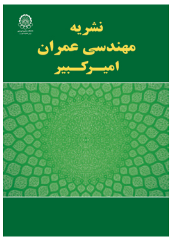

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The Effect of Belt Truss Level on the Performance of Steel High-Rise Buildings Subjected to Near-Field Earthquakes

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ABSTRACT: In this study based on conducting several non-linear dynamic time history analyses subjected to the both types of near and far field three components earthquake records, the seismic response parameters of inelastic behavior of tall buildings with belt truss frameworks have been investigated. A three-dimensional basic outrigger braced tube model as well as three other resistant skeletons which contain different configurations of belt trusses in height, have been designed according to the Iranian seismic code 2800 (4th edition) and Iranian national building code (steel structures-division 10). The dynamic response parameters of all studied structures have been assessed under influence of free field three components earthquake records. Because the overall dynamic response of the studied structures would change subjected to record by record separately, the corresponding response velocity spectra of each of the selected records were notified numerically. Furthermore, in order to denote the effects of higher modes, the aforementioned response velocity spectra were evaluated corresponding to the natural period of the studied structures. Having accurate evaluation of the analytical results indicate that the existence of belt truss causes a significant increase in structural stiffness and mitigates drift and base bending moment. Also the highest drift demand obtained for the model without belt truss and the model with belt truss located at 0.5H, occurs relatively in 0.83 to 0.9 of normalized height. This demand parameter calculated for the model with the top belt truss occurs in 0.5 to 0.8 of normalized height.

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1- Introduction

The structural stiffness plays a great role when the height of buildings increases. The application of outriggers and belt trusses in tall buildings provides both of enough stiffness and reduction in the weight of the materials [1].

In the conventional outrigger-braced skeleton, the shear walls or braced frames and perimeter columns were connected by huge trusses (as rigid arms), in which a part of the external over-turning moment convert to a vertical couple of forces in the peripheral columns. Moreover, in the idea of virtual outriggers, this conversion is performed by the story diaphragm which is infinitely stiff in its own plane. It is noticeable that the aforementioned rigid arms have significant role in the performance of the whole resistant skeleton [2, 3]. Taranath (1979) denoted that the behavior of resistant structures with one belt truss in regards to reduction of top displacement, the optimum place of the belt truss would be at the 0.455 of structure height [4]. In 1983 a formulation base on a few simplified assumptions and the criteria of the minimum drift, presented by Stafford Smith and Salim [5]. Yet, this formulation is not exact, and may use in the approximate calculation of forces and deformations. Rutenberg and Tal (1987) investigated the effect of several lateral load distributions, ranging from uniform to triangular shapes, in relation with the optimum location of the outriggers [6]. A simple model for estimating the seismic period of high rise buildings with belt truss was provided by Nicoreac and Honderkamp (2012) [7].

Researches on the response of three-dimensional models by changing the location of belt truss and its effects on the drift, base shear, base moment, axial load and plastic hinge mechanism, still have not been accurately studied from the non-linear dynamic viewpoints. In the present study, in addition to have a comprehensive assessment on the mentioned subjects, the characteristics of near- and far-field records and their effects on the responses of tall buildings have been performed and discussed.

To achieve these goals, several non-linear time history dynamic analyses were performed on the studied models. The seismic designation process has been completed according to the Iranian seismic design code 2800 [8]. All of the sections of members and the connection zones of the studied models have been designed based on the Iranian national building code (steel structures-Division 10) [9]. Yet, non-linear behavior of members and specification of plastic hinges were defined based on FEMA 356 [10].

