A Computational Study on Fracture Process Zone For Single Edged Notched Beam Specimen of Geo Polymer Concrete

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Abstract- *As the demand for concrete as a construction material increases, so only the demand for Portland cement. The production of cement is increasing about 3% annually. On the other hand, the climate change due to production of cement is also increasing causing global warming. So we have go for alternate materials which would be useful for replacement of cement as well as one which would have minimum adverse impact on environment. One such material is Geopolymer concrete. This Geopolymer concrete has good physical property compared to conventional concrete. Most important feature of Geopolymer use of cement is completely nullified hence very less adverse effect to environment.*

Failure of concrete due to fracture is one of the most dangerous and disastrous thing happening in concrete. Hence it is necessary to design concrete to withstand the failure due to fracture. The conventional designing technique does not take into account the flaws present in the component and assume the component is free from any flaws. This may not be correct all the times. These internal flaws may be the reason for initiation of cracks and failure of concrete or any other material. Hence it is necessary to design the components considering the internal flaws in the component. This current study attempts to study the fracture behavior of Geopolymer concrete computationally by giving an initial flaw. ABAQUS-FEM software was used to carry out the study on Geopolymer concrete. The fracture parameters were studied for different molarity of Geopolymer concrete 8 and 12 Molar Geopolymer concrete was used in this study. The initial flaw size was also varied from 0.05d to 0.2d. The results were obtained computationally.

Keywords- CSTR-PID-ZN-Fuzzy-MRAM-MATLAB.

I. INTRODUCTION

1.1 GENERAL

As demand for concrete as a construction material increases the production of Portland cement also increases which in pollutes the environment there by causing global warming which is a alarming problem all over the world. This has raised the world to go for alternates for conventional concrete which would have the same properties of conventional concrete but on the other hand it should have less impact on the environment.

As a possible solution for this problem initially, Glukhovsky followed by Davidovits suggested that artificially synthesized alkaline activated aluminosilicate cementations systems can have excellent durability and may exhibit many other useful properties such as high compressive strength, low shrinkage, acid and fire resistance. He termed this material as Geopolymer. This material not only has good properties but produce less adverse effect to environment.

Safety is an essential concept of engineering design, and it tends to receive greater attention when the consequences of failure are severe. Every industry has its own safety requirement and guidelines to meet its own safety requirements, which includes protection of life and environment against possible hazards due to failures. The safety requirements for different industries vary from one another depending upon their functionality. Mechanical safety is one of the most important of all. Thus considerable steps have been taken in ensuring mechanical safety of the structural components. Usually, for mechanical safety, the design guidelines are based on stress computations and give importance to strength alone. However, the concept of designing solely for strength, and using highest strength material without regard to fracture toughness is unreliable. The conventional stress- based approaches assume the component is homogenous and do not have any flaws or defects present in them. But unfortunately in reality all the structural components have some defects or flaws present in them. If these flaws are not taken into consideration the structural component may fail well before its ultimate strength. These flaws are neglected by the conventional design approach hence they cannot be relied on all occasions. Hence the structure has to be designed considering the defects or flaws in structural components. Due to these flaws the component's actual strength cannot be taken and new strength has to be found out for designing.

1.2 Geopolymer concrete:

Davidovits (1988) introduced the term 'Geopolymer' to represent the mineral polymer resulting from geochemistry. Geopolymer, an alumina-silicate polymer, is synthesized from predominantly silicon (si) and aluminum (Al) material of geological origin or by-product material.

1.2.1 Basic Properties of Geopolymer Concrete:

Based on available experimental evidence, the Geopolymer concrete has good compressive strength, Tensile strength, flexural strength, fracture toughness

Geopolymer concrete when compared to normal concrete has following properties:

- Increased early strength
- Low shrinkage
- Increased freeze-thaw resistance
- Increased sulphate resistance
- Increased corrosion resistance
- Increased acid resistance
- Increased fire resistance
- Low curing time

1.2.2 Applications of Geopolymer concrete:

- Pre cast concrete like Railway sleepers, Electric power poles
- As a replacement for cement to reduce green house effect
- In the presence of alkalis enhancing bonding between paste and aggregates
- In the production of building materials like bricks, blocks, tiles, pipes, and ready mixed concrete products.
- Long term improvement in strength.

