Finite Element Analysis of Reinforced Concrete Column Under Lateral Load

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ABSTRACT

To serve its purpose a structure must be safe against collapse and serviceable in use. Serviceability requires that deflections be adequately small to keep the cracks within tolerable limits. Although the widely followed ACI Code suggests a detailed method of deflection calculation, it often cannot exactly perceive the actual behavior of a structure. For this purpose, finite element analysis, using ANSYS, was performed. The research aimed of developing a program for the analysis of a column fixed at base and observes lateral deflection. Concept of key point, nodes, meshing and separate elements was used to model the concrete and the reinforcement. The scope of the study is limited to lateral load only applied at the midpoint at the top height in X direction. The same operation can also be performed in Y direction. The current application facilitates using random size of column with random height. But to serve the purpose of a single story, the work was done considering only one story height.

***Keywords* -** finite element, key point, lateral load, mesh, nodes

I. Introduction

The finite element method is a general technique for constructing approximate solutions to boundary-value problems. The method involves dividing the domain of interest into a finite number of simple sub-domains, the finite elements, and using variation concepts to construct an approximation of the solution over the collection of finite elements.

Structural analysis is the computation of structural responses corresponding to a given load on a specific structure. It implies that there are three basic components of structural analysis: the structure itself, the loading and the response. In structural analysis, the quantities defining the first two are assumed known and the quantities defining the third are sought.

There are a number of empirical and semi-empirical methods of deflection calculation proposed by different codes. Among them, ACI is the most renowned and practiced method for calculating deflection. But this method overlooks some column behavior and material properties. For example, it does not consider the heterogeneity of concrete: it idealizes concrete as homogenous and isotropic material. These limitations can be overcome by powerful finite element method. Material non-homogeneity, complicated boundary condition can be accommodated by proper FE modeling.

There has been limited previous work on simulation of earthquake ground motion using finite-element methods. The behavior of RC columns under increasing load has been simulated by many researchers. One analysis regarding the effects of several variables known to influence the behavior capacity of column (Pfrang and Siess,1964). Concentrically and eccentrically loaded unrestrained RC columns has been tested and studied at the same length. Since there was relatively little information available concerning eccentrically loaded conditions with restrained ends, all analytical studies of the problem has been directed toward the determination of column capacity. To observe the thorough behavior of column that affects the strengths, its behavior with increasing load is required.

Most of the analysis methods for the RC columns are based on the equilibrium and compatibility. The materials properties of the section are incorporated to observe the realistic behavior. The elastic analysis of a RC beam can be carried out by means of transform area concept, where steel are in compression and tension are replaced by equivalent concrete areas.

Computer programs for the analysis of RC structures are under development in many parts of the world. The purpose of the current work was to develop a computer program, using ANSYS, for analyzing the deflection of column under lateral load, examine the effect of the strength and ratio of flexural reinforcement on the carrying capacity of the column and to widen the scope of the program so that analysis and design can be performed repeatedly in order to take care of the changes in the capacity of the column due to change in section.

II. Modeling of RCC Column

In the current analysis, square size column was considered and the number of longitudinal bars was limited to four only for simplifications. No tie reinforcement was considered for the design. The height of each column was taken to be 10 feet and subjected to lateral load at top only..

III. FEM Software Used

ANSYS finite element analysis software enables engineer to perform multiple tasks as, to build computer models of the structural components, applying operating loads, study physical responses like: stress levels, temperature distributions. The ANSYS program has a comprehensive graphical user interface (GUI) that gives user easy, interactive access to program functions, commands, documentation and reference material. AN intuitive menu system helps users navigate through ANSYS program.

IV. Elements type adopted

For representation of concrete, an eight node solid element SOLID 65 was used. The solid element has eight nodes with three degree of freedom at each node viz. translations in the nodal x, y and z directions. The element is capable of plastic deformations, cracking in three orthogonal directions, and crushing. The most important aspect of this element is the treatment of non-linear properties.

The reinforcement for the finite element model was assumed to be perfectly elastic and identical in tension and compression. The internal reinforcement is modeled using three dimensional spar elements LINK 8, with plasticity. Two nodes are required for this element. Each node has three degrees of freedom, translation in the nodal x, y and z directions. The element is capable of plastic deformation.

