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2.9 The combination of architectural and structural solutions in the project of the rehabilitation center, which was awarded 1st place at the architectural competition “Steel Freedom”

As is generally acknowledged that metal structures, due to their high reliability, industrialization, the ability to provide architectural expressiveness, the isotropy of the material itself, and invulnerability to various factors, occupy a prominent place in the field of construction and mechanical engineering. Considering the above and the requirements for the student project set out by the organizer of the competition “Steel Freedom” [187] – Asotsiatsiia “Ukrainskyi Tsentr Stalevoho Budivnytstva” (Association “The Ukrainian Steel Construction Center”) [188], the R-240 team's project "Rehabilitation Center for Servicemen and War Veterans in the city of Zhytomyr" was developed using large-span steel structures.

During the work on the project, analogues related to rehabilitation and using long-span structures were analyzed. Let's consider some of them:

Unileão School Veterinary Hospital / Lins Arquitetos Associados [189]

The University Veterinary Hospital Unileão / Lins Arquitetos Associados is an institution created to train veterinary students under the guidance of professors and to provide medical care to animals. The hospital is designed to serve both small and large animals and has animal housing, laboratories, a surgical center, classrooms and administrative facilities. The main architectural and constructive solution of the project is a large roof, separated from the building, which provides shade and a comfortable microclimate. This roof is curved and provides ventilation by escaping hot air, and some areas are equipped with translucent polycarbonate sheets to take advantage of natural light. This roof is supported by long-span structures. Below is an image of this building (Figure 1). Here you can see the use of steel structures in the interior of the building.

a  b 

Figure 1 – The interior of the Unileão School Veterinary Hospital

The Educan School for Dogs, Humans and Other Species / Eeestudio + Lys Villalba building was also considered [190]. The building is intended for animals, but trusses are used here, so it is considered in this context. The authors of the project paid a lot of attention to ecology, so the reuse of materials was widely used here, including long-span structures. Thanks to the materials and constructions, the building has a light and clean architecture (Figure 2).

a  b 

Figure 2 – The interior of the Educan School for Dogs,
Humans and Other Species

In the process of developing the architectural project of the rehabilitation center in Zhytomyr, the use of steel structures became a key point that determined the unique character and appearance of this rehabilitation center. The facade with a cantilever structure, extending to 9 meters, not only makes the building recognizable among others, but also significantly improves its appearance, giving a feeling of lightness and freedom (Figure 3).

Figure 3 – The exterior of the projected building

The functional approach to the design of the rehabilitation center significantly influenced its architectural image and appearance. The use of steel structures with the possibility of extending 1nd-3th floors thanks to the cantilever made it possible to use the space effectively and increase the number of wards on one level. This made it possible to reduce the overall height of the building, while providing the necessary functionality and convenience for patients and staff. Reducing the overall height of the building is important for the integration of the object into the landscape and the surrounding environment. In addition, it made it possible to minimize the building area and optimize the use of the territory, which is important for creating a harmonious and aesthetic space.

The selection of the pitch of the columns was carried out taking into account the provision of comfortable proportions in all rooms, which provides comfortable and ergonomic conditions for users. This approach also contributes to the optimal use of space and provides effective work and rest conditions for all users of the center (Figure 4).

a

b

a – plan of the ground floor; b – plan of the 1st floor

Figure 4 – Planning diagrams

It was decided not to hide the structural elements, but on the contrary, to integrate them into the design of the facade in such a way that they become not only functional, but also aesthetically attractive elements. Thus, X-bracing, which ensure the stability of the cantilever, perform not only a technical role, but also become artistic accents, which are visible from the main viewing point (Figure 5).

