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Determining the Optimum Spans for Special Steel Moment Resisting Frames with Special Eccentric Braces

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Abstract: Steel structure with especial eccentric moment resisting steel frames is an efficient system in terms of convenient implementation, uncomplicated facilities, well-organized enforcements, in-site construction and assembly and the possibility of monitoring and precise control and is thus, widely employed in various countries around the world. Given the significance of construction costs and its association with selected structural system, number of the floors, beam span length, location of columns and the soil type, this study investigates the optimum values of these parameters. The aim of the present study is to find the optimal topology with respect to architectural and applicability considerations. To this end, models with structural hybrid systems and simple steel frames with eccentric bracing capable of formability especial for 5, 10 and 14 floors were selected. The selected models were assumed with equal area and two different soil types. In order to provide parking space based on the urban development regulations, models were considered with span length of 5.6, 7.5 and 11.2 m for 2, 3 and 4 car parks, respectively. Having analyzed the models and designed structural members and foundations, amount and cost of the building material were estimated based on the available rates and the results were compared using figures. The most economical structures were proposed for both soil types and the number of floors.

Key words: Optimal span, hybrid system, special frames, eccentric braces, optimization, regular structure

INTRODUCTION

Optimization of structures has often been a constantly challenging issue for designers and consulting engineers, specifically since the emergence of high-rise building as a basic need of communities. To this end, many professors, researchers and engineers in structural designing have been seeking an optimal topology, shape and section which apply for all different types of structures. Naturally, optimization of these features is absolutely difficult and currently such issues are dealt with using various advanced models, especially probabilistic models, however in some cases, the obtained optimum structures are not appropriate in terms of architectural and construction design and even aesthetics and impose additional costs (e.g., producing the obtained section).

Among many studies on structure optimization, Sanaei and Babaei (2012, 2011) developed topology optimization for continuous structures using cellular automata algorithms. Liang *et al.* (2000) investigated the topology optimization for multi-story steel frames and proposed optimal topology for 6 and 12 floors frame. In a study called "Topology optimization for braced frames", Stromberg *et al.* (2012) proposed the most optimal bracing topology using four-nod elements of Finite Element Method. Their findings represent an interesting topology.

Babaei and Sanaei employed a combination of genetic algorithm and ant colony to investigating the multi-objective topology and the size of the braced steel frames and obtained Pareto front. Babaei also investigated the number and the optimal position of trusses with respect to target weight and displacement in core structural systems and truss belts. Rahjoo and Mamaqani (2014) examine the seismic behavior of 6, 12 and 18 floors cross-braced frames with different layouts. Low, medium and high ductility of reinforced concrete frames were studied and their cost differences were compared (Babaei, 2015a). A similar study was conducted for reinforced concrete moment resisting frames in order to discover the optimal layout of columns based on the architectural considerations and the optimal span for structures with 5-10 floors was proposed (Babaei, 2015b).

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MATERIALS AND METHODS

This study aims at determining the optimal topology in steel moment frame seismic systems with medium and high ductility and high ductility eccentric braces based on architectural considerations and regulations for providing parking space. To this end, structural models with regular spans of 5.6, 7.5 and 11.2 m (to accommodate two, three and four cars, respectively) on soil type II and III and in accordance with Iranian 2800 code and regulation (2013, 2005) were considered. According to this code, structural analyses for structures up to 50 m can be carried out using linear methods. Thus, models with 5, 10 and 14 floors were considered. These models are similar to those reported or under evaluation by Babaei for other type of steel frames.

In the course of the present study, first, the characteristics of structural models were identified, then the designed structures and their members were analyzed and finally, their best sections were selected using advanced software facilities. The costs of finalized sections for the structural frames and foundations for different models were estimated and the ultimate construction costs were calculated accordingly for each model. Charts and diagrams were used to compare and contrast the results.

RESULTS AND DISCUSSION

In order to make the results of the models comparable, dimensions and the area of the plans were selected in a way that their axial distances were consistent with architectural considerations. Therefore, a square shape plan with dimensions of 23 m will satisfy the architectural constraints and provisions. In order to calculate the seismic force with static method, the coefficient of structural behavior models was R = 10, basic acceleration A = 0.35, importance coefficience I = 1 and height of the floors H = 3.5 m. Two extensive uniform live loads of 200 and 100 kg/m^2 were applied to the floors and roofs, respectively along with a 100 kg/m^2 live load for the floor partitions and 700 kg/m^2 dead load to all the floors. Table 1 displays the details of eccentric brace framing and the length of linking beam. Composite roofing system was used for all the models. In spite of the fact that roofing cost is not a function of the number of structure floors, slight differences in the roofing costs for different span length are presented in the results.

