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Short project notes

Construction of the shopping center Ada Mall in Belgrade

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ABSTRACT

Ada Shopping Mall is located at the corner of Radnička and Paštrovićeva Street in Belgrade, closed to Lake Ada Ciganlija. The building has a gross area of about 100.000m². It consisted of reinforced concrete structure with three underground and four above-ground levels and a steel roof structure. The foundation pit protection was made by bored and bored secant piles in combination with two different Top-Down methods during construction. The excavation depth was up to 25 m. As the building was built in rock mass, during excavation blasting was applied. During construction a monitoring system was implemented. This paper provides an overview of the construction process of shopping mall.

1 Introduction

In May this year it will be exactly two years since the completion of construction of the shopping center Ada Mall, located at the corner of the Radnička and Paštrovićeva street in Belgrade, close to lake Ada Ciganlija. In this article it will

be explained how the building was constructed, which construction technologies were applied and what kind of problems constructors had to solve.

Figure 1. Shopping Center Ada Mall under construction

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2 Reinforced concrete structure

The structure was of irregular basis, which should simulate the isohypses of the hill that was cut down and the future shopping center was inserted in that place.

The building with a gross area of about 100,000 m² consists of reinforced concrete structure with three underground and four above-ground floors and a steel roof structure. The spans between the columns are mostly 8x8m, while their height was up to 26 m. The floor heights of the underground floors are 3.20 m and 3.90 m, and the above-ground 5.5 m and 6 m.

The Floor slabs were geometrically and performingly very complex and challenging. Flat slab was supported directly by columns with exception in zones with large spans where high beams or post tensioned beams were introduced. The architectural requirements were such that it was not always

possible to keep the continuity of the columns, so this problem was solved by transfer beams. The construction abounds in many cantilevers, denivelations and a large atrium opening in the middle with two footbridges. The Floor slabs have thickness of 25cm and 30 cm, and the gross area of one Floor slab is up to 16,000 m².

3 Foundation pit protection, top-down method and construction of the building

As already mentioned, the building was cut into the existing hill, and additional to that, there was a request for a large number of parking places, so three underground floors were designed. According to these requests, the excavation depth along Radnička Street was 12 m and almost 25 m along Visoka Street.

Figure 2. The Third Floor Slab Plan

Figure 3. Longitudinal section of the building in the direction from Visoka Street (left) to Radnička Street (right)

The protection of the foundation pit and excavation was done with drilled piles along the perimeter in combination with the construction of the building in the top-down method. The perimeter wall was strutted by floor slabs, and their construction followed the excavation.

Accordingly, the building was divided into Part A (lower terrain - along the lake and Radnička Street) and Part B (higher terrain - along Visoka Street).

Figure 4. Construction Plan - division of the building into part A and B and application of two types of top-down methods 1 and 2

Figure 5. Construction Plan - division of the building into parts A and B and application of two types of top-down methods 1 and 2

3.1 Monitoring

Before the construction started, a monitoring system was set up to control the entire construction of the building 24 hours a day:

- displacement on inclinometers installed within perimeter piles
- rotation on tiltmeters
- vibrations (due to blasting and construction of the building)
- settlement and displacement of neighbour buildings by geometric observation
- noise.

Thus, it was easy to detect and follow any suspicion during construction. With the help of inclinometers and tiltmeters, information was obtained on whether there was displacement of neighbouring buildings, neighbouring roads and the construction of the foundation pit protection.

All this information was posted on the website from where the required result could be read at any time, and the telephone of managers of the project were directly connected to the server so that, in case of any displacements, they would receive a text message which would warn them of the problem and they could take necessary action after working hours as well.

3.2 Construction of part a of the building

Part of the building along the lake had problems with groundwater because of the proximity of the Sava River. Therefore, secant piles were chosen for pit protection, and they were drilled up to depth of waterproof layers of the soil. Horizontal drainage was used as a permanent solution for groundwater and high buoyancy. It consists of the system of channels with a collecting pool from which water will be permanently pumped out during the lifetime of the building.

