BEARING CAPACITY ANALYSIS OF COFFERED SLAB ON BUILDING OF CLINICAL CENTRE IN NIS

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Summary: *Bearing capacity analysis of a coffered slab of the existing building of the Clinical Center Nis is shown. Due to the change of space using, it was necessary that slab withstand a concentrated load of air handling units. It was found that ribs should be strengthened. The new solution design layers of styrodur and ferroconcrete over the slab. Mechanical properties of styrodur, laboratory tested, were used for modeling styrodur by Winkler's model. Analysis of new solution showed that structure repair was not necessary.*

Keywords: *Coffered slab, concentrated load, Winkler's model of styrodur, ultimate limit state*

1. INTRODUCTION

Coffered slab consists of series of ribs on a small distance from each other and thin plate over them. The advantage of a coffered slab compared to traditional reinforced concrete slab is a possibility of bridging large spans. Therefore it is applied in designing of halls and other buildings where it is necessary to design a large space without columns. The benefit of coffered slabs compared to solid slabs was investigated and it was confirmed that a coffered slabs have greater bearing capacity [1].
The ribs can be designed parallel to supporting sides forming a square or rectangular cassettes or at an angle of 45̊ forming a diagonal cassettes. For easier removing of formwork, ribs are usually formed with variable width so that the width at connection with the slab is 2 cm larger than the bottom edge [2].
Coffered slabs are derived monolithic or prefabricated. They can be classical reinforced or prestressed. Prefabricated prestressed coffered slab used in Serbia have been developed at the Institute for testing of materials IMS. Structural system consists of prefabricated cells, square or rectangular shapes, which is formed by four columns and a coffered slab between them. Connection of columns and the slab is achieved by prestressing cables which are pulled through the holes in the columns at the slab level, and between the two neighboring slabs. After the setting up of cables, the space between the edge ribs of adjacent slabs is filled with concrete forming a prestressed girder. In the case of larger

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spans, slab can be formed of several parts, whereby parts are merged into a monolithic whole by prestressing of secondary ribs [3].
It is often the case of change of space using of buildings, which leads to changes in load. If construction does not have sufficient capacity to receive and transfer the new design load, it is necessary to strengthen the structure. The possibilities of applying carbon fiber plates, as well as the concreting reinforcement ribs as methods of strengthening of coffered slabs were analysed. It was confirmed that the carbon fiber plates bonded in a tension zone of coffered slab increase its capacity, but the effect of concreting reinforcement ribs is higher than strengthening by carbon fiber plates [4, 5].
The paper analyzes the prefabricated prestressed IMS coffered floor construction at the existing facility of the New Clinical Center in Nis. Due to the change of space using coffered slab need to receive and transfer the concentrated load of the air handling units (AHU). Bearing capacity analysis of coffered slab was performed using modeling method and finite element method. Concentrated load of the AHU causes the concentration of influences in some ribs of coffered slab. Based on the calculation and adopted reinforcement in the old facility project, it has been found that the ribs of the slab do not have sufficient bearing capacity and that their strengthening are required. Classic rehabilitation of slab applying carbon fiber plates, concreting additional stiffening ribs, or reinforcing by steel profiles were not applied.
Paper examined whether ferroconcrete layer over styrodur can provide uniform distribution of concentrated loads and reduce the concentration of influences in the ribs of the slab. Mechanical characteristics of styrodur were tested in the laboratory and applied for real modeling of styrodur by short elements with corresponding axial stiffness, which can accept and transmit compressive forces.
The analysis showed that the ferroconcrete layer, concreted over styrodur layer, and over the existing coffered slab, allows uniform distribution of concentrated loads of AHU, thus avoiding the concentration of influences in the ribs of the slab, so their strengthening were not necessary.

