FINITE ELEMENT MODELLING OF STRENGTHENED SIMPLE BEAMS USING ANSYS

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ABSTRACT

An experimental study was undertaken to establish the relationship between compressive strength with Splitting Tensile Strength and Modulus of Elasticity of Geopolymer Concrete. The stress - strain curve of OPC concrete originally proposed by Popovers is validated for Geopolymer concrete with some modification in curve fitting factor. The stress - strain behavior of Geopolymer concrete using sand and M-sand was studied and compared with the experimental investigation. The beams were made with Geopolymer concrete having compressive strength in the range of M20 - M35 by heat curing as well as ambient curing using river sand and M- sand. The experimental ultimate moment was found to be about 40- 60 % higher than the predicted ultimate moment. Due to the high stiffness of reactive Geopolymer concrete, the actual deflections of the beams were found to be slightly lower than the allowable values under service loads. The observed crack widths under service loads were within acceptable limits. It was found that GPC made with sand and M-Sand had better structural integrity. Hence, there is a high potential to produce GPC using sand and M-Sand. Design examples as well as comparison of test results with Numerical Analysis using ANSYS 13.0 are presented in this thesis.

Keywords:- *ANSYS 13.0,Beam section ,Geopolymer concrete*

INTRODUCTION

Concrete is the most commonly used construction material. Ordinary Portland Cement (OPC) is conventionally used as the primary binder to produce concrete. The manufacturing of the Portland cement releases enormous amount of green house gas emission to atmosphere, which is an energy intensive process.

India is the second-largest cement producing country in the world after China. The country’s cement production was 300 million tones during the year 2010 and the figure is expected to double, to reach almost 550 million tones by 2020, as per the estimates by the Cement Manufacturers Association (CMA). On the other hand, global warming has become a major concern due to the climatic changes. The global warming is the increase of Earth's average surface temperature due to the effect of greenhouse gases. Among the greenhouse gases, CO_2 contributes about 65% of global warming. Therefore, efforts are being taken to develop the other forms of cementious materials for producing concrete. One such material, Geopolymer Concrete is produced with activated fly ash as a binder there by eliminating Portland cement. The base material, such as fly ash, is activated by alkaline solution to produce the binder, which is rich in Silica (Si) and Aluminum (Al). The emission of CO_2 to the atmosphere is approximately one tone, and this is due to the production of one ton of Portland cement, and hence, the cement industry is held responsible for CO_2 emissions to a greater extent. In order to address the global warming issues, several efforts are in progress to reduce the use of Portland cement in concrete. These include the utilization of supplementary cementing materials such as fly ash, granulated blast furnace slag, silica fume, metakaolin and rice-husk ash, and the development of alternative binders to Portland cement.

LITERATURE REVIEW

Sunilaa George et al (2008) suggested that river sand is widely used for concrete as fine aggregate. The increased cost of river sand and depletion in ground water table due to illegal sand mining leads to finding an alternative for fine aggregate without compromising the strength. The authors proposed a mix design for mix M30 grade of concrete using quarry dust and manufactured sand by replacing the river sand. Four mix proportions were made to test the effect of inclusion of quarry dust and manufactured sand in concrete and the results were compared with the control specimens. It was found that the strength of the concrete is enhanced in both the types of replacements.

Gui Feng Liu et al (2011) reported that experimental studies on C30 concrete with manufactured-sand were carried out under conditions of freeze-thaw cycle, which is based on the testing of raw material performance and concrete mix ratio; The authors reported the comparative studies on the changing laws of the mass, strength and the relative dynamic Elastic Modulus of concrete were developed in three cases which were freeze-thaw cycle, freeze-thaw cycle and acid corrosion, and freeze-thaw cycle and alkali corrosion. The test results showed that the mass, strength and the relative dynamic Elastic Modulus of concrete with manufactured-sand decreased evidently with the increasing of times of freeze-thaw cycle.