Table 1: Geometric properties of the eccentric brace and link beam

Span (m)	Link beam length (m)	θ°
5.60	1.00	33
7.50	1.20	42
11.20	2.00	53

AISC 2006 procedure codes (LRFD), Iranian National Regulations on steel building part 10, concrete buildings part 9, loads on buildings part 6 (2013), 2800 codes (3rd and 4th edition) (2005), architectural terms and conditions and the management and planning organization were used in designing structural members.

Steel sections were of ST37 type, the reinforcement bars for the foundation employed with the yield strength of 4000 kg/m^2 and the foundation concrete had a compression strength of 30 MPa. I shapes were employed for the steel sections of beams, columns and braces with different heights and thicknesses.

Models were analyzed and optimal sections are assigned to the structural elements using heuristic. Required materials and the total cost of the building models were estimated. Figure 1-12 represent the results and comparisons for the models. Table 2-5 also indicate the weight and cost comparison for different spans.

A total of 18 simple steel frame structures with special eccentric bracing frames were examine according to Table 1. Table 2-5 display the results. The results of the present study can be summarized as follows:

- The optimal span length for five-story structures in both soil types is 5.6

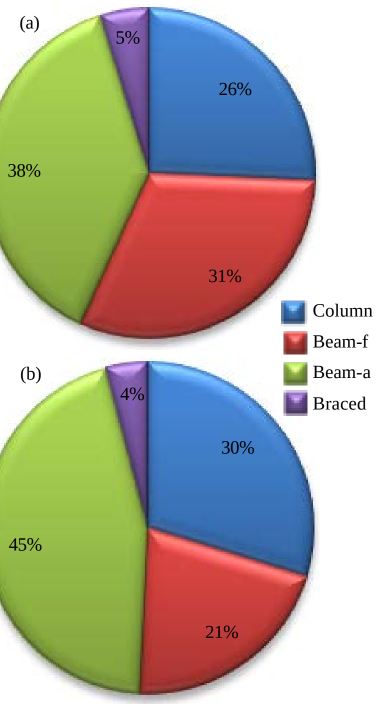

Fig. 1: Weight percentage of structural members 5 story with 5.6 m spans and soil: a) type II and b) type III

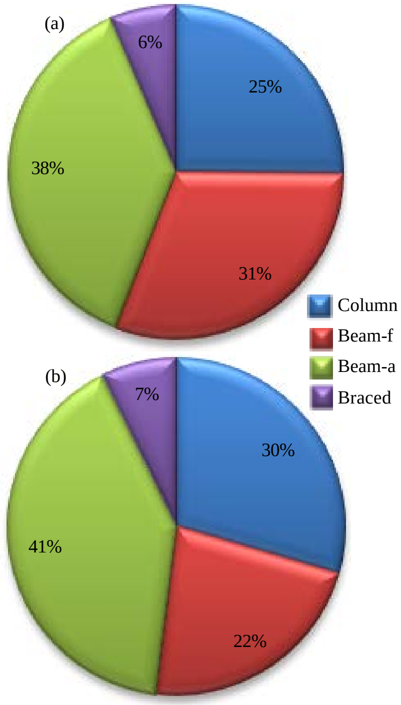

Fig. 2: Weight percentage of structural members 5 story with 7.5 m spans and soil: a) type II and b) type III

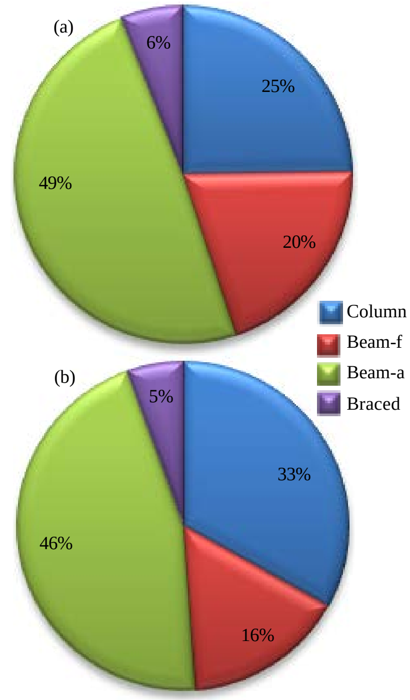

Fig. 4: Weight percentage of structural members 10 story with 5.6 m spans and soil: a) type II and b) type III

