Numerical Evaluation of Alkali Activated Reinforced Geopolymer Concrete Column

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ABSTRACT

Geopolymer concrete is a type of concrete that is made by reacting aluminate and silicate-bearing materials such as fly ash or slag from iron and metal production with a caustic activator. It can be a suitable substitute for ordinary Portland cement (OPC) concrete. Geopolymer concrete is considered as green concrete since the reduced CO2 emission and due to the usage of waste materials for manufacturing.A lot of studies are undertaken in the field of the usage of geopolymer concrete in structural memberssuch as beams, columns, slabs, etc. In this paper, geopolymer concrete columns are modeled usingthe Finite Element Modeling software ANSYS, and the behavior of the same column under axial loading and eccentric loading is studied. The axial behavior of the geopolymer concrete column is compared with the axial behavior of the conventional M30 concrete column and also the behavior of the geopolymer concrete column under axial load is compared with that of 50mm eccentric load.

Keywords: Geopolymer concrete, Axial loading, Eccentric Loading

1 Introduction

Cement concrete is the most commonly used material in construction. According to the EPA, the average person consumes roughly one ton of cement concrete per year. Concrete manufacturing has a great effect on the environment due to greenhouse gas emissions which have the main impact on global warming. Nevertheless, Portland cement is considered the main contributor to gas emissions in concrete production, where Portland cement is responsible for about 74% to 81% of the CO2 amount emitted from typical concrete mixes [1]. The emitted CO2 from the Portland cement industry is considered a main environmental issue, where about 3% of total global greenhouse gas emissions are produced by the cement industry [1].

In addition to the environmental problems caused by the cement industry and the large amounts of energy consumed in the Portland cement production process, conventional cement concrete has many durability problems, such as sulphate attack, alkali-aggregate reaction, and low fire resistance. Hence, the development of eco-friendly construction materials as an alternative to cement concrete has become one of the main objectives of the scientific community [2].

Geopolymer concrete (GPC) is a type of concrete that is produced by using industrial by- products such as Ground Granulated Blast Furnace Slag (GGBS), Fly ash, Metakaolin, silicafume etc. as binding materials which have cementitious properties. Industrial by-products are converted into binding material by using alkali activators such as Sodium Hydroxide (NaOH) and Sodium Silicate (Na_2SiO_3). Alkali Activated Geopolymer concrete has attracted considerable attention since its first use as an alternative material to the well-known traditional Portland cement concrete (PCC) due to its superior properties and environmental impact. Geopolymer concrete can be manufactured without Portland Cement (PC), so it can be considered green concrete. Alkali activated concrete (AAC) has been confirmed to have good mechanical

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characteristics in addition to reducing CO_2 emissions. Geopolymer concrete is not only reducing CO_2 emissions but also consumes large amounts of industrial waste like slag and fly ash [2].

Geopolymer concrete have significantly lower CO_2 emissions than OPC concretes [3]. It also possesses advantages such as better thermal insulation properties [3], higher temperature/fire resistance [3], providing a viable use for waste materials that are often disposed of in landfill [4], low creep and shrinkage [4], excellent chemical resistance [3], higher compressive and tensile strength [4] etc. Although there are many works reported on the experimental works on various geopolymer concretes, the studies on structural behaviour of geopolymer concrete is limited. In this study, numerical evaluation of geopolymer concrete column is done and the results are compared with conventional concrete column.

2 Modelling Of Geopolymer Concrete Column

A Geopolymer concrete column with the same dimensions as that of the validated conventional concrete column is designed and is shown in Figure 1. The concrete was modeled by using an eight-noded solid with 65 element. This solid element consists of eight nodes with three degrees of freedom at each of these nodes with translations in the nodal x, y, and z directions. The steel reinforcement was modeled using the Link 8 element. This Link 8 element contains two nodes with three degrees of freedom at each of these nodes with translations in the nodal x, y, and z-directions. The steel element used for FEM modeling was assigned to be an elastic- plastic material and identical in tension and compression [5]. The specimen is a square column having a dimension of 150mm × 150mm and a height of 1500mm. The top cover to reinforcement is provided as 20 mm and the side cover to reinforcement is 20 mm. Main reinforcement 4 Nos of 12 mm diameter and lateral ties of 8 mm diameter at 150 mm c/c are provided [6].

