Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 50(2) (2018) 93-96
DOI: 10.22060/ceej.2017.11257.4995

Effect of Uplift on Behavior of Steel Structures and Response Modification Factors

F. Behnamfar[1]*, F. Pouyan[2], M. Omidi[3], H. Zibasokhan[1]

[1] Department of Civil Engineering, Isfahan University of Technology, Isfahan, Iran
[2] International Institute of Earthquake Engineering and Seismology, Tehran, Iran
[3] Senior Structural Engineer, National Iranian Oil Company, Ilam, Iran

ABSTRACT: In design of structures for applied loads, the common assumption is that the structure is tightly attached to its base, i.e. no vertical rigid-body motion can happen at the same place. During a major earthquake, the couple of axial forces associated with the overturning moment can overcome that of the gravity loads in lateral load bearing columns and result in an uplifted column. With a building losing some of its contact points to the ground, a reduced lateral stiffness can be expected. This in turn can result in a reduced seismic base shear. At the same time, the structural members around the uplifted part can undergo large local deformations and perhaps a more extensive seismic damage. Illuminating the above predictions is the incentive of this research. In this paper, in the numerical part, a number of steel frames having various numbers of stories and bays are studied in two cases of without uplift (fixed base) and with uplift. The methods of analysis are the non-linear static and dynamic analysis procedures. According to the findings, the uplift phenomenon generally has an important role in changing the behavior of structure and reduction of its response. At the same time, it can result in locally increased damages that sometimes can add up to total failures. The results showed that uplift increases the structural period and the absorbed energy, and decreases the displacements of most parts of the structures and their internal forces.

Review History:

Received: 26 December 2015
Revised: 7 March 2017
Accepted: 8 March 2017
Available Online: 3 April 2017

Keywords:
Uplift
Steel Structures
Non-linear Static Analysis
Non-linear Dynamic Analysis
Seismic Response

1- Introduction

Uplift in structures is defined as separation between foundation and ground due to columns tensile force caused by lateral loads. Foundation uplift occurs for the foundations not attached positively to the ground. A temporary separation between ground and the structure acts like a base isolation mechanism and decreases seismic response of structure during earthquake. Although, local failure of structural members can happen with uplift phenomenon because of high ductility demand. Investigations show that uplift reduces axial force and shear force of the columns [1-5]. Also, uplift increases lateral displacement of a structure [3, 4]. Closure between natural frequency of structure and the dominant frequency of excitation increases useful effects of uplift on structural behavior [6, 7].

Most of previous uplift researches are qualitative and concentrated on structures with limited DOFs (degrees of freedom). In this paper, static and dynamic non-linear analyses are performed on two cases of steel frames without uplift (fixed base) and with uplift for several structures having various numbers of stories and bays. Response spectra of the frames are derived based on this study. Response modification factors are introduced for considering uplift effect on the fixed-base structures.

2- Methodology

In this research, uplift effects on steel structures with different shape ratios (height to width ratio) are studied. Hence, 2-D steel frames with different number of stories and bays and with two kinds of lateral resistant systems including moment frame and X concentric braced frames are assumed. Three categories of structures with 5, 10 and 15 stories (height of each story=3 m) are selected for this purpose and number of bays are assumed to attain different shape ratio including 0.66, 0.83, 1.11, 1.67, and 3.33. A gravity load of 22 kN/m is considered on the beams of the frames. The lateral load is distributed consistent with the first mode of structures (i.e. triangular distribution) in the non-linear static analysis. Lateral load is increased to attain two target displacement levels defined by ASCE41-13 including Life Safety (LS) and Collapse Prevention (CP) performance levels. Lateral displacements equivalent to 2.5% and 5% of building height for moment frames and 1.5% and 2% of building height for braced frames are defined for the considered performance levels, respectively. Non-linear static and dynamic analyses are conducted on the assumed frames using SAP2000 software with and without uplift effects. Details of uplift definition in modeling are demonstrated in Figure 1.