Figure 6. Reading data from inclinometer within pile

Figure 7. Noise recording

Figure 8. Tiltmeter

Figure 9. Horizontal drainages channel system with large collecting pit (between axes 24-25 / 01-02)

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After the secant piles along the perimeter and the piles at the column locations in the berm zone were completed, wide excavation started up to the bottom of the foundation slabs

in part A with the formation of the berm, which can be seen in Figures 10 and 11.

Figure 10. Part A wide excavation (up to the depth of 12 m) with the formation of a berm (zone 1) where piles were drilled at the column locations

Figure 11. Part A wide excavation with formed berm (zone 1) where piles were drilled at the column locations

Since the steel piles were made at the column locations, the top of the berm was levelled, and a formwork was installed on the ground, which will remain trapped until the excavation of the berm starts. See Figure 12.

Construction of the building started from the foundation slab up to the height of the first-floor slab from where the berm was bridged. Head beam above secant piles was struttled by floor slab. In places where the span of the slab was large, temporary steel columns (piles) and / or a temporary steel frame structure were previously made (before excavation).

Figure 12. Installed formwork at the surface of the berm

Figure 13. Part A under construction

Figure 14. Strutting by -1B slab over the berm (the slab is supported by temporary steel frame and steel pile (future RC columns))

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Thus, it was possible for the building to emerge from the ground very quickly and continue its construction unhindered, while the berm below was removed paralely. Excavated soil was exported from the building. As there was

flysch in this part of the building, the berm was excavated with the help of powerful hammers and rippers that were mounted on excavators (Figure 15).

Figure 15. Excavation of the berm under finished structure with hydraulic hammers and rippers

Figure 16. Excavation of the berm under finished structure. Secant piles, temporary steel columns (piles), formwork installed at the berm

Excavation was followed by careful uninstalling of the formwork. The steel columns were secured with struts before they were completely released, depending on their current load, and then concreted to the height of the first next floor.

Extremely strong rock mass (Figure 5.) appeared in one part of construction site, near river, whose strength was up to 190 MPa of axial stiffness. It was impossible to do excavation in this zone. Machines broke down, hammer spikes cracked, diamond teeth on rangers of pile drilling machines melted.

Nothing else could be done except blasting. Considering that the construction site was in the urban part of the city, blasting was neither simple nor easy. Neighbouring residential buildings had to be considered. Additional devices were installed on neighbouring buildings in the blasting zone, and they measured the displacement (horizontal and vertical) whose results had to be within the permitted limits.

Figures 17-21. Broken drilling rigs, diamond teeth on the ranger and the spikes of a hydraulic hammer

Figure 22. Drilling a hole for explosives

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The blasting itself was done with nonel (explosive) with double decelerators so that larger number of explosions could go one after the other with a delay of a few milliseconds. Its complexity clearly shows that it was a special blasting, which was in many ways different from that in quarries outside the urban environment.

The following picture shows the area along Radnička Street that was blasted. In this zone vertical excavation was done without protection.

Figure 23. The explosive was inserted into the holes and interconnected with decelerators

Figure 24. Extremely strong rock zone where vertical excavation was done without protection

There was a huge problem with the stability of the berm along Paštrovićeva Street, at the place where the transformer station of the factory and the old warehouse used to be. Oil leaked at that place for years, so the quality of the soil was weakened. The ground collapsed during the excavation and there was a danger that the stability of the street would be endangered.

The steel frame structure between the berm and the building could not be mounted due to the danger of landslides. On the other hand, even the formwork on the ground could not be installed, because the berm itself could not hold the load of the new slab.

Strutting by steel pipes was applied as one of the possible solutions. See Figure 25.

