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Optimal Intermediate Steel Moment Resisting Frames with Different Spans and Story Numbers

[1]Mehdi Babaei and [2]Mohsen Jabbar
[1]Departments of Civil Engineering, Faculty of Engineering, University of Zanjan, Zanjan, Iran
[2]Department of Structural Engineering, University of Zanjan, Zanjan, Iran

Abstract: In this study, the performance of intermediate steel moment resisting frames in terms of the required steel materials per unit area was evaluated. For this purpose, three building models of 5, 10 and 14 story moment resisting frames with 5.6, 7.5 and 11.2 m spans with medium ductility level in two soil types of II and III were designed based on the Iranian Standard No. 2800-03 and the design and construction of steel construction code. It is worth noting that in the mentioned frames, according to the new loading regulations, partition load is considered as live loads. After analysis and design using ETABS and SAFE Software and estimate the drawing with SAZE NEGAR and SAZE90 Software, the required materials were determined and for comparison related charts and graphs were provided. Results showed that increasing of span length is more effective factor in the required steel than increasing of stories. To reduce the required materials it is suggested to avoid long spans.

Key words: Structural systems, intermediate moment resisting frame, optimal span, story, analysis

INTRODUCTION

The performance of a building during an earthquake depends on many factors including: the structure's configuration and proportions, its dynamic characteristics, the hysteretic behavior of the elements and joints, the type of nonstructural components, the quality of the materials and workmanship, adequacy of maintenance, the site conditions and the intensity and dynamic characteristics of the earthquake ground motion experienced (Yun *et al*., 2002). As of 1994 Northridge California Earthquake, designers would assume that typical connections function properly when subjected to reversal loading but the poor performance of welded moment frame connections lead to the introduction of innovative moment resisting frames of different kinds.

Steel Moment Resisting Frames (SMRFs) comprise columns and beams that are typically joined by welding or high-strength bolting or a combination of both. Shearing and flexural actions in the members contribute the most in lateral resistance of these types of structures. Yun *et al*. (2002) worked on the seismic performance of SMRFs. Seismic performance evaluation of SMRFs is studied through incremental dynamic analysis (Asgarian *et al*., 2010). Among many studies on the performance and structural optimization, special SMRFs, braced steel frames (Babaei and Mousavi, 2015), composite structures (Babaei and Taherkhani, 2015), reinforced concrete structures (Babaei 2015a, b) and continuum structures (Sanaei and Babaei, 2011, 2012) have been studied and reported in the literature.

In this research, to provide comparable results, building models of 5, 10 and 14 stories are selected to evaluate short, mid and tall building structures. Different topologies for columns arrangements are selected and the size of plan is defined so that the floor are remain similar for all models. All assumptions are defined according to the previous studies.

RESEARCH METHODOLOGY

In this research, the performance of intermediate moment resisting frames in terms of steel consumption per unit area, bar consumption in foundation and the volume of foundation concrete in different spans and story numbers were evaluated. In intermediate moment frames system, 5, 10 and 14 story moment frames were used. A total of 18 structures with 5.6, 7.5 and 11.2 spans in two soil types II and III with seismic system were modeled.

In terms of loading, all the structures in this study have been approved for live load of 100 kg/cm^2 for roof, 200 kg/cm^2 for story and partition live load of 100 kg/cm^2 for story and dead load of 700 kg/cm^2 for roof and story, according to the Iranian National Building Code: Part 6 (2013).

Corresponding Author: Mohsen Jabbar, Department of Structural Engineering, University of Zanjan, Zanjan, Iran