Mahendra Chitlange and Prakash S. Pajgade (2010) studied the steel fiber reinforced concrete with artificial sand as fine aggregate. Three matrices with compressive strength of 20, 30 and 40 MPa were designed and reinforced with crimpled steel fibers at dosage rate of volume fraction 0, 0.5, 1.0, 1.5 and 2.0 percent. The specimens were prepared, cured and tested for compressive strength, flexural strength and split tensile strength. The strength of steel fiber reinforced natural sand concrete (SFRNSC) and steel fiber reinforced artificial sand concrete (SFRASC) have been compared with the test data from the present study. The promotional use of artificial sand will conserve the natural resources for the sustainable development of the concrete in construction industry.
Fernández-Jim nez and Palomo (2003) studied the suitability of various types of fly ash to be Geopolymer source material. These researchers proved that to produce optimal binding properties, the low-calcium fly ash should have the percentage of unburned material (LOI) less than 5%, Fe_2O_3 content should not exceed 10%, and low CaO content, the content of reactive silica should be between 40-50%, and 80-90% of particles should be smaller than 45 m.

Earlier Balaguru et al (1999) suggested Geopolymer coating to protect the transportation infrastructures as well as the use of Geopolymer composites to strengthen concrete structures. They reported that to strengthen reinforced concrete beams, Geopolymer composites have been successfully applied. In terms of fire resistance, durability under ultra violet light, the performance of Geopolymers was better than the organic polymers, and did not involve any toxic substances. In that study, Geopolymers with the Si/Al ratio was more than 30.

Cengiz Duran Atis (2003) discussed some important Engineering properties of plain concrete. From the existing literature, a large volume of selected experimental data has been collected and then analyzed. Particular emphasis has been given to study the effects of concrete strength on the tensile strength (flexural and splitting tensile), modulus of elasticity and Poisson’s ratio of concrete. They also conducted the study on the effect of the size of specimens on the compressive strength and modulus of elasticity of concrete. The adequacy of some of the familiar relationships for predicting the tensile strengths of concrete and modulus of elasticity has been critically examined, and suitable expressions are suggested to cover concrete strength up to 120 MPa.

Hardjido and Rangan (2005) studied the test parameters which covered certain aspects of manufacture of Geopolymer concrete, reported the stress-strain behavior of the concrete with compressive strength in the range of 40 to 65 MPa. Tests were carried out on 100mm x 200mm cylindrical Geopolymer concrete specimens. Test results show that a good agreement exists between the measured stress-strain relations of fly ash based Geopolymer concrete and those predicted by a model developed originally for Portland cement concrete.

Rangan (2008) reported that the behavior and failure mode of fly ash-based Geopolymer concrete in compression is similar to that of Portland cement concrete. Test data show that the strain at peak stress is in the range of 0.0024 to 0.0026. Earlier Collins et al (1993) have proposed the stress-strain relation of Portland cement concrete in compression is correlates well with experimental results.

Djwantoro Hardjito et al (2005) compared the values of Young’s modulus of fly ash-based Geopolymer concrete with that of Aitcin and Mehtha who used the granite type of coarse aggregate. The Young’s modulus of Portland cement concrete with fcm=84.8 MPa was 31.7 GPa, while for concrete with fcm=88.6 MPa, Ec=33.8 GPa . The values reported in this paper are at the lower end of those calculated using the empirical expression given in the Australian Concrete Structures Standard, AS3600

Dattatreya et al (2011) studied the behaviour of room temperature cured reinforced GPC flexural members. A total of eighteen beams were tested in flexure. Three conventional concrete mixes and six GPC mixes of target strength ranging from 17 to 63 MPa and having varying combinations of fly ash and slag in the binder phase were considered. The reinforcement was designed considering a balanced section for the expected characteristic strength. All the specimens were tested under two point static loading. The studies demonstrated that the load carrying capacity of most of the GPC beams was in most cases marginally more than that of the corresponding conventional OPCC beams.

Rangan (2009) reported the test data on fly ash-based Geopolymer concrete. These reports cover the material and the mixture proportions, the manufacturing process, the fresh and hardened state characteristics, the influence of various parameters on the fresh and hardened state concrete, the utilisation of the material in structural members, and the long-term behavior like reinforced beams and columns. On the long-term properties, laboratory experiments have shown that the fly ash-based Geopolymer concrete undergoes low creep and very little drying shrinkage. After 52 weeks under sustained load of 40 % of the compressive strength, the drying shrinkage strain measured was approximately 100 x 10-6 and the creep factor (the ratio of creep strain to elastic strain) was found to vary between 0.44 and 0.63 when the compressive strength of concrete was approximately 60.

