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Selection of the Effective Cross-Section of Structural Steel Columns of a Multi-Story Building

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Annotation: This article compares the geometric characteristics of a proposed steel tie-bar and selected steel tie-bar using computer software. The economic efficiency of the proposed composite column made of steel is presented.

Key words: High-rise buildings, structural steel column determined by computer software, proposed structural steel column, moment of inertia, steel consumption, column deformation, column priority.

Introduction

Currently, the frames (load-bearing structures) of multi-story skyscrapers are mainly made of steel. This is due to the high strength of steel, its reliability and lightness compared to other structures. Steel constructions are relatively earthquake resistant. It is well known that with the demand of time, the need for steel structures in the construction industry is increasing. Frames (load-bearing structures) of multi-story buildings are mainly composed of steel columns and steel beams. Steel columns are made of rolled metal or structural steel sheets. The advantages of rolled steel profiles compared to the assortment of rolled profiles are that they can be made in different geometric sizes, and it is possible to increase the priority of the construction. Steel columns serve to receive permanent and temporary loads from the main elements of the building and transfer them to the foundation.

If the height of the building is high, the consumption of steel for the building will increase, which will lead to an increase in the economic performance of the building. Therefore, in our research work, we conducted research on reducing the metal consumption of steel columns made in the factory by the rolling method and increasing its uniformity.

The main part.

In order to study the deformation and strength of structural steel columns in a multi-story building, we conducted calculations in a 31-story building with a height of more than 100 m, the plan of which is shown in Fig. 1. The building shown in Figure 1 consists of a "barrel" structural system, and the distance between axes 1-7 and A-J is 29.6 m. Here, the shaft acts as a circular core of 40 cm thick reinforced concrete. The center of Bikirlik nucleus is located on the 4-G axes and its radius is 12 m. The floor height is 3.3 m. To ensure the vertical superiority of the building, the basement part consists of 3 floors and is 7.5 m deep from the ground level.

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A total of 9 proposed structural steel columns are located between axes 3-5 and V-D in the unique multi-story building plan shown in Figure 1. The cross-sectional shape of the steel column of this structure is shown in Figure 3. In order to apply the structural steel column to the project, it is first necessary to determine the geometrical characteristics of the cross section.

