8th International Conference on Seismology & Earthquake Engineering
11-13 Nov. 2019, Tehran, Iran

THE APPLICATION OF THE FORCE ANALOGY METHOD (FAM) IN PUSHOVER ANALYSIS FOR STEEL MOMENT RESISTING FRAMES

Shayan SAFAEI
M.Sc. Graduate of Earthquake Engineering, Amirkabir University of Technology, Tehran, Iran
shayan_safaei@aut.ac.ir
Arsam TASLIMI
M.Sc. Graduate of Earthquake Engineering, Amirkabir University of Technology, Tehran, Iran
rsamtaslimi@aut.ac.ir
Payam TEHRANI
Assistant Professor, Department of Civil and Environmental Engineering, Amirkabir University of Technology, Tehran, Iran
payam.tehrani@aut.ac.ir

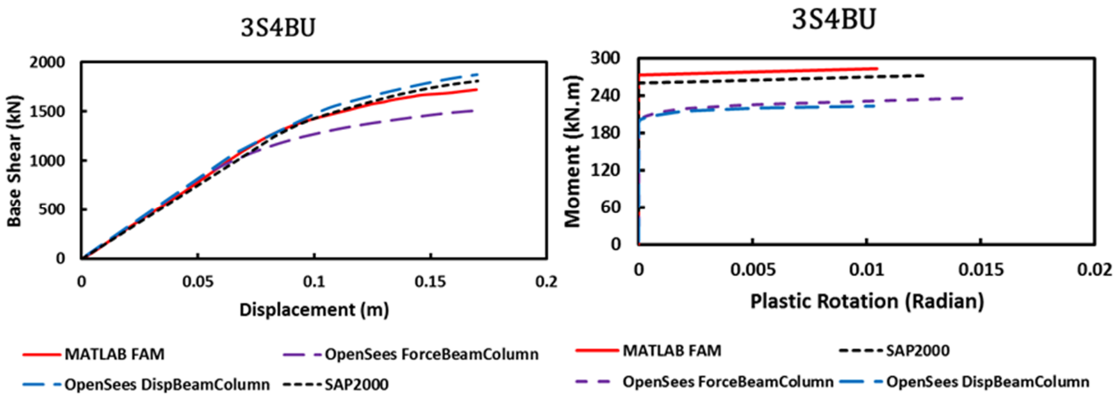
Keywords: Force analogy method (FAM), Force-based fiber element, Displacement-based fiber element, Pushover analysis, Special moment resisting frame

The force analogy method (FAM) is an analytical tool for structural analysis with material nonlinearity. This method uses the concept of residual displacement in its formulation in which the nonlinearity is represented by a series of changes in displacements instead of changes in stiffness (Li and Wong, 2014). One of the outstanding features of FAM in comparison with the FEM is that in FAM the global stiffness matrix of the structure remains unchanged during nonlinear analysis process which will lead to the more time-efficient and easily converged method of analysis (Song and Li, 2012).

In this paper, the precision and efficiency of the FAM in static nonlinear analysis (pushover analysis) has been compared to other common element types such as forced-based and displacement-based fiber elements and SAP2000 super elements. In addition, the effects of elastic axial deformation of the members on the performance of the structures, which have not been investigated before using FAM, has also been implemented through analysis by modifying the stiffness matrices of the structural elements. Having achieved this goal, a computer code has been developed in MATLAB to analyze the structures using improved FAM.

To investigate the differences between the results of the FAM and other mentioned methods, at first, six 2D steel special moment resisting frames with different configurations which were derived from two different 3D archetypes have been developed. These frames were modeled using four various models for capturing nonlinearity including SAP2000 super elements, OpenSees force-based and displacement-based fiber method, and FAM with the difference in height, number, and length of spans. Then the accuracy of FAM in predictions of pushover curves, base shear forces, and plastic rotation of the critical hinges was investigated conducting nonlinear static analysis. The results indicated that in general, the predictions obtained using the FAM had a good agreement and compatibility with those from other methods of analysis currently used in practice for seismic performance assessment of structures.

Figure 1 illustrates the comparison between the pushover curves of 3-story 4-bay frame based on the different methods of analysis. Moreover, target displacements, base shear values at target displacements and the deviation of a method from FAM for all 2D frames are presented in Table 1. The results from all displacement-based methods including FAM, displacement-based fiber elements of OpenSees and SAP2000 super elements, are in good agreement. However, it should be noted that on average some differences are observed between these results and those obtained using the force-based fiber elements of OpenSees. These differences are due to the different inherent formulation between the forced-based fiber element and other displacement-based methods. In general, the results indicate that FAM can be considered as an acceptable method for performing nonlinear static analyses, and it can be an alternative method of analysis for practical engineering applications.



(a) (b)

Figure 1. Results of 3-story 4-bay frame, a) Pushover curves, b) Moment-plastic rotation of critical hinges.

Table 1. Target displacements, base shears and their deviation in different methods.

Frame Label	Target Displacement (m)	Base Shear (kN)				Deviation (%): FAM vs.		
		FAM	OpenSees FBC*	OpenSees DBC**	SAP2000	OpenSees FBC	OpenSees DBC	SAP2000
3S3BU	0.19	1366	1176	1468	1414	16.15	6.94	-3.40
3S4BU	0.17	1720	1511	1870	1804	13.81	8.00	-4.63
7S3BU	0.37	1544	1258	1576	1486	22.67	2.09	3.86
7S4BU	0.32	1948	1618	2023	1920	20.37	3.75	1.42
10S3BU	0.42	2502	2012	2625	2468	24.33	4.69	1.37
10S4BU	0.37	3270	2662	3428	3230	22.82	4.61	1.23

*ForceBeamColumn **DispBeamColumn

REFERENCES

Li, G. and Wong, K. (2014). *Theory of Nonlinear Structural Analysis: The Force Analogy Method for Earthquake Engineering*. John Wiley & Sons.

Song, S.Q. and Li, G. (2012). Inelastic Dynamic Analysis of Steel Structure Using Force Analogy Method. *Applied Mechanics and Materials*, *166*, 304-309, Trans Tech Publications.