Dattatreya et al (2011) reported that studies were carried out on the behaviour of room temperature cured reinforced GPC flexural members. In flexure a total of eighteen beams were tested in. Six GPC mixes of target strength ranging from 17 to 63 MPa having varying combinations of fly ash and slag in the binder phase and three conventional concrete mixes were considered. Using balanced section the reinforcement was designed for the expected characteristic strength. Under two point static loading, all the specimens were tested.

Ambily et al (2011) studied the shear behavior of reinforced GPC and OPCC beams. One OPCC mix and three GPC mixes were considered for the study. All the beams were provided with the same shear and flexural reinforcement and the beams were tested under two point loading with two shear span to depth ratios of 1.5 and 2 for each of the mixes. The details of the mix designs of GPC mixes, parameters were also investigated in this study. Casting of RGPC beams, testing and evaluation of structural behavior with respect to cracking, service load, deflections at various stages and failure modes were studied. Comparison of shear design procedure of beams was made by conventional IS 456 2000 approach and Modified compression field theory.

Lloyd and Rangan (2010) studied extensively on fly ash-based Geopolymer concrete. Test data were used to identify the effects of salient factors that influence the properties of the Geopolymer concrete and proposed a simple method for the design of Geopolymer concrete mixtures. Test data of various short-term and long-term properties of the Geopolymer concrete and the results of the tests conducted on large-scale reinforced Geopolymer concrete members show that Geopolymer concrete is well-suited to manufacture precast concrete products that can be used in infrastructure developments. The authors also include brief details of some recent applications of Geopolymer concrete.

Rangan B.V et al (2017) reported the test data on fly ash-based Geopolymer concrete. The author also covers the material and the mixture proportions, the manufacturing process, the fresh and hardened state characteristics, the influence of various parameters on the fresh and hardened state concrete, the utilisation of the material in structural members, and the long-term behaviour like columns and beams. The test variables were the longitudinal tensile reinforcement ratio and the compressive strength of concrete. The behaviour of the Geopolymer reinforced columns and beams was similar to that of members made of Portland cement concrete. The test results have also shown that the design provisions of the current codes and standards are applicable to reinforced fly ash-based Geopolymer concrete members.

Ali Abbas (2010) has developed the finite element models using a smeared crack approach for concrete, three dimensional solid elements (solid 65) for concrete, three dimensional solid elements(solid 45) for steel plate and three dimensional layered elements(solid 46) for carbon-fiber-reinforced plastic plate(CFRP).Three- dimensional finite element analysis was conducted to obtain the response of the strengthened beams with steel and CFRP plates in terms of applied load - deflection, tension force distribution in the strengthening plates along the reinforced concrete beams, and bond force distribution in the beam with CFRP plate and beam with steel plate.Results from the ANSYS finite element analysis are compared with those obtained from experimental results and other available numerical results. The comparisons show good accuracy.

EXPERIMENTAL PROCEDURE

his chapter presents the results of the experimental program on geopolymer reinforced concrete beams, and presents the detail of the test program. Forty eight reinforced geopolymer concrete beams were casted using sand and M-sand and tested. The test parameters covered a range of values encountered in practice, with different reinforcement ratio (under, balanced and over). Observation shows that first cracking location is 0.43L ~ 0.45L from the support. Maximum load carrying capacity at 1st cracking was observed for over reinforced beam, but on the other, it was the balanced condition beam at ultimate load. Maximum deflection at failure was also observed for the beam that under reinforced section. The sizes of test specimens were selected to suit the capacity of test equipment available in the laboratory. The compressive strength of concrete and the tensile reinforcement ratio were the test parameters for beam specimens. The behaviour, the crack patterns, the failure modes, and the load versus deflection characteristics are described. The effects of different parameters on the strength of beams are also presented.