2- Methodology

The organized study of this research includes, the modal and

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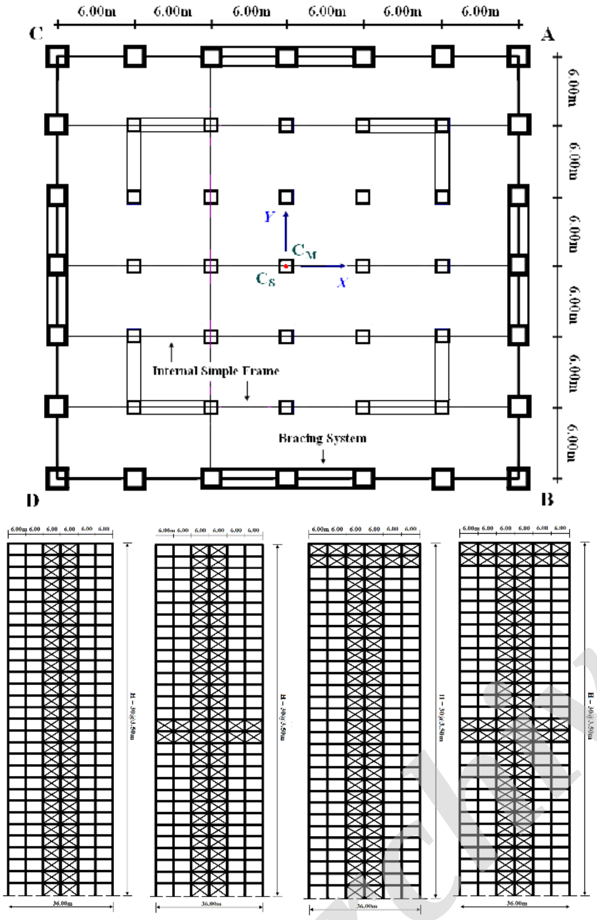
linear static analyses in the first phase. Then, the non-linear time history analyses were conducted under three component records. The studied models are four 30 story structures with different configurations of belt trusses. Moreover, the belt truss panels have the height of two stories. The height of each story is 3.5 m and the plan of all studied models are similar with six identical bays in both directions of X and Y, as shown in Figure 1.



(a) (b) (c) (d)

Figure 1. The plan and elevation of the studied structures, CM: mass center, CS: shear center; a) model without belt truss; b) model with middle belt truss; c) model with top belt truss; d) model with middle and top belt trusses

Dead and live loads were selected based on the Iranian national building code (Division 6) and are respectively 0.5 t/m^2 and 0.2 t/m^2 similar for all stories and for the roof are 0.5 t/m^2 and 0.15 t/m^2, respectively [11]. Furthermore, the shapes of all sections are shown in Figure 2.

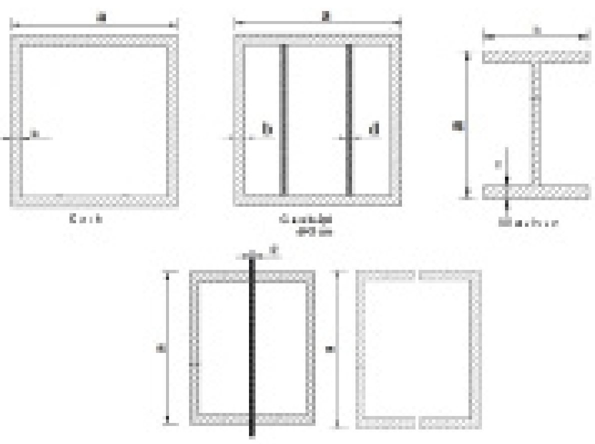


Figure 2. The shapes and dimensions of all sections a: Depth of the sections, c: Thickness of the plate=2 cm

A great number of non-linear dynamic time history analyses were conducted on the studied models subjected to an ensemble of free field recorded ground motions. To supply numerical stability in the analyses, the Newmark Beta method which is an unconditional stable time integration procedure has been selected via γ=0.25 and β=0.5 [12]. Yet, in the process of the analyses the effects of P-Δ have been considered, too [13].

3- Results and Discussion

One of the most important response parameters which control the design process of tall buildings is the seismic drift. The corresponding curves are illustrated in Figure 3. For the model with no belt truss, the inter-story drift ratio obtained under the records SCS and JFP due to the Northridge 1994 in California, are relatively large. Obviously, the maximum drift occurred at the normalized heights of 0.83H to H. Also, H is the total height of the studied models. Yet, for the models with the top belt truss, the corresponding location is at 0.5H to 0.8H. Furthermore, for the model with the middle belt truss, this location is similar to that of the model without belt truss. Therefore, the application of belt truss shall be lead to significant decrease in the lateral drift. From the dynamic view, the amount of reduction depends on the directivity characteristics of the base imposed earthquake record. For example, under the record NWH 1994 the reductions in the maximum drift for the models with top, middle and two level belt trusses are about 15, 38 and 30 percentages, respectively. Moreover, subjected to the record WPI 1994, the corresponding values are 26, 13 and 33 percentages, too. In the assessment of maximum dynamic base shear, the existence of belt truss system would cause an increase in this response parameter. The calculated increase under various near field records are not similar.