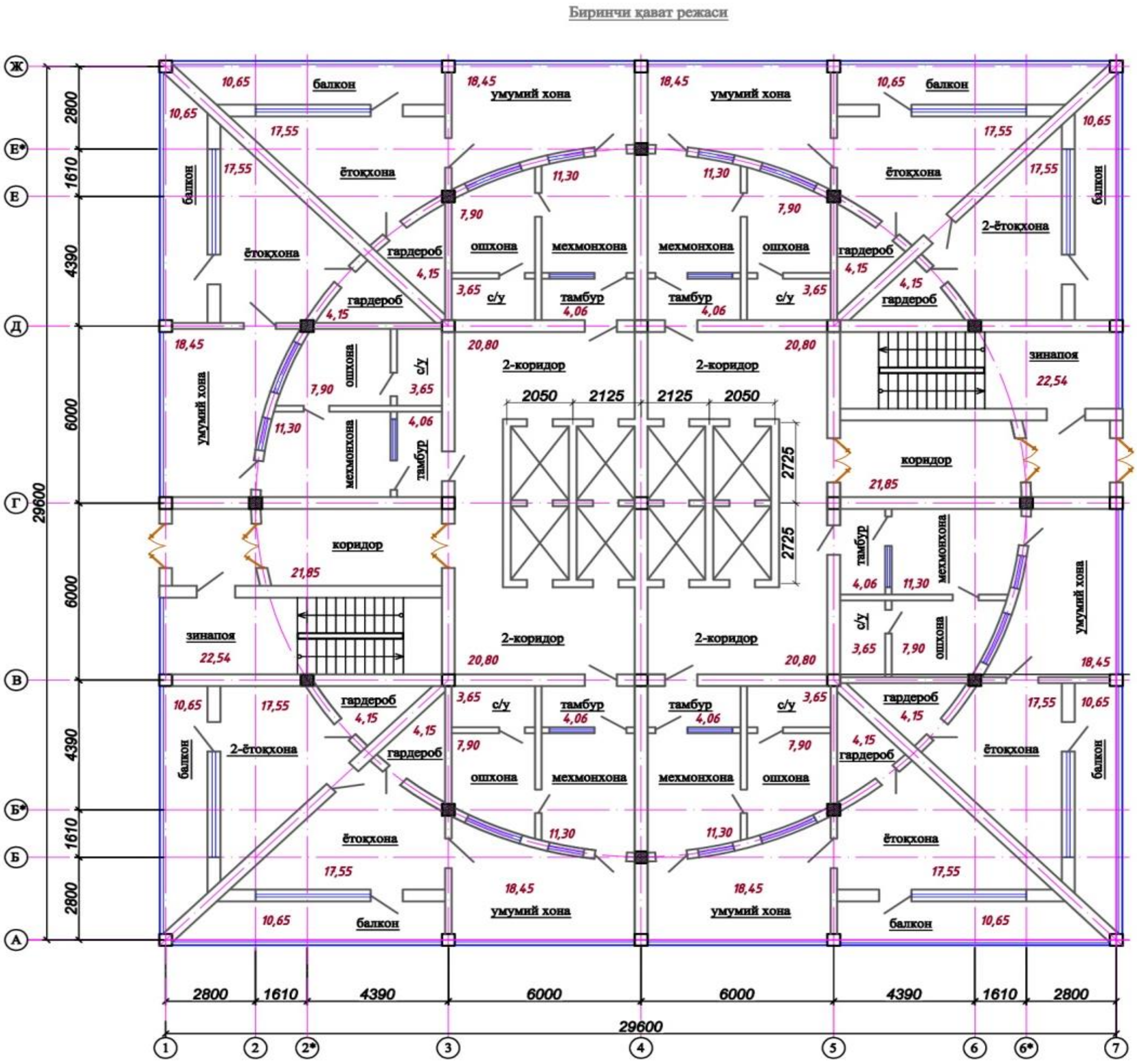

Figure 1. Plan of the first floor of a unique multi-storey building.

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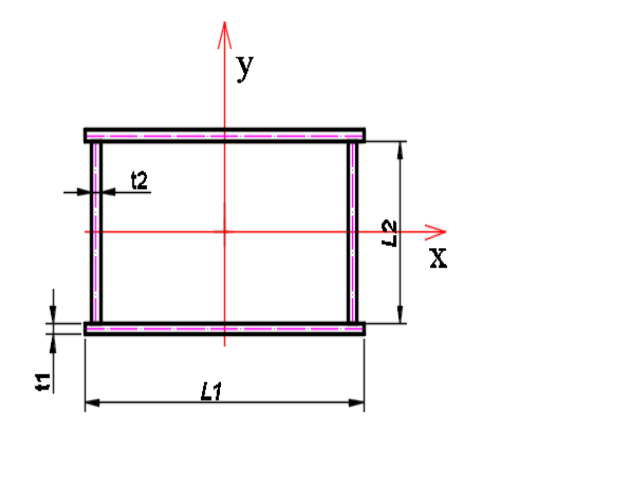

Figure 2. Structural steel column cross-section determined by computer software.

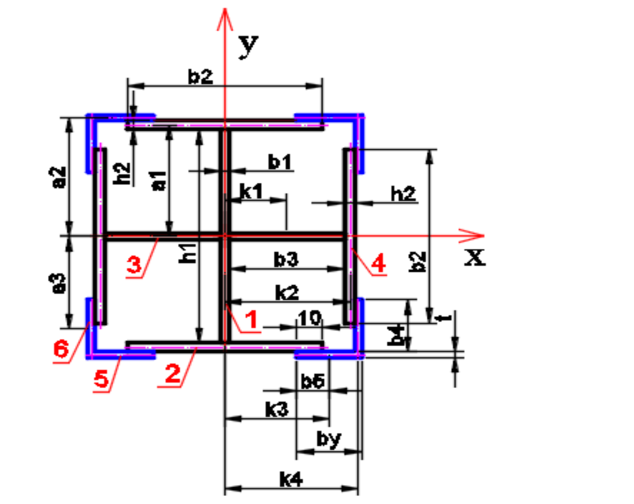

Figure 3. Cross section of the proposed structure steel column.

