REHABILITATION-UNDERPINNING OF OBJECT DUE TO REMOVAL (DEMOLITION) OF GROUND FLOOR COLUMNS

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Summary: *Due to new use of the building, it was necessary to remove 6 pillars of the ground floor, whose demolition has to ensure the uninterrupted functioning of the places in object above ground. The existing building has ground floor, first floor and attic. Bear loading structure is combination of reinforced concrete columns (middle part) and vertical and horizontal reinforced concrete elements which are located in facade walls. First floor slab is made from LMT brick elements, which are resting on the longitudinal reinforced concrete beams. Instead of the removed columns a steel I-girders of two different spans (l=12.40m and 10.60m) were places in transverse direction. Girders were made from two I-beam interconnected in levels of top and bottom flanges. These new girders, which upheld the upper floor structure, are resting on new reinforced concrete columns. New columns are built in axes 3′/C, 3′/D, 3′/E, and in 1/C,1/D, 1′/E. The spatial stability of the newly designed structure is provided by bracing in the level of the upper flange of new steel crossbeams. Reinforced concrete individual foundations of new concrete columns were built on replaced soil. Existing strip and individual foundations were under concreted.*

Keywords: *rehabilitation, underpinning, steel structure, reinforced concrete columns, foundations.*

1. INTRODUCTION

The existing building is in base a×b=23×25m with ground floor, first floor and attic. The first floor and the attic has a function of kindergarten. The ground floor use to be a bus repair service. Investor's project task made a changes in the use of ground floor and basement. The purpose of this new parts of the building should be a pool with additional

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rooms and a coffee bar. The new functions of the building has caused a need for a removal of six columns in the ground floor. Pool was dig into the middle part of the building in their place. Technical facility was placed in newly built basement outside main building. It was also required to set up and design of new galleries above parts of the ground floor. Such a challenging change of the object use has caused a need to design a very special construction which was made from large section steel I-girders. Purpose of this girders was to receive loads from upper part of the building. Steel girders rests on capitals of newly built reinforced concrete columns. Foundations of these columns are reinforced concrete individual blocks interconnected to each other by binding beams. Because of the high underground water level and low soil strength, it was necessary to do a soil removal and compacting, so new foundations could be built on new, increased strength ground. Picture 1. shows appearance of the existing building and part of the first floor and the attic.

Figure 1. The external appearance of the building with a first floor and the attic

2. DESCRIPTION OF STRUCTURE - EXISTING CONDITION

The existing building has combined masonry walls with reinforced concrete horizontal and vertical ring beams. The central part of the building – first floor relies on two longitudinal beams which are located in the axis 2 and 3. These beams are based on reinforced concrete pillars in each of the A, B, C, D and E axis. Based on the excavation depth, shape and dimensions of the existing foundation were determined. It was noted that the foundation level was very shallow, and in the layer of the embankment. Existing foundations in the middle of the building, because of the building repurposing, must descend to the newly designed level (cca. 110cm). Also, longitudinal wall in axis 4 needed to be lowered to level of -470cm.

Figure 2. Under concreting and excavation of facade wall in axis 4.

Due to high underground water level under concreting of wall was finished in two height stages with parts wide 100-120cm. After finished first phase concreting a combined mechanical-hand excavation started. During all phases of concreting lowering of groundwater was done in order so that work could be carried out in the dry conditions. Figure 2. shows phase excavation works.

3. NEWLY DESIGNED PART OF THE BUILDING

Figure 3. shows ground floor plan with marked columns that are removed-demolished. Figure 4. presents cross section of the building with structure for underpinning of upper floors.

