Analysis of deformation of RC beam with addition of fly ash: a Finite element based modeling

Balwant Kaur[1], Parminder Kaur[2], Ankush Kuamr Jain[3]

[1,2]M.Tech Student (Structural Engg), Department of Civil Engineering, Poornima University

[3]Assisatant Professor, Department of Civil Engineering, Poornima University

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Abstract:

The buildings are composed of various structural units like column, beam and wall. The experimental study to understand the strength behavior of such component is widely developed by various researchers. On the other hand, to make the safe, durable and efficient structure some important modeling aspect is also required. Finite element analysis based software ANSYS is based suitable to determine the deformation, equivalent elastic stress and equivalent elastic strain. In the present study a RC beam is modeled and the cement & sand quantity is replaced by fly-ash in the varying percentage from 0% to 60%. The results of the study are revealed that the total deformation and maximum deformation is decreased with the effect of fly-ash. The obtained results indicated that the 50% fly-ash content is best suitable based on the deformation parameter in concrete mixture.

Key Words: ANSYS 15.0, Deformation, Fly Ash, M-sand

Introduction

Finite Element Analysis (FEA) was developed by R. Courant in 1943; it was depended on the RITZ methods. FEA is used for numerical analysis and minimization of error in calculation. Manually calculation is very much typical to do so that there are so many analytical methods to solve it in a very fast and easy way. FEA is using widely in now a day mostly in structural engineering and aircraft engineering. Here is a software ANSYS that can be used to create a model on it and analyze it in a very fine manner. ANSYS create mesh on the model and accurately calculate all the parameter using FEA phenomenon. FEA can be divided into four generations from 10 to 15 years. Now there are some changes

in the direct stiffness method from 1934 to 1970. In fig 1, discretized element of a model is showing, how a large element can divide into small parts like a mesh. From finite element analysis, the complicated problem can be solved easily. It can be numerical and the analytical method is a very much long and time-consuming method as compare to the analytical approach.

