STRUCTURE OF OFFICE AND RESIDENTIAL BUILDING IN ROOSEVELT STREET IN BELGRADE

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Summary: *In this paper, the calculation of the load bearing reinforced concrete structure of an office and residential building in Roosevelt Street in Belgrade with a total area of 12,000 m2 is presented. The building has two underground floors, ground floor + Gallery + six floors + top floor, total height of approximately 29.00m. The floor structure of the building is made of solid reinforced concrete slabs cast on site and vertical reinforced concrete elements in the form of columns of different cross sections and shapes along the height of the building and reinforced concrete walls. The axial distances of the columns above ground level are 6.00 m and 7.80 m. From the ground floor to the first floor in the part of lamella B, coupled round columns with a diameter of Φ50 were used and the dimensioning was carried out according to the standard SRPS EN 1994-1-1. Above the first floor all the columns are constructed of square cross-section. The foundation was constructed on a full reinforced concrete slab with a thickness of dp = 70.0 cm. The protection of the underground floors was performed in a combination of piles, head beams and steel struts in the function of constructing the foundations and walls of the building by excavation stages. The calculation of the structure was performed according to SRPS standards and Eurocode.*

Keywords: *structure, RC slab, RC wall, coupled column, pile, struts*

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2. INTRODUCTION

The location of the building is on cadastral parcel no. 2042/1, K.M. Palilula, Belgrade with the main entrance from Roosevelt Street no.21. The entrance to the underground garages is from Ivankovačka Street. According to the architectural project, two lamellas of the building are planned, lamella A and lamella B, which are separated from the ground floor by dilatation. The number of floors of the office building - lamella B is:

- two underground floors (-P2,-P1),
- ground floor, (PZ)
- gallery, (G)
- six floors(6 SP), and
- top floor (PS1).

In the part of the residential building of lamella A, there are two underground floors (-P2 and -P1), ground floor (PZ), gallery and five floors (5SP) + top floor (PS1). The dimensions of the base of the above-ground floors are 24.75x25.60m for lamella A, or 33.0x24.15 for lamella B. The area of the underground floors is approximately 2,500m2, while the total area of the building is 12,000.00m2. The height of the residential part of the lamella A building is 26.76 m, measured from the ground floor level, while the office part of the lamella B is 30.05 m high. The building has two underground garages with garage ramps and one car lift. Vertical transport is provided with three elevators as well as stair communications. The facade of the building towards Roosevelt Street is a semi-structural facade with an Al-interrupted thermal bridge. Other facades are classic with thermal insulation and finishing. Fig. 1 and Fig. 2 show the layout of the first floor and the longitudinal section through the building.

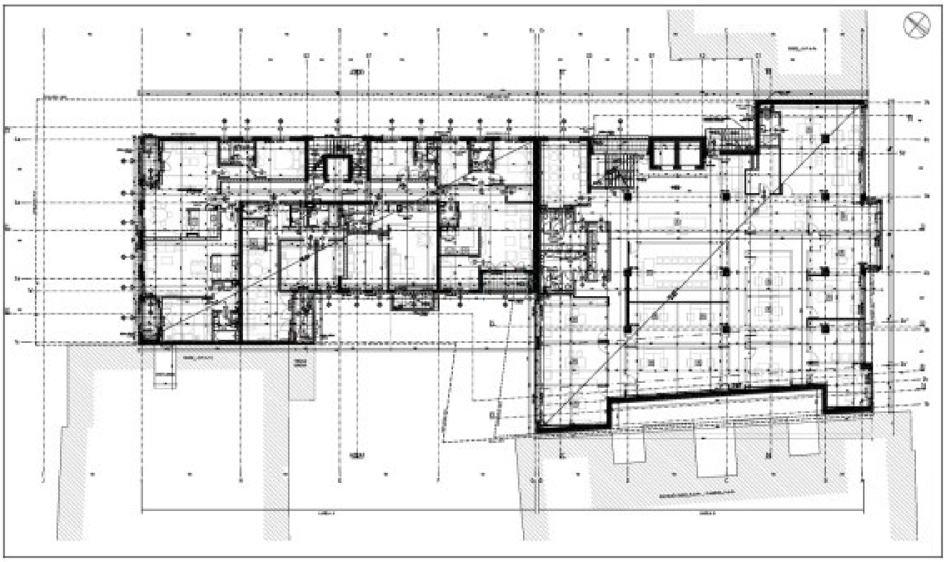

Figure 1. Layout of the first floor

Figure 2. Longitudinal cross section of the building

3. STRUCTURE

2.1. Reinforced concrete (RC) structure

Architectural background drawings, geotechnical study in accordance with the influences from the design of the structure, report on geophysical testing with seismic micro-zoning, as well as with the backgrounds of neighboring buildings located on the boundaries of the parcel were used for the design project of the structure.