V. Failure criteria of concrete

Concrete is a quassi-brittle material and has different behavior in tension and compression. In compression, the stress-strain curve for concrete is linearly elastic up to 30 percent of the maximum compressive strength (Shah, 1995). Beyond the maximum compressive strength, the curve into the softer region and eventually crushing failure occurs at ultimate strain. For ANSYS input of concrete, it requires the elastic modulus of concrete (E_c), ultimate uni-axial compressive strength (f_c'), Modulus of rupture (f_r) and Poisson's ratio (ν). The value of compressive was taken to be 8000 psi and the Poisson's ratio was taken to be 0.18.

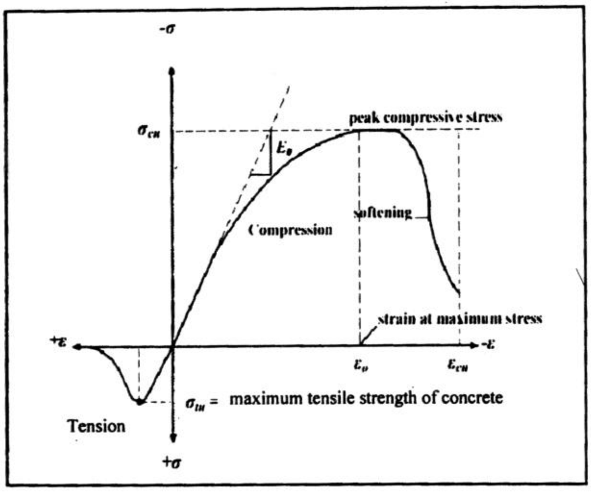

Fig.1 Failure criteria for concrete

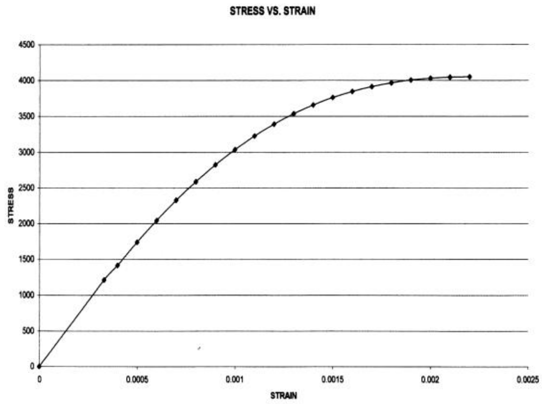

Fig.2 Stress-strain curve for concrete in ANSYS

VI. Failure criteria of steel

The steel element used in ANSYS was considered to be perfectly elastic material and identical in tension and compression. The Poisson's ratio was taken as 0.3.

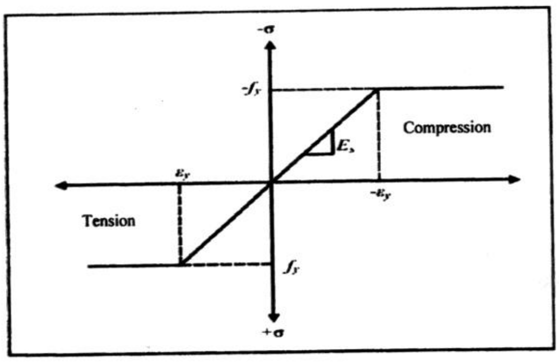

Fig.3 Stress-strain curve for steel

VII. Mesh Sensitivity

FEM is the outlines of the elements used to model the object of interest. An important aspect of FE modeling that affects the analysis is the aspect ratio of plane elements. The aspect ratio describes the shape of the element in the assemblage. The optimal aspect ratio at any location within the grid depends largely on the rate of change of displacement in different directions. In the current analysis, key-point was first generated with 32 key-points and connected the solid element. In case of the link element, line was first generated within solid element and connected for the generation of the reinforcing bar.