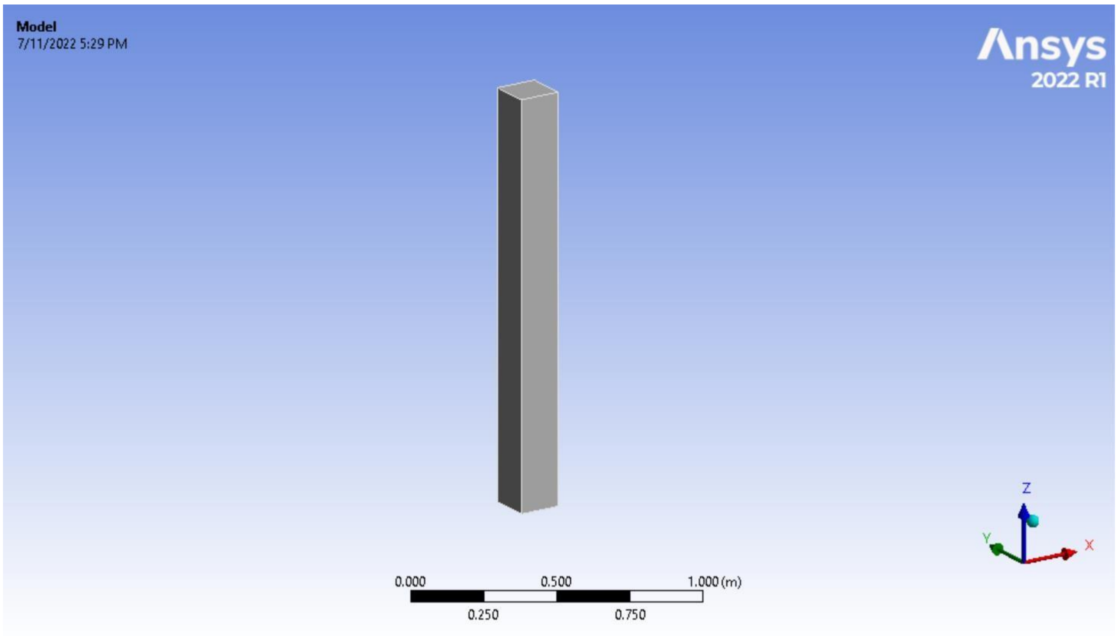

Figure 1: *Geometry of Geopolymer Concrete Column*

Here, the modeling work is done in Space claim, and modeling is completed in the geometry building stage. Meshing was done by setting mesh attributes under the meshing option and then by using the mesh tool. The concrete and reinforcement parts mesh with a default sizing of 18.75 mm and coarse meshing is provided [5]. The meshed column is shown in Figure 2.

To get a unique solution, displacement boundary conditions are given to constrain the model. At the support and loading points, there is a need to apply the boundary conditions, to ensure that the FEM model created acted in the same way as that of the experimental column. The support is modeled in such a way

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that fixed support is introduced [6], [7]. Two types of loads, that is axial load and 50mm eccentric load are given to the column [8].

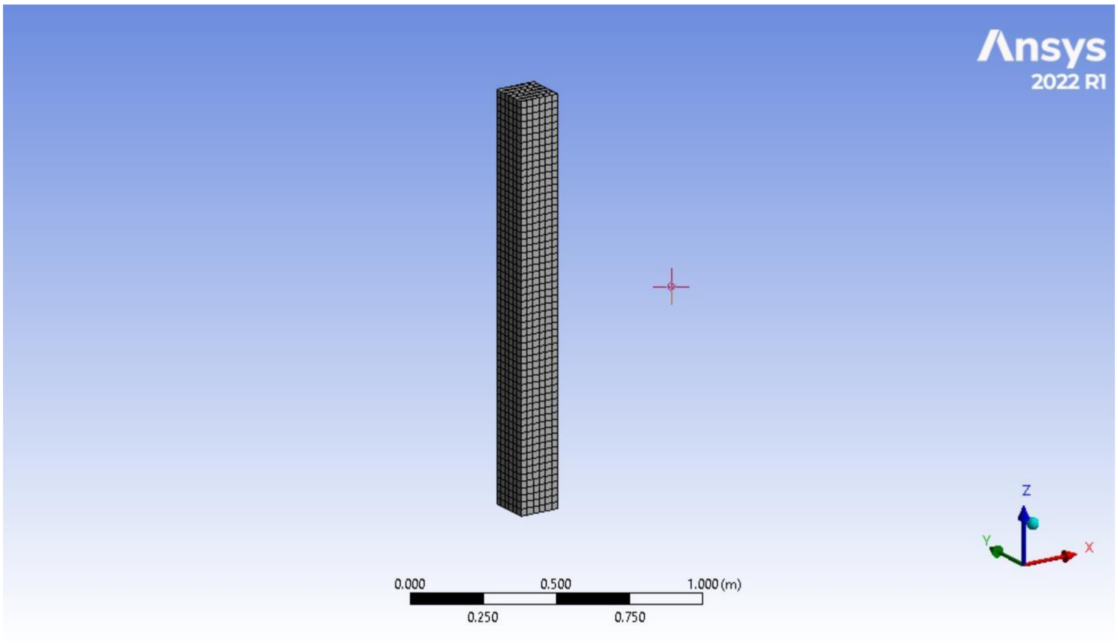

Figure 2: *Meshing of geopolymer concrete column*

3 Results and Discussions

The displacement convergence method is used in this study. In this method, the input is given as displacement in steps and the corresponding load will be produced. Finally, an ultimate load is reached where we get the maximum deformation. The deformations of the geopolymer concrete column under axial loading and 50mm eccentric loading are shown in Figure 3 and Figure 4 respectively.