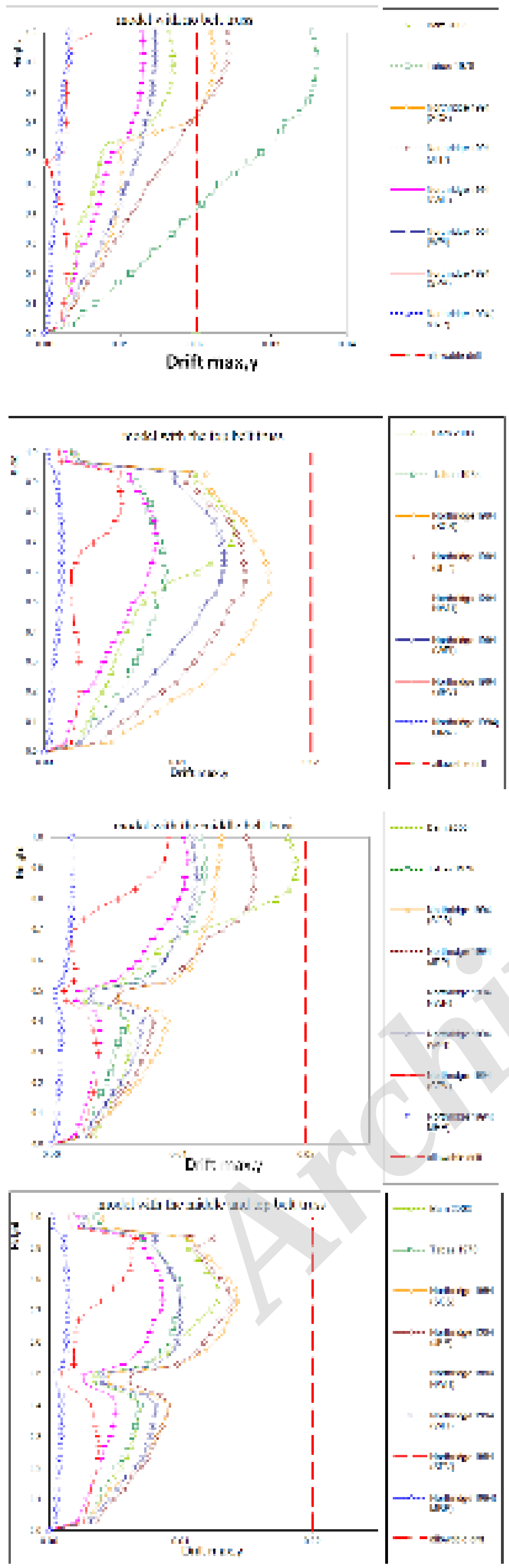


Figure 3. The envelop curves of the maximum drift parameter of the studied models at point A of the plan (Figure 1)

4- Conclusions

In this research, the seismic response parameters of steel tall buildings with the system of belt trusses have been evaluated. Assessment of the analytical results denotes that the use of belt trusses would lead to relatively lower drift demand especially at their own levels. In this case, the seismic performance level of main structural elements would meet the life safety limit.

As a notification point, under the 1994 NWH record, the single belt truss system which provided at the top or at the middle height of the resistant structure could reduce the maximum drift by 15 % and 38 % respectively. Meanwhile, providing the first outrigger at the top and the second one at the middle height of the resistant structure, reduces the maximum seismic drift by 30 %. Moreover, for the model without belt trusses, the highest seismic drift occurred at the 0.83H to H too. Yet, the corresponding locations for the models with the top belt truss are about 0.5-0.8 of total structure height.

Generally, the existence of an essential relationship between the probable maximum structural response parameters subjected to an earthquake record and the locations of the corresponding modal periods axis of the resistant skeletal system which are defined in the velocity response spectra, can be noted as a criterion to determine the ability of the record which would cause the most damages.

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