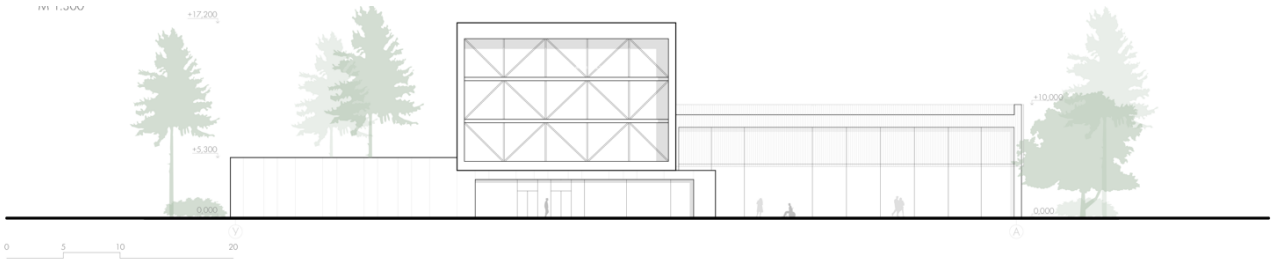


Figure 5 – Side elevation of the building

Structures used in the pool and dining room to provide large spans have not only practical importance, but also play an important role in interior design, adding to it aesthetic value and purity of forms. The section shows the use of trusses in the pool and other structural elements of the building (Figure 6).

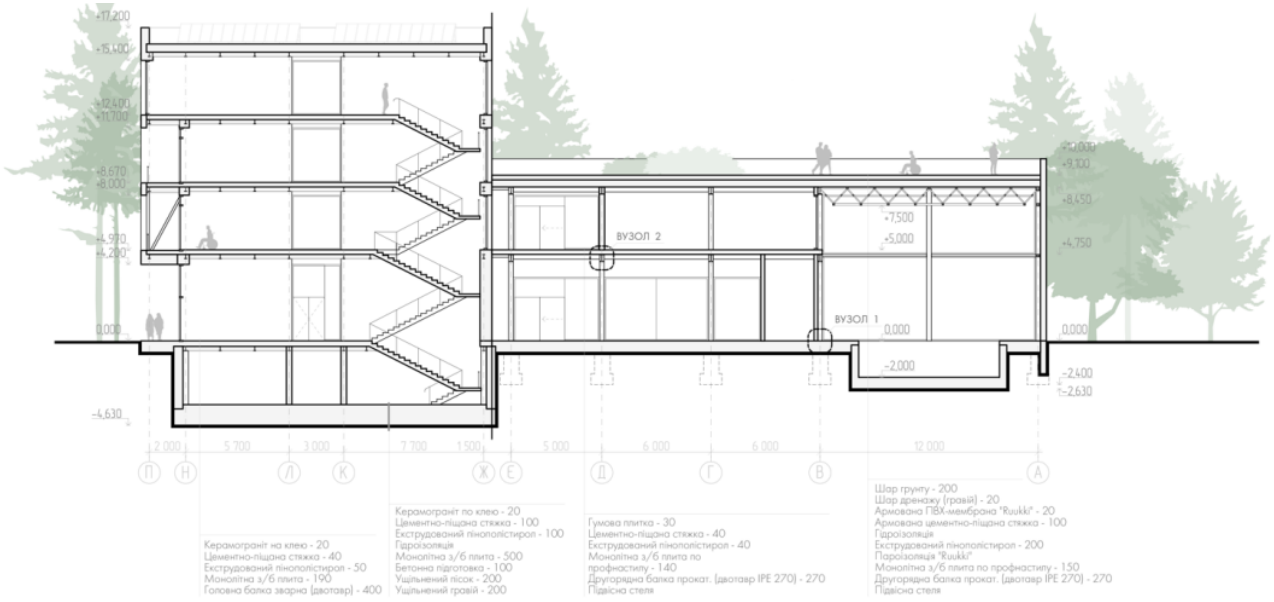
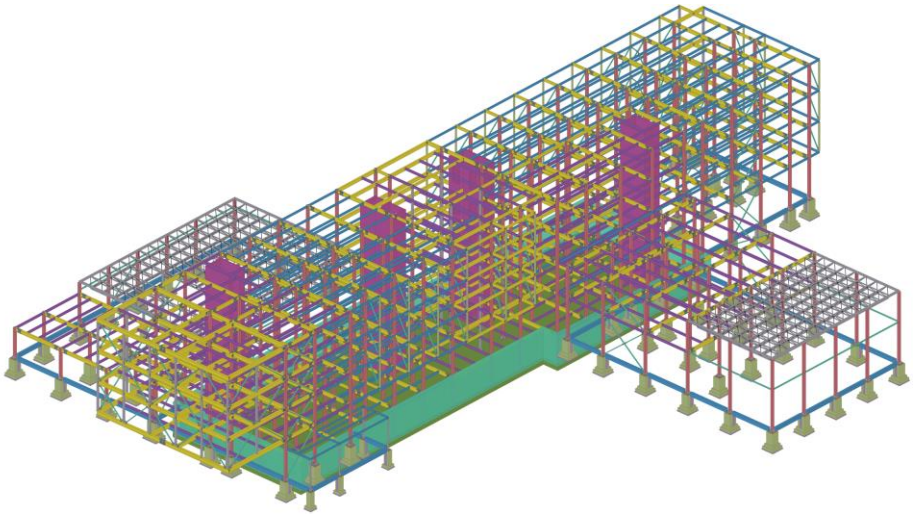