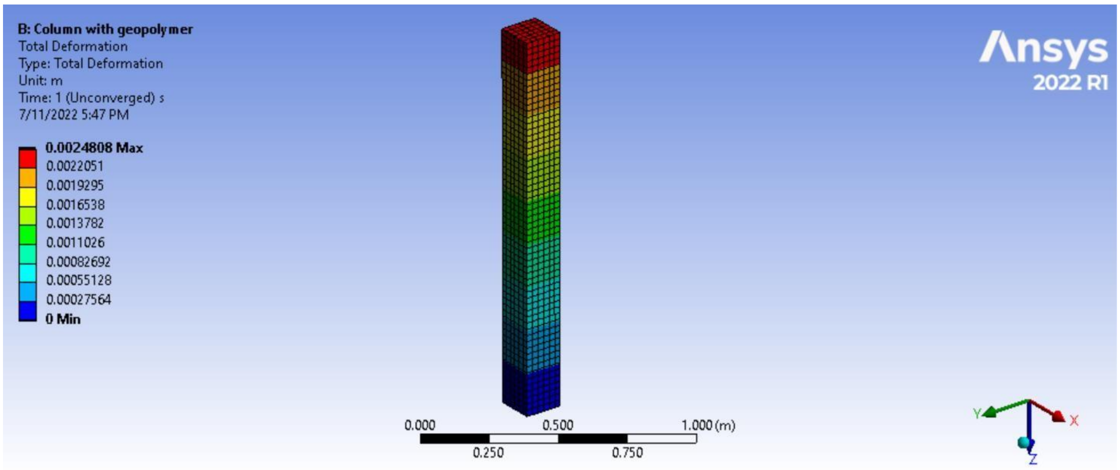

Figure 3: *Deformed model under axial load*

The maximum lateral deformation that occurred in the geopolymer concrete column under axial loading is 2.48mm and the maximum lateral deformation that occurred in the geopolymerconcrete under 50mm eccentric loading is 33.34mm. Eccentric loading causes a huge rise in lateral deformation compared to axial loading. It is better to design geopolymer concrete columns to avoid situations that may lead to the acting of eccentric loading. But compared to normal reinforced concrete columns, geopolymer concrete columns perform well under axial loading and eccentric loading which is an advantage.

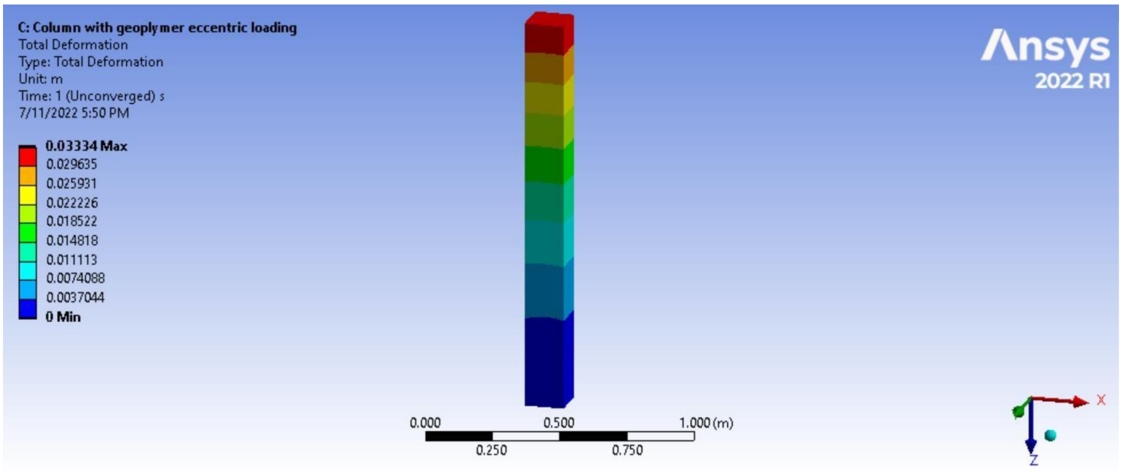

Figure 4: *Deformed model under 50mm eccentric load*

When the displacement is provided stepwise, corresponding load will be obtained. From that load displacement behaviour, peak load is obtained. The load-deformation graphs of the geopolymer concrete column under both axial loading and 50mm eccentric loading are shown in Figure 5 and Figure 6 respectively.