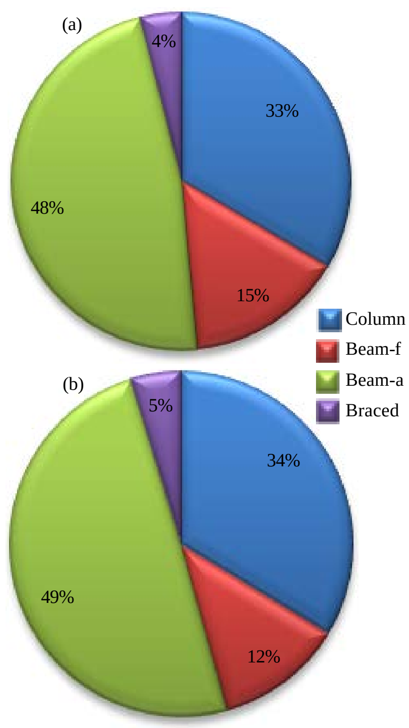

Fig. 3: Weight percentage of structural members 5 story with 11.2 m spans and soil: a) type II and b) type III

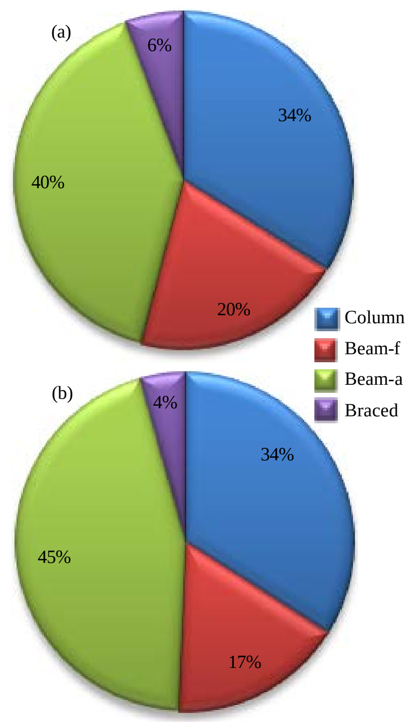

Fig. 5: Weight percentage of structural members 10 story with 7.5 m spans and soil: a) type II and b) type III

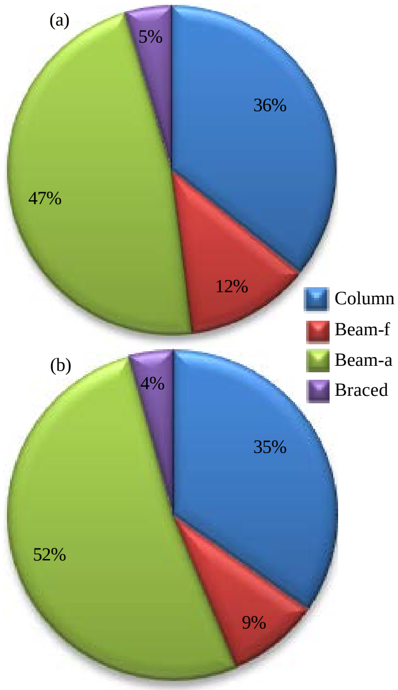

Fig. 6: Weight percentage of structural members 10 story with 11.2 m spans and soil: a) type II and b) type III

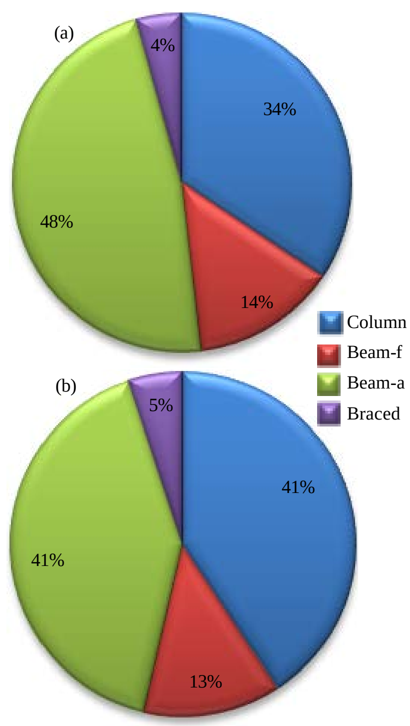

Fig. 7: Weight percentage of structural members 14 story with 5.6 m spans and soil: a) type II and b) type III