II. LITERATURE REVIEW

M. Al-Mukhtar, S. Henkel, H. Biermann, P.Hübner (2009) With welded joints, stress concentrations occur at the weld toe and at the weld root, which make these regions the points from which fatigue cracks may initiate. To calculate the fatigue life of welded structures and to analyze the progress of these cracks using fracture mechanics technique requires an accurate calculation of the stress intensity factor SIF.

Prabir SARKER (2008) The conventional binding agent in concrete is Ordinary Portland cement (OPC). However, cement production is highly energy-intensive and involved in CO2 emission to the atmosphere. Therefore, it is important to search for alternative low-emission binder for concrete in order to reduce the environmental impact caused by the production of cement.

ShilangXu, M.ASCE, Yanhua Zhao, and ZhiminWu(2006) Fracture energy represents the average total energy consumption during a complete crack propagation process. The use of one fracture property, the RILEM fracture energy, on its own is not sufficient to characterize the fracture behavior during crack stable and unstable propagation periods.

D Hardjito et al (2005) This paper presents the results of a study on fly ash-based geopolymer concrete. The test parameters covered certain aspects of manufacture of geopolymer concrete. The paper also reports the stress-strain behavior of the concrete with compressive strength in the range of 40 to 65 MPa. Tests were carried out on 100mmx200mm cylindrical geopolymer concrete specimens.

D. Hardjito and B. V. Rangan (2005)Concrete usage around the globe is second only to water. An important ingredient in the conventional concrete is the Portland cement. The production of one ton of cement emits approximately one ton of carbon dioxide to the atmosphere.

Zdenek P. Bazant, Emilie Becq-Giraudon (2001) This article shows how the fracture energy of concrete, as well as other fracture parameters such as the effective length of the fracture process zone, critical crack-tip opening displacement and the fracture toughness, can be approximately predicted from the standard compression strength, maximum aggregate size, water–cement ratio, and aggregate type (river or crushed).

YeoushangJenq, and Surendra P. Shah(1985) Attempts to apply linear elastic fracture mechanics (LEFM) to concrete have been made for several years. Several investigators have reported that when fracture toughness, *Kk*, is evaluated from notched specimens using conventional LEFM (measured peak load and initial notch length) a significant size effect is observed.

III. FINITE ELEMENT MODELLING

3.1 AIM OF INVESTIGATION

The main objective of the study is to evaluate the fracture properties of geopolymer concrete using FEM software. One of the fracture property being fracture process zone.

3.2 SCOPE OF THE STUDY

- To analyze, Isgeopolymer concrete a better alternate for concrete.
- Studying the physical properties of geopolymer concrete is essential, but if it is made without analyzing its fracture behavior is off no use.
- Hence in this project, study on the fracture behavior and fracture parameters of geopolymer concrete are made.

3.3 NEED FOR THE STUDY

- In major structures like nuclear power plant, dams, microscopic analysis of the concrete is important since even pre existing cracks can create major problem
- Even a small crack can propagate and become critical one during its life period that may lead to catastrophic failure.
- In concrete, flaws are not avoidable but the limitations shall be minimized so the limitations are determined by evaluation of fracture parameters.

3.4 FINITE ELEMENT MODEL

Abaqus - finite element software was used to model the geopolymer concrete and conventional concrete. The inputs for the models were obtained from past results and referring to journals.

3.4.1 Specimen details

- 4 Nos conventional M30 concrete beam of size 1200x200x100
- 4 Nos 12 molar Geopolymer concrete beam of size 1200x200x100
- 4 Nos 8 molar Geopolymer concrete beam of size 1200x200x100

Notch at the centre

- A notch was given at the center of the models. The size of crack was varied from 0.1d to 0.2 d and different models were created. The crack sizes provided we 10, 20, 30 and 40 mm respectively.

