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Economic Effects of Beam Spans, Number Of Stories and Soil Type on Special Steel Moment Resisting Frames with X-Bracings

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ABSTRACT

Building structures in many places of the world are under earthquake forces, as they are in Iran. The most common method of controlling drift and displacement is to use steel braces or reinforced concrete shear walls that run on many different forms and configurations. Braced systems are generally of centric (CBF) or eccentric (EBF), depending on the shape and behavior of the system. Design of the cost-effective building systems and finding the best layout for braces and columns are the main significance of this study. For this purpose, different structural models with different number of spans, stories, and soil types are modeled and investigated. Special steel moment resisting frame structures with X bracings containing 5, 10 and 14 floors and spans of 5.6, 7.5 and 11.2 meters and soil type of II and III, according to the Iranian regulations, have been designed, and estimated. The results are presented by graphs and compared. The span of 7.5m in buildings with 5, 10 and 14 stories is obtained as optimal in the soil type I, while span of 5.6 is obtained optimal in the soil type III for 14-storey buildings.

Keywords: *X-Bracing, Optimization, Weight, Special Ductility Level, Steel Moment Resisting Frame.*

1. INTRODUCTION

Since approximately %30 of the total building costs involves the cost of structural system, optimization of the structural system is always a challenging issue for designers and engineers and it worth to overcome this problem.

Special steel braced frame structures with centric braces is one of the systems that are widely used in building structural systems. Braces used in this type of structures are to control structures against lateral forces as well as gravity loads. Today, many factors such as the owner interests, aesthetics and region regulations should be considered and satisfied in the design procedure. The cost of a building has a direct relationship with a series of some factors such as the topology, shape, and size of the elements, number of floors and soil type of where the structure is to be built.

The impact of ductility levels on the total cost of reinforced concrete moment resisting frames is studied and reported by Babaei [1], including special, intermediate and ordinary moment resisting frames. In the field of continuum optimization of structures Sanaei & Babaei utilized the weighted sum method (WSM) to convert multi-objective optimization problem (MOOP) into a single-objective optimization problem (SOOP) and they found that cellular automata algorithms (CA) offers better results [2-3].

Optimization of core and outrigger-belt truss systems studied and interesting results for the optimal number and location of trusses suggested [4-5]. Babaei and Sanaei [6] have investigated multi-objective optimization of braced steel frames using a combination of genetic algorithm and ant colony.

Lauren et al. [7] studied to optimize the geometry of the steel braces system with the aim of optimizing the geometry of braces in the frame. Their results showed there are several methods for connecting discrete and continuous elements.

The main purpose of this study is to obtain the most economical structures for different floor numbers and soil types. In addition, in the analysis and design of structures, AISC 2006 Regulations and section 10 and section 6 of the National Building Regulations for loadings and concrete structures satisfied.

Method of the study and models explained and introduced in section 2, which is similar to studies have been performed or under implementation by Babaei et al. [8-11]. Section 3 gives the result by comparing the material usage and structural cost for different models, and section 4 concludes the paper.

2. METHOD AND MODELS

In this study, 18 cases investigated, including nine models in soil type II with three span types and with 5, 10, and 14 stories and the other models in soil types III with similar characteristics evaluated. The size of building assumed to be 23m by 23m and the location of the building to be in Tehran.

Three types of spans are defined for models as 5.6, 7.5 and 11.2, providing location for two, three, and four cars, respectively, so that the area for all models to be similar. Figure 1 shows the plan layout, columns and bracings arrangement.

According to the Iranian regulations the relative risk of earthquake in Tehran is very high and A=0.35, structural behavior coefficient R=9, coefficient of the importance of building I = 1.0. All stories have the same height as 3.5m. The bearing capacity of the soil assumed 2.4kg/m2.

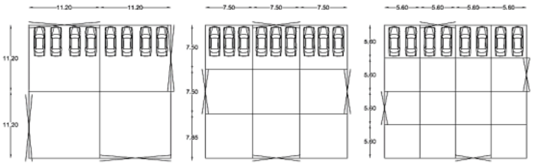

Figure 1: Plan view of models

Loads of 700kg/m^2 for dead loads and 300kg/m^2 for live loads are considered. Earthquake forces calculated. Sections made by steel plates defined for beams and columns, and channel sections are used for braces. The design and calculation of the models and foundations performed, and all the material and cost of the structural elements estimated.