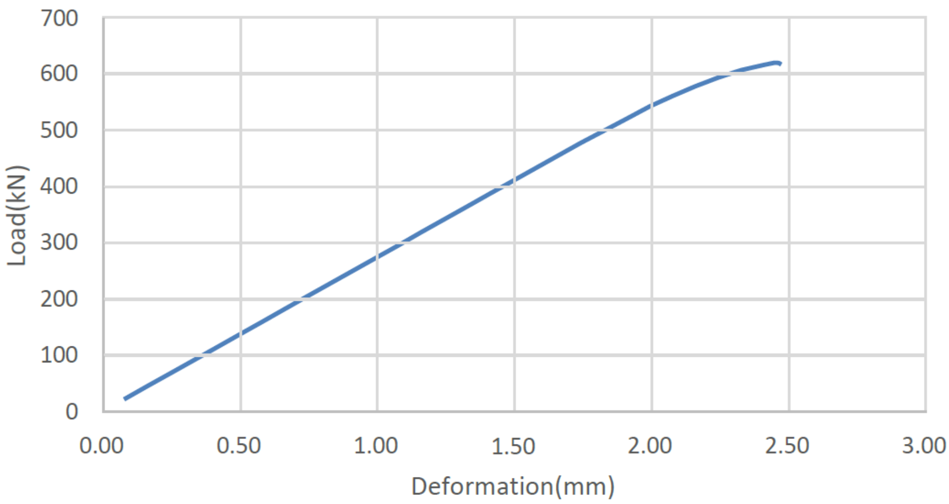

Figure 5: *Load-deformation curve under axial load*

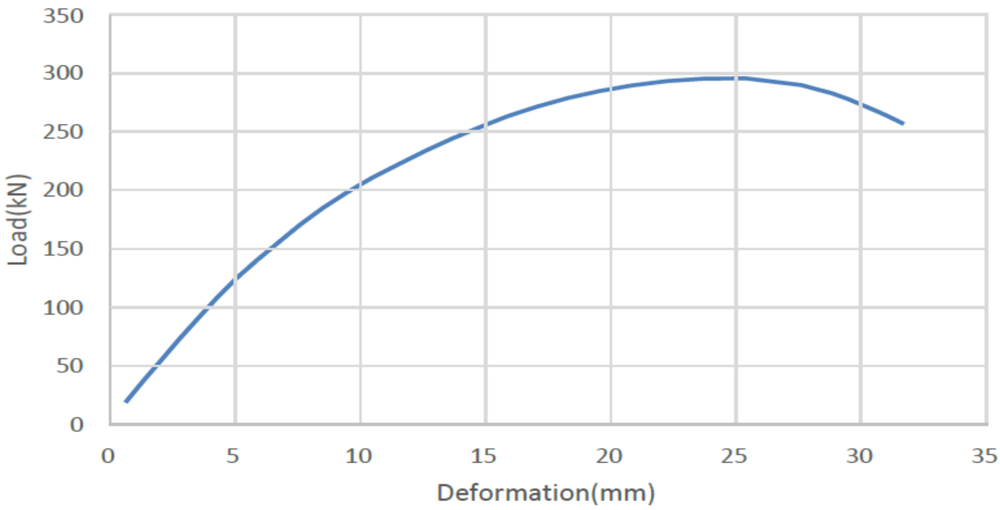

Figure 6: *Load-deformation curve under 50mm eccentric load*

The results obtained by applying displacement on the conventional reinforcement concrete column under axial load and geopolymer concrete column under axial and 50mm eccentric loading are shown in Table 1.

Table 1: *Load deformation characteristics of columns*

Specimen	Loading Condition	Peak Load (kN)	Maximum Lateral Deformation (mm)	Maximum Axial Deformation (mm)
Geopolymer Concrete Column	Axial Load	619.48	2.48	2.47
	50mm Eccentric Load	295.48	33.34	3.05
Conventional RC Column	Axial Load	416.21	3.73	2.00

From Table 1, it can be seen that the geopolymer concrete column behaves well under axial and eccentric loading conditions. The geopolymer concrete column could take a maximum load of 619.48 kN under axial load and a maximum load of 295.48 kN under 50mm eccentric load. The geopolymer concrete column was subjected to a maximum lateral deformation of 2.48mm under axial loading and 33.34 mm under 50mm eccentric loading. The load-carrying capacity of the column decreased when it is subjected to an eccentric loading. And also the maximum lateral deformation has also increased under eccentric loading. Compared to the performance of the conventional reinforced concrete column considered, the geopolymer concrete column performed better.

4 Conclusion

Based on the study, it can be concluded that it is effective to use geopolymer concrete for the construction of structural members such as columns. Geopolymer concrete column performs similar or better than conventional concrete columns. The use of geopolymer concrete increases the load-carrying capacity and decreases the amount of deformation. The load carrying capacity of the column decreases with the increase in the eccentricity of loading.

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