The main load-bearing structure was designed and constructed as solid reinforced concrete slabs cast on site, thickness: dp = 22.0cm, dp = 30.0cm and foundation slabs dp = 70.0cm, which are supported by the walls, elevator core and reinforced concrete columns of different cross-sections and shapes as a function of the influences according to which they are dimensioned, such as circular columns in the lower floors of section Φ50, a / b = 40/40, and a / b = 30 / 30cm.

Floor reinforced concrete structures are full cast slabs supported by the beams of different cross sections and vertical load-bearing wall elements. The thicknesses of reinforced concrete wall panels are from the level of the ground floor with a thickness of d = 20 cm, while the wall thicknesses of the underground floors range from d = 20, 25 and 40 cm as a function of static influences. The constant loads of the structure are adopted according to the materialization as defined by the project task of the architectural part of the project and the architectural descriptions and details. Equipment loads were adopted for all types of installations according to the data from the respective installation projects. The architectural design defines the constructive distance and floor heights.

During the calculation of the structure of the building, the following loads were analyzed according to the valid regulations SRPS and EN 1991-1-1: 2002 for loads, as follows:

-office areas:	p = 2.00 kN / m2
-surfaces on which it is possible to gather people:	p = 3.00 kN / m2
-access areas:	p = 4.00 kN / m2
-communications and stairs:	p = 3.00 kN / m2
-roof:	s = 1.00 kN / m2
-residential part-lamella A:	p = 1.50 kN / m2
-ramps in the garage:	p = 2.50 kN / m2
-wind load:	
-load from seismic influences:	

The structure of the building is calculated for its own weight of the structure, constant and live loads, loads from snow, wind and seismic loads. The structure was modeled in the Tower 6 software. Several models were formed, as follows:

- plane models of floors used for dimensioning the slabs. Deformations, bending moments, transversal forces and support forces are controlled in order to secure the structure from the punching shear of the slab.
- spatial model, used for calculation of influences from vertical and horizontal loads, whereby the columns are continuous along the entire height of the building. With this model, all horizontal loads are entrusted to reinforced concrete walls. (Fig. 3-spatial model of the structure-appearance from Roosevelt or Ivankovačka Street)

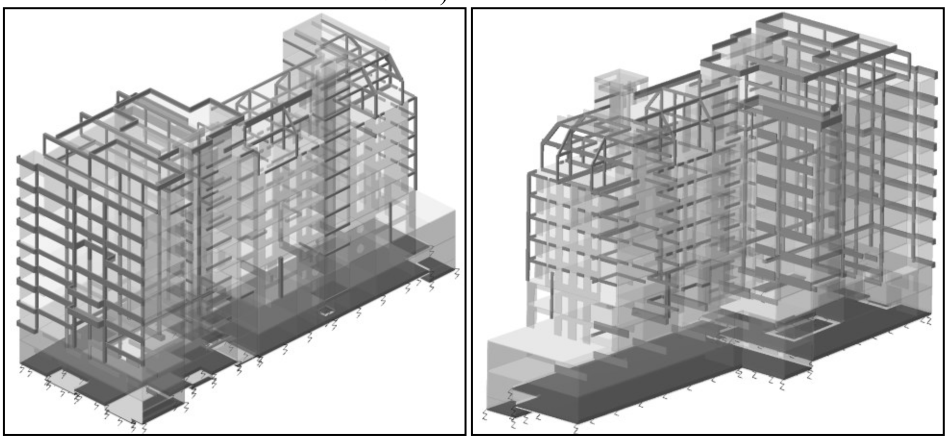

Figure 3. Spatial model of the structure

- spatial model which assigns to frames 25% of the total seismic force. Based on the results of the calculation, the ductility of the columns and walls of the building, the maximum displacements for the envelopes of the maximum influences, and then the influences for dimensioning the structure are controlled. The dimensioning of the structural load bearing elements was carried out for the influences according to the load combinations, in everything as shown in the static calculation. The concrete class of all load-bearing elements of the building structure, which are cast on site, is for slabs and columns C35 / 45, and for all other parts of the structure C25 / 30, according to the standard SRPS EN 206-1, and the reinforcement is B500, according to the standard SRPS EN 10080 and mesh MAG 500/560.