BEAMS

General Behaviour of Beams

The specimens were tested under monotonically increasing load until failure. As the load increased, beams started to deflect and flexural cracks developed along the span of the beams. Eventually, all beams failed in a typical flexure mode. Figure 4.1 shows an idealized load-deflection curve at mid-span of beams. The progressive increase of deflection at mid-span is shown as a function of increasing load. The load-deflection curves indicate distinct events that were taking place during the test. These events are identified as first cracking (A), yield of the tensile reinforcement (B), crushing of concrete at the compression face associated with spalling of concrete cover (C), a slight drop in the load following the ultimate load (C’), and disintegration of the compression zone concrete as a consequence of buckling of the longitudinal steel in the compression zone (D). These features are typical of flexure behaviour of reinforced concrete beams.

RESULTS AND DISCUSSION

There are two types of post processing in ANSYS 13.0 program; general and time history. The later provides a step by step variation of any desired variable such as stress strain at various nodes or within any element in the model. The former provides and lists capabilities for the ultimate results (last time step) such as deformations, contour plots of stress and strains, and allows an automatic output of history.

Figures 5.5 and 5.6 shows the concrete and reinforcement model in ANSYS 13.0 respectively.

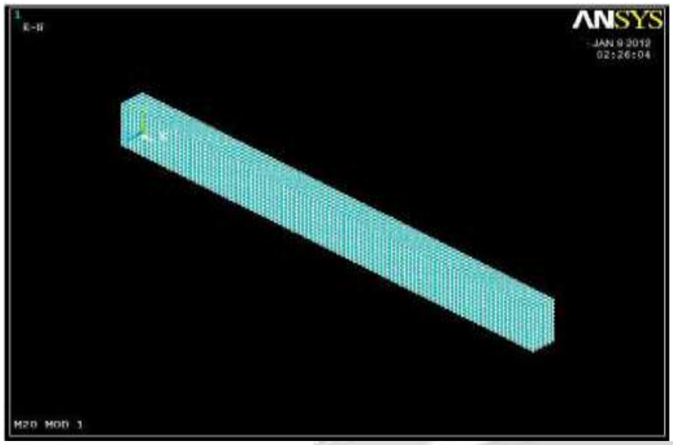


Figure 5.5 Model in ANSYS

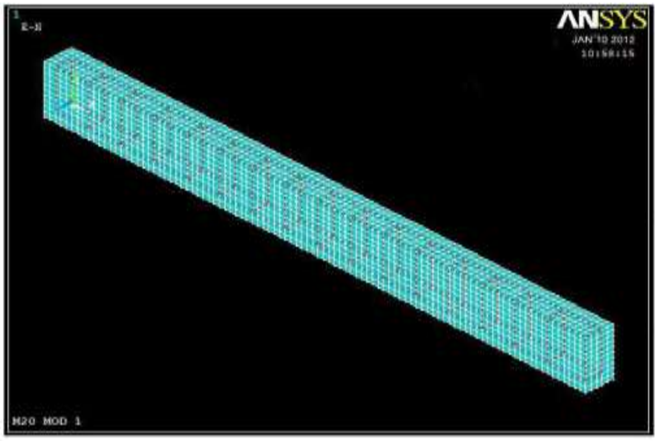
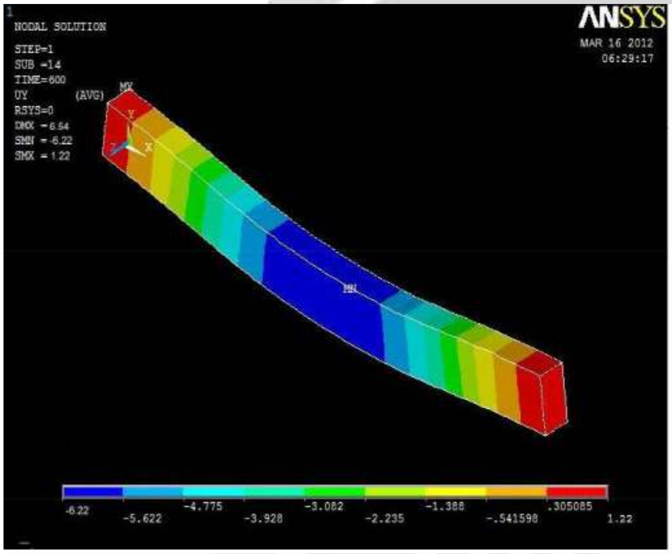
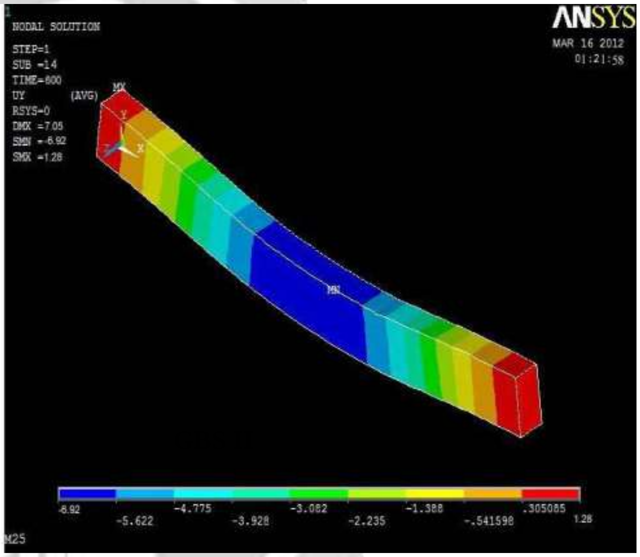