3. RESULTS

Special braced steel structures with X-bracings modeled and materials usage and cost of them obtained. These results are shown in Figures 2 to 19.

The results indicate that spans of 7.5m are most economical in all types of soil type II for structures with 5, 10 and 14 stories. In soil of type III, the most economical and most optimal span for structures with 5 and 10 stories is span of 7.5m and the span of 5.6m is optimum for models with 14 stories.

The weight of the element sections used in both soil types and three types of storey numbers span of 7.5m is optimum. The weight of the steel used in the foundations for span of 11.2m is the optimal. The optimal volume of concrete used in the foundations in the 5 and 10 storey models is for span of 7.5m, and in 14 storey models, the span of 5.6m needs the minimum concrete for foundation.

By increasing the number of stories, the structural cost for two soil types (II, III) become closer, and the cost of the spans of 11.20m increased drastically.

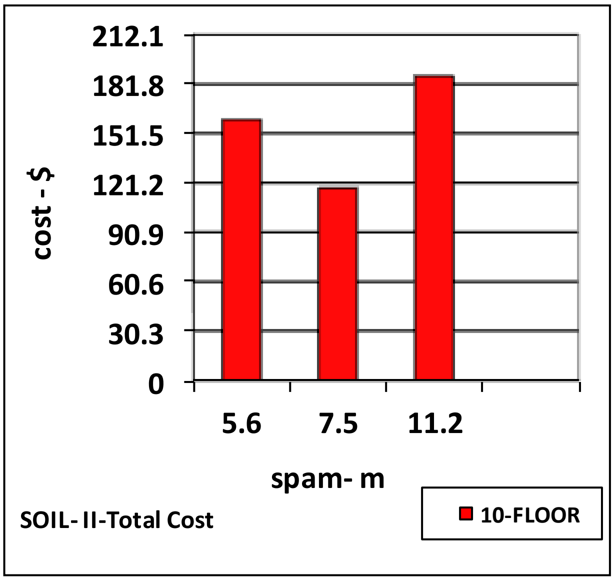

Figure 2: Total structural cost for 10-storey models, soil type II

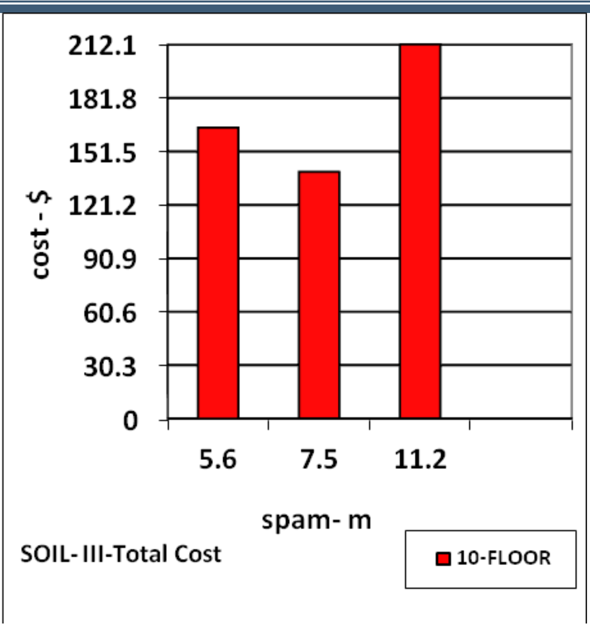

Figure 3: Total structural cost for 10-storey models, soil type III

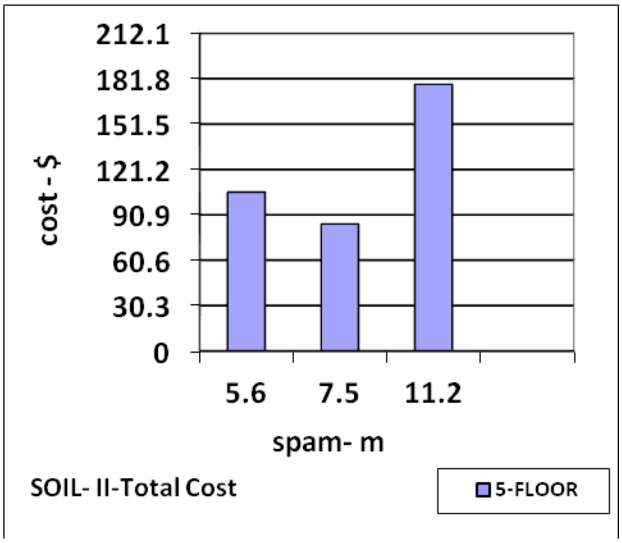

Figure 4: Total structural cost for 5-storey models, soil type II

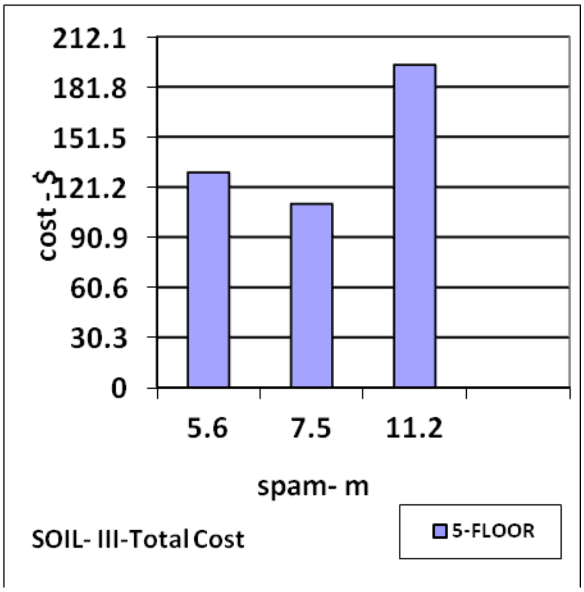

