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Cyclic Behavior of Battened and Latticed Columns and Proposing a Substitute Super-Element

M. Biabannavard[1], F. Behnamfar[2*], H. Zibasokhan[2]

[1] Senior Structural Engineer, Consulting Engineers, Tehran, Iran
[2] Department of Civil Engineering, Isfahan University of Technology, Isfahan, Iran

ABSTRACT: In this paper, lateral behavior of latticed columns is investigated by the finite element method. I-shape rolled sections of IPE120 to IPE200 are used for latticed column specimens in this study. Shell and solid elements are used for plate sections and welds in the finite element model, respectively. The columns considered are under gravity and lateral loads. Variation of gravity load ratio is investigated. Boundary conditions of the FE models are clamped at bottom and rotation restrained at top. Lateral loads are applied to the columns to cause bending about the non-material axis crossing the latticed side of the column. Non-linear characteristics of these columns including lateral elastic and plastic stiffness values, shear yielding and dissipation of energy (hysteretic curves area), are derived under monolithic and cyclic loading. Based on this study, increasing axial gravity loads, decreases initial stiffness considerably. It also decreases lateral capacity of the columns. Initial stiffness and lateral capacity reduction is considerably affected by axial load ratios under 0.2 (i.e., 20 percent of axial capacity of the column) and after that reduction rate decreases. A super-element that is able to consider behavior of these columns with an integrated section is proposed based on results of the nonlinear finite element analysis. This super-element considerably increases the computation speed by substituting an element with only six degrees of freedom in place of a finite element model with a large number of elements.

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1- Introduction

Latticed columns are widely used in Iran. Thus, special lateral behavior of these columns needs to be investigated comprehensively. German Institute of Standards (DIN) and American Steel Code (AISC) extensively studied behavior of battened and laced columns, respectively. Wide flange sections are usually used and also seismic risk at most parts of these countries are low unlike Iran. Nevertheless, more investigation about latticed column is required in Iran.

Many researches have been conducted on latticed columns and specially laced ones [1-9]. Most of investigations concentrated on critical load of these members. Although, there is not a proper substitute element to simply consider nonlinear behavior of these elements in real structures. A substitute super-element with limited DOFs is proposed in this paper to model linear and nonlinear behavior of battened and laced columns.

2- Methodology

Suggestion of a substitute element considering shear deformation effects in non-linear zone about non-material axis crossing the latticed side of the column is the main goal of this research. I-shape rolled sections including IPE120 to IPE200 are used in studied specimens in the form of battened and laced columns. Non-linear static analysis is used and ultimate 200 mm lateral displacement is applied in top of the column along with different axial gravity load in the column. The space between two profiles of the section is selected to create the same gyration radius about both section axes. All specimens have the same height of 3000 mm.

To study the effect of axial load, samples are considered to carry out different axial gravity load of $P/Py=\{0,0.2,0.4,0.6,0.8\}$ that P and Py are the axial load of column and the load capacity of column, respectively. Boundary condition of the FE models are clamped at bottom and rotation restrained at top. Boundary condition and loading of studied columns are shown in Figure 1. Finite element method and ANSYS software are used for simulation real behavior of studied samples. Considering symmetry, only half section of columns is modeled. Shell elements (shell143 element) are used for plate sections and solid elements (solid45 element) for welding, in FEM models.

To verify result of non-linear analysis of FE model, an experimental battened column specimen [4] was simulated in ANSYS software. Figure 2 shows a good agreement between experimental and FEM load-displacement curves.

