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Cost Evaluation of Columns Arrangements in Special Steel Moment Resisting Frames with Special Chevron Braces

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ABSTRACT

Building structures are subject to displacement under the influence of forces resulting from earthquake. The most common method of controlling such displacements in steel structures, which are usually of lateral type, is the use of braces. Depending on designing requirements and feasibility, braces are available in various forms. Configuration of bracing systems is generally of concentric or eccentric type. Concentric bracings greatly increase the structural stiffness compared to the moment resisting frame, and limit the lateral displacement of the structure. On the other hand, given the great importance for the construction cost, finding the best type of structure in terms of the distance of columns/beam spans, number of stories on different soil types has been studied in this paper. In this paper, special steel moment resisting frames with chevron eccentric bracing with various storey numbers and spans with two soil types (types II and III) have been analyzed and designed according to the considerations of American and Iranian regulations and codes. The obtained results have been presented and compared as some charts and graphs. Based on the results, in soil type II, 7.5m span has been obtained as the optimal model for 5, 10, and 15-story buildings. In soil type III, 7.5m span is the most optimal model in 5-storey buildings.

Keywords*: Chevron Concentric Braced Frames, Stiffness, Lateral Displacement, Steel Moment Resisting Frame.*

1. INTRODUCTION

Steel frame structure with CBF is a system that is widely used in building structures. Brace used in this type of structures in addition to the strengthenning of the structure, is responsible for controlling lateral displacement of a structure against lateral forces, including wind or earthquake loads. Today, many parameters such as the owner needs and some requirements such as urban planning conditions of each area should be considered in the design of structures.

Sanaei and Babaei developed the cellular automata (CA) algorithm regarding the optimization of typology of structures, and showed that this method has a high accuracy and speed compared to the existing algorithms [1-2]. Evolutionary algorithms have been developed for single and multi-objective optimization of steel structures [3-4].

Lauren et al. [5] investigated the optimization of the geometry of braces in steel systems to determine the optimal geometry of braces in frames, the results of which showed that there are several methods for discrete and continuous joining of elements. They proposed a method for an optimum design of a robust steel frame system. The impact of ductility levels on the total cost of ordinary, intermediate, and special reinforced concrete moment resisting frames (RCMRF) was investigated and compared and interesting results have been obtained and reported [6].

The effect of arrangement of columns in RCMRF and other steel moment resisting frames (SMRF) with and without braces has been investigated [7-12] and interesting results have been obtained. However, the main purpose of this article is to find optimal arrangement in SMRF with Chevron braces with special ductility level. All structural features, such as spans, number of stories, soil type and other parameters, have been considered according to the previous and ongoing studies for other structural systems [7-12], so that the results obtained for structural systems would be comparable.

The total cost of a building has a direct relationship with parameters including the arrangement and spacing of columns, number of stories, and soil type in the building site. In this study, 18 structural models have been examined, which include 9 models in soil type II and another 9 models in soil type III with 5.6, 7.5, and 11.2 meters of spans and 5, 10 and 14 storey numbers. To obtain comparable results, plan of the structural models were considered to be $23m \times 23m$ and building site was considered in Tehran. The study aims to find the most economical structure in terms of span, storey number, and type of soil.

In the next section, method of the study and assumptions are developed, and then the obtained results are illustrated in results section. The last section consludes the article by comparing the results and proposing the optimal topologies and configuration for the system.

2. METHOD

In this study, 18 structural models have been studied. Structural features and parameters are assumed similar to the previous and ongoing research [7-12]. Plan of models is shown in figure 1. The plan is considered with an approximate dimension of 23×23 and with an area of 530 square meters per story.

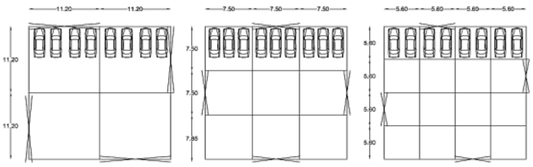

Figure 1. Plan of the arrangement of columns, braces and vehicles

Tehran is considered as the location of this study with very high risk of earthquake so the basic acceleration of the plan A=0.35, structural behavior coefficient R=9, and the building importance coefficient of I=1.0. The roof system is considered to be in form of composite deck and height of the stories is considered to be 3.5m. According to the urban planning conditions regarding the distance of columns to create enough space for parking of 2, 3 and 4 vehicles between columns, the distances of columns, which defines the topology, were selected to be 5.6, 7.5, and 11.2m to park 2, 3, and 4 vehicles, respectively. Models are selected with different number of stories and in three types of 5, 10, and 14 stories and with soil types of II and III. Bearing capacity of the soil under the foundation is considered 2.4kg/cm^2. Dead load of stories is considered to be equal to $700kg/m^2$, and live load is considered to be equal to $300kg/m^2$ as uniform loads. Earthquake forces are manually calculated and applied in stories according to the Iranian codes. Sections used for beams and columns are made of steel plates and braces are made of channel sections.

