Hybrid Column Designs for Industrial Buildings

V Veselov¹, M Abu-Khasan¹, V Egorov¹
¹Emperor Alexander I Saint-Petersburg State Transport University.

E-mail: pgups1967@mail.ru

Abstract. The article analyzes the possible application of hybrid steel-concrete structures for industrial buildings, presents new developments in the structural forms of columns, supports, as well as ways to interface steel-concrete elements. The calculation of the steel-concrete step column is performed, the analysis of the reduction in steel consumption and other advantages of hybrid steel-concrete structures in comparison with traditional solutions of steel and reinforced concrete columns is made. The use of hybrid steel-concrete structures is effective mainly in compressed elements: columns, posts, supports, compressed parts of beams and trusses, crane beams, frame and arched structures.

1. Statement of research objectives
Hybrid (combined) structures made of steel concrete, steel-reinforced concrete are increasingly used in the frames of high-rise buildings and bridge structures, as well as in the floors of industrial and civil buildings, because have significant advantages over steel and reinforced concrete: high bearing capacity, lack of formwork in some cases and manufacturability, compression of concrete and an increase in its strength by 1.5 ... 2.5 times, aesthetics, resistance to mechanical stress, reduction of creep and shrinkage of concrete, reduction flexibility and increased local stability of steel elements, increased dynamic rigidity, steel shell spacing, high fire resistance, good corrosion resistance. as a result, there are economic advantages: reduction in steel consumption, reduction in weight, and reduction in labor intensity of manufacture [1-2].

The range of combined steel-concrete structures in the Russian Federation is still insufficiently developed, incl. for structures of industrial buildings with bridge cranes, where the application is relevant primarily due to heavy dynamic loads. At the Department of Building Structures, PGUPS, hybrid steel-concrete structures and their units are being developed [3-4].

2. Practical application and results
The use of hybrid steel-concrete structures is effective mainly in compressed elements: columns, posts, supports, compressed parts of beams and trusses, crane beams, frame and arched structures. At the same time, concrete can sometimes be placed in the stretched parts of structures, but taking into account the compression of concrete due to prestressing [5-6]. A number of load-bearing structures of buildings and structures with the use of steel concrete have been developed, which are patented by the authors. The search for rational cross-sections for steel-concrete columns has been performed. For industrial buildings with heavy lifting equipment, a hybrid design of a stepped column has been developed, protected by a patent solution (application No.2020141271 of 12/14/2020) [7-8].
3. Practical Relevance
The proposed stepped column consists of a crane section with a rigidly attached crane section through a traverse (Fig 1). The above-crane part is made of a steel tubular profile of rectangular cross-section with a head, filled with concrete, while the height of the cross-section of the above-crane part increases from the head to the traverse (Fig. 2, 3). The crane part is made of a steel box-shaped profile of a composite section with a base, consisting of belts and walls and filled with concrete, the walls have a concave shape inwardly of the column cross-section and are united by tie rods in the middle part of the section, on the inner surfaces of the belts of the crane part there are stops made of rod segments reinforcement or stud bolts (Fig. 4, 5, 6) [9-10].

Figure 1. General view of the stepped column
1-above-crane part, 2-crane part, 3-traverse, 4-steel tubular profile, 5-head, 6-concrete, 7-steel box section of compound section, 8-base, 9-belt, 10-wall, 11-tie rods, 12-stops.
The variable height of the section of the above-crane part can be ensured by making a steel tubular profile from a rolled square tube by slanting it into two parts, followed by their reversal and joining during welding [11-12].
The crossbeam, the head of the crane section and the base of the crane section are made of steel sheets and are combined with a steel tubular profile and a steel box section by welded seams.

The rectangular closed shape of the cross-section of the steel tubular profile makes it possible to more effectively perceive the bending forces in the overcrane part from external loads, to ensure its stability relative to both axes of the section, which leads to a decrease in the material consumption of the stepped column [13-14].

The decrease in the height of the cross-section of the steel tubular profile from the traverse to the head corresponds to the diagram of the bending force in the above-crane part from external loads, which leads to a decrease in the material consumption of the stepped column.

Filling the steel tubular section of the crane section and the steel box section of the crane section with concrete increases the bearing capacity of the column under the action of general bending stresses, as well as local bending of the walls of the tubular section 4 and steel box section, which makes it possible to reduce the dimensions of the column cross-section, steel consumption and, as a consequence, to reduce the material consumption of the stepped column [15-16].

The presence of concrete and walls in the crane section makes it possible to effectively perceive and redistribute heavy dynamic loads transferred to the traverse over the entire section of the column, which reduces material consumption and increases the reliability of the stepped column.

Concrete, being in a closed loop of the steel tubular profile of the crane section and the steel box section of the crane section, has high strength characteristics, increases the fire resistance and corrosion resistance of steel elements, which reduces material consumption and increases the reliability of the stepped column [17-18].

The distance between the walls of the steel box-shaped profile decreases from the chords to the center of the section of the crane section, which ensures a decrease in the volume of concrete in the less stressed part of the section of the column and, as a result, reduces the material consumption of the stepped column.

### Table 1. The results of calculating the options of the stepped column.

| Design model | Section of elements | Maximum deformations, $f/H$ | Steel consumption, $\text{кг per column per } 1\text{м}^2$ |
|--------------|-----------------|-----------------------------|---------------------------------|
| Steel column (steel C255) | Above-crane part: Pipe concrete 45B1. Crane part: pipe concrete 50B1 and branches from pipe 490x8 and 100x10, grille 70x6mm. Above-crane part: pipe concrete with tr. 299x8mm. | 1/560 | 2880 26,7 |
| Steel concrete column, steel C255, concrete B30) | Crane part: branches from pipe concrete with tr. 180x8mm and 180x6mm, grille - 76x4. | 1/750 | 1500 13,9 |

The presence of tie rods ensures the perception of lateral pressure from concrete by the walls of the steel box-shaped profile during the manufacture of the column, allows for the reduction of concrete, and also increases the local stability of the walls, which reduces the material consumption of the stepped column.
The load-bearing capacity of a stepped column is ensured by the selection of the concrete class, steel grade, cross-sectional dimensions of steel elements, the tension of the tie rods, and the step of stops.

The application of the proposed technical solution will reduce the consumption of materials and increase the reliability of the stepped column [19-20].

As a comparison, a comparative calculation of a 22.55 m high stepped column made of steel and pipe concrete for an industrial building with overhead cranes with a lifting capacity of 100 tf was carried out. The calculation results are shown in Table 1. The elements of the steel-concrete column were simplified in the design to the pipe-concrete elements to perform the design in accordance with SP 266.1325800.2016.

4. Conclusion
A number of load-bearing hybrid steel-concrete, steel-reinforced concrete structures for industrial buildings, incl. under heavy dynamic load. The proposed solutions are patented with the participation of the authors for columns, supports, crane beams, trusses, frame and arched structures. The use of the developed technical solutions will reduce the consumption of materials and increase the rigidity of the supporting structures while increasing the reliability and durability of the building frame. A comparative calculation of a stepped column made of steel and pipe concrete for an industrial building with bridge cranes was carried out, the effect of reducing the consumption of steel by 48%, and increasing the rigidity of the frame by 25%.

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