2.2. Coupled reinforced concrete columns of diameter Φ50

Due to architectural reasons, the dimensions of the columns from the ground floor to the first floor in the office part of the lamella B building are limited. In four columns (according to Fig. 4) the influences from the cross-sectional forces are significantly higher, while the dimensioning of ordinary round columns does not provide stability and load-bearing capacity, therefore the dimensioning of the column was performed with concreted II steel profile obtained by welding sheets II 270x25xL1 (flanges) and II220x20xL2 (rib), ie coupled columns of diameter Φ 50, loaded with a combination of pressure and biaxial bending.

Column height	L = 640.00cm
Maximum normal force of g + p	N_{Ed} = 5.491.80 kN
Maximum moment in the y direction of g + p:	My, Ed = -189.90 kNm
Maximum moment in z direction of g + p	Mz, Ed = -51.20 kNm

Table 1. Influences in the column obtained by the Tower software package

N_{Ed}	$V_{z,Ed}$	$M_{y,Ed}$	N_{Ed}	$V_{y,Ed}$	$M_{z,Ed}$
Sa[kN]	[kN]	[kNm]	[kN]	[kN]	[kNm]
5491.8	338.25	65.32	5491.766	174	11.85
		-189.91			-51.16

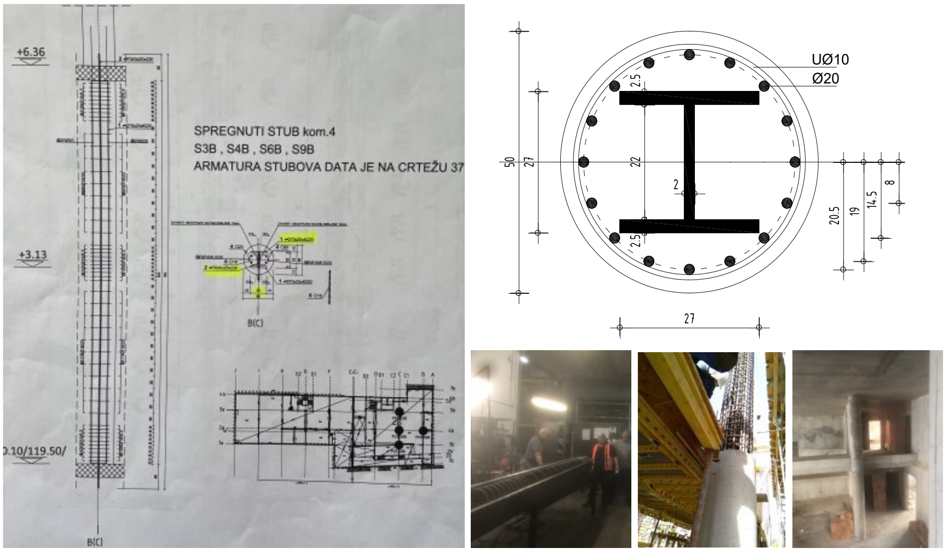

Figure 4. Position and construction of coupled columns with influences

The most favorable profiles for coupling were analyzed, and the I profile was adopted as the most optimal for coupling from the conditions of punching of short element at the gallery level, with the connection of welded I140 hot rolled girder to the rib of welded coupled column. The basic material for the steel construction of the column is steel S235. Figure 4 shows the installation of a welded girder in the workshop. First, a basket of reinforcement is placed on the spot, into which a welded girder is inserted with a crane, and all elements of the coupled column are welded on site, circular formwork is installed, and geodetic control height and horizontal position was performed, and then the concreting of the columns was approached.

2.3. Reinforced concrete beams at ground floor level POS 4B, 3B and 2B

These beams are located in axes D, C and B at ground level, dimensions b/h = 80/70cm for beams in axes D and C, and b/h = 60/70cm in axis B. These beams are supported by columns above the ground floor. Vertical influences are introduced eccentrically in relation to the load bearing walls of the underground floor (-P1), due to the necessary opening for the passage of the car in the garage. The dimensioning of these beams was carried out according to the influences, and the shear forces were accepted with the necessary reinforcement and with the extension of the beams in the upper part of the walls at least 50.0 cm, on which the beams are supported. The thickness of the load-bearing walls to the foundation slab is dz = 20 and 40 cm thick. Fig. 5 shows the position of the beams and photographs of the formwork with reinforcement.