Corresponding author, E-mail: farhad@cc.iut.ac.ir

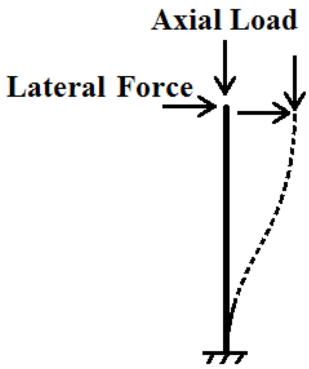

Figure 1. Boundary condition and loading

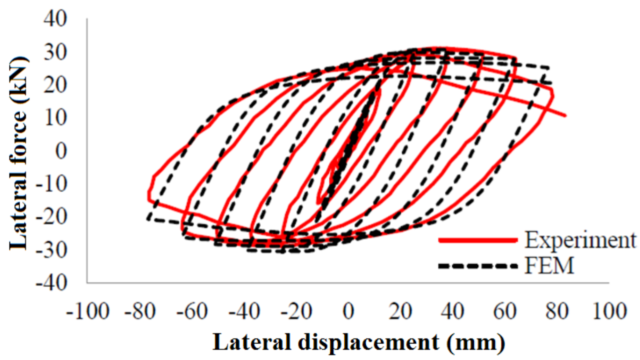

Figure 2. Comparison of load-displacement results of experimental and FE models

3- Results and Discussion

The proposed super-element has 6 DOFs according to Figure 3. Characteristics of this element are defined based on nonlinear load-displacement curves obtained by FE analysis.

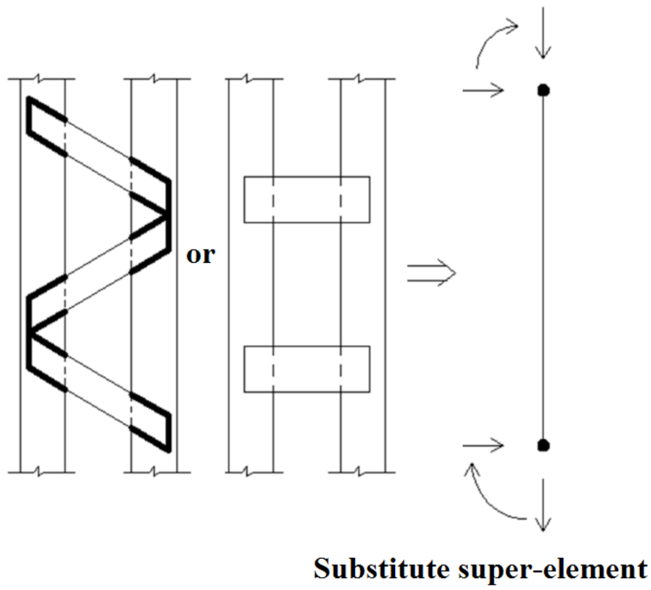

Figure 3. Substitute super-element DOFs

3- 1- Non-linear load-displacement curves

Non-linear behavior of specimens is investigated monotonically and cyclically using FE model with different axial load. Load-displacement curves of samples showed that laced columns have better lateral behavior in compared with battened columns because of truss action of lacings in laced column. Increasing axial load of columns increases difference between laced columns and battened columns. A comparison between theory initial stiffness of the columns and initial stiffness of nonlinear FE model shows that increasing axial load of the column, severely increase effect of shear deformation on lateral initial stiffness of latticed column that is not considered in theory formulas.

3- 2- Substitute super-element parameters

The FE model of latticed column has numerous DOFs. Consequently, Using FEM in structures having latticed column considerably increases analysis time. In addition, this method is almost impractical for large structures. Also, based on the results, ignoring shear deformation effect of battens and lacings, cause large errors in analysis. Hence, a simple replacement element could be introduced based on results of nonlinear FEM analysis considering shear deformations effects. The characteristics of the suggested element could be easily derived by regression simple algebraic formulas based on nonlinear results. Thus, each latticed column of structure is replaced by a super element as a substructure and reduces analysis time, considerably. Also, characteristic parameters of the proposed element could be derived quickly and with proper accuracy by regression of simple algebraic formulas on nonlinear results.

4- Conclusions

Cyclic behavior of battened and laced columns under various axial loads has been investigated in this paper. This study shows that increasing axial load up to 20 percent of column capacity, considerably decreases initial stiffness, strength, and energy dissipation capacity of the latticed column. Increasing axial load ratio more than 0.2, decreases the reduction rate. Based on results, laced columns have better dissipation energy capacity because of truss action of lacings in comparison with battened column especially at higher axial load ratio. Practical formulas and curves for linear and nonlinear behavior of latticed columns are derived based on numerical analysis for suggested axial-bending substitute super-element. This simple method reduces numerous DOFs in FE model of a latticed column to 6 DOFs at ends of the column super element. Therefore, calculations time decreases significantly.

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