Figure 5.6 Reinforcement Model in



GBS I



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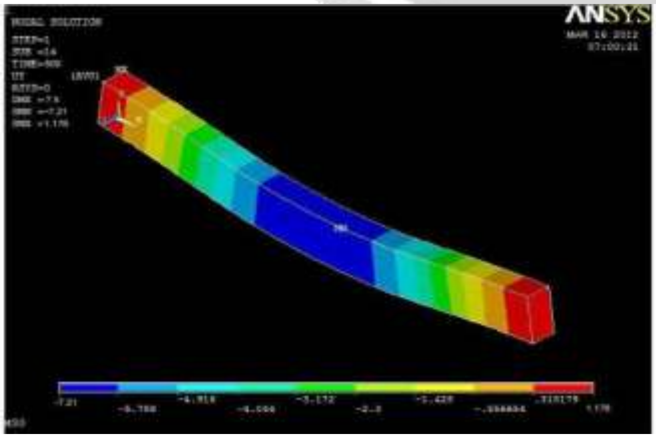
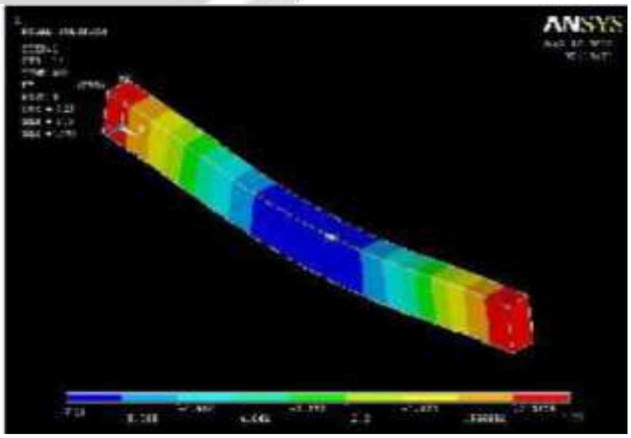
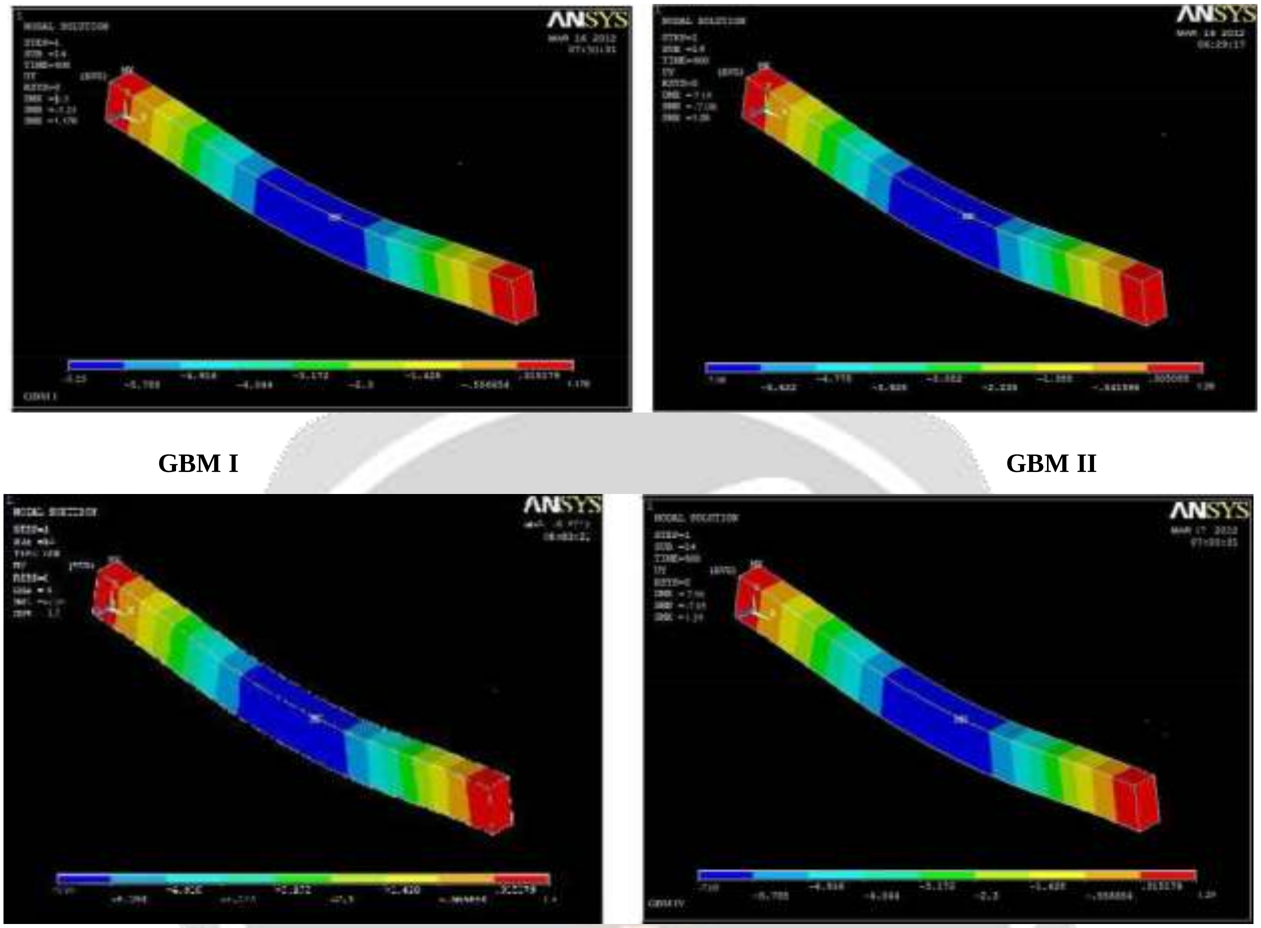