2. BEARING CAPACITY ANALYSIS OF COFFERED SLAB

Bearing capacity analysis of coffered slab was done in the software package "Radimpex Tower 6". Geometry of mathematical model was prepared according to the drawings in the old facility project. Slab 6 cm thick was modeled with surface finite elements, supported by ribs 36 cm height.
The ribs have variable width and a mean value of the ribs width is 17.5 cm. The ribs were modeled with beam finite elements, which were supported by main girders. The main girders are formed by the two edge ribs of coffered slab and space through which prestressing cables were placed. The width of the main girders is variable, with the mean value of 53.5 cm, while the height is 36 cm.
The main girders are supported by columns which were modeled as simply supports. RC walls were modeled as a linear supports. All concrete elements were made of class MB40 and they were reinforced with steel RA400 / 500-2.
Styrodur layer 10 cm thick and ferroconcrete layer 12 cm thick were performed over coffered slab. Axonometric view of a mathematical model of the structure is shown in Figure 1.

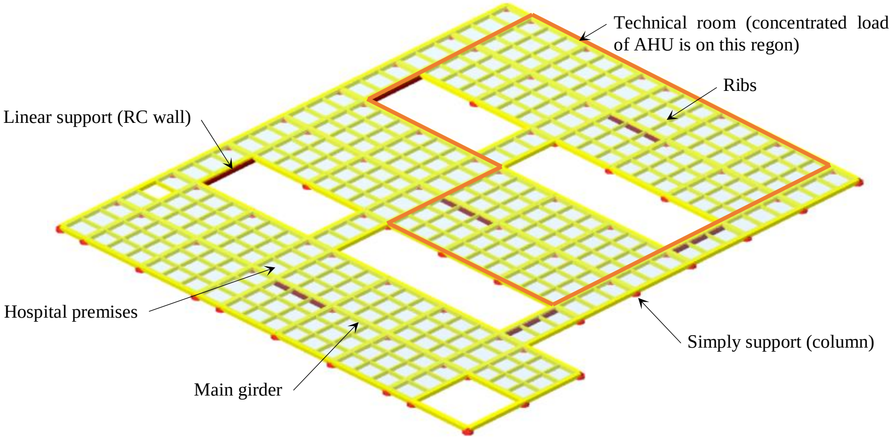

Figure 1. Axonometric view of the mathematical model of the analysed coffered slab

One part of the space is intended for the technical room in which AHU will be placed, while the other part is intended for hospital premises.
On the part of the technical facilities, dead load includes the weight of the floors and ferroconcrete. The intensity of the dead load is 3.35 kN/m^2. The intensity of the live load on that part is 1.50 kN/m^2. On the part of the hospital premises dead load includes the weight of the floors and the intensity of dead load is 2.87 kN/m^2. The intensity of the live load on that part is 4.00 kN/m^2. The intensity of the dead load of the ceiling structure and the installations is 0.50 kN/m^2 and that load acting on the ribs of the slab.
Own weight of construction was accounted automatically by software package. Air handling units are made within the parts. Each part will be supported in the corners over the steel plates. This load was modeled as a point load, with the intensity and position of the load determined in accordance with the technical specifications of AHU.
Walls were modeled as a linear load intensities 16.00 kN/m^1. Partition plasterboards walls were modeled as distributed load throughout the slab and intensity is 1.00 kN/m^2. Prestressing was modeled as equivalent load, and the initial cable tensioning force in ribs is 340 kN, and initial cable tensioning force in girders is 880kN.
From the geometry of the cable route the equivalent load was calculated. Losses of prestressing force equal to 20% of the initial tensioning force are adopted. Seismic load is not included in the project because the dominant influence on the basic ceiling was not expected.
The structure is dimensioned according to the applicable Regulations for concrete and reinforced concrete BAB87, and according to the limit states theory. The maximum required area of reinforcement in the slab is shown in Figure 2.
After examining the structure project it was determined that the existing reinforcement is Ø5/10 cm (Aa = 1.96cm^2) in the lower zone and Ø5/10 + Ø6/40 cm (Aa = 2.67 cm^2) in the upper zone above the ribs of the slab. As the required area of reinforcement is less than the existing reinforcement, slab can receive and transmit new design load.

