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# ON THE CONVENTIONAL FINITE ELEMENT SIZES IN PSEUDO-STATIC SEISMIC ANALYSES OF 2D FRAMES

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**Abstract.** *Pseudo-static analysis is an analysis approach in many seismic codes. With attention to the dependence of the results to the finite elements sizes, this paper examines the sufficiency of the finite elements as large as the structural element, for 2D frames' pseudo-static analyses, using Euler-Bernoulli theory. As the consequence, structural elements' sizes are adequate to be considered for finite elements sizes. Further study is however recommended.*

## 1 INTRODUCTION

Earthquakes are of major disasters, and the infrastructures, and in general buildings, should be designed such that to stand or damaged slightly against earthquakes. Many national codes are prepared, presenting comments for better seismic designs, e.g. see [1-4]. Nevertheless, the designs are all based on seismic analyses, which can be divided in the two categories of static and dynamic analyses, both including sub-categories. Pseudo-static is a linear static analysis approach belonging to the first category. Regardless of the analysis approach, conventionally the first step of seismic structural analysis is discretization of the models in space and arriving at MDOF (Multi-Degree-Of-Freedom) structural properties at the degrees of freedom. Finite Element Method (FEM) is broadly accepted for discretization in space, conventional in practical seismic analyses. Specially, because of the approximation in the shape functions, discretization by finite elements is involved in errors and inexactness, inversely depending on the number of the degrees of freedom, or to say better, directly on the elements sizes. Being concentrated on seismic analysis of frame structures, traditionally we consider each beam or column as one finite element, e.g. see Figure 1.

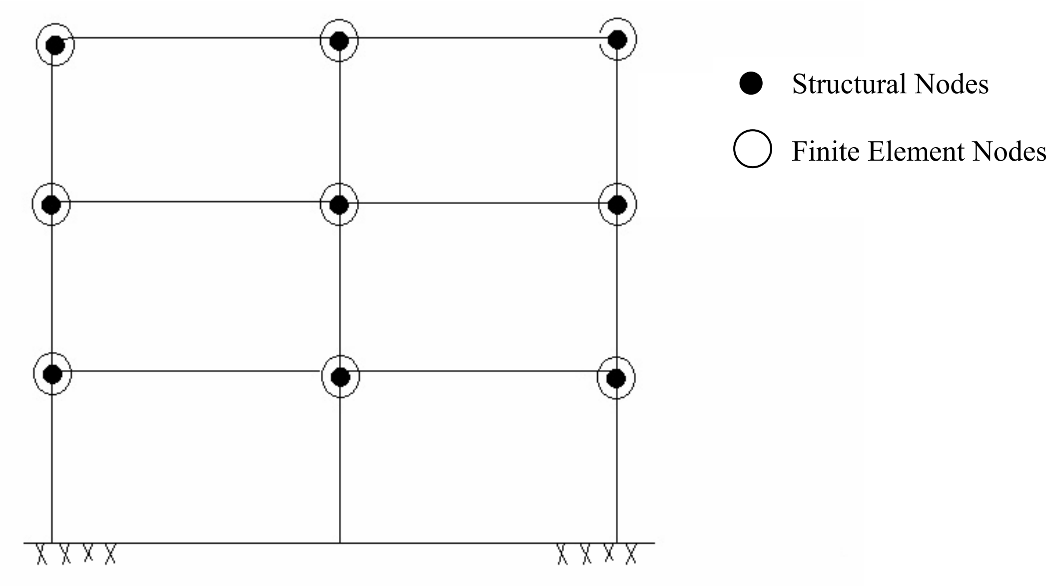


Figure 1: Typical placement of finite elements' nodes and elements in seismic analyses.

The objective in this paper is to briefly study the amount of inaccuracy caused by this convention in linear static analysis of frames against earthquakes, i.e. pseudo-static analyses. For the numerical study the designs are considered in accordance with the seismic standards of Iran [4-6]. In Section 2, a brief theoretical study on the inaccuracy caused by finite elements sized as large as the structural elements is presented. Numerical study of the claims, in Section 2, is presented, in Section 3; and finally, with a brief review on the achievements, the paper is closed in Section 4.

