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STRENGTHENING AND OVERBUILDING OF CAR SERVICE „AUTOMAKEDONIJA“ IN SKOPJE, MACEDONIA

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Repair of the existing buildings has always been a great challenge for the building companies and for the civil engineering scientists, as well. When there is no available design documentation, a chain of activities precede to the main design for repair: measuring, in situ geotechnical investigations, determination of the quality and quantity of the built-in materials with various methods, etc. An example for repair and strengthening of the existing structure of a car service in Skopje, Republic of Macedonia, is presented in this paper, as well as a new steel structure for overbuilding.
Keywords: strengthening, mechanical properties, reinforced concrete structure, steel structure

INTRODUCTION

The building of the car service “Automakedonija”, located in Avtokomanda in the city of Skopje in Republic of Macedonia, consists of two parts: the first one built in 1968, and the second one in 2006. The first one is used as a car service, and the second one has been adopted for offices and showroom. The new part of the building is physically separated with an expansion joint and it works independently of the old building.

There is no design documentation for the structure of the old building from the construction period. Therefore, for the aims of the new building, geotechnical exploration of the soil has been performed during 2005 for the aims of the new building foundation. Last year, the Investor required an expert opinion about the bearing capacity of the existing structure, which is single storey reinforced concrete frame structure.

Five frames in x-direction and four frames in y-direction were originally roofed with a reinforced concrete slab. A layer of low quality concrete with single slope and hydro-insulation were placed over the flat concrete roof slab for drainage and protection of the atmospheric water and snow influence. Few years ago, when the new part of the building was constructed, the old building was roofed with metal sheeting, installed over a light steel structure. In that way, the reinforced concrete roof slab was completely protected of outside influences.

An expert team from the Faculty of Civil Engineering in Skopje performed measuring and survey of the old building, as well as estimation of the quality and the quantity of the built-in materials and static analysis of the bearing capacity of the existing old building. The obtained reinforcement for the external columns in the building envelopes was greater than the existing built-in one, therefore there was a necessity of additional reinforcement. This problem was solved with another strengthening solution, reinforced concrete walls at the corners of the building. This solution gives an opportunity of re-distribution of the structural loads and of the bending moments, therefore the columns in the building envelope will be affected by loads with lower intensity.

The resulting expert elaborate, see [2], states that: „For the aims of overbuilding of administrative-business space onto the existing reinforced concrete slab, completion of Main Design for overbuilding is recommended. The new design should give a solution not only for the new storey, but also for the strengthening of the existing ground floor structure with stiffening of the building for satisfying the complete static and dynamic requirements".

The Main Design, see [1], consists of strengthening of the reinforced concrete structure and new steel structure for overbuilding.

QUALITY OF THE BUILT-IN MATERIALS

Building geometry

The orthogonal frames of the old building structure consist of reinforced concrete columns and beams. The dimensions of all columns are 40/40cm, while the beams are with rectangular cross sections of two different sizes: the internal beams in x-direction are 50/45cm, while all the others are with dimensions of 40/45cm, see Figure1.

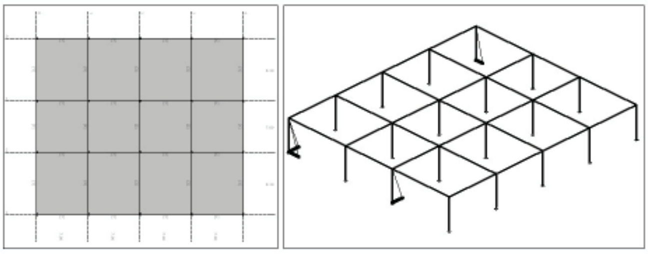

Figure 1. a) Layout of the building; b) 3D model of the building

In order to determine the thickness of the roofing reinforced concrete slab, few holes were drilled in it. Slab thickness dp=15cm has been determined, and over it a layer of low quality concrete was placed with obviously smaller granulation and strength, with thickness of 5-15cm that enabled a slope for drainage of the atmospheric water.