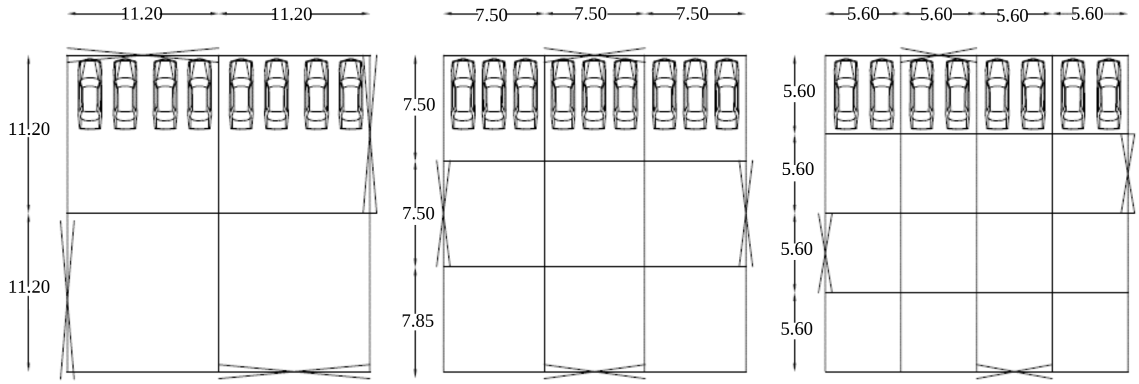

Fig. 1: Plan and parking arrangements

Regulations used are: AISC (2005) (LRFD Method), Iranian National Building Codes (Part 6, 2013; Part 10 2013), terms and conditions of architecture and urban planning management. Project profile: Plan dimensions of 23×23 (530 m^2).

In this study, according to the Standard No. 2800-05 the behavior modulus of intermediate steel moment structures is R = 7, the acceleration of the plan is A = 0.35 and the importance modulus of building is I = 1, roofing system is composite and height of all floors is 3.5 m. The location of project was in Tehran, Iran (Fig. 1). Study procedure according to the assumptions and type of system and its characteristics are:

- Analysis and design of structure skeleton and foundation
- Drawing the output of structure design
- Drawing of structure foundation
- Quantity surveying and estimating (skeleton, roof, foundation, excavation, metal framing, armature)
- Drawing the corresponding figures and graphs and presenting the results

ANALYSIS AND DESIGN OF MODELS

In mentioned system intermediate moment frames in 5, 10 and 14 story with 5.6, 7.5 and 11.2 spans in two soil types II and III were investigated. Comparison of intermediate moment frames in two soil types II and III are shown in Fig. 2-7.

As shown in Fig. 2, the required steel consumption in the 11.2 and 7.5 spans comparison with 5.6 span in 5 story structures in both types soil have 65-90% increase. However with the same span consumption in the soil type III is about 10% more than the soil type II.

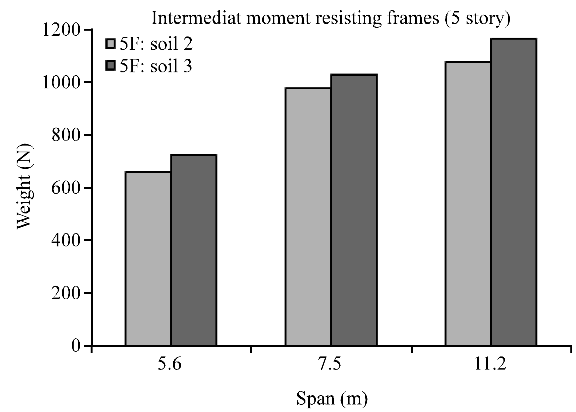

Fig. 2: Unit weight for the 5 story structure with different spans

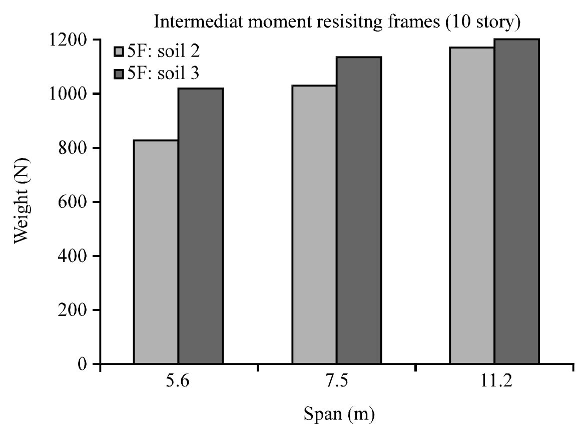

Fig. 3: Unit weight for the 10 story structure with different spans

Figure 3 illustrates less changes in steel consumption for 10 story structure with different spans in soil type III in comparison with 5 story structure. However, these changes for 5 story structure with both types soil were same as each other.

