A modified lateral load pattern for linear static analysis

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ABSTRACT

linear static analysis is one of the most widely used methods proposed by the codes for the seismic analysis of structures. Several methods have been presented for determining the static lateral load pattern. In spite of the simplicity of these procedures, their accuracy especially for structures in which the influences of higher modes are significant is not desirable. In this study, a new method is developed to improve the lateral load pattern in linear static analysis. To achieve the proposed lateral load distribution, firstly, the average responses of some structures subjected to some earthquakes are acquired. Then, regarding the dynamic responses of the structures, the static lateral load pattern compatible with the average responses is developed. Eventually, to derive a straightforward and hands-on lateral load distribution, using a statistical study, some relations coupled with a graph are developed. Since the proposed method is developed based on the structural responses resulting from linear dynamic analysis (time-history analysis), it is shown that the suggested way despite its simplicity and efficiency, presents appropriate accuracy in predicting the responses of the structures subjected to seismic excitations. The developed lateral load is applied for three frames with 5, 10 and 14 stories. The inter-story drifts of these frames are achieved under 14 earthquake excitations. After that, the proposed lateral loads of code 2800 and FEMA 356 are used on these frames and the responses are derived. The outcomes show that whereas the average error of the proposed lateral load for these frames is around 7, 5 and 7%, the average errors of code 2800 and FEMA 356 are almost 20, 10 and 25%. Comparing the inter-story drifts for the developed lateral load pattern with the dynamic results, validates its performance. The developed method is evaluated for a set of structures with different fundamental periods. Results show that the method gives higher accuracy in comparison with the static method of Iranian standard 2800 and FEMA 356. Also, the developed procedure can be considered as an appropriate technique for determining lateral load distribution in seismic codes.

KEYWORDS

Linear static analysis, lateral load pattern, higher modes effect, dynamic analysis, seismic codes

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1.Introduction

Equivalent static analysis is one of the most practical methods for seismic analyzing of buildings [1-3]. In this method, lateral load distribution throughout the height significantly affects the structural responses e.g., the damage level, internal forces and the seismic behavior [4,5]. The lateral load pattern in equivalent static analysis has been the research interest in the plethora of studies [6,7]. Some studies focused on an optimum lateral load pattern for static analysis [8-19].

A literature review on the lateral load distributions indicates that the previous patterns have some shortcomings such as disregarding the higher mode effects and are the same direction for the lateral forces. This study aims to developing a new lateral load distribution achieved based on dynamic analysis to boost the responses of equivalent static analysis.

2.Methodology

In this research, to develop the lateral load pattern, the following relations are applied:

$$\ddot{y}_i + 2\zeta\,\omega_i \dot{y}_i + \omega_i^2 y_i = -\frac{L_i}{M_i}\ddot{u}_g(t) \quad (1)$$

$$L_i = \phi_i^T M\, r \quad (2)$$

$$M_i = \phi_i^T M\, \phi_i \quad (3)$$

Where ζi is damping ratio. ω_i is circular frequency . y_i is the displacement of a SDOF system for mode i[th]. y_i can be acquired using Duhamel's integral as follow:

$$y_i(t) = -\frac{L_i}{M_i\,\omega_{Di}}\int_0^t \ddot{u}_g(\tau)\, e^{-\zeta_i \omega_{Di}(t-\tau)} \sin\omega_{Di}(t-\tau)\, d\tau \quad (4)$$

Knowing y_i , the displacement of j[th] floor level is obtain as follows:

$$u_j = \sum_{i=1}^{n} \phi_{ji}\, y_i \quad (5)$$

Where ϕ_{ji} is the j[th] component of the i[th] vibration mode. The drift ratio can be achieved as follows:

$$\Delta_j = u_j - u_{j-1} \quad (6)$$

Since earthquakes have different properties such as energy, frequency content and so on, for seismic analysis, the responses of several dynamic analyses should be considered.

$$\overline{\Delta_i} = \sum_{k=1}^{N_E} \Delta_{ik} \Big/ N_E \quad (7)$$

Where N_E is the number of earthquakes. $\bar{\Delta}_i$ is the average of drifts for each story. Eventually, the lateral force of each floor level is achieved using Eq. .

$$F_j = k_j \overline{\Delta_j} \quad (8)$$

k_j is the stiffness of the j[th] story.

To develop the lateral load, a set of steel frames (intermediate ductility) from two to fourteen stories are considered. These frames are analyzed subjected to twenty seismic ground motions from FEMA 440 for soil type C. A hands-on graph is presented for obtaining the lateral load distribution (Fig. 1). In Fig.1, Hs is the height of selected floor level and H is the height of frame. Some interpolation relations are presented in Fig. 1, to predict the floor level force/base shear (y) based on the period (x) and the ratio of Hs/H.

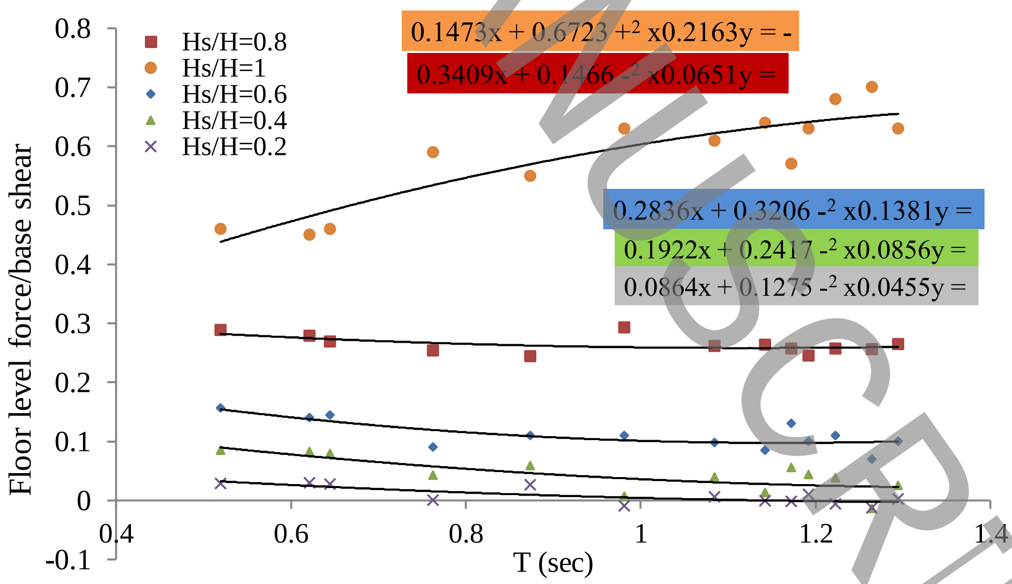

Fig. 1. A graph for acquiring the lateral force distribution along the height of building

3.Results and Discussion

The proposed relations are used to analysis of seven new frames. In comparison with the dynamic responses of these frames subjected to 14 new earthquakes, the developed method presents reasonable outcomes. Comparing the inter-story drifts of these frames subjected to lateral load patterns of FEMA356, Iranian seismic code, and the developed method with the dynamic responses under earthquake excitations shows that whereas the outcomes of the developed method is close to the dynamic ones, there is a significant gap between the responses of FEMA356 and Iranian seismic code with the dynamic responses.

4. Conclusions

In this research, a new lateral load distribution for equivalent static method is developed. This method that is based on dynamic responses is capable of considering higher mode effects and the different directions for lateral forces. In this method, a graph and some relations are presented to achieve the lateral force of each floor level based on the ratio of Hs/H and the fundamental period of the frame. Evaluation of some new examples confirms the validity of the proposed procedure.

5.References

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