Quality of the concrete

The quality of the built-in concrete was determined with in-situ testing, using the method of Schmidt hammer. The testing has been performed on two columns – one external and one internal and on the upper layer of the reinforced concrete slab. The measuring with the Schmidt hammer requires large, flat and clean surface for obtaining reliable results, therefore the measuring of the lower part of the slab and the beams was not possible. Ten measures have been performed for each of the mentioned elements, and the average values are represented in the following Table 1:

Table 1. Concrete class measured with Schmidt hammer

element	concrete class [MPa]
external column	36.7
internal column	36.5
slab – upper side	20.4

These results were not sufficient; therefore kerns had been taken out as another method for confirmation of the concrete class for all structural elements. One cylindrical sample was taken from the slab and two from the beams, see Figure 2.

Figure 2. Three sample cylinders taken from the slab and the beams

The obtained results for the samples are presented in the Table 2:

Table 2.Concrete class obtained with sample kerns

label	ϕ	h [mm]	V	G [gr]	γ [kN/m3]	Fc [MPa]
slab I	94	103.4	717.2	1746.4	24.35	31.1
slab II	94	93.6	649.2	1528.9	23.55	27.6
G-1 beam	94	93.1	645.7	1527.6	23.66	23.2

- **Quality of the reinforcement**

With opening of the structural elements, i.e. removing the mortar layer and the protective concrete layer, the reinforcement in the elements was determined, see Fig. 3. All of them have been reinforced with smooth reinforcement GA 240/360, typical for the period of the building construction.

a)  b) 

Figure 3. Reinforcement in the structural elements: a) slab, b) beam

- **Foundation of the building**

Due to the fact of non-existing design documentation, individual foundations with dimensions of 80x80cm were assumed at foundation depth of 0.8m. The choice of the soil for the static analysis was influenced also by the results in the Elaborate for the performed terrain investigations and laboratory testing for the site location, which was completed before the construction of the new building, see [3].

STRENGTHENING OF THE RC STRUCTURE

The strengthening of the existing reinforced concrete structure has been performed by adding reinforced concrete walls that contribute to the horizontal stiffness of the structure, as well as to its seismic eligibility. Four reinforced concrete walls are designed to be placed, two in each orthogonal direction. The walls in x-direction are placed along the axes RX1 and RX4, while in y-direction along RY1 and RY3 axes. The position of the reinforced concrete walls is given in the Figure 1b. The walls have dimensions: length 1.5m and width of 40cm. They are designed of concrete MB 30, while the reinforcement is RA 400/500-2. The reinforced concrete walls are founded over foundation band at level -0.50 m, according the drawings of the existing foundations. If necessary, during the foundation works, the foundation can be modified depending on the existing foundations. In order to provide complete connection between the column and the reinforced concrete wall, the protective concrete layer of the column should be removed. Afterwards, reinforcing of the wall follows. The protective concrete layer should be renovated during the concreting of the wall. The reinforced concrete wall is designed to terminate 5 cm below the beams with placement of expanded polystyrene, in order not to introduce an additional load to the beams of the existing structure.

The integral calculation of the existing strengthened and overbuilt structure is performed with three dimensional model, using the sophisticated software package TOWER6. The analysis of the loads comprises: permanent loads, imposed loads, loads of the overbuilt steel structure and seismic loads. The maximal period obtained due to seismic action is 0.338 sec in x-direction, and 0.3079 sec in y-direction. The appropriate maximal displacements at a level of the existing structure are 4.94 mm and 4.1. mm. The control of the bearing capacity of the structural elements has been performed using the characteristic loads envelope, according to the Rulebook for concrete and reinforced concrete – PBAB 87. Detailed representations of the load cases, geometry of the structure, bending moments envelopes and necessary reinforcement were given in the Main design of the overbuilding, see [1]. Typical examples are presented in the Figures 4 and 5.