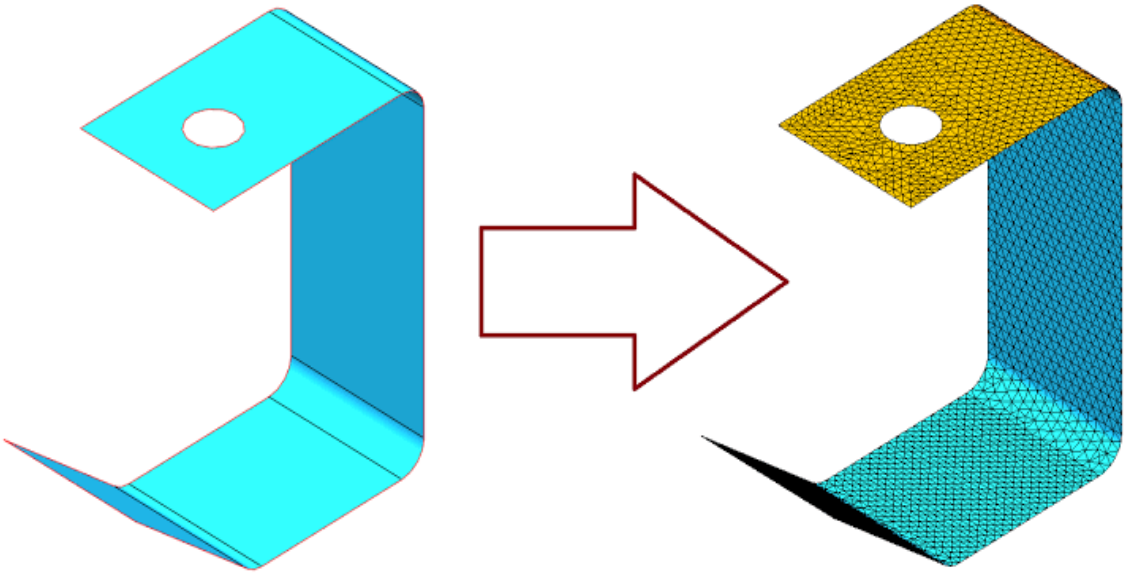

Fig. 1 Meshing of discretized element

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Generally, the finite element method is also known as finite element analysis, in this method normally finding the approximate solution by using the numerical technique with the help of partial differential equations and sometimes also uses an integral equation. The finite element method is working on the built-up algorithm in which its divides all parts into many small numbers of elements and then analyze the elements with making the relationship between these elements. FEM is using the Galerkin method to solve the equation. In this method, some polynomial approximation function is also working to solve. In this method, the spatial derivatives are changed to a partial differential equation by eliminating the spatial derivatives. ANSYS is the structural analysis software can solve complex structural engineering problems and make faster & better design decisions. With the finite element analysis (FEA) many tools are available in the software, which can customize and find solutions for structural & mechanics

problems and characterize them to analyze multiple or more than one design model. ANSYS is mechanical & structural analysis software used in whole the engineering industry to reduce the costs of testing & optimize their product designs. Civil engineers use ANSYS for structure analysis of projects as bridges, high-rise buildings, stadiums, dams, etc. By experimenting with innovative design in a virtual environment, engineers and designers can analyze strength, safety, environmental considerations, and comfort.

Concrete is a complex and composite material, mixture of cement sand and aggregates (Harith Mohammed Zaki et al., 2019). Concrete is strong in compression but it is weak in tension (Kristiawan, 2006), so reinforce the form of mesh, wire, and bars to improve the tensile strength of concrete. For more strength stressing methods are used nowadays. Fly ash formed in various sizes but these sizes similar to the cement particles and these slightly larger than pozzolan cement (Kiattikomol et al., 2001). Fly ash similar properties of cement when cement mix with water then hydration reaction between both material for bonding and as similar fly ash have also hydration reaction occur water mix time. M-Sand is an alternative replacement of river sand (Kumar et al., 2018) because according to growing in construction industry increased the demand of sand. More uses of river sand are destroying the nature so replace the river sand in construction material. M-sand have many advantage as compare river sand, it's cost effective as material and as transportation of material also reduce the cost. Manufactured sand, manufacture at industry from crushed hard rock and easily available near at the construction site. Due to the M-sand reduce the construction cost and main advantage of m-sand is, can easily controlled the size of sand so get the exact grading of sand as require of the construction. Structural steel is used for making different types shaped of construction material. In most industrialized countries structural steel sizes, shapes, storage practices, mechanical properties such as strengths, chemical composition, etc., are organized by standards. Most structural steels are very stiff with respect to cross-sectional area; those have high second moments of area, that structural steel shape, such as channel section, I-beams, which means they can support the high load without extreme sagging.

The replacement of material in concrete, beneficial for high rise building and bridge structure because the strength of concrete increased and density of concrete mix decrease. Replacement of material in the concrete mix, it's not a new technique, already various experimental studies carried out according to

parameters and as per the properties of the material (Mohamed, Heba et al., 2011, Huang, Chung-Ho et al., 2013, Mengxiao, Shi, et al.,2015, Rao, S. Krishna, et al., 2016, Singh Sarbjeet, et al., 2016, Sonnenschein et al., 2016, Hama, Sheelan M., and Nahla N. Hilal 2017, Zhang, Yuliang, et al., 2018, Agrawal, U. S., et el., 2019, Khan, Mehran, et al., 2019, Zhou, Hongyu, and Adam L. Brooks, 2019). So in this study an analytical approach is used to find out certain important parameters which are unable to determine in the laboratory.

The main purpose of this study is to analysis and modeling of RC beam performed on ANSYS 15.0 software. ANSYS software mainly used for mechanical projects, now in these day's ANSYS used for civil projects also, because this software is work on the FEM (finite element method), which gives appropriate result to analysis the structure. In this discrete the member into small parts and found the results on every part. Total deformation, equivalent strain and stress are the important parameters which are investigated in the study with the use of additive like M-Sand and fly ash.

2. Methodology

The following methodology are considered during the analytical approach in the dissertation work-

- Modeling and analysis on beam with change material properties using ANSYS.
- Result evaluate for different parameters with Rcc beam.
- Analyzed the beam for different material in concrete such as Fly ash and M sand in concrete.
- To analyze the deflection, Equivalent stress, and Equivalent strain of beam.
- Obtained results are compared with previous results.
- The differences on the obtained results are explained through graph and tables.