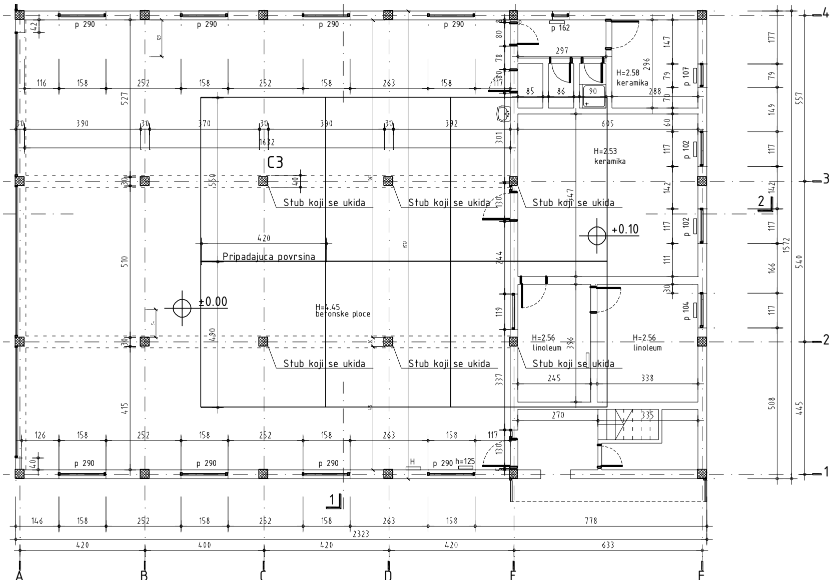


Figure 3. Ground floor plan columns that are removed (C2, D2, D3, C3, E2 and E3)

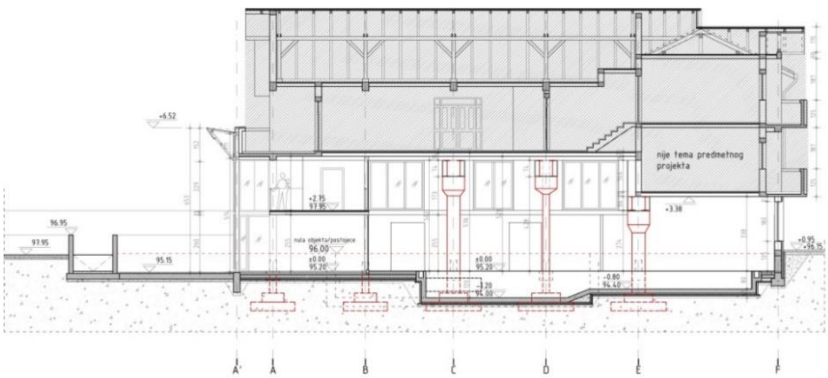


Figure 4. Location of new columns and steel beams for the building underpinning

Newly designed structure which support building floor and attic was made from steel I-girders and reinforced concrete columns. Support reactions, at the place of the removed (demolished) pillars, are submitted as concentrating forces on transverse bearing frame system. This was made possible because of the existence of longitudinal beams in the axes 3 and 4. First floor slab, which is made from LMT brick elements, rests on the longitudinal reinforced concrete beams and façade walls ring beams.

4. NEW STEEL GIRDERS IN AXIS C, D AND E

Influences on the new steel beams are determined based on the force acting on the top of the column which is removed. New steel I-beams rests on the capital no top of the new reinforced concrete columns. Under steel IPB1-700 beam bearing plate was placed and concreted with special high strength fine-grained concrete Sika Grout 212. (Shaded part on Figure 5.). Columns were designed using recommendation from [1] and [2].

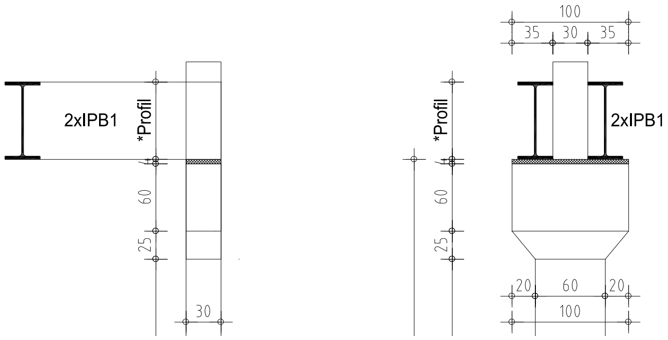
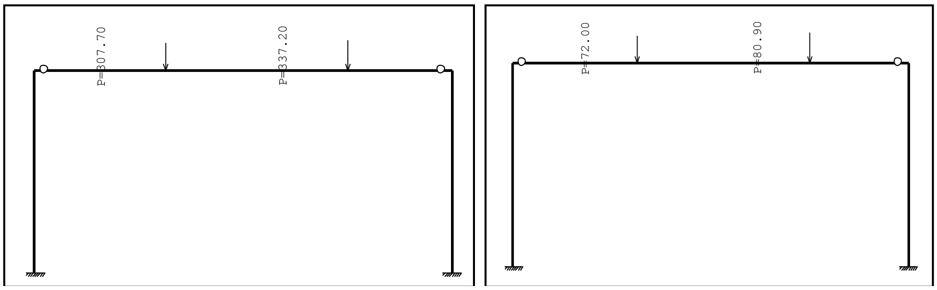


Figure 5. The capital of the new RC-column and steel I-beams for underpinning the building

4.1 Dimensioning of steel I-girders in axis C, D and E

Redistribution of loads generated by removed RC columns on the ground floor is acomplished by new girders made of hot rolled steel I beams.