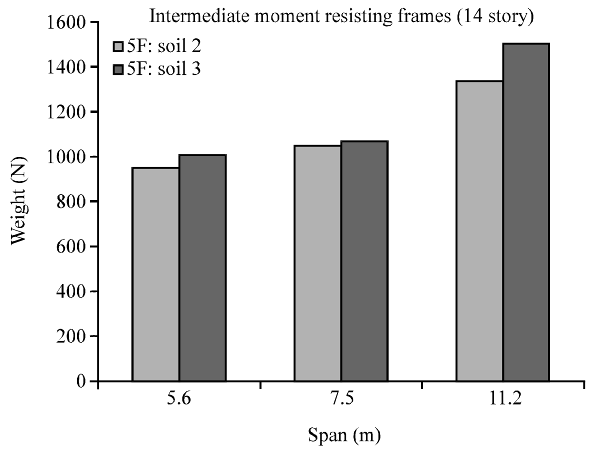

Fig. 4: Unit weight for the 5 story structure with different spans

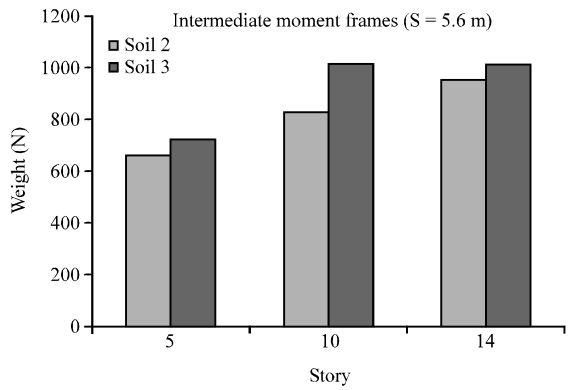

Fig. 5: Unit weight of structure with 5.6 m span for different story

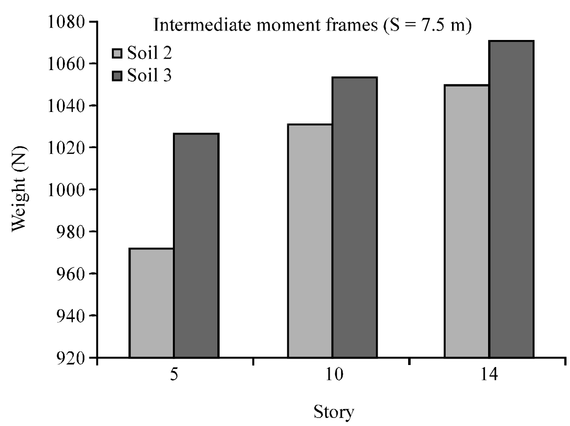

Fig. 6: Unit weight of structure with 7.5 m span for different story

As shown in Fig. 4, increased consumption of steel in 14 story structure with different spans is variable but in 11.2 span has a progressive increase and almost 40%.

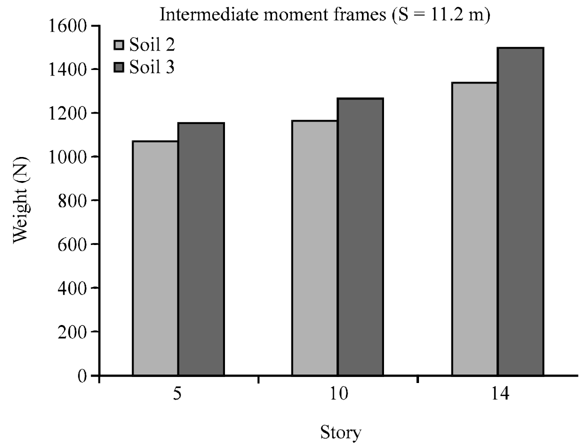

Fig. 7: Unit weight of structure with 11.2 m span for different story

Table 1: The required steel (kg/m^2)

	Span (m)					
	5.6		7.5		11.2	
Story numbers	Soil II	Soil III	Soil II	Soil III	Soil II	Soil III
5	67.36	73.73	99.17	104.70	109.61	118.37
10	84.23	103.59	105.14	115.42	119.16	129.34
14	97.09	103.22	107.10	109.21	136.67	153.20

It can be seen in Fig. 5 that steel consumption in 10 and 14 story structures in soil type III with 5.6 span are almost the same. The consumption dropped 70% in 5 story structure.

As shown in Fig. 6 in 7.5 span the steel consumption in 5 story structure in soil type II is significantly less than soil type III.

Figure 7 illustrate the increased consumption of steel in 10 and 14 story structures with 11.2 span in comparison with 5 story structure are 20 and 40%, respectively. In Table 1, steel consumption (kg/m^2) in intermediate moment resisting frames are summarized.

CONCLUSION

In this research, the performance of steel intermediate moment resisting frames in terms of steel consumption per unit area was evaluated. It was found that increasing of spans is more effective factor in steel consumption than increasing of stories. To reduce consumption it's better to avoid using tall spans. Increase of stories in short spans also can be the reason for more steel consumption but not as much effective as spans height. Naturally soil type III causes more consumption than soil type II but in each type soil the increase of consumption in different spans and stories is almost constant. As a result, increasing of spans height causes the increasing of beams height and in terms of architecture makes problem.

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