Figure 6 – Section of the building

The type of the structural steel system in projected rehabilitation center is a combination of moment or rigid frames and braced frames (Figure 7), where columns and beams create the main flat supporting units of the framework – frames itself (Figure 8).

Since the building is multifunctional, quite large in plan (91.5 × 68.9 m between grids) and has different heights of individual parts, so there is a possibility of significant deformation of the frame elements due to daily and annual temperature fluctuations and different temperature and humidity conditions of the premises. To avoid the appearance of uncontrolled adverse displacement and to delimit zones of different function, the building is divided by expansion joints [5, p. 101, cl. 17.2] into three blocks. Each block is an independent framework and is not connected to adjacent structures.



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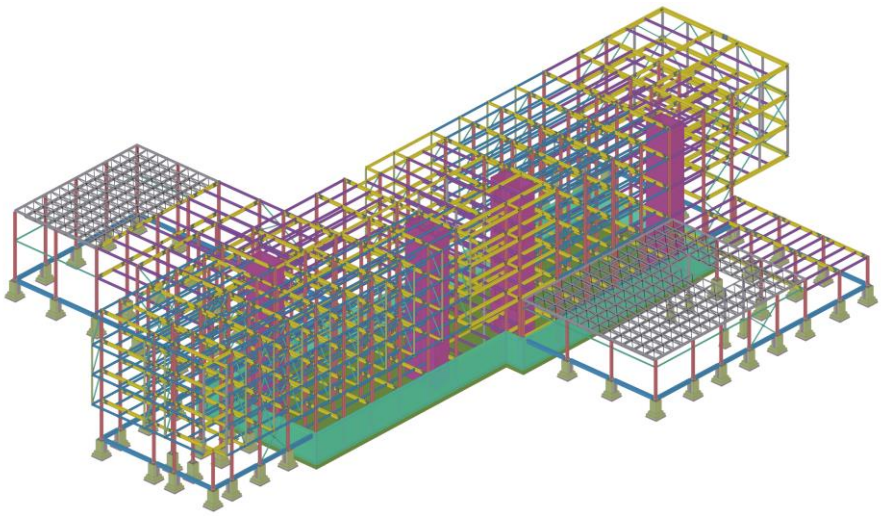


b

a – front view; b – rear view

Figure 7 – Structural model of the steel framework

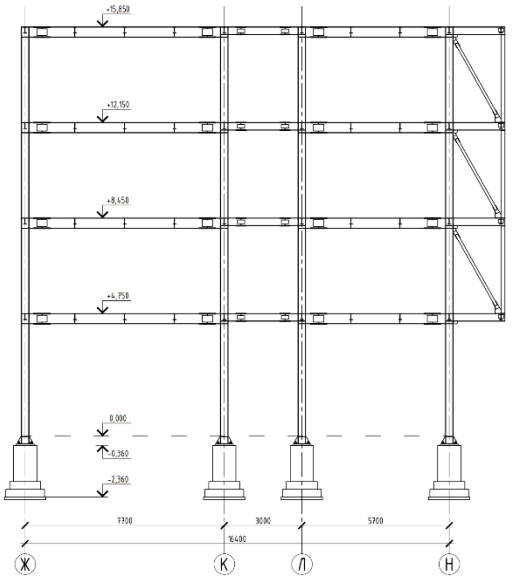
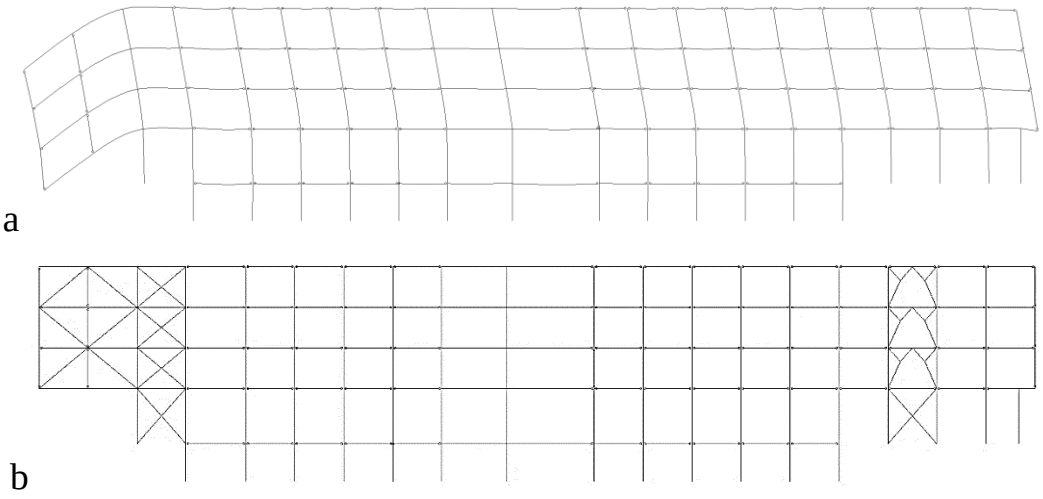