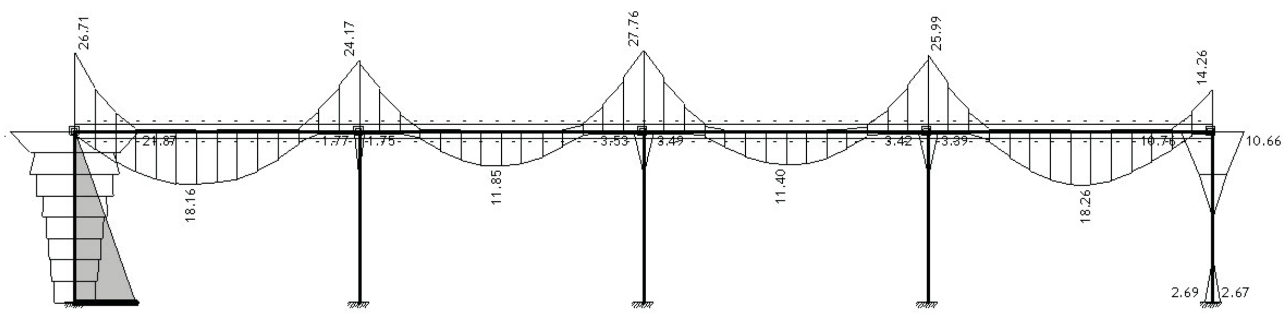

Figure 4. Maximal bending moments in one of the frames in y-direction

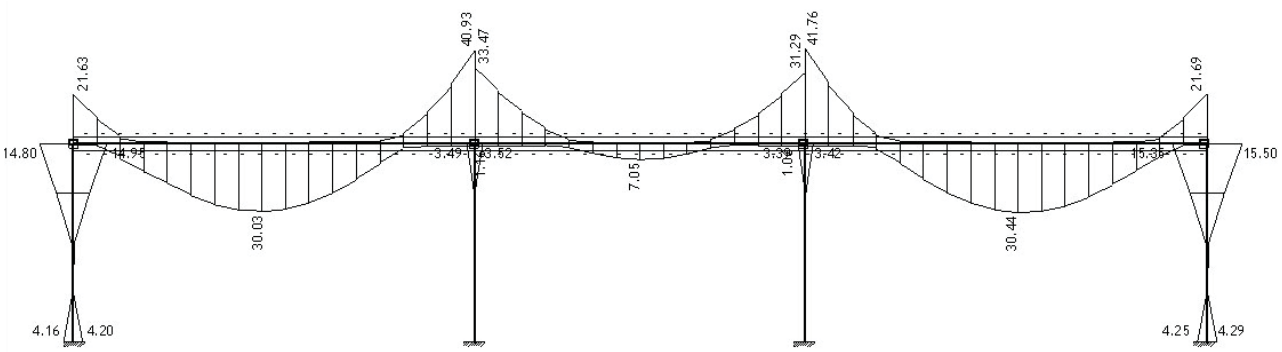

Figure 5. Maximal bending moments in one of the frames in x-direction

STEEL STRUCTURE FOR OVERBUILDING

The overbuilding is designed of light steel structure with tubular square and rectangular cross sectioned profiles. Before the construction of the steel structure, the layer of low quality concrete with single slope and the hydro-insulation with average thickness of 10cm should be removed from the reinforced concrete slab, which represents a load of 2.4 kN/m2. The columns are designed as SHS150.6 placed over the existing reinforced concrete columns. The connection of the steel columns with the existing structure is performed using 8 anchors of ∅16 for each column, sealed in the perforated holes (∅25) in the concrete. The part of the overbuilding between the rows B and D and the lines 2 and 4 is elevated with a ridge in the middle (line 3). The edge parts are lower, with drainage towards the building sides, see Fig. 6.

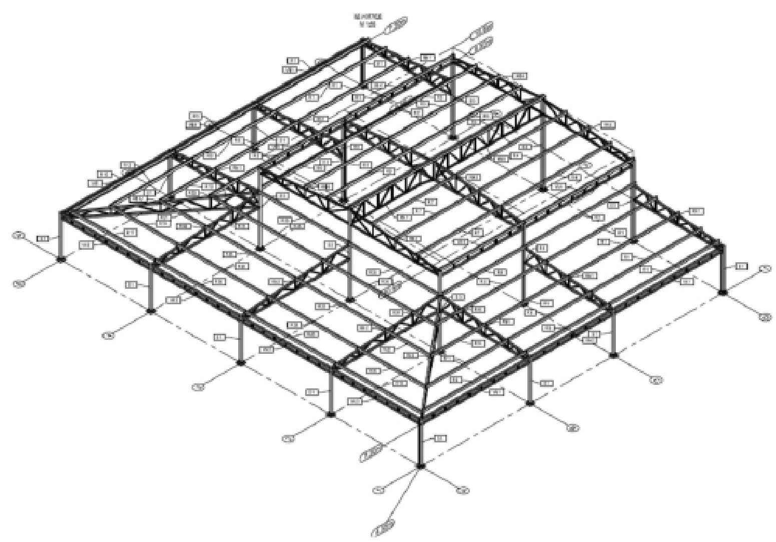

Figure 6.Three-dimensional model of the steel structure for overbuilding

Span structure consists of truss girders framed in the columns. The trusses are placed in the rows B, C and D with span of 7m each, except the truss between the lines 2 and 4 which span is 14m, i.e. there is a lack of a column at position C-3. Sliding trusses are designed between the columns A-1 and B-2, as well as between the A-5 and B-4.