Slika 6 Reactions from longitudinal beams for permanent and live load

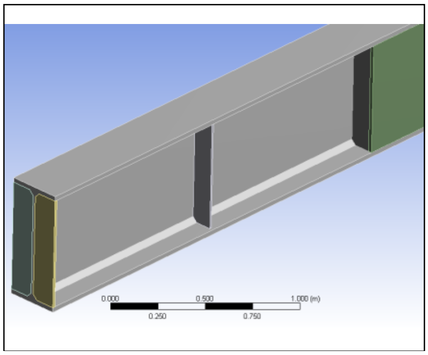
Girders was formed from steel with yield strength of $f_y=240MPa$ and permissible stress of $\sigma_{dop}=160MPa$.
Maximal bending moment in steel beam is:

$$M_{\max} = M_{G,\max} + M_{P,\max} = 1214.35 + 271.36 = 1485.71 kNm$$

Required moment of resistance of beam $W_{x,pot} \geq M_{\max} / \sigma_{dop} = 9285.7 cm^3$ 2xIPB1-700.

A steel girder is composed of two hot rolled steel I-beam strengthened by two side steel plates and cross placed steel stiffening plates (Figure 7. left). Additional strengthening by two vertical 2≠636×20 steel plate was done in the middle part of the girder. Determining factor for dimensions of transverse steel girders and steel plates was deflection of beam. Upper floor needed to be without any influence of the settling or deformation of lower parts of the building. Composite action was considered as in [3].

Calculated deformation was divided in two parts.
Permanent load (g) vertical deflection was $u=19.9mm$ which gives ratio of deformation of $10400mm / 19.9mm = 523 \rightarrow l / 523$.
Total load (g+p) deflection $u=23.3mm$ gives ratio $10400mm / 23.3mm = 446 \rightarrow l / 446$
Thus cross-section meets the established deformation criteria of $l / 300$.



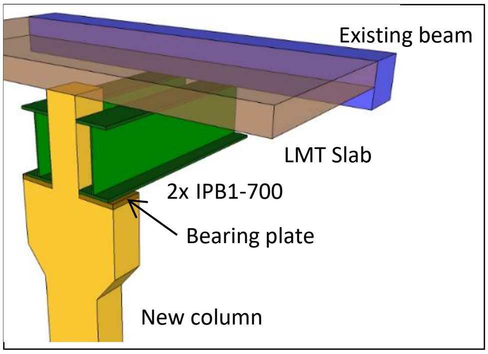


Figure 7. Steel beam with stiffeners and added plates, RC column with capital

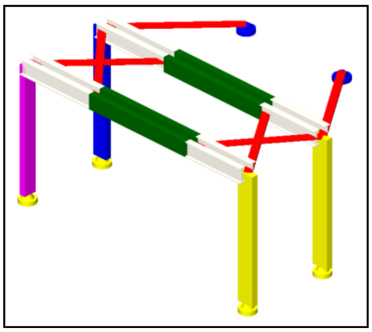


Figure 8. Structure of the transverse steel girder and the reinforced concrete columns

The transverse stability of the new frame was, in static sense, constrained columns with hinged connection to steel girders. Longitudinal stiffness was achieved by placing the rigid stiffener in the form of braces formed from the hot-rolled steel U-profile, as it was presented on figure 9.

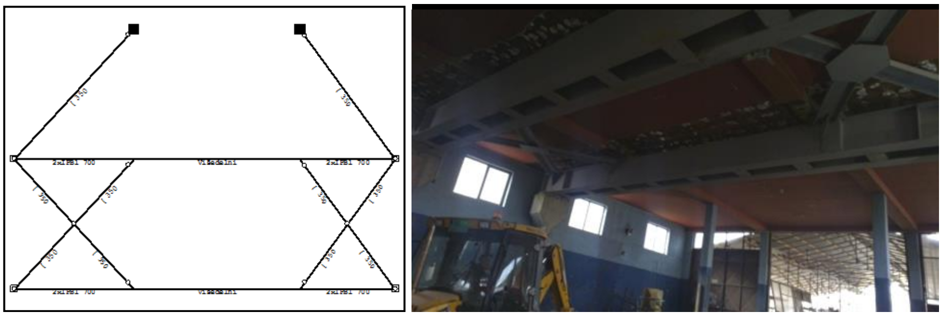


Figure 9. The spatial model and constructed support-bracings

5. DEMOLITION OF EXISTING STRUCTURE

The most complicated part of the execution of underpinning existing structure floors and the attic is a way of execution and methods-phases of construction. In the project first planned operation was execution of underpinning of longitudinal RC beams around columns, and then demolition of the existing columns, walls and foundations. The first carried out operation on the object was making of a new reinforced concrete columns with capitals. Preparation of steel I-beams was carried out in the workshop and then pair of I beams were then transported to building site. Lifting and carrying of I-steel beams outside the building was performed by auto crane. Transport inside the building was carried out by two smaller portable cranes (Figure 10.).