Figure 5: Total structural cost for 5-storey models, soil type III

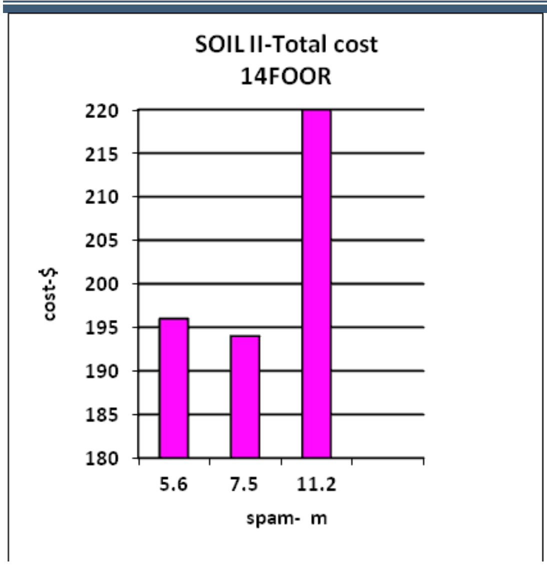

Figure 6: Total structural cost for 14-storey models, soil type II

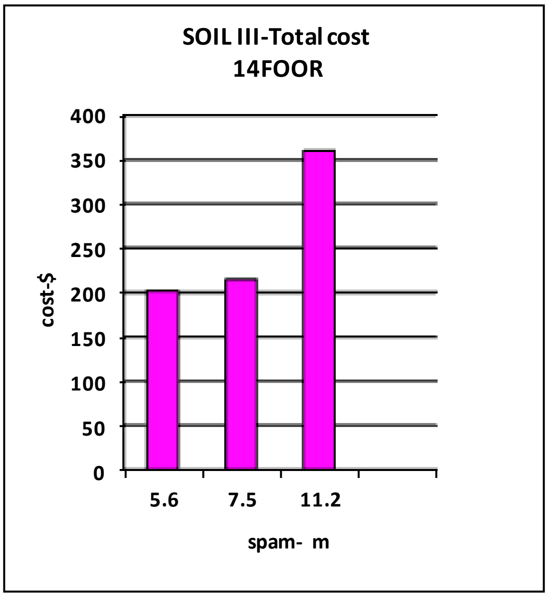

Figure 7: Total structural cost for 14-storey models, soil type III

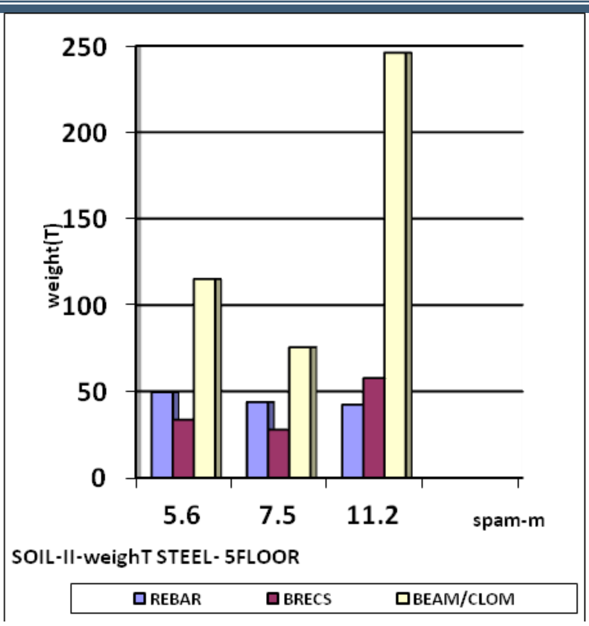

Figure 8: Weight of steel for 5-storey models, soil type II

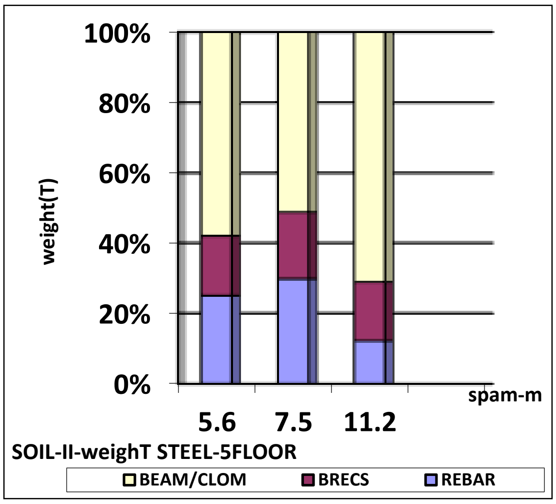

Figure 9: Percentage of weight of steel for 5-storey models, soil type II

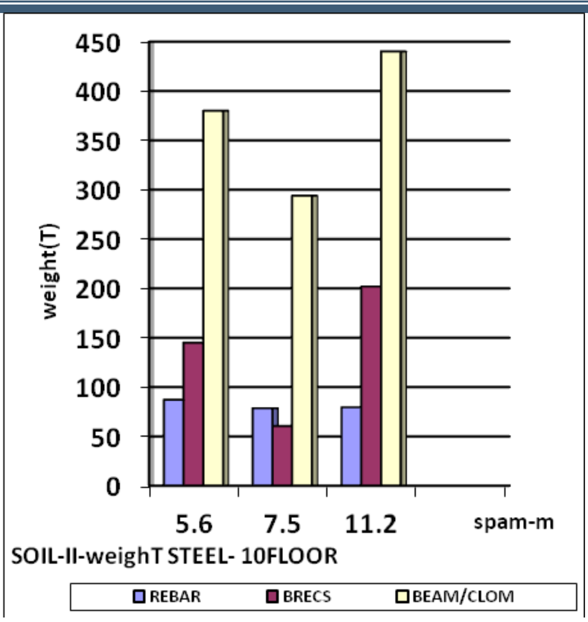

Figure 10: Weight of steel for 10-storey models, soil type II

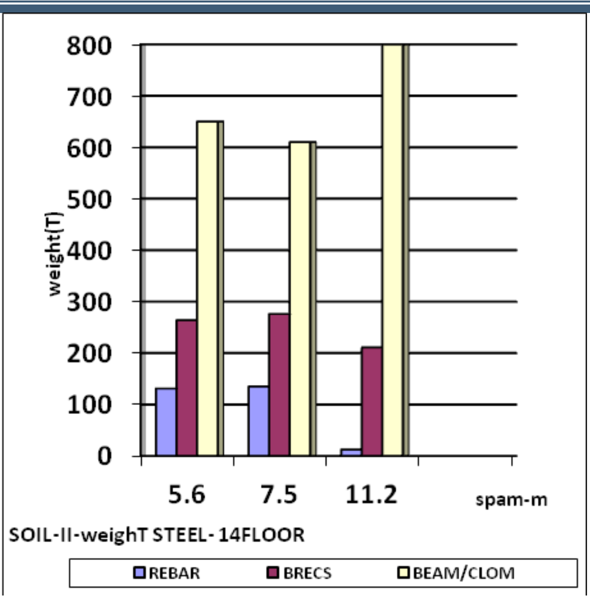

Figure 12: Weight of steel for 14-storey models, soil type II