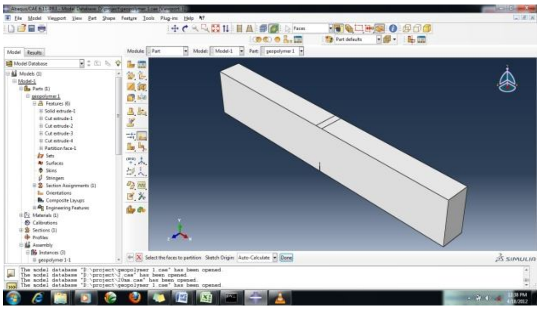

Fig 3.1 Beam model with a 40 mm crack at the centre

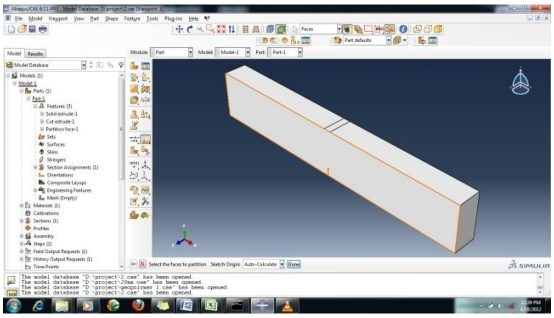

Fig 3.2 Beam model with a 30 mm crack at the centre

3.4.4 Loading

Three point loading was used in this study an area was created at the centre to stimulate the loading in that of a loading frame. Loading was given in range of 0.5 kN and the beam was loaded till deflection crossed the permissible limit. The support was given at a clear span 1000mm

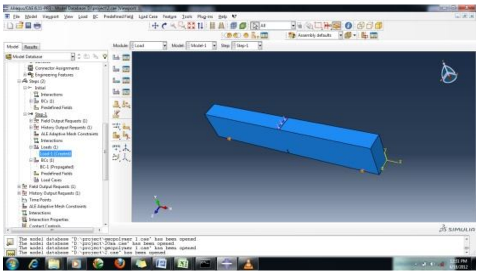

Fig 3.3 Three point loading applied to the bea

3.4.5 Meshing

Meshing has to be different in the crack region and all other places. A global mesh size of 1 and a 8 noded linear brick element at crack region and A global mesh size of 40 and a 4 noded tetrahedron element is used at all other regions.

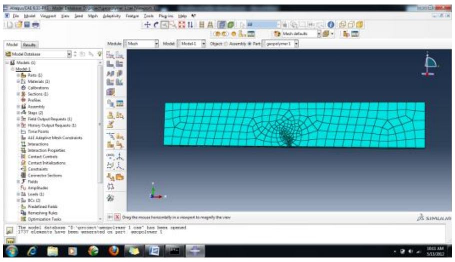

Fig 3.4 meshing of the beam

3.4.6 Deflection

The maximum central deflection was found out for every 0.5 kN and readings were noted. The deflected model showed the crack started to open up and started to propagate as the load increased. The load vs deflection curve was drawn for each specimen.

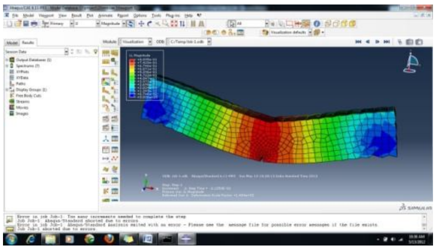

Fig 3.5 Deflected shape of the beam

3.4.7 Fracture process zone

The main objective of this study is the study of fracture process zone. From the FEM model the fracture process can be easily seen. The zone where the crack is going to propagate as the stress or load on the beam is increased.