After analyzing, designing, and determining the optimal sections for the structural members, designing the foundation is done with the assumption of a single type of bars. Then, the final drawings are prepared and drawn with all the details. Metering and cost estimation of the required materials and total structural cost is implemented according to the latest cost list.

3. RESULTS

In this study, special steel structures with chevron braces (CBF) were studied. In terms of distance of columns, three types of 5.6, 7.5, and 11.2 m, in terms of number of stories, 5, 10, and 14, and in terms of siol type under the foundation, two soil types of II and III were considered. Loading was similar to the previous research for all the models in terms of spans, number of stories and soil type of soil [7-12]. The location of placing braces is selected in a way so that a regular structure is created and building does not experience any torsion.

Results are shown in Figures 2 to 9. According to these results, the most economic model in soil type II in all story types of 5, 10, and 14 was arranging columns with 7.5 m distance. In soil type III, the most economical and most efficient structures with 5, 10 and 14 stories, are models with 7.5 meter in span. In terms of weight of the required materials in both soil types and three story types, 7.5 meter span is optimal. But, in terms of weight of rebar required in the foundation, 11.2 meter span has an optimal weight.

In terms of the volume of concrete used for the foundation in structures with 5, 10 and 14 stories, 5.6m, 7.5m and 5.6m spans were optimal, respectively. By increasing the number of stories, the total structure cost in the two soil types (II and III) becomes closer together, but, a significant difference was obtained in models with 11.2 meter of span in comparison with other spans.

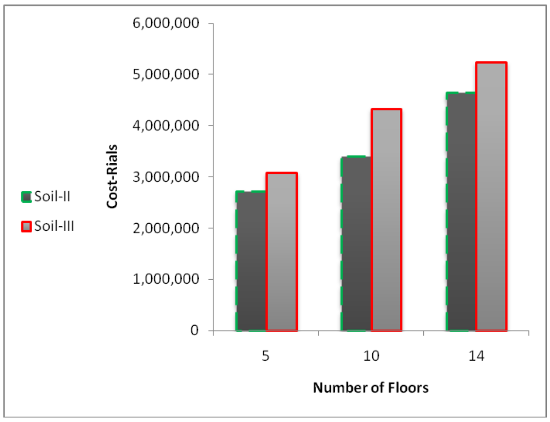

Figure 2: Total structural cost based on the number of stories and soil type

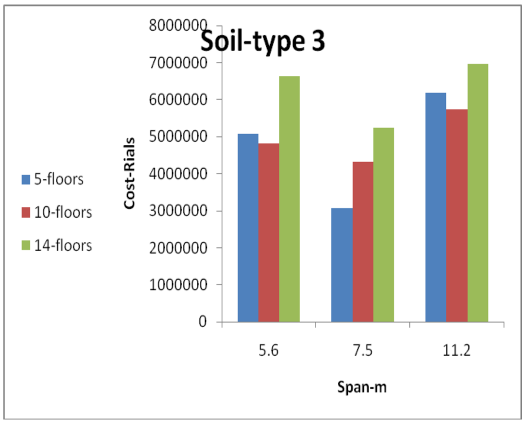

Figure 3: Total structural cost based on span and storey numbers: (soil type III)

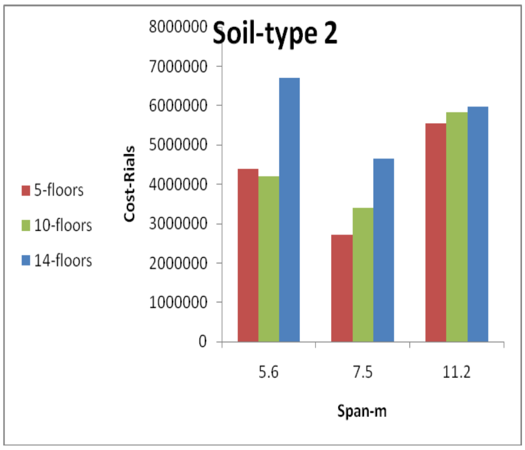

Figure 4: Total structural cost based on span and storey numbers: (soil type II)

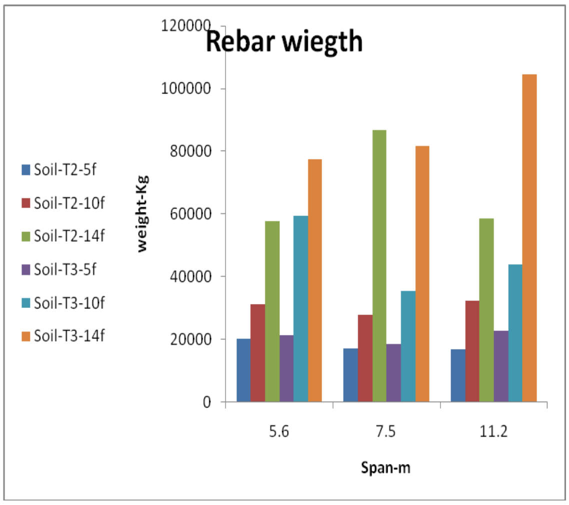

Figure 5: Required rebar weight for foundation in terms of span, soil type and number of stories