Figure 5. Transverse beams b / d = 80/70 for supporting the columns to the roof slab

2.4. Reinforced concrete wall between axes G2-J in axis 4a - POS Z6A

This reinforced concrete wall is dz = 30cm thick from the foundation slab, or dz = 20cm from the ground level. Above elevation zero, the wall is led to the roof slab of the top floor on lamella A as a facade wall. The specificity of this wall is that the wall in the underground and above-ground part is not in the vertical plane, but the upper part of the wall is connected to the lower part via a trapezoidal-shaped torsion beam. The axial distance between the upper and lower part of the wall is 40 cm. This is a consequence of providing the dimensions required for the installation of parking mechanism for cars in the underground part of the building. Fig. 6 shows the above mentioned wall with a trapezoidal torsion beam and reinforcement and photographs of the constructed wall.

Figure 6. Connection of the facade wall above the ground floor with the torsion beam b/d =140/70

2.5. Reinforced concrete structure on lamella B

In the part of lamella B, a business space was designed, which imposed the choice of the shape of the vertical load-bearing reinforced concrete walls and the internal arrangement of columns of different shapes and cross-sections by levels. From the ground floor to the first floor, the columns are of circular cross section Φ 50, ie square from the first to the second floor b/d =50/50cm. From the second to the fourth floor, the dimensions of the columns are b/d=40/40cm, and from the fifth to the top floor (PS1), the dimensions are b/d=30/30cm.

Figure 7.Columns of the ground floor, gallery and first floor

Fig. 7 and Fig. 8 show photographs of the columns from the ground floor, the gallery and the first and sixth floors. The calculation and dimensioning of coupled round columns was carried out according to SRPS EN 1994-1-1

Figure 8.Columns of the sixth floor

2.6. Reinforced concrete structure on lamella A - Top floor PS1

On the top floor of lamella A, a pool of 30 m2, depth h = 1.80 m with water load V = 450kN, has been designed. The supporting structural system in axis 2a is a part of the reinforced concrete half-frame (POS 707A) suppotred by the wall of POS Z11A and a cantilever part up to the axis of the top floor PSC1. The circumferential beam is a static system of a simply supported beam with a overgang, at the end of which the POS 706A (longitudinal parapet beam of the roof slab) is suppotred. The following figures show these positions.

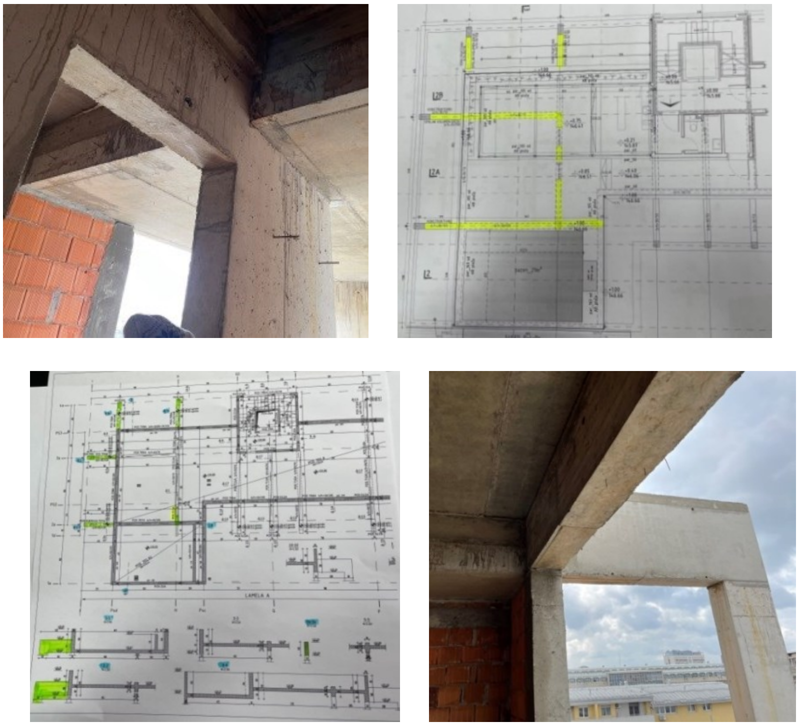

Figure 9. Structure for supporting the pool on lamella A

2.7. Foundations of the structure

The foundation of the structure was made on a reinforced concrete foundation slab with a thickness of d = 70.0 cm, in accordance with the allowable load bearing capacity of the soil. The influences and conditions given in the geomechanical study prepared by the company GEOPRO DOO, 7 Ucitelja Miloša Jankovica Street, Belgrade, No. 96/18 were analyzed. The depth of the foundation was adopted at the elevation of -7.80-8.20 m for lamella A, and 7.50-9.00 m for lamella B. During the design of the foundation, the construction elements were taken into account to protect the excavation of the foundation pit and adjacent buildings. Due to the phased construction of the protective structure of the foundation pit, the foundation slab is concreted in several segments. Figure 10 shows the derived part of the foundation slab of the first segment and the installed reinforcement of the second segment.