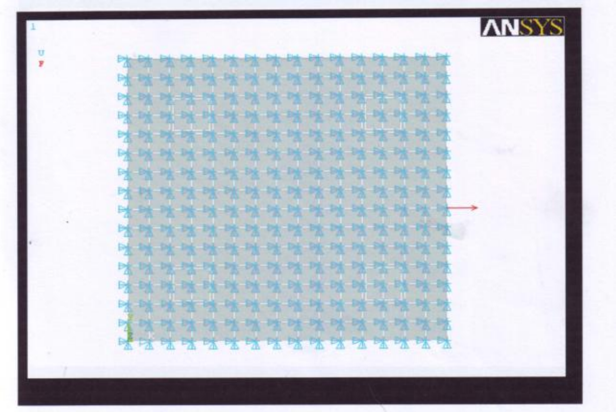

Fig.4 Plan view of column in ANSYS

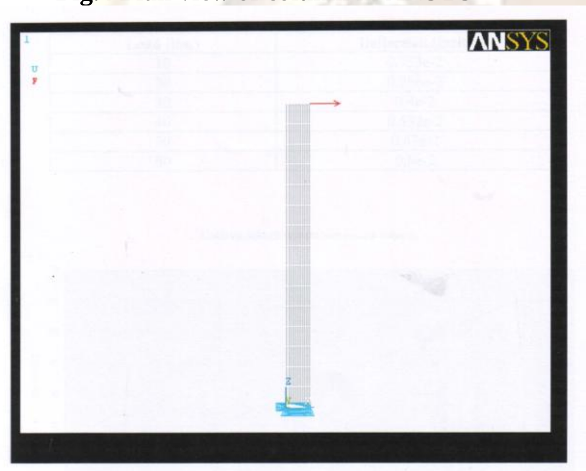

Fig.5 Front view of column in ANSYS

VIII. Results and Discussions

The objective was to determine the comparative capacity of a column when subjected to load on a storey. The size of the column was used as 10 inch by 10 inch, 12 inch by 12 inch, 14 inch by 14 inch, 16 inch by 16 inch, 18 inch by 18 inch, 20 inch by 20 inch and 22 inch by 22 inch.