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

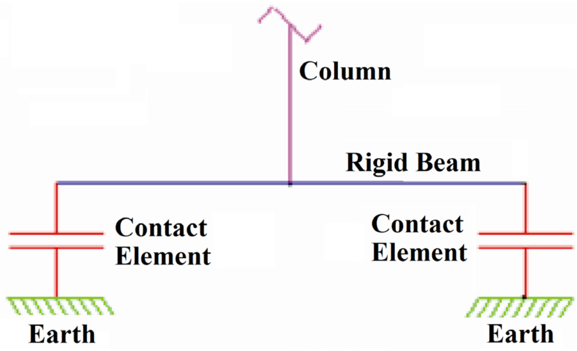

Figure 1. Details of uplift modeling

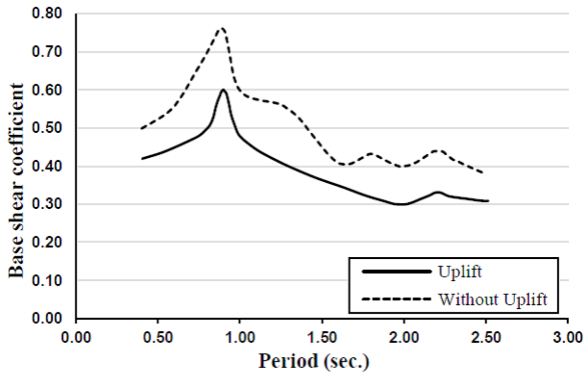

Figure 2. Acceleration spectra of studied structures

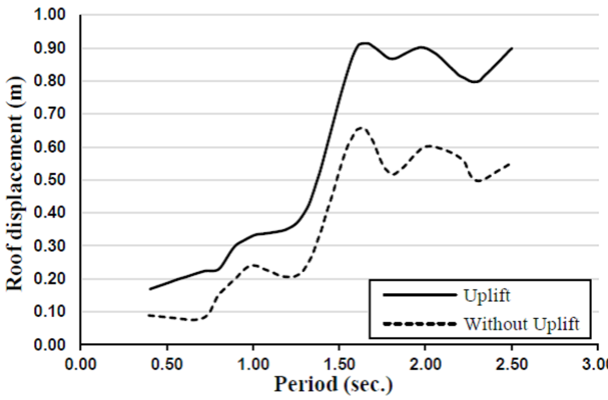

Figure 3. Displacement spectra of studied structures

3- Results and Discussion

3- 1- Non-linear static analysis

This investigation proves that uplift consideration decreases base shear of structure. Regarding constant number of bays, increasing the number of stories and building height increases uplift effects and difference between two base shear-maximum displacement curves of structure with and without uplift. Also, uplift in structure causes less plastic deformation and energy dissipation with the same displacement in comparison with structure without uplift.

Curves of capacity spectra against structure demand show higher spectral acceleration for structures with uplift compared with the ones without uplift in all cases. Also, intersection between capacity and demand spectra curves show higher values for the structures with uplift. Therefore, considering uplift in structures for the design earthquake increases lateral displacements and in the same time decreases base shear of structure.

3- 2- Non-linear dynamic analysis

Non-linear dynamic analysis demonstrated that rotation of structure due to uplift leads to higher maximum displacements in structure in comparison to structures without uplift. Based on these results, lateral displacement of structures with a larger number of bays or a smaller shape ratio is similar for in both cases of uplift analyses. Lateral displacements of moment frames have less sensitivity to uplift in comparison with braced frames. This means that a smaller amount of uplift occurs in moment frames in comparison to the braced frames. Also, considering uplift, increases the effective structural period. This is more obvious in dual system frames rather than moment frames. The results showed that uplift decreases the base shear coefficient and relative drift of members and consequently internal forces of members. Acceleration spectra (base shear normalized to g) and displacement spectra of studied structures for with/without uplift cases are shown in Figures 2 and 3, respectively. Also, cumulative energy dissipation curves of different earthquake records demonstrate that considering uplift increases energy absorption.

4- Conclusions

In this research, effect of uplift on seismic behavior of steel structures with 5 to 15 stories, was studied. The results showed that uplift increases the structural period and lateral displacements of structure, and decreases deflections of most parts of structure and its internal forces. Increasing the shape ratio of structure increases uplift effects. Also, uplift affects on braced frames are more extensive than moment frames. The major portion of energy is dissipated in the form of rigid body motion in structures with uplift. Therefore, structures with uplift have a smaller plastic dissipated energy and consequently less member damage compared with the structures without uplift.

References

[1] A.A. Hucklebridge, R.W. Clough, Seismic Response of Uplifting Building Frame, Journal of the Structural Division, 104(8) (1978) 1211-1229.

[2] M. Midorikawa, T. Azuhata, T. Ishihara, A. Wada, Shaking table tests on seismic response of steel braced frames with column uplift, Earthquake Engineering and Structural Dynamics, 35(14) (2006) 1767-1785.

[3] M. Midorikawa, T. Sudo, T. Asari, T. Azuhata, T. Ishihara, Three-dimensional seismic response of ten-story steel frames with yielding base plates allowed to uplift, Journal of Structural and Construction Engineering, 74(637) (2009) 495-502.

[4] X. Qin, N. Chouw, Experimental investigation of uplift effect on structures in earthquakes, 2010 NZSEE Conference, Auckland, New Zealand, (2010).

[5] F. Khoshnoudian, M. Shahreza, F. Paytam, p-delta effects on earthquake response of structures with foundation uplift, Journal of Soil Dynamics and Earthquake Engineering, 34(1) (2012) 25–36.

[6] I.N. Psycharis, Effect of Base Uplift on Dynamic Response of SDOF Structures, Journal of Structural Engineering, 117(3) (1991) 733-754.

[7] S.K. Smith, Parametric Analysis of Dynamically Loaded Concenterically Braced Steel Frames Allowed to Uplift, M.Sc. thesis, University of Washington, USA, (1995).

[8] ASCE/SEI 41-13, Seismic Rehabilitation of Existing Buildings, American Society of Civil Engineers, Reston, Virginia, (2013).

Please cite this article using:

F. Behnamfar, F. Pouyan, M. Omidi, H. Zibasokhan, Effect of Uplift on Behavior of Steel Structures and Response Modification Factors, *Amirkabir J. Civil Eng.*, 50(2) (2018) 315-326.

DOI: 10.22060/ceej.2017.11257.4995