Finally, the conclusion of the report is described in the last chapter of the report

3. Results and Discussion

A verification study conducted for beam made of RCC with replacement of cement & sand by fly ash & M sand respectively on varying the percentage. Total deformation and maximum deformation was found from each modification in beam and compare with the RCC beam specimen. Accuracy of the specimen's result is depending on the mesh size, shape, properties, etc. the finite element mesh for the beam specimen was given in the figure 2, where the beam is divided into so many finite parts.

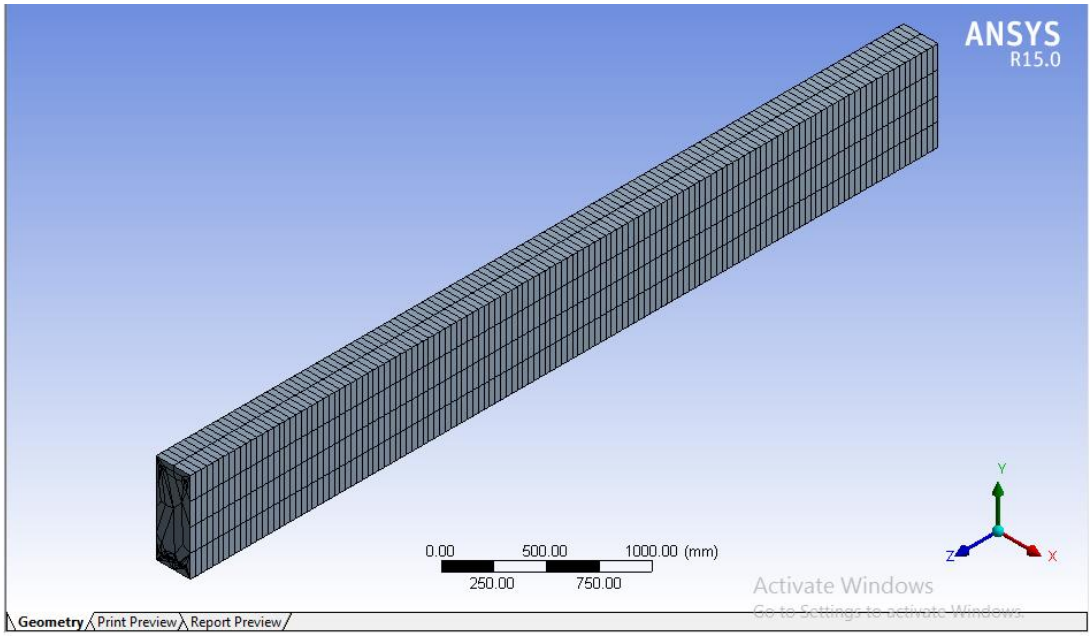

Fig. 2 Mesh of beam in ANSYS Workbench

Total deformation:

In ANSYS Workbench deformation are two types' total deformation and directional deformation. Both deformations are used to find displacement through stress. Directional deformation acts in directions like X, Y & Z. In the case of total deformation, it is the square root of the total of the square of X, Y & Z direction. Total deformation = SQRT(X^2+Y^2+Z^2)

Where X, Y & Z are directional deformation.