Figure 25. Strutting of the building in part A, zone along Paštrovićeva Street

Figure 26. Part A of the building under construction in an advanced phase

3.3 Construction of part B of the building

This part of the building was done on a much higher terrain; the depth of the excavation was up to 25 m. Therefore, a different construction technology was applied in relation to the part A.

Drilled piles Ø800 and Ø1000mm were made along the perimeter of the structure, as part of the protective structure

of the excavation. Construction began at the level of the third floor (Top-Down zone 2). The hill was levelled so that the pile drilling machines could move. Steel piles over 23 m long were made on the places of future columns and walls. Later, in the top-down phase, these piles are supports on which the entire structure stands, while one floor after another is being excavated successively under the built object.

Figure 27. Construction of part B, zone 2

Figure 28. Construction of part B, Top Down 2

Due to install the steel pipe within the dimensions of the future column or wall, the piles are very long from the point of required high precision. Any deviation from the verticality and the projected position means additional problems in the top-down where the steel pipe has to be cut and shortened to provide correct position according to the project and not to enter the parking space or garage area.

A special concrete platform was provided for this project. Concrete platform contained a hole in the middle which was aligned with the drilled hole for pile. On the top of the platform a steel pipe with a "cross" is passed through the mentioned hole, which is a guideline. The "cross" had the possibility of fine adjusting at its ends. Precisely, that pipe-guide shapes the direction of the installation of steel pile-column. See Figure 29. Figure 30 shows a steel pile instalation. After that,

the reinforcement cage is installed, and then the pile is concreted. See Figure 32.

Figure 29. Concrete platform with steel guide

Figures 30 and 31. Installation of the steel pile through the "guide" for pile installation

Figure 32. Typical pile at the column location

Figure 32. shows a typical pile at the column location. A hole with a diameter of 600 mm or 800 mm is drilled at column location from the third floor to a depth of 4 m below the bottom of the foundation slab (through 5 floors, it is slightly more than 23 m). A reinforcing cage for the pile base is put down through mentioned hole and concrete is poured right after. A steel pipe with a diameter of 329 mm and the reinforcement of the pile are dropped into the fresh concrete. The next day, the steel pipe was filled with concrete, and the hole was filled with sand on the outside (between steel pipe and soil). Sand is very important because of a buckling prevention for the pipe (steel column) when the load from the upper floors is applied. Additionally, it is easy to release the sand around the pipe and clean steel surface to provide

welded connection between the steel pipe and slab.

Since all the piles were built at the column locations of zone 2, the formwork of the third-floor slab was placed on the ground. This formwork remained captured until the excavation under began.

The slab formwork consisted of the formwork tables with dimensions 4m x 4m which remained attached to the concrete slab also at the moment of excavation in the top-down phase. Later the same tables were lowered with the help of straps and birches (see Figures 41 and 42).

The reinforcement of the slab was done over the formwork tables. Steel structure, which enabled the connection between the piles and the slab, was welded to the pile in the zone of steel piles - future columns. See Figure 34.

Figure 33. Installation of formwork tables of the third-floor slab on the ground (Part B, zone 2)

Figure 34. Steel structure for connection of piles and slab

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After concreting the slab of the third floor, the construction of the next floor continued upwards. Due to the slope of the terrain, the top down 2 (as

indicated in Figures 4 and 5) of the part B of the building, could not be done before merging part A and part B of the building.

Figure 35 .Part A is in an advanced phase and is progressing towards part B where the construction started from the 3rd floor upwards

Figure 36. Fault in zone 2 and transition from limestone breccias to clays

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The main problem was the neighbouring building which provided large horizontal forces on structure under construction. As zone 2 is the only one with previously erected building (from the third floor upwards), it was necessary to finish the whole zone 1 of part B (Figures 4 and 5) in order to start the top down works below that part. This enabled the horizontal forces to transfer from one side to the other, i.e. to provide the existing structure to be strutted by

head beam and the perimeter piles along Paštrovićeva Street. The fault and transition from the limestone breccias to claystones was additional problem under the existing structure (zone 2).