The truss girders at the lower part (RN1, RN2 and RN3) have been designed with flanges of SHS100.5 and diagonals and verticals of SHS60.4. The truss girders in the upper part in the rows B and D (RN4) have been designed with flanges of SHS80.4 and diagonals of SHS50.3, see Fig.9. The truss in the row C (lines 2 and 4), with a span of 14m has been designed with flanges of SHS100.5 and vertical and diagonal elements of SHS80.4 and SHS60.4. The connection along the lines 1 and 5 and row A, at the lower part, is realized with Vierendeel girders, as well as for the connection along the lines 2 and 4, at the upper part, see Figure 10.

Joints of the structural elements have been performed with welding. The whole steel structure is made of steel with quality C0361 (S235).

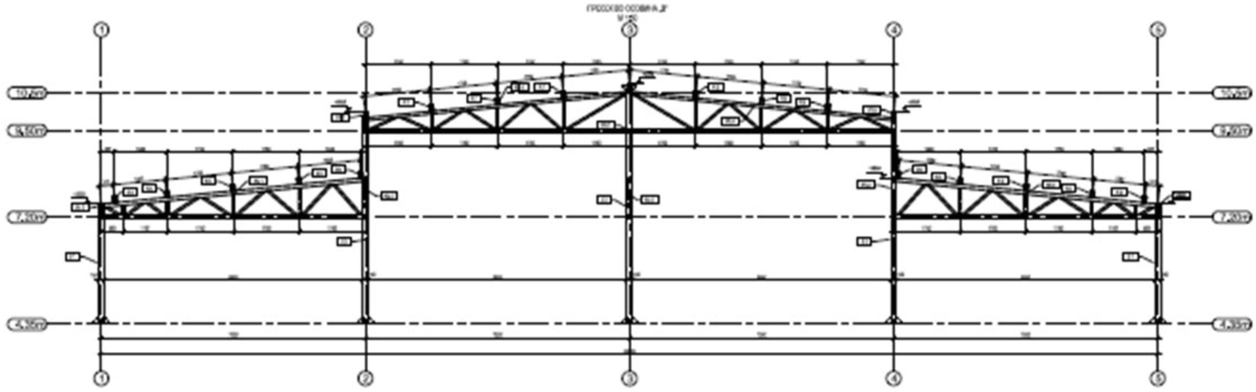

Figure 7. Section along B-axis

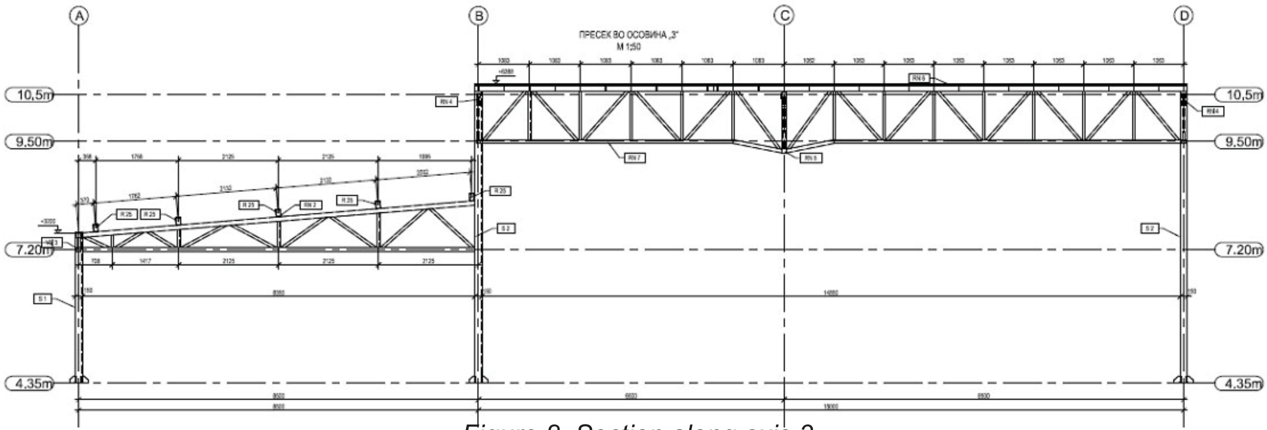

Figure 8. Section along axis 3

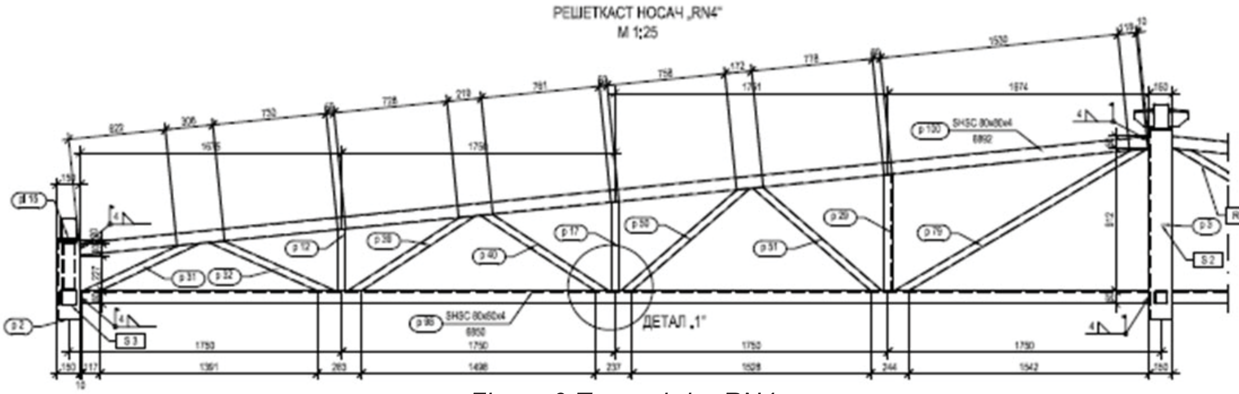

Figure 9.Truss girder RN4

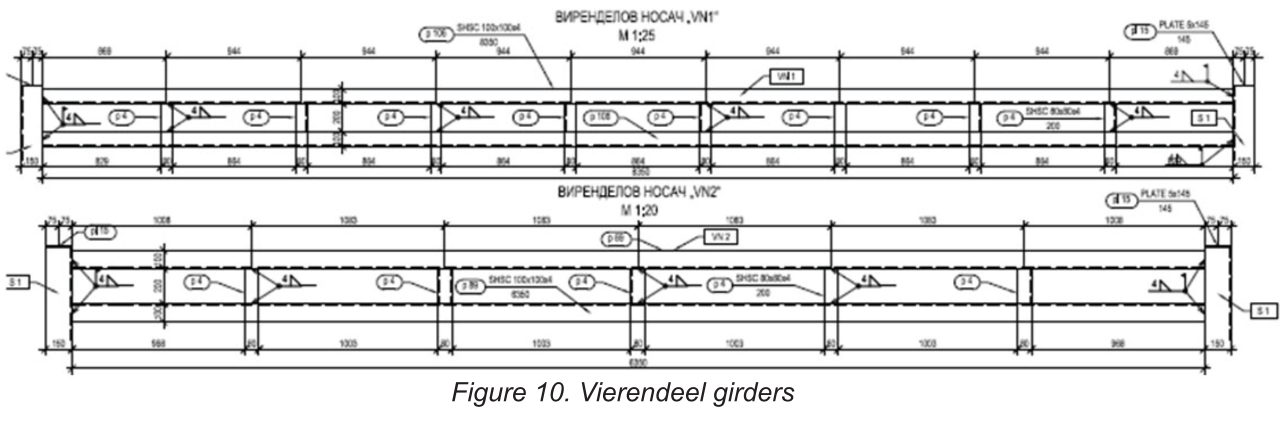

Figure 10. Vierendeel girders

The static analysis of the steel structure has been performed with the software package SAP2000. The model of the structure is special, consisted of frame elements. The influences of the permanent loads, snow, wind and seismic loads have been taken into account for the calculation. Control of the stresses and stability of the structural elements has been performed, as well.

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