Figure 10. Excavated basement and placing of the steel I-beams

Figure 11. shows existing columns that are chosen for demolition and already raised steel I-beams before their connection. Beams were then interconnected with steel plates.

Figure 11. Existing columns for demolition and new steel girders

Due to the impossibility of measuring forces (dilatation by strain gauges), a surveying solution is chosen to establish the current situation by measuring the deflection state before columns demolition.

Then, after the removal of columns measuring of elastic deflection was done. Space below the longitudinal beam and the steel I-beams was filled with SikaGrout 212, a special high quality mortar, which in a few days achieves necessary compressive strength.

On the temporary supports spacers are placed and pouring of the same material was also performed under the steel beams. Before these operations, frames with presses are set, and force was entered in areas near supports on reinforced concrete columns. Figure 12. shows temporary frames an hydraulic presses for uplifting the steel beams.

Figure 12. Lifting of steel girders by hydraulic presses

After curing the grouting mixture, the demolition of existing columns was carried out, as shown in Figure 13. Columns were cut off just below steel beams and then removed from building. New steel-RC frame then took over the load from upper floors.

Figure 13. Demolished columns

Special curiosity are the so-called "hanging supports" e.g. supports formed from short RC columns created under existing reinforced concrete beams and on top of the new steel beam. Figure 14. shows columns on top of the steel beam. Wall under that beam was also demolished, while top part of the wall remained intact.

Figure 14. New short columns on top of the new steel I-beam

Figure 15. The inner part of the building with the newly designed structure and pool

Figure 15. shows the structure of the galleries and the functional part of new purpose of the building. New shallow swimming pool was build and partially filled with water.

6. CONCLUSION

Based on the presented analysis it can be concluded that in changes in part of the building usage, or demolition columns, all the parameters that affect the stability of the existing building must be determined precisely. First you must thoroughly research the current state of structure (beams, columns, foundations), then test the soil layers at which the new foundations will be placed on. Before the beginning of construction works on the rehabilitation of the building is necessary to get surveying record of the current situation, and then periodically make measurements of corresponding points while underpinning the construction of the first floor is done. After the demolition of the columns a measured elastic deformation in a steel girders can be compared with the calculated value. Execution of this specific tasks must be done by a specialized company.

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SANACIJA-PODUHVATANJE OBJEKTA USLED UKLANJANJA (RUŠENJA) STUBOVA PRIZEMLJA

Rezime: *Usled nove namene objekta, bilo je neophodno ukloniti 6 stubova prizemlja, čijim se rušenjem mora obezbediti nesmetano funkcionisanje dela objekta iznad nivoa prizemlja. Postojeći objekat je spratnosti PR+S+PK, dok je noseća konstrukcija u kombinaciji armirano-betonskih stubova (središnji nivo) i vertikalnih odnosno horizontalnih armirano-betonskih serklaža koji se nalaze u fasadnim zidovima. Međuspratna konstrukcija sprata je u vidi LMT tavanice oslanjena na podužne armirano-betonske grede. Umesto porušenih stubova postavljaju se poprečni čelični I-nosači različitih raspona (l=12.40 i 10.60) u vidu 2 I-nosača međusobno povezanih u nivoima gornjih odnosno donjih nožica, koji poduhvataju postojeću spratnu konstrukciju. Ovi nosači se oslanjaju na novoprojektovane armirano-betonske stubove koji se nalaze u osama 3´/C, 3´/D, 3´/E, odnosno 1/C, 1/D, 1/E. Prostorna stabilnost novoprojektovane konstrukcije obezbeđena je spregovima u nivou gornjih pojaseva čeličnih poprečnih nosača. Fundiranje novih armirano betonskih stubova je ostvareno u nivou zamenjenog tla. Postojeći temelji se podbetoniraju u vidu trakastih temelja odnosno temeljnih samaca.*

Ključne reči: *sanacija, poduhvatanje, čelična konstrukcija, armirano-betonski stubovi, podbetoniravanje, fundiranje.*