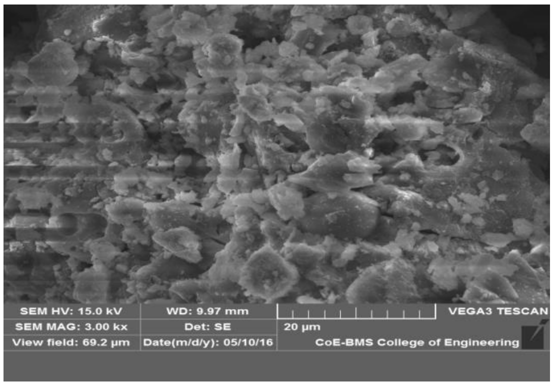

Fig 10: Microstructure image of 14M GPC

Observation: The microstructure image shows that the mix is non-homogenous. And the present of free unreacted flyash particles are not visible in the microstructure. Only few voids are present in the microstructure as shown.

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D. Microstructure analysis.(16M)

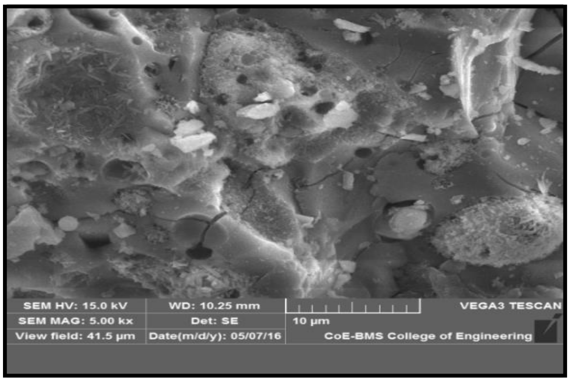

Fig11: Microstructure image of 16M GPC

Observations: The microstructure image shows that the mix is non-homogeneous. Presence of partially reacted flyash particle are seen here and there. Presence of voids can also be seen.

VI. CONCLUSIONS

1. From the test results it was seen that the fracture energy increased with increase in in molarity range from 12M to 14M by 3.4% after which it showed decreasing trend in the molarity range of 14M to 16M by 37.65%.
2. The fracture toughness shows increasing trend in molarity range from 12M to 14M by 20.97% after which it decreased in the molarity range of 14M to 16M 33.4%.
3. From the load deflection curve for various molarities the normal stress shows increasing trend in molarity range from 12M to 14M by 20.9% after which it showed decreasing trend in the molarity range of 14M to 16Mby 33.2%.
4. From the SEM analysis of microstructure of GPC, it is observed that the microstructure of 14M GPC has fully reacted flyash particles with very few voids in the microstructure which results in high strength properties in 14M GPC when compared with 12M and 16M GPC.
5. Hence from the above investigations, it can be concluded that molarity of NaOH solution effects the fracture behaviour of GPC with ambient curing. Optimum molarity range must be determined for achieving good fracture properties in GPC with ambient curing.

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AUTHORS PROFILE

Dr. G.NARAYANA, Professor and Head, Department of Civil Engineering, S.J.C Institute of Technology, Chickballapur. He has wide range of knowledge & 20 years of experience in teaching as well as researches in Structural Engineering field. He is also a Structural Designer and Consultant for many Projects. He published several papers in national and international journal.

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