GBS III



GBS IV

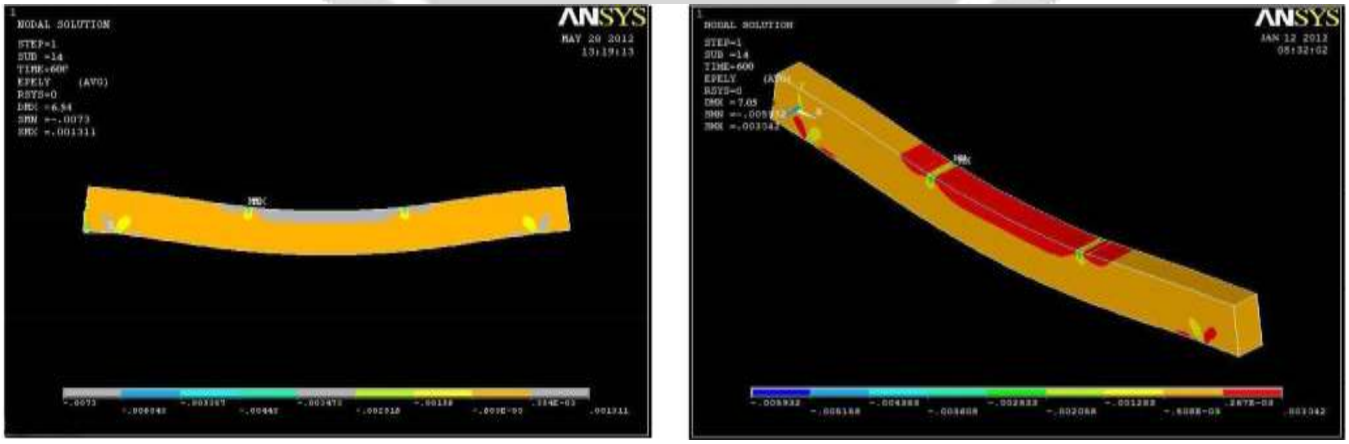
Figure 5.7Deflection for Beams with Sand under Ambient Curing for Balanced Section in ANSYS 13.0



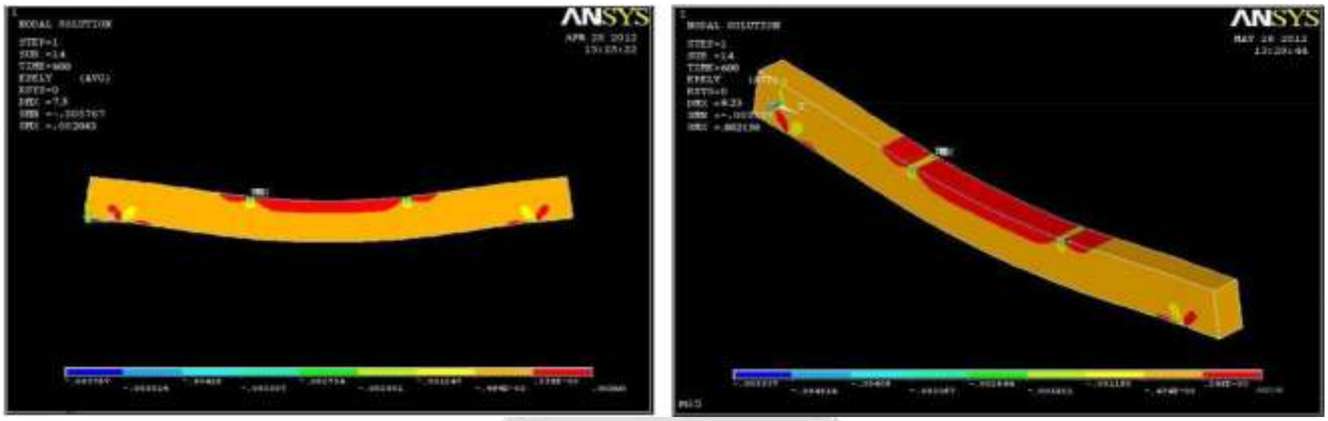
GBM I **GBM II**

GBM III **GBM IV**

Figure 5.8 Deflection for Beams with M-Sand under Ambient Curing for Balanced Section in ANSYS 13.0