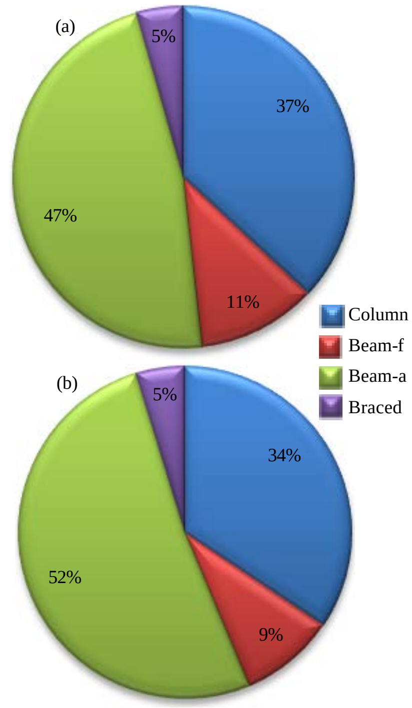

Fig. 8: Weight percentage of structural members 14 story with 7.5 m spans and soil: a) type II and b) type III

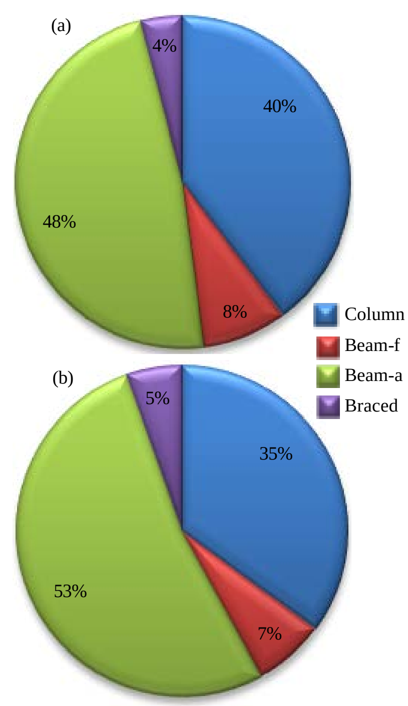

Fig. 9: Weight percentage of structural members 14 story with 11.2 m spans and soil: a) type II and b) type III

Table 2: Weight comparison for different spans

Weight						
	5 story		10 story		14 story	
Soil-type	II (%)	III (%)	II (%)	III (%)	II (%)	III (%)
5.6	40	60	44	56	47	53
7.5	42	58	45	55	45	55
11.2	44	56	43	57	46	54

Table 3: Price comparison for different spans

Price						
	5 story		10 story		14 story	
Soil-type	II (%)	III (%)	II (%)	III (%)	II (%)	III (%)
5.6	44	56	45	55	48	52
7.5	44	56	46	54	46	44
11.2	45	55	44	56	46	54

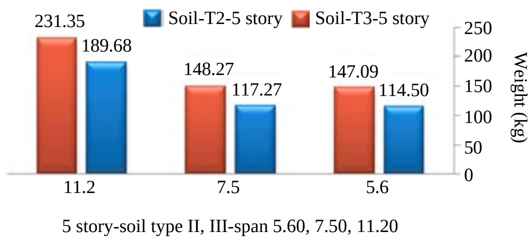

Fig. 10: Weight of structural members for 5 story with different spans and soil type II and III

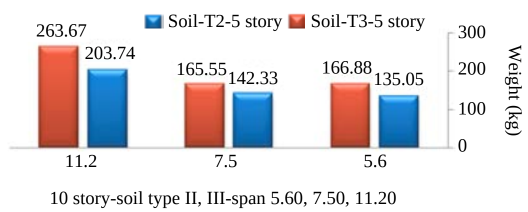

Fig. 11: Weight of structural members for 10 story with different spans and soil type II and III

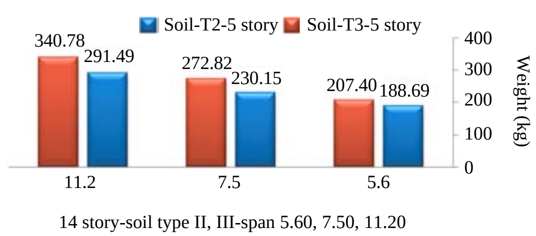

Fig. 12: Weight of structural members for 14 story with different spans and soil type II and III

- The optimal span length for 10 story structures in both soil types is 5.6 and 7.5, respectively
- The optimal span length for 14 story structures in both soil types is 5.6

Table 4: Price comparison based on span length in soil type of II

Soil type II	5 story (%)	10 story (%)	14 story (%)
5.60	23	23	23
7.20	31	31	31
11.20	46	46	46

Table 5: Price comparison based on span length in soil type III

Soil type III	5 story (%)	10 story (%)	14 story (%)
5.60	28	28	25
7.20	28	28	33
11.20	44	44	42

- In all the models with 5-14 floors, total construction cost for soil type III is estimated to be more at least 10% than soil type II

CONCLUSION

The aim of the present study is to find the optimal topology with respect to architectural and applicability considerations.

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