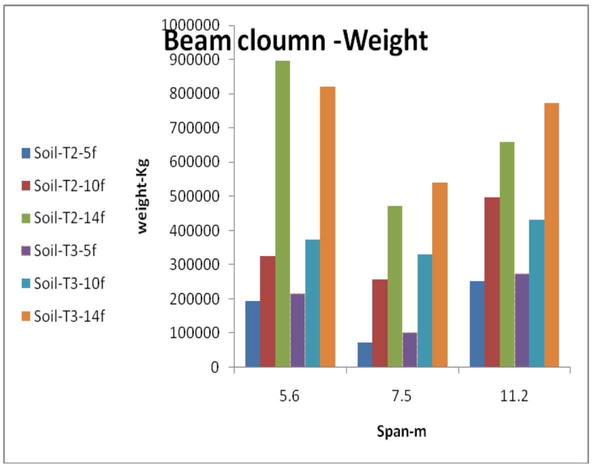

Figure 6: Required steel forbeams and columns in terms of soil type, span and number of stories

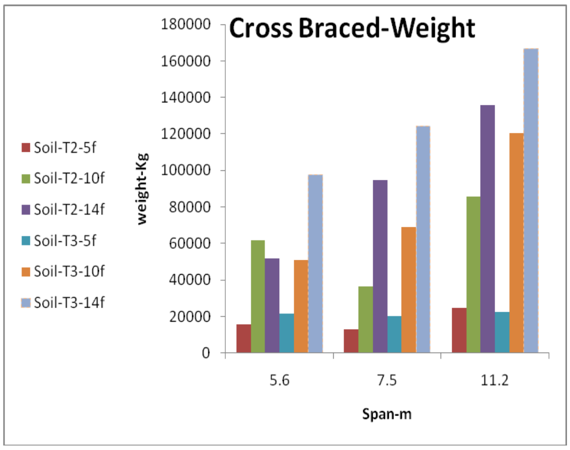

Figure 7: The weight of braces in terms of span, soil type and number of stories

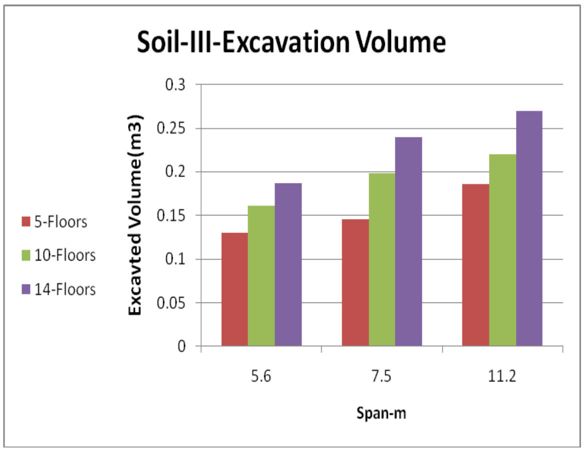

Figure 8: The volume of excavation in terms of number of stories and span: (soil type III)

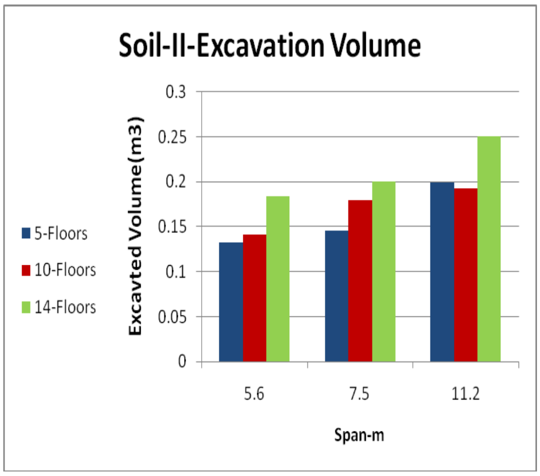

Figure 9: The volume of excavation in terms of number of stories and span: (soil type II)

4. DISCUSSION AND CONCLUSION

According to this study, steel structures that are constructed in soil type II for building models with 5, 10 and 14 stories, 7.5 meter span is the optimal span among 5.6 and 7.5m spans.

By changing the soil type from type II to type III, the best span is still the same 7.5m. The optimal required rebar in the foundation also occurs in 5.6m, and by changing the soil from type II to type III, a great different was observed in the taller building models. The required weight of braces in soil type II is optimal in spans of 7.5m, and in soil type III it is again optimal in spans of 7.5m. The total cost per square meters of foundation, which is the main objective of this study, is in its most optimal model in soil type II and III and in models with 7.5m span. By increasing the distance of columns, the dimensions of beams, columns and braces greatly increase which causes the total weight and total cost of the structure to be increased. This difference is clearly visible particularly in bracings.

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