Figure 8 – Typical moment resisting frame on the right side of the main block

The rigidity and lateral stability of the framework in the transverse direction (in the plane of the frame) is ensured by the rigidity of the elements themselves and fully restrained (FR) moment beam-to-column connections.; in the longitudinal direction (perpendicular to the plane of the frame) it is provided by groups of vertical bracing. In addition, concrete elevator shaft-cores and concrete floor slabs on corrugated metal deck play a significant role in creating the framework's rigidity, preventing mutual displacement of vertical elements.

The bracing systems were designed separately for each temperature block of the building [5, p. 103, cl. 17.5]. The X-brace was used in the plane of the facades and the portal bracing in the passageways to preserve the functionality of the internal volume. The cross-section of the bracing is a square hollow section (SHS). The bracing ensures the correct operation of the framework (Figure 9), absorb horizontal forces and transmit them to the foundations

A distinctive feature of the frame is a spatial cantilever structure 9 m long. The high ratio between the strength and density of steel and the obtained permissible deflection values [6, p. 7, cl. 5] in the structural analysis and design software application (Figure 10) prove the feasibility of using steel structures and the practicality of realizing the concept. The structural 3D-model of the framework was created in Tekla Structures, and the structural analytical model was made in the Ukrainian CAE-software "LIRA-SAPR 2022".