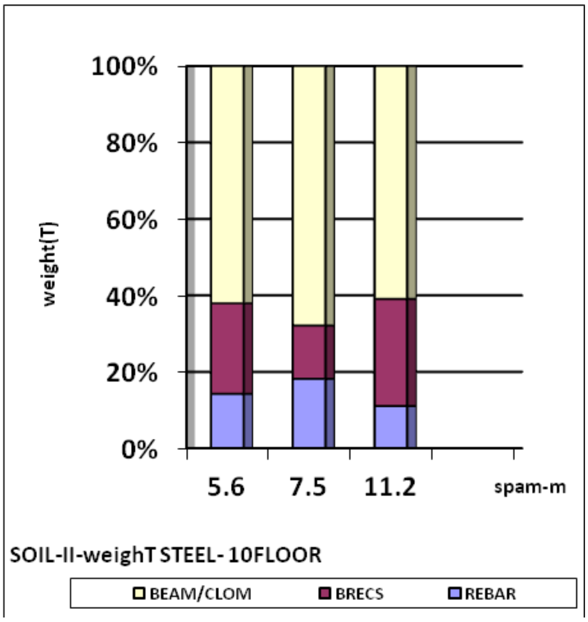

Figure 11: Percentage of weight of steel for 10-storey models, soil type II

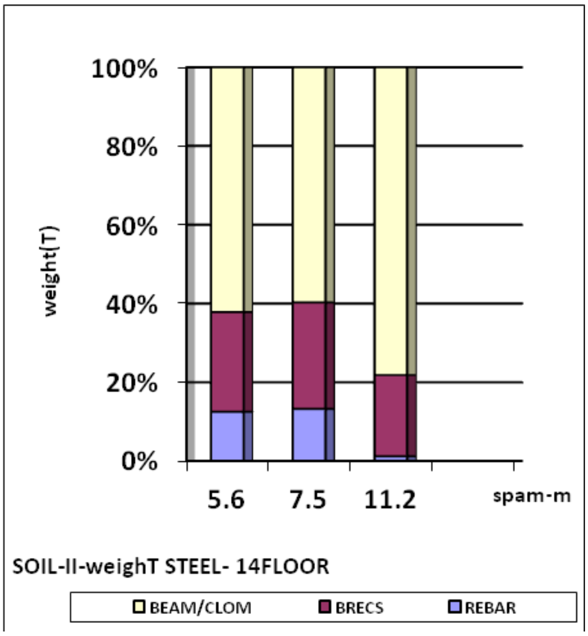

Figure 13: Percentage of weight of steel for 14-storey models, soil type II

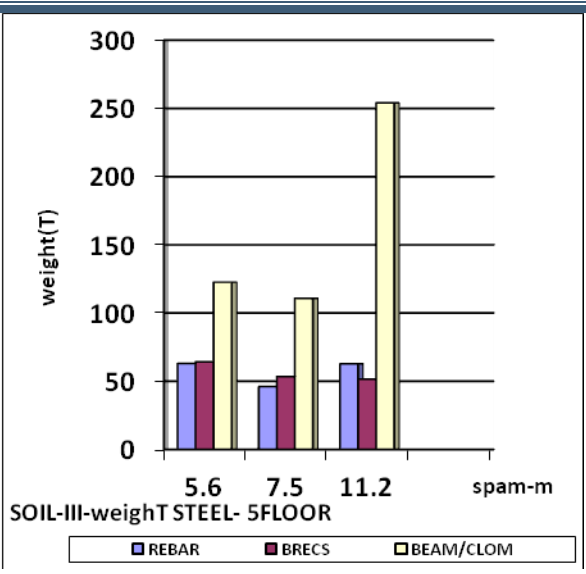

Figure 14: Weight of steel for 5-storey models, soil type III

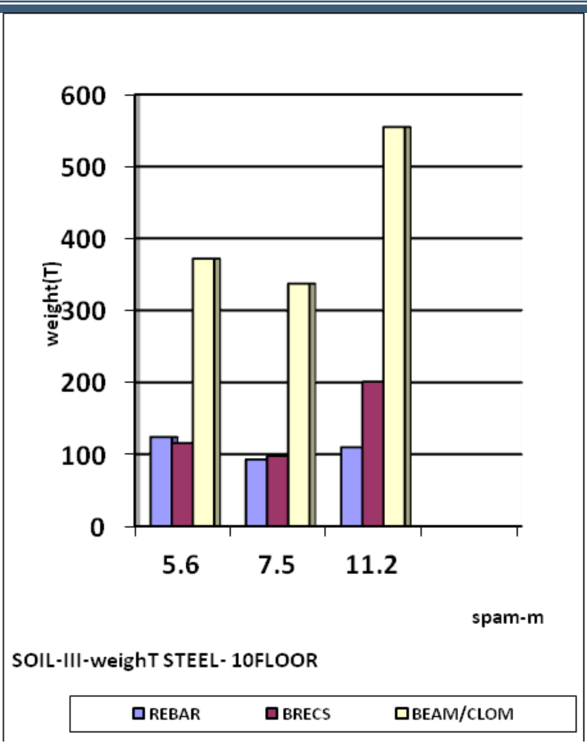

Figure 16: Weight of steel for 10-storey models, soil type III

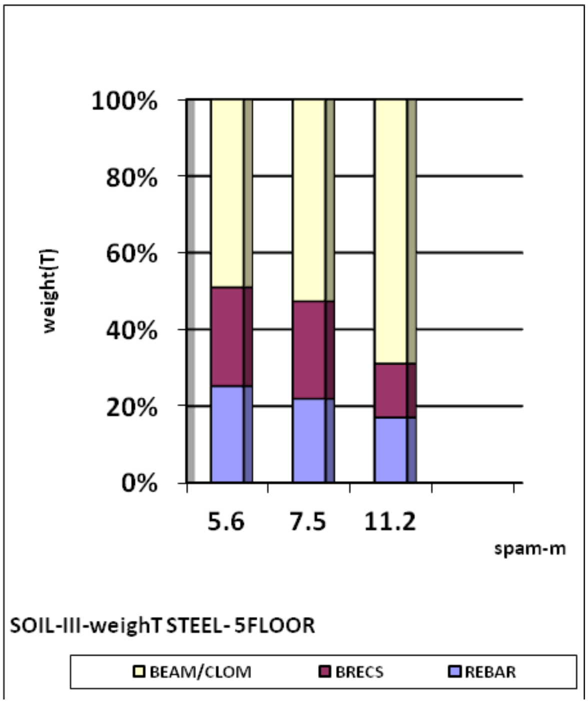

Figure 15: Percentage of weight of steel for 5-storey models, soil type III

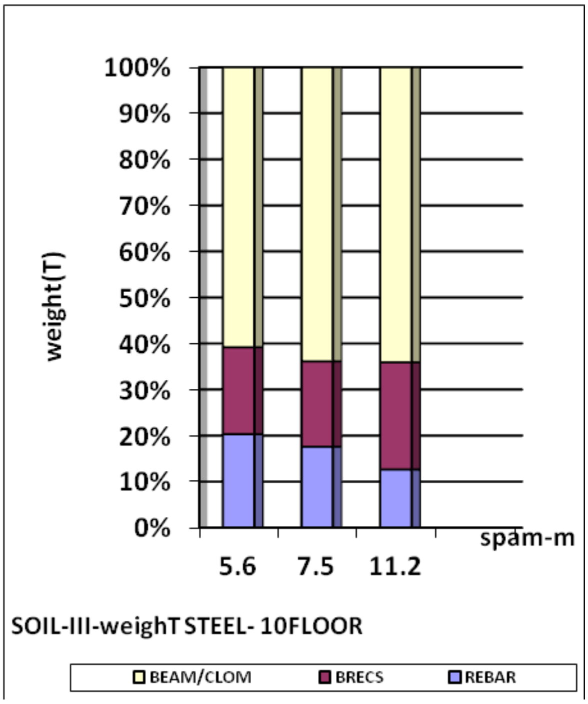

Figure 17: Percentage of weight of steel for 10-storey models, soil type III