## 2 THEORITICAL STUDY

In pseudo-static analysis of structures against earthquakes, a total design lateral load, i.e. base shear force, is being determined, taking into account the structural system, it's importance, and the soil type and seismicity of the region; then, the lateral load is being distributed between the frames potentially resisting against this load according to the stiffness of the frames; later, the lateral load for each frame is being distributed between the floors levels, with special attention to the top floor, leading to the typical case displayed in Figure 2, for each 2D frame [1-4]. The resulting distribution of forces and displacements in the 2D frame

Figure 2: Typical distribution of the lateral load of earthquake in pseudo-static analyses.

need to be added to the distribution of forces and displacements caused by the dead and live loads, according to the seismic code, e.g.

$$\begin{gathered} D+L \\ 0.75[D+L\pm(E \text{ or } W)] \\ 0.75[D\pm(E \text{ or } W)] \end{gathered} \quad (1)$$

(D stands for the dead load; L implies the live load, E denotes the load of earthquake, and W represents the wind load), according to the Iranian codes [4,6].by considering the typical distributions of live and dead loads as displayed in Figure 3, and putting it besides the distribution in Figure 2 and also Eq. (1), and not forgetting the superposition principle in linear analyses [7], it would be apparent that pseudo-static analysis is a static analysis against loads that do not change, unless at structural nodes (see Figure 1). Consequently, in view of the considerations in the simplest column-beam theory [8] and strength of materials [9], it is reasonable to except sufficient accuracies, when locating the finite elements nodes on the structural nodes. This is studied numerically in Section 3.

## 3 NUMERICAL STUDY

The 2D frame in Figure 4 with structural members introduced in Table 1, located on a type II soil [4], and designed according to Iranian codes (see [4-7, 10-12]) is undergone pseudo-static seismic analysis, considering the beam column members using Euler-Bernoulli beam theory, and elements sized according to Figure 1. Separately, the much more accurate results are obtained using about twenty times smaller elements. Accordingly, the errors of top and mid-floor displacements in the direction of the earthquake load are reported in Table 2. The structural system is changed to a special moment resisting frame (see also Table 3) and the study is repeated, resulting in Table 4, similar to Table 2, displaying the sufficiency of the provided accuracy.

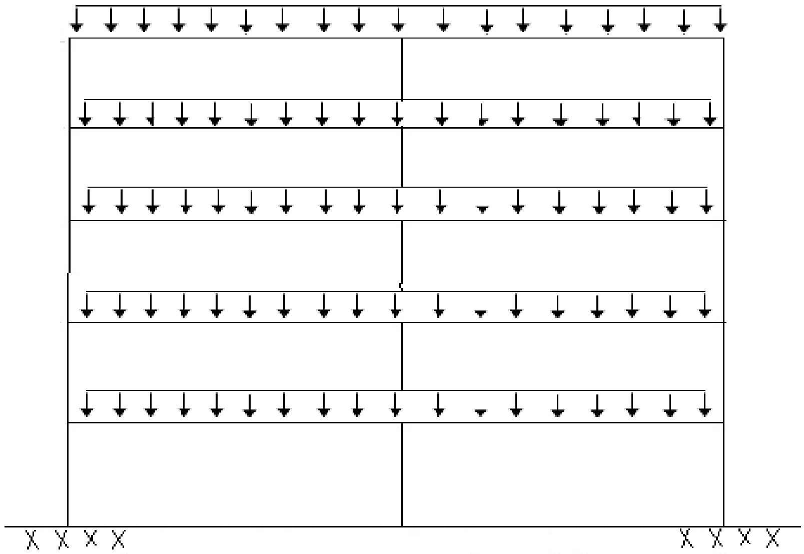

Figure 3: Typical distribution of live and dead loads in pseudo-static analyses against earth-quake.