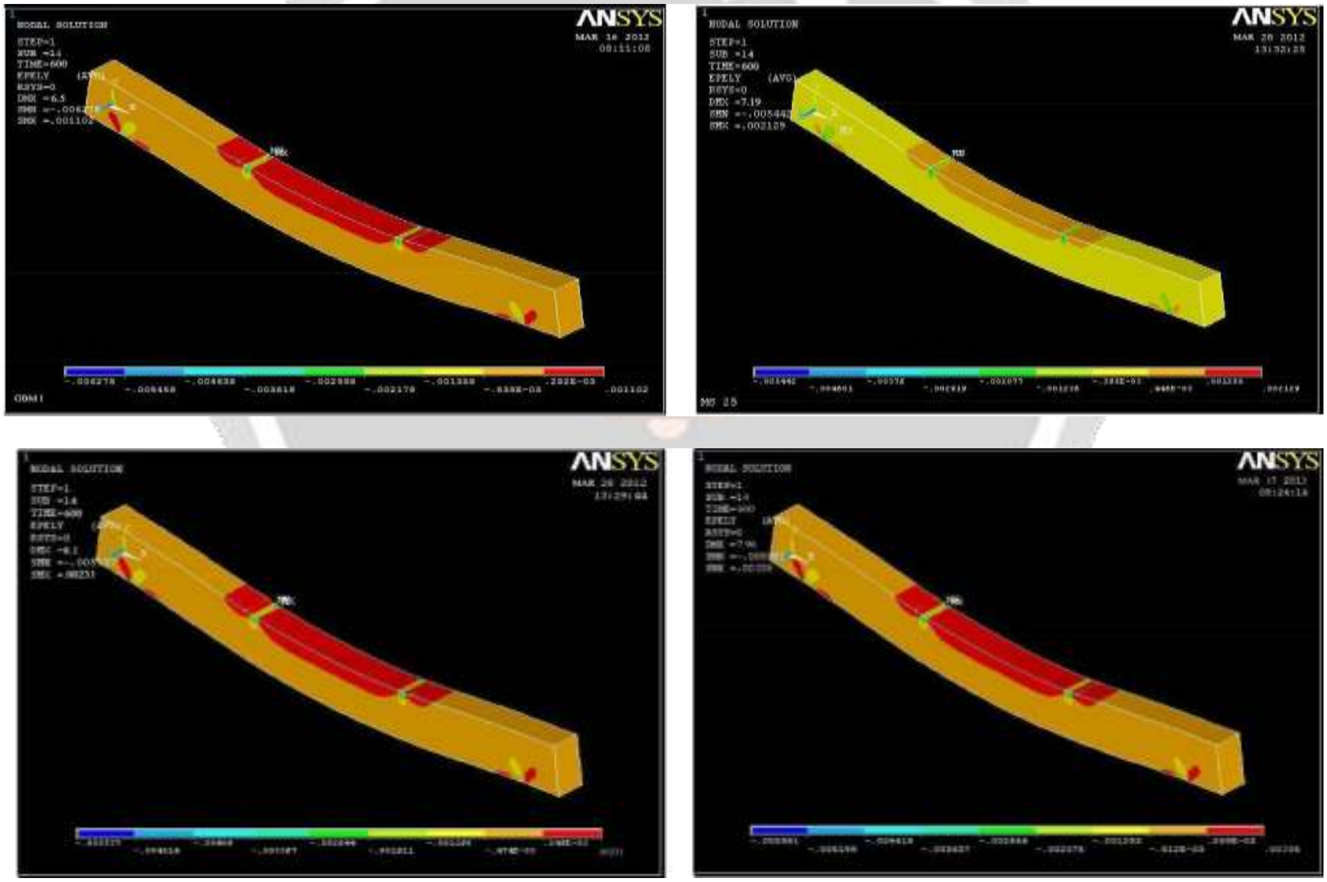


GBS I **GBS II**



GBS III **GBS IV**

Figure 5.9 Strain for Beams using Sand under Ambient Curing for Balanced Section in ANSYS 13.0



GBM III **GBM IV**

Figure 5.10 Strain for Beams using M-Sand under Ambient Curing for Balanced Section in ANSYS 13.0

CONCLUSION

The basic material of the geopolymer based on fly ash is of prevailingly amorphous character, only seldom containing needle-shaped minority crystals. The depth of the section is 5% less for Geopolymer concrete using sand and 10% less for Geopolymer concrete using M-206 sand when compared to conventional concrete reported in the literature. Moment-curvature curves have the same trend as that of the load-deformation curves. It is observed that when the load is increased, the specimen loses its flexural rigidity due to deflection and reduction in effective moment of inertia due to development of crack. The experimental load deflection results obtained from the test conducted on beam specimens are compared with ANSYS 13.0 results and the graphs are plotted for various mix proportions. Experimental results are found to have good agreement with finite element analysis.

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