Figure 10. Execution of the foundation slab from the parts

4. PROTECTIVE STRUCTURE OF THE FOUNDATION PIT

The protective structure with the dimensions of the foundation pit is designed and constructed in such a way as to ensure the excavation of the foundation pit according to the dimensions of the newly designed building, respecting the regulation lines, contour and elevation of the new foundation structure of the office and residential building. The foundation of the building was made at a depth of 7.5-9.0 m in relation to the current elevation of the terrain. If we compare these elevations with the position of the lithological environments isolated in the local terrain profile, the conclusion is that the contact between the foundation and the soil will be realized in the layer of deluvial sediments. The part of the building where the parking mechanism for cars is planned, will be founded in a layer of deluvial-proluvial sediments. Before the start of the works on the protective structure, the removal of existing buildings on the existing site was carried out. The construction of the protective structure of the foundation pit was carried out through several phases, knowing that the vertical excavation in these environments can be held without upgrading to a height of 1.6 m. The protective construction is made of drilled piles Φ 600, in the first phase of the static system there are cantilever line girders, at the top of the piles it is connected by a main beam of dimensions a / b = 60 / 60cm. In the second phase, the static system is a simply supported beam in the ground and a support that is spread at the level of the ground floor, ie the P-1 slab.
The soil is approximated by elastic supports whose stiffness is defined according to the formula of Dr. Vesić. The calculation of piles in the GEO 5 program was analyzed in parallel. The calculation controls the displacements of the pile tops at the level of the head beams, the intensity of reactions of elastic supports and compares with the values of possible passive soil resistance, bending moments and transversal forces. Dimensioning of the piles was carried out with coefficients of 1.80. In the static calculation, two types of drilled piles were analyzed, namely piles of length l = 16.0 m, and piles of length l = 14.0 m.
It is planned that the piles will be made of concrete of strength class C25 / 30 (MB 30), and the reinforcement is B500, according to the standard SRPS EN 10080 and mesh reinforcement for the wall MAG 500/560. The following figures show photos of piles and steel struts.

Figure 11. Execution of construction and protection of foundation pit excavation

5. CONCLUSION

The structure of the mentioned building was designed and executed as extremely specific with large different structural elements for both lamellas, which are conditioned by architectural requirements and conditions in a location limited by dimensions. In the calculations and dimensioning of individual structural load-bearing elements, optimal solutions were adopted from coupled columns, eccentrically loaded ground floor beams, torsion beams of the facade, construction of floors and frames for carrying roof pools. Figure 12 shows the street facade of Roosevelt and the facade of the building towards Ivankovačka Street.

Figure 12. Main and back appearance of the building

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КОНСТРУКЦИЈА ПОСЛОВНО СТАМБЕНОГ ОБЈЕКТА У РУЗВЕЛТОВОЈ УЛИЦИ У БЕОГРАДУ

Резиме: *У овом раду је дат прорачун носеће армиранобетонске конструкције поисловно стамбеног објекта у Рузвелтовој улици у Београду укупне површине 12.000 м2. Објекат има две подземне етаже и надземни део од коте нула је спратности ПЗ+Галерија+6СП+повучени спрата ПС1, укупне висине цца 29.00м. Међуспратна конструкција објеката је од пуних армиранобетонских плоча ливених на лицу места и вертикалних армиранобетонских елемената у виду стубова различитих попречних пресека и облика по висини објекта и армиранобетонских зидова. Осна растојања стубова изнад коте приземља су 6,00м и 7,80м. Од нивоа приземља до првог спрата у делу ламеле Б коришћени су спрегнути округли стубови пречника Ф50 и димензионисање је спроведено по стандарду СРПС ЕН 1994-1-1. Изнад првог спрата су сви стубови квадратног попречног пресека. Фундирање је изведено на пуној армиранобетонској плочи дебљине дп=70.0цм.Заштита подземних етажа је изведена у комбинацији шипов, наглавних греда и челичних разупирача у функцији израде темеља и зидова објекта по фазама ископа. Прорачун конструкције је вршен према СРПС стандардима и према Еврокоду.*

Кључне речи: *конструкција,аб плоча, аб зид,спегнут стуб, шип, разупирачи.*

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