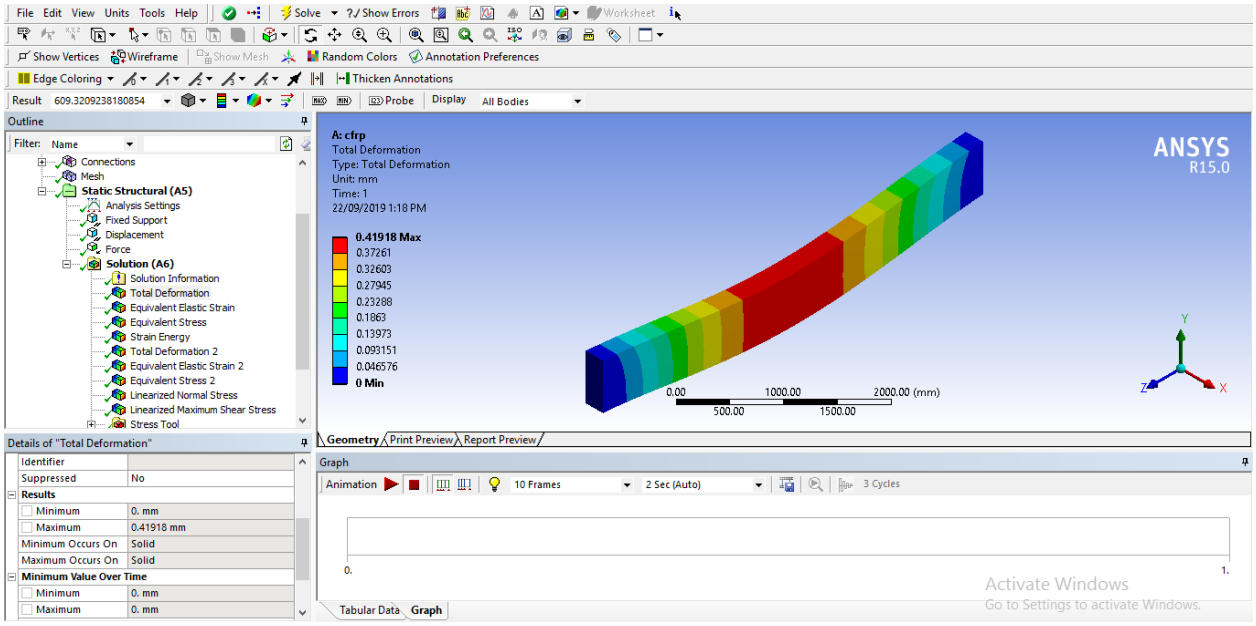

Fig 3 Total deformation on body due to Fly ash

Figure 3 defines the total deformation on the whole body. Different colour of the specimen in deformation shows the different level of deformation. Graph video is also shown at the bottom of the window. Total 145749 nodes created in this model, number of nodes are depend on the mesh size Colour describes the value like maximum deformation at the centre showing a red colour and blue colour describe the zero deformation. This total deformation is on the whole body defines in node numbers and deformation. Result data on all 145749 nodes are available in mm, it can easily export in excel sheet. That data cannot be shown in this study because of number of nodes are high in range.So at the time of modelling a path is created in construction geometry, deformation on that path is defined on the length of the specimen. Figure 4 describes total deformation on path provide on the body. Total deformation from solving this path is in mm on a given length. Then a length vs total deformation in mm graph is plotted. colour describe the range of deformation on defined path. Path is from one top edge to another top edge of the beam.