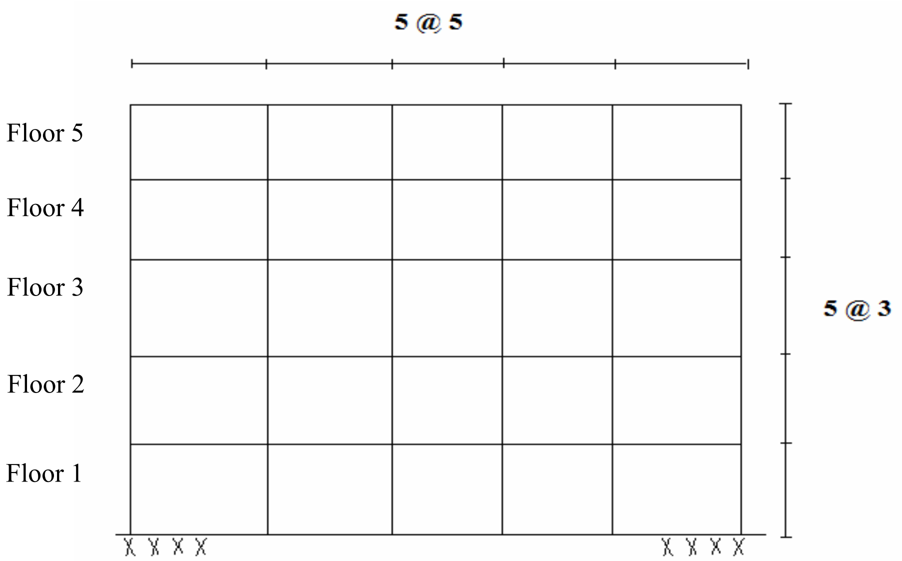


Figure 4: Some main features of the frame under study.

| Floor | Side column | Middle column | Beam |
|---|---|---|---|
| 1 | TUBO 250*250*15 | TUBO 260*260*20 | IPE 360 |
| 2 | TUBO 220*220*15 | TUBO 240*240*15 | IPE 330 |
| 3 | TUBO 220*220*15 | TUBO 240*240*15 | IPE 330 |
| 4 | TUBO 200*200*15 | TUBO 200*200*15 | IPE 270 |
| 5 | TUBO 200*200*15 | TUBO 200*200*15 | IPE 270 |

Table 1: Structural members of the frame in Figure 4 considering ordinary moment resisting structural system for the frame.

| Loading | Top Floor Displacement in the Direction of Earthquake | Mid-height Floor Displacement in the Direction of Earthquake |
|---|---|---|
| Earthquake Load | 0.062 | 0.067 |
| Combined Dead Live and Earthquake | 0.083 | 0.030 |

Table 2: Errors of the analysis of the frame introduced in Figure 2 and Table 1 (%).

| Floor | Side column | Middle column | Beam |
|---|---|---|---|
| 1 | TUBO 220*220*15 | TUBO 240*240*15 | IPE 330 |
| 2 | TUBO 200*200*15 | TUBO 220*220*15 | IPE 330 |
| 3 | TUBO 200*200*15 | TUBO 220*220*15 | IPE 330 |
| 4 | TUBO 160*160*12 | TUBO 180*180*12 | IPE 300 |
| 5 | TUBO 160*160*12 | TUBO 180*180*12 | IPE 300 |

Table 3: Structural members of the frame in Figure 4 while change the system to special moment resisting frame.

| Loading | Top Floor Displacement in the Direction of Earthquake | Mid-height Floor Displacement in the Direction of Earthquake |
|---|---|---|
| Earthquake Load | 0.049 | 0.076 |
| Combined Dead Live and Earthquake | 0.065 | 0.101 |

Table 4: Errors of the analysis of the frame introduced in Figure 2 and Table 3 (%).

## 4 CONCLUSION

After brief theoretical and numerical study on the analyses of two dimensional frames designed against earthquakes, we can claim about the adequacy of the finite elements' sizes equal to the structural elements sizes. Further study, specifically for cases with complicated geometries and loadings' discontinuities along structural members, or analyses involved in nonlinearities are recommended.

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