As we mentioned, after merging the parts A and B the conditions for starting the top-down method in zone 2 and building the floors down (from the third floor to the level 2) are met.

Figure 37. The direction of the fault in zone 2 and the transition from limestone breccias to clays

Figure 38. The first connection of the parts A and B was made with the third floor slab

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The excavation under the formwork tables began. It is important to emphasize that in zone 2 as well as in the entire zone B and most of the zone A, excavation is constantly

difficult due to the rock mass that had to be blasted using the already mentioned technique.

Figure 39. Blasting under formwork tables and the third floor slab (part B, zone 2)

Figure 40. Excavation in the top-down phase below the constructed part of the building (part B, zone 2)

After finishing excavation under the existing slab at the height of one floor, the formwork tables are lifted down to the next lower level.

Figure 42. shows the anchors for the column that are left from the upper floor for the column below, which will be done

in the next phase. It is the same with the walls. Both the pillars and the walls are concreted with self-compacting concrete from the upper floor through previously left holes in the slab.

Figure 42. One of the hung slab in the top-down phase (part B, zone 2)

Figure 43. Shutter erection of formwork of the perimeter wall - formwork with one-sided formwork

Figure 44. Column reinforcement installing around the steel pipe of the pile

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After the excavation reached the foundation slab, in the specific case of five underground floors in the top down work, the complete mechanization passes through the entire

building and exits through the prepared ramp in the zone towards Radnička Street.

Figure 45. Scheme of the last phase of excavation and evacuation of machinery from the building

Figure 46. Scheme of the last phase of excavation and evacuation of machinery from the building

Figure 47. Cancellation of the temporary exit ramp

Figure 48. Temporary ramp is cancelled. Mechanization from Visoka Street passes under the building to Radnicka street going outside

Figure 49. Passage of machinery under the building and exit to the ramp along Radnička Street

3.4 Construction of the last floor of the entire building and steel roof structure

After merging the parts A and B of the building, regardless of the top-down works, the last floor could be completed.

Construction of the roof steel structure started after completion of construction of concrete structure above ground. As the surrounding streets were extremely busy, installation of steel structure was performed from the atrium zone of the ground floor slab, and inaccessible parts were finished with the help of cranes that remained inside the building.

Figure 50. Unobstructed construction of the last floors while the top down works are performed in the underground

Figure 51. Installation of the steel roof structure from the atrium zone of the ground floor slab

Figure 52. Steel structure under construction

Figure 53. The construction of steel and concrete structure in parallel

Figure 54. Anchor plate for steel column

4 Problems

There were other problems in addition to the mentioned ones regarding blasting, the high strength of the soil and the top-down method.

Extremely complicated geological structure of the soil and the frequent transitions from one type of soil to another, which was not predicted by Geomechanical Report, provided a new problem for construction. There was a septic tank for several houses on the adjacent plot. Formed berm was constantly soaked by it, and numerous layers of bad material between the two rock masses led to the formation of a sliding plane which caused damage of the steel columns in local area

Figure 55. Different layer of the bad soil in the rock mass

Figures 56 and 57. Damaged steel columns due to a local landslide

Figures 58 and 59. The failure of the steel column after the landslide. Steel column is bridged by a lattice steel structure placed on the slab above it. The load from the damaged column was transferred to the adjacent columns

In part B of the building, phase 2 of the Top-Down method, a bomb from the Second World War was found between the first and the second floor slabs. That stopped further works for a while.

Figure 60. The place where the grenade was found (between the slabs of the first and the second floor)

Figure 61. World War 2 grenade

5 Conclusion

It should be noted that 43,000 m³ of concrete, 7,050 tons of reinforcement and 770 tons of roof steel were used for the construction of the Ada Mall. Moreover, 13 tons of explosives were used in order to excavate over 150,000 m³ of rock out of a total of 250,000 m³, mostly thanks to the indisputable skills of domestic builders.