Figure 3 shows a cross-section of a proposed steel sheet structure column in a high-rise building column. Moments of inertia for each element of this column can be determined by the following expressions.

The moment of inertia of element 1 (1) is determined by the expression:

$$J_{x1} = \frac{b_1 \cdot h_1^3}{12}; \quad J_{y1} = \frac{h_1 \cdot b_1^3}{12}; \tag{1}$$

The moment of inertia of element 2 is determined by expression (2).

$$J_{x2} = \frac{b_2 \cdot h_2^3}{12} + a_1^2 \cdot b_2 \cdot h_2; \quad J_{y2} = \frac{h_2 \cdot b_2^3}{12}; \tag{2}$$

where is equal to $a_1 = \frac{h_1 + h_2}{2}$.

The moment of inertia of element 3 is determined by expression (3).

$$J_{x3} = \frac{b_3 \cdot b_1^3}{12}; \quad J_{y3} = \frac{b_1 \cdot b_3^3}{12} + k_1^2 \cdot b_3 \cdot b_1; \tag{3}$$

where is equal to $b_3 = \frac{h_1 - b_1}{2}$; $k_1 = \frac{b_3 + b_1}{2}$

The moment of inertia of element 4 is determined by expression (4).

$$J_{x4} = \frac{h_2 \cdot b_2^3}{12}; \quad J_{y4} = \frac{b_2 \cdot h_2^3}{12} + k_2^2 \cdot h_2 \cdot b_2; \tag{4}$$

where is equal to $k_2 = b_3 + \frac{h_2 + b_1}{2}$

The moment of inertia of the 5th element is determined by the expression (5).

$$J_{x5} = \frac{b_y \cdot t^3}{12} + a_2 \cdot b_y \cdot t; \quad J_{y5} = \frac{t \cdot b_y^3}{12} + k_3^2 \cdot t \cdot b_y; \qquad (5)$$

where is equal to $a_2 = \frac{h_1}{2} + h_2 + \frac{t}{2}; \quad k_3 = \left(\frac{b_1}{2} + b_3 + h_2 + t\right) - \frac{b_y}{2}$

The moment of inertia of the 6th element is determined by the expression (6).

$$J_{x6} = \frac{t \cdot b_4^3}{12} + a_3^2 \cdot b_4 \cdot t; \quad J_{y6} = \frac{b_4 \cdot t^3}{12} + k_4^2 \cdot t \cdot b_4; \qquad (6)$$

where is equal to $a_3 = \left(\frac{h_1}{2} + h_2\right) - \frac{b_4}{2}; \quad k_4 = \frac{b_1}{2} + b_3 + h_2 + \frac{t}{2}; \; b_4 = b_y - t$

Using expressions (1), (2), (3), (4), (5) and (6), the total inertia of the cross section of the structural steel column in Figure 3 with respect to the X and Y axes through expressions (7) and (8) we determine the moments.

$$J_x^y = J_{x1} + 2 \cdot J_{x2} + 2 \cdot J_{x3} + 2 \cdot J_{x4} + 4 \cdot J_{x5} + 4 \cdot J_{x6} \qquad (7)$$

$$J_y^y = J_{y1} + 2 \cdot J_{y2} + 2 \cdot J_{y3} + 2 \cdot J_{y4} + 4 \cdot J_{y5} + 4 \cdot J_{y6} \qquad (8)$$