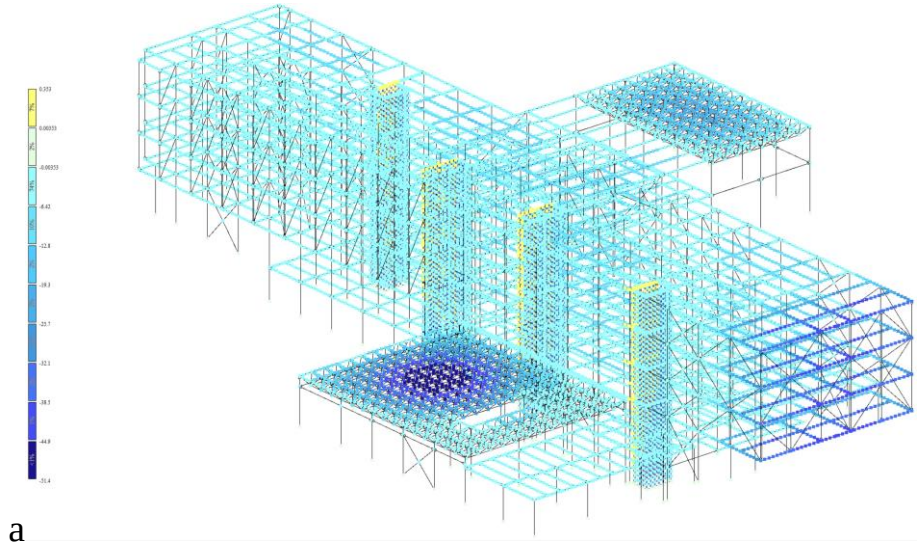


a

b

a - incorrect operation (no bracing); b - correct operation

Figure 9 – The framework's operation



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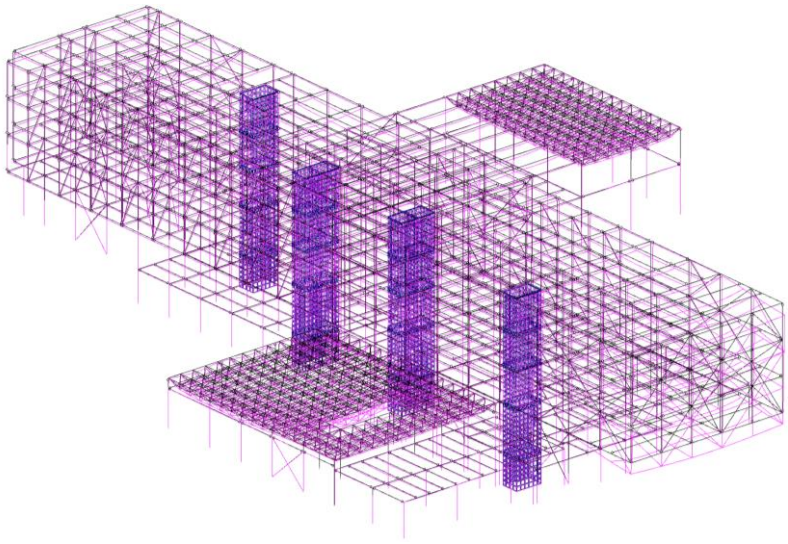

b

a – mosaic of displacements of elements along the Z-axis;

b – initial and deformed schemes

Figure 10 – The structural analytical model

The pool and dining room covering structures are three-dimensional structural frameworks – space trusses based on pentahedra with a construction height of 1 m, which made it possible to cover large spans and give architectural expressiveness to the premises while maintaining their height. This design discretely distributes internal forces within the system and transfers them to the supports. The force applied to any node of the structure first causes internal forces in the elements adjacent to this node, and then the spatial response of the entire system, which resembles the response of a continuous medium. When the structure is loaded the distribution of the potential energy of deformation in the places of occurrence of the greatest tensile forces is close to uniform, which is another advantage of such structures [193].

Unfortunately, Ukrainian enterprises are currently unable to produce the full range of rolled sections that were manufactured at the steel mills destroyed by russia. Given this challenge of the present day, it was applied welded composite sections and profiles available in Ukraine, including imported ones from the European Union countries.

In accordance with the requirements of the competition project, the building's characteristic joints were developed in detail:

1. Fully restrained (FR) moment connection with pre-welded bracket on the column and high-strength bolts (Figure 11).

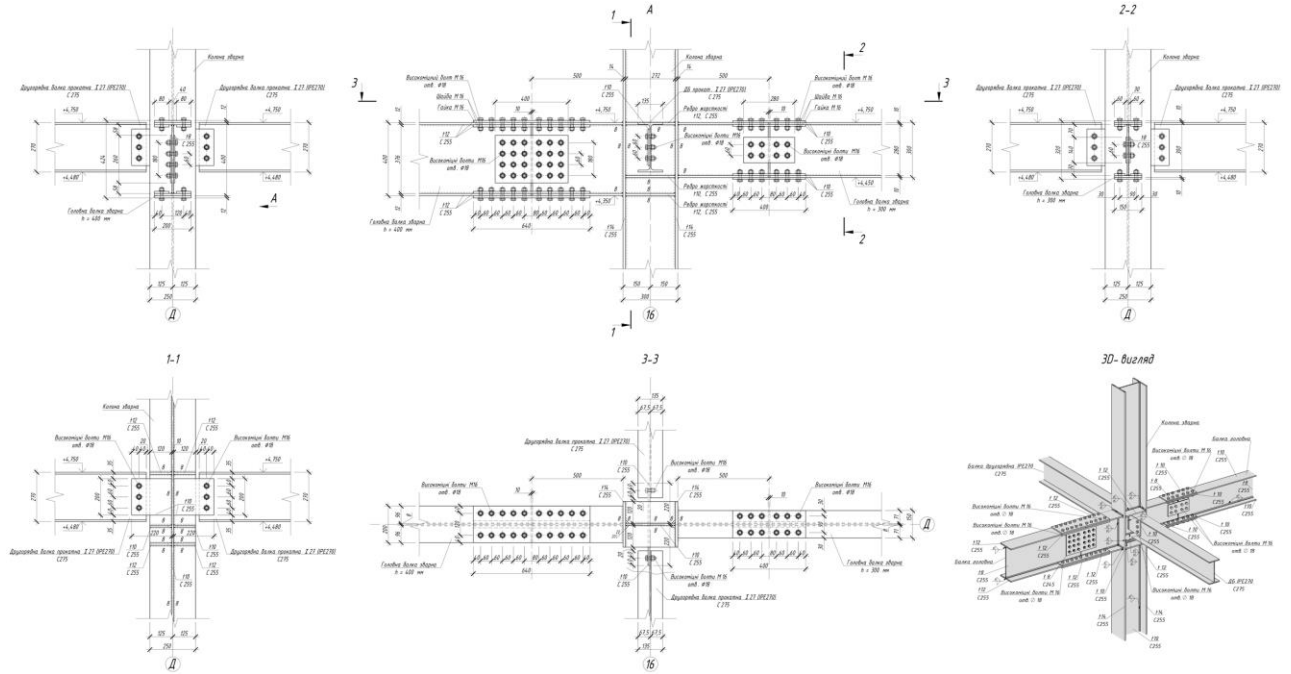

Figure 11 – Beam-to-column connection

2. Column base plate with stiffeners (Figure 12).

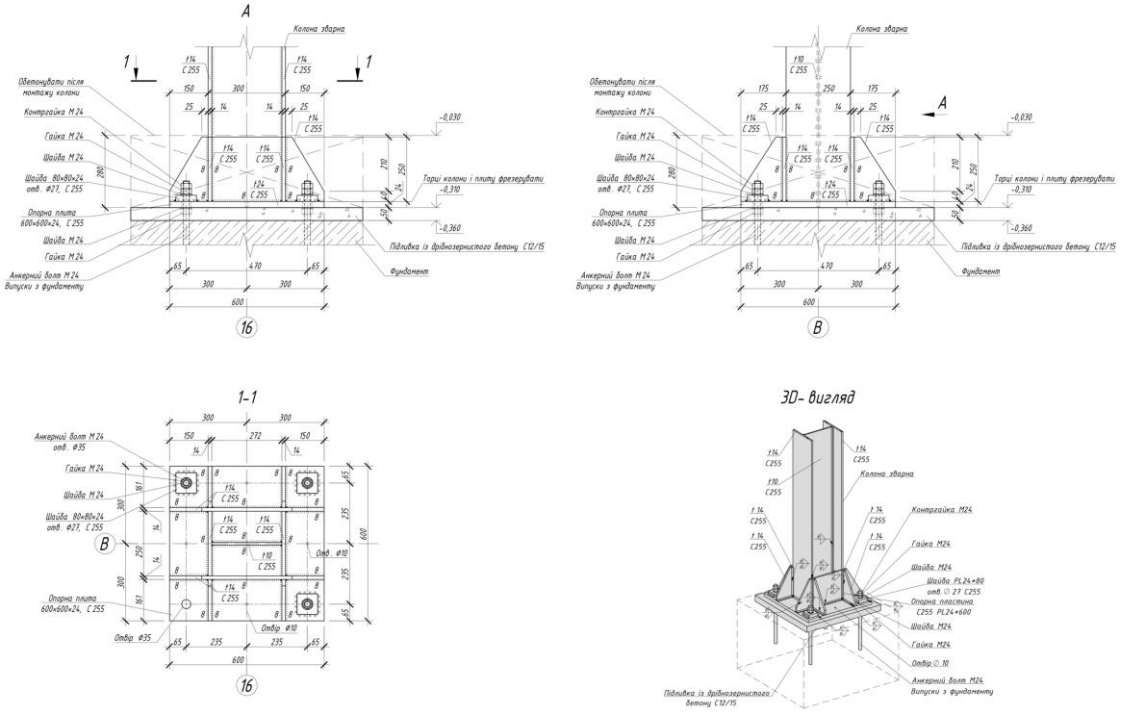

Figure 12 – Column-to-base-plate connection

The physical realization and ease of installation of the frame is confirmed by the chosen layout of elements.

In conclusion, it is worth noting that during the creating of project, the features of the metal framework were considered in the context of rehabilitation centers relevant for Ukraine, the ways of its use to emphasize the features of the architectural image. Steel structures are reliable, durable and open up new possibilities for architects. In the future, they will become useful for the post-war reconstruction of Ukrainian cities without any doubt.