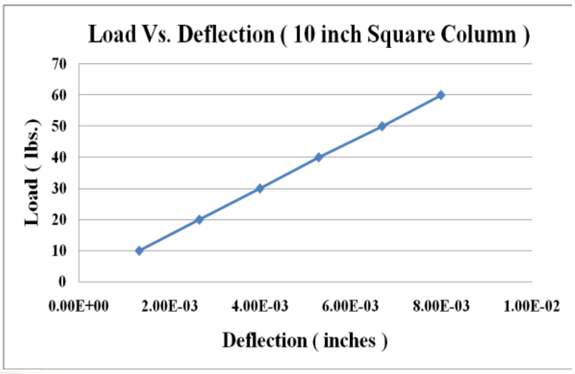

Fig. 6 Load Vs. Deflection for 10 inch square column

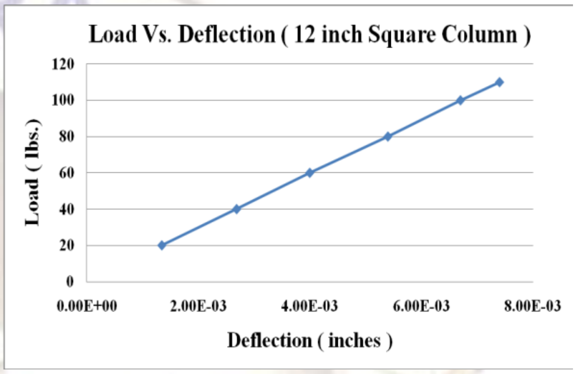

Fig. 7 Load Vs. Deflection for 12 inch square column

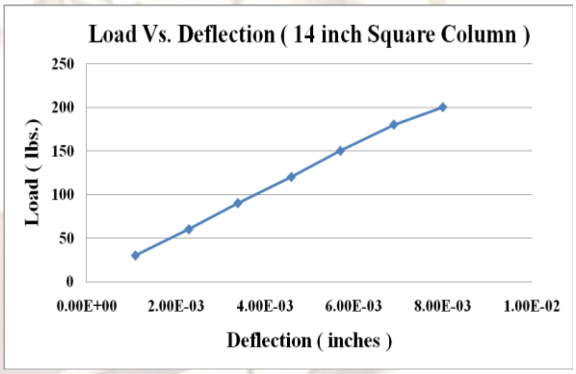

Fig. 8 Load Vs. Deflection for 14 inch square column

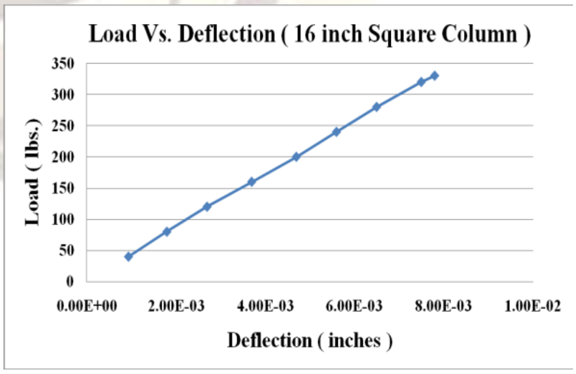

Fig. 9 Load Vs. Deflection for 16 inch square column

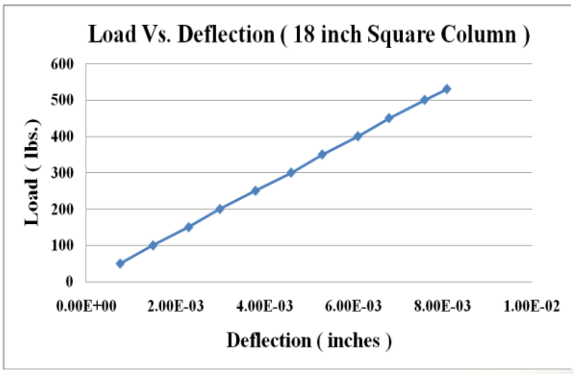

Fig. 10 Load Vs. Deflection for 18 inch square column

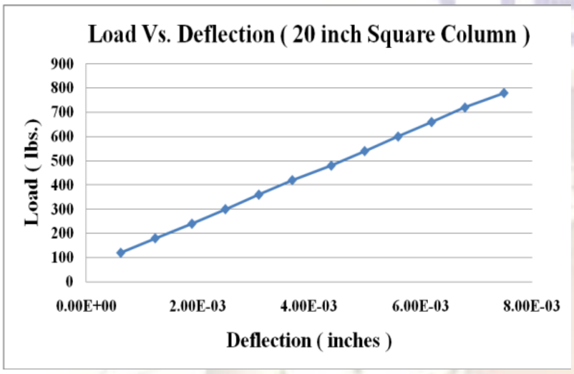

Fig. 11 Load Vs. Deflection for 20 inch square column

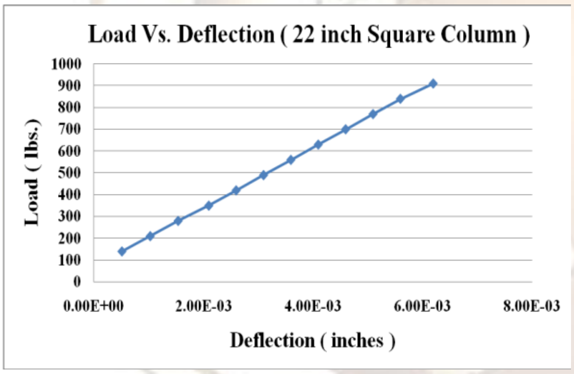

Fig. 12 Load Vs. Deflection for 22 inch square column

It was observed from the results that the relationship between deflection and capacity of the column is close to linear and with the increasing size of column the capacity also increases.

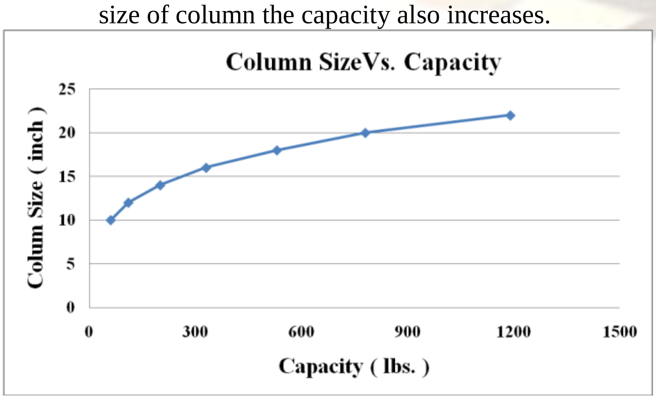

Fig. 13 Column Size Vs. Capacity

IX. Conclusion

The study was intended to investigate the possibilities of performing nonlinear finite element analysis of RCC column under lateral load using ANSYS package software. Only non-linear stress-strain realtions for concrete in compression have made it possible to reach ultimate load. It was also observed that with increasing the column size by 2 inches, the capacity increased by almost 80 percent. The findings of the study may corroborated by laboratory testing. Sensitivity analysis reagrding the variability of other parameters may also be considered like : number of reinforcements can be altered, tie rods may be introduced and high strength concrete can be considered.

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