The plan calculation of the building shown in Figure 1 was carried out using computer software Lira-Sapr 2017R3. In order to compare the proposed structural steel, we applied the cross-section shown in Figure 1 to the design of the structural elements included in the computer programs. The structural steel columns shown in Fig. 1 were selected for cross-section by the computer program under the influence of permanent and temporary loads, as well as vertical and horizontal seismic forces acting on the building. Due to the different dimensions of the structural steel columns selected by the program, the building was divided into 5 levels and the columns were unified. The cross-sectional dimensions of structural steel columns selected by computer software are presented in Table 1. The geometric characteristics of the proposed structure shown in Figure 3 and the total moment of inertia of the steel columns were determined by the expressions (7) and (8) given above. The thicknesses of the steel columns of this structure were equalized and its cross section was compared. It can be seen that the deformation of the columns is reduced when the cross-sectional surfaces of the columns are equalized and their angles are compared. Therefore, the calculation results obtained by computer programs and the comparison results with the proposed structure of Figure 3 with the steel column are presented in Table 2.

Table 1. The results of the comparison with the steel column in Fig. 2 selected by the computer program.

№	Floors	Column dimensions (мм)	Column cross-sectional area (см2)	Column moment of inertia (J см4)	Total steel consumption (т)
1	1-5	2-560x16, 2-280x12	246	91 917	28,7

2	6-12	2-540x16, 2-280x12	240	83 663	39,2
3	13-18	2-500x16, 2-280x12	227	68 581	31,8
4	19-25	2-500x16, 2-280x12	227	68 581	31,8
5	26-31	2-500x16, 2-280x13	227	68 581	31,8
					163,1

Table 2. Comparison results of the proposed structure with the steel column in Figure 3.

№	Floors	Column dimensions (см)	Column cross-sectional area (см2)	Column moment of inertia (см4)	Column total steel consumption (т)	Economy of general steel (т)	Economy compared to table 1 (%)
1	1-5	1-3; -540x6 2-4; -500x6 5-6; -140x4	229	92 155	26,6	2,0	7
2	6-12	1-3; -520x6 2-4;-500x6 5-6;-130x4	221	83 812	36,1	3,0	8
3	13-18	1-3; -485x6 2-4; -460x6 5-6; -130x4	209	68966	29,3	2,5	8
4	19-25	1-3; -485x6 2-4; -460x6 5-6; -130x4	209	68966	29,3	2,5	8
5	26-31	1-3; -485x6 2-4; -460x6 5-6; -130x4	209	68966	29,3	2,5	8
					150,6	12,5	8

As shown in Table 1, when we calculated the 9 main load-bearing columns in the middle of the 31-story building, it was found from the results of the analytical calculation that the structural steel columns of the building selected by the program were 7% lower than the proposed columns with the columns of the lowest 1-5 floors. up to 28.7 tons of metal consumption was saved. Up to 8%, i.e. 39.2 tons of metal consumption is saved when comparing the columns of the upper 6-12 floors of the building. Up to 8%, i.e. 95.4 tons of metal consumption is saved compared to the rest of the columns of the upper 13-31 floors of the building. The metal consumption per column of the multi-story unique building based on the assortment is 163.1 tons, while the metal consumption per proposed column is 150.6 tons. Saving of steel consumption for 9 main load-bearing columns of the building was 12.5 tons. As a result of comparing the structural steel columns in Table 1, the total steel economy of the column was 8%.

Conclusion: According to the results of calculations of a steel structural column, the cross section of which is made of sheet metal, shown in fig. 3, the following conclusions were made:

1. If the proposed steel column plan is applied to 9 of the 25 main load-bearing steel columns of the building shown in Figure 1, the total steel consumption is 8%. This is 12.5 tons. If the structural steel column is applied to 25 columns of the building, the steel consumption can save 312.5 tons of steel.

2. If the cross-sectional surfaces of the columns are equalized and their angles are compared, the deformation of the proposed columns will decrease by 8%. This will help ensure the priority of the entire building. It makes it possible to ensure the normal deformation limit under the influence of horizontal seismic forces.

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