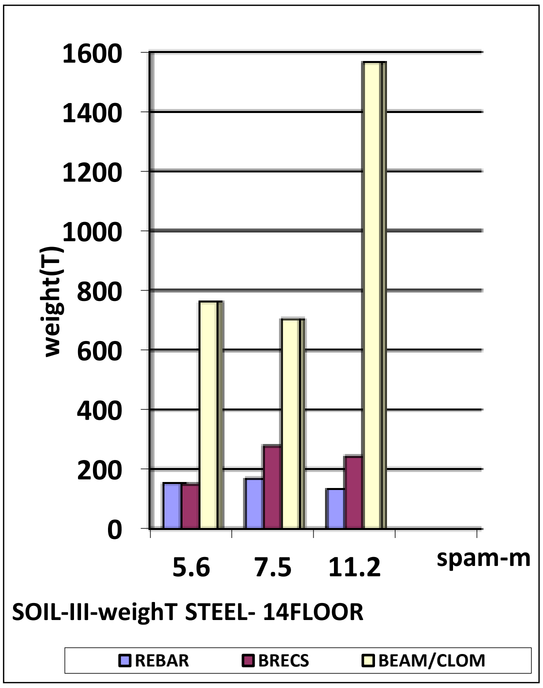

Figure 18: Weight of steel for 14-storey models, soil type III

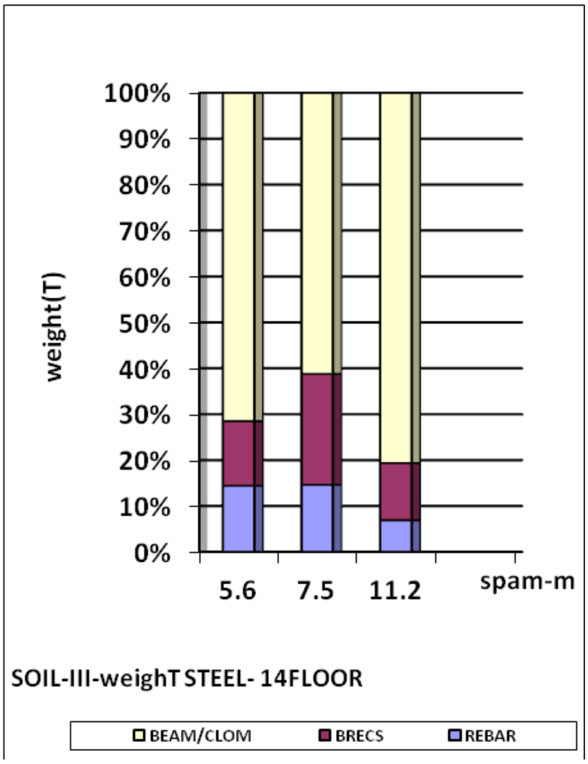

Figure 19: Percentage of weight of steel for 14-storey models, soil type III

4. CONCLUSION

According to the studies of building models with 5, 10 and 14 stories in soil type II, among the spans of 5.6, 7.5, and 11.2m, the optimal span obtained 7.5m. By changing the type of soil to III the best spans are 7.5m and 5.6m for 10 and 14 storey models, respectively. Reinforcements used in foundations in the spans of 7.5m are the minimum, so that by changing the type of soil to III it needs more materials.

The weight of the braces in spans of 7.5m shows the best amount for both soil types. The volume of concrete used for foundations in this model is also the minimum.

Total cost per square meter, which is the most important aim of this study, in the soil type II is spans of 7.5m for models with 5 to 14-storey number. In the soil of III for models of 5 and 10-storey, span of 7.5m is the optimal, but in 14-storey models, span of 5.6m is optimal.

By increasing the span length, the size of the columns, beams and braces increases drastically, so that increases the size and weight of the structure. It is clearly visible, especially materials needed for braces.

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