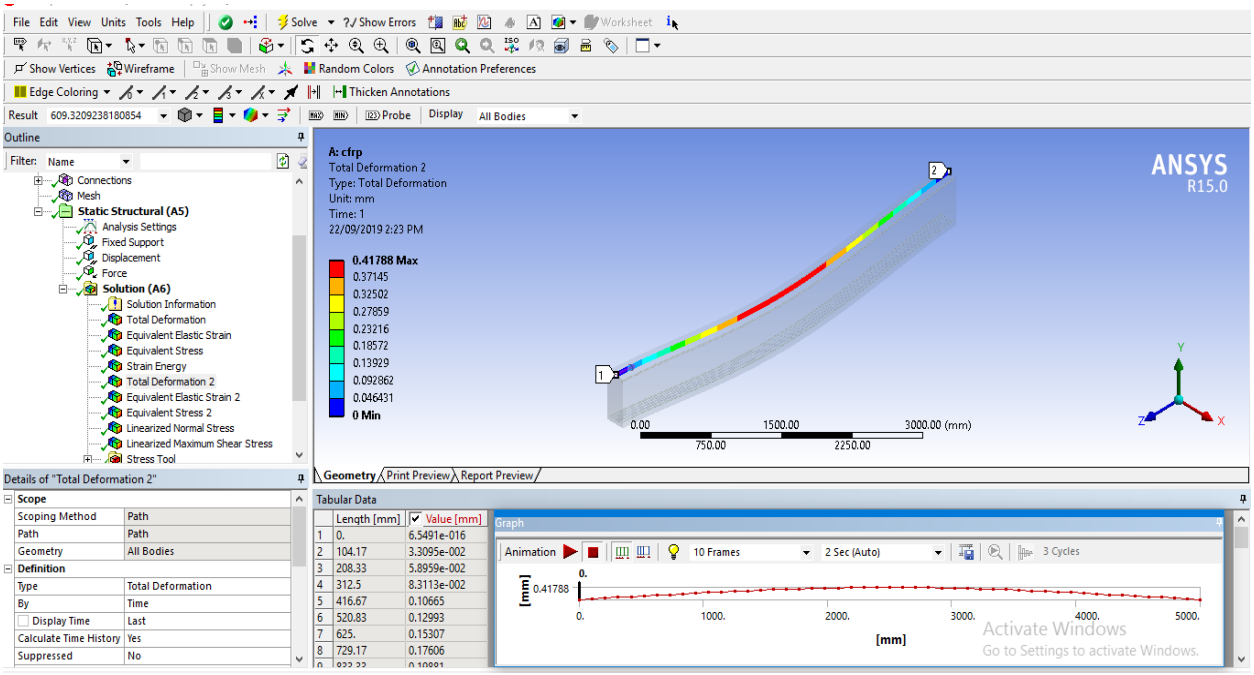

Fig 4 Total deformation due to Fly ash on path

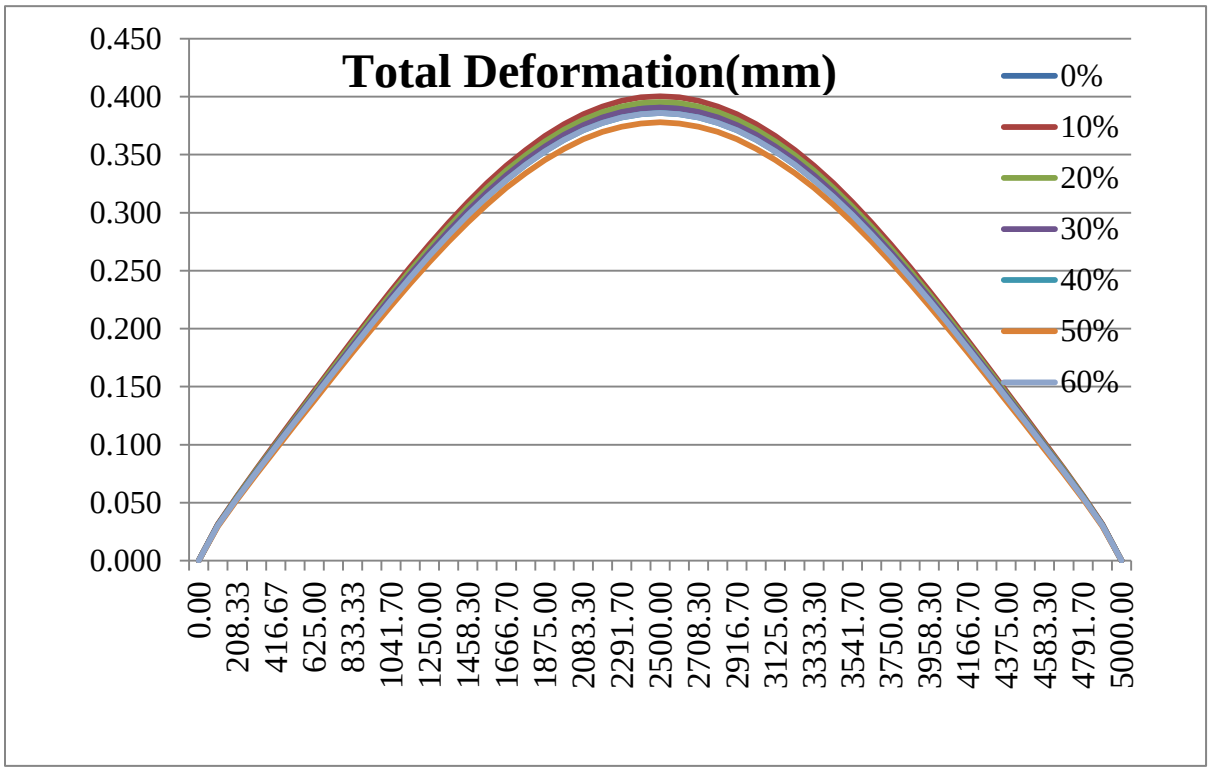

Fig 5 Total deformation vs Length of Fly ash Specimens

As figure 6 defines the maximum deformation is on the center in every % range reason is fixed beam having displacement on the bottom face and point load is on the center downward and at the corner, there is zero deformation. Colour describe the percentage wise result of total deformation, define that when percentage of fly ash is increased than deformation is also increasing.

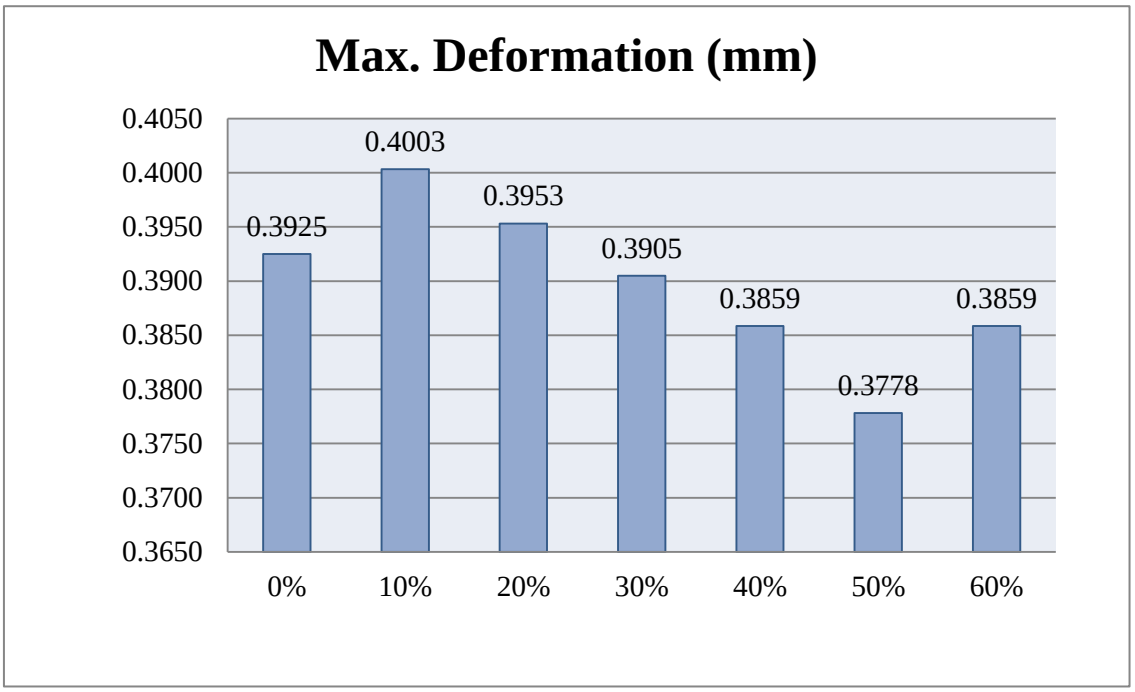

Fig 6 Maximum Deformation vs % of Fly ash

Conclusion:

Based on the investigation of RC beam with the effect of fly ash and M-Sand on concrete mixture, following conclusion can be drawn:

- The total deformation curves shows that till the addition of 10% fly ash content the total deformation is increased while further addition up to 50% fly ash content this deformation reduced significantly. However an incremental trend is also observed at 60% fly ash content.
- The maximum deformation obtained at 10% addition of fly ash further increase in the content of fly ash decreases the maximum deformation till 50% content, thereafter (at 60% fly ash content) content marginal increment is observed.

- It can concluded that based on the total deformation and maximum deformation parameter the 50% fly ash content is an optimum content for the RC beam on concrete mixture. However optimum content can vary after the investigation of equivalent elastic strain and equivalent elastic stress parameter, which will be the part of future study.

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