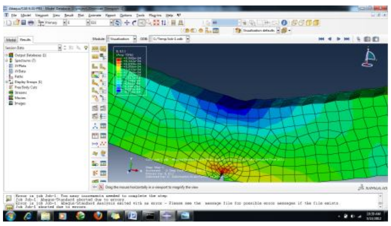

Fig 3.6 Fracture Process zone on the beam

IV. RESULTS

4.2 Load vs deflection curves for different models and different crack size

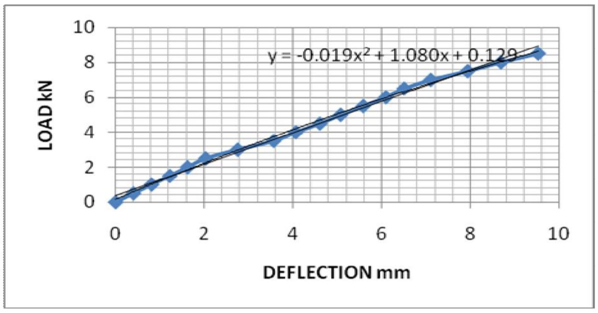

Fig 4.1 load vs deflection curve 40 mm crack size of control beam

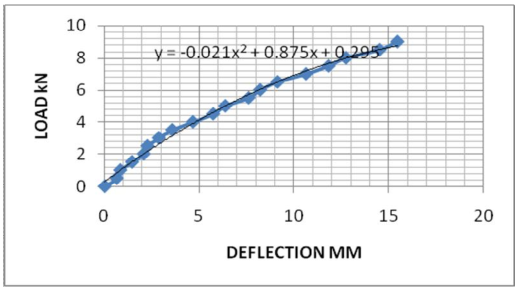

Fig 4.2 load vs deflection curve 40 mm crack size of 8m GPC

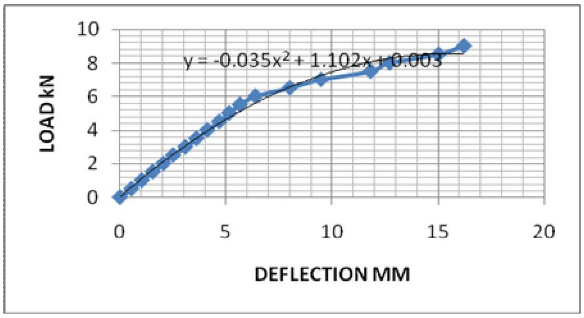

Fig 4.3 load vs deflection curve 40 mm crack size of 12m GPC

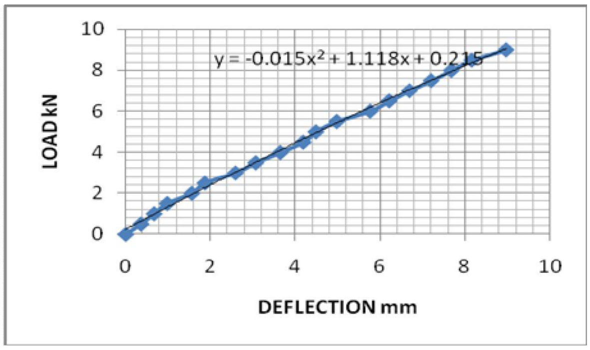

Fig 4.4 load vs deflection curve 30 mm crack size of control beam

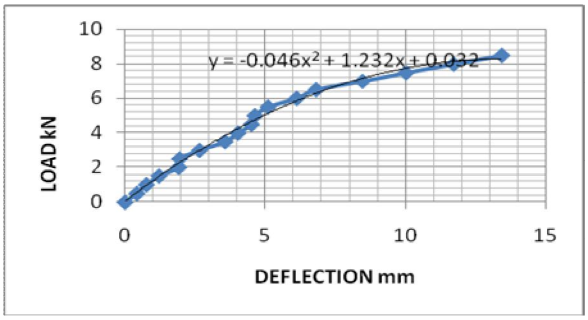

Fig 4.5 load vs deflection curve 30 mm crack size of 8m GPC

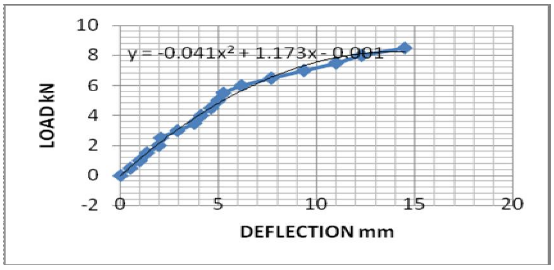

Fig 4.6 load vs deflection curve 30 mm crack size of 12m GPC

V. CONCLUSIONS

- Different fracture parameters have studied for normal concrete and geopolymer concrete.
- The fracture parameters of Geopolymer concrete have been compared with conventional concrete
- The fracture parameters stress intensity factor k, critical J-integral, fracture energy and fracture process zone
- The fracture parameters studied by the molarity of Geopolymer concrete in Phase -I and also varying the notch to depth ratio from 0.10 to 0.4.
- The stress intensity factor for Geopolymer concrete was higher when compared to that of normal conventional concrete with 12 molar Geopolymer concrete having the highest value.
- The K value of Geopolymer concrete was 20% more when compared to that of normal conventional concrete.
- The value of K decreases as the notch to depth ratio increases ,the notch of size 40mm & 20 mm has more stress intensity required for the crack to propogate when there is less flaw in the structure.
- The values of J-integral for conventional were near to that Geopolymer concrete with Geopolymer concrete of 12 molarity having a little higher value
- Comparing the result of fracture energy obtained by analyzing 40mm & 30 mm notched beams, the value of fracture energy decreased as the notch to depth ratio was increased since more energy is required for the crack to propagate when there is less flaws in the structure.
- The analytical results showed a great agreement with the experimental results.

Similarly the fracture parameters stress intensity factor k,critical J – integral, Fracture energy and fracture process zone will be studied analysing 10 mm &20mm Beam in Phase – II and overall results can be compared.

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