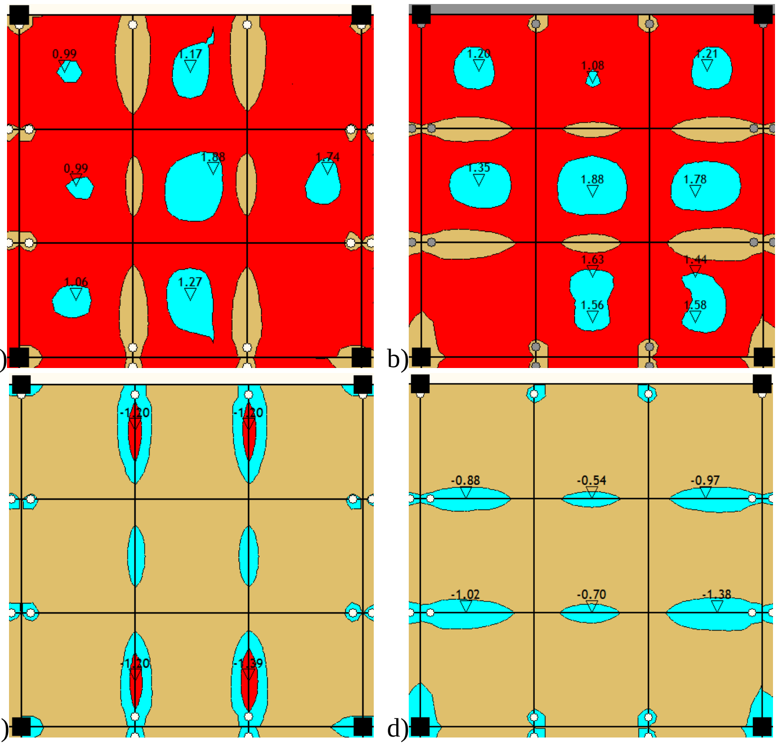

Figure 2. Requred reinforcement in the slab: a) lower zone x direction; b) lower zone y direction; c) upper zone x direction; d) upper zone y direction

Figure 3 shows the required area of reinforcement in classical reinforced ribs. After examining the structure project it was determined that the existing reinforcement in classical reinforced ribs is 4Ø14 (Aa = 6.16 cm2) in the lower zone. The required area of reinforcement is larger than the existing one, so one concludes that the ribs can not receive and transmit new design concentrated load of the AHU. This is due to the concentration of influences in the ribs due to the concentrated load of AHU.

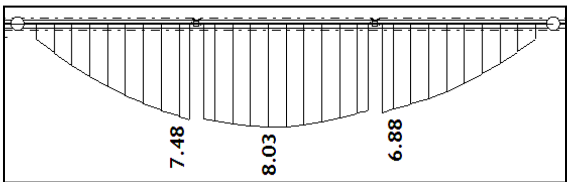

Figure 3. The required area of reinforcement in the most loaded rib

Prestressed elements are designed in accordance with the Regulation on technical measures and requirements for prestressed concrete PNB71 from 1971. year, according to a permissible stress theory. Stresses in the girders and prestressed ribs are within the permissible range, so they can receive and transmit new design load.

Based on the results of the static structural analysis and dimensioning it can be concluded that classical reinforced ribs of coffered slab can not receive and transmit new design concentrated load of AHU and their strengthening is necessary. The structure was not strengthened by conventional methods, but analysis was conducted in order to determine whether the real behavior of the ferroconcrete layer and the styrodur layer, which are designed over the existing coffered slab, can uniformly transfer concentrated load of the AHU, which would avoid the need for strengthening of the structure.

3. BEARING CAPACITY ANALYSIS OF COFFERED SLAB WITH REALISTIC MODELING OF STIRODUR AND FERROCONCRETE

Styrodur layer 10 cm thick and ferroconcrete layer 12 cm thick were made over coffered slab. These layers are not just coverings, but they have a certain bearing capacity. In order to cover the capacity of these two layers, a model in which the ferroconcrete layer was modeled with surface finite elements, while stirodur was modeled with rod elements 10 cm lenght, which can receive and transmit compressive forces only, was made. In this way, the styrodur layer was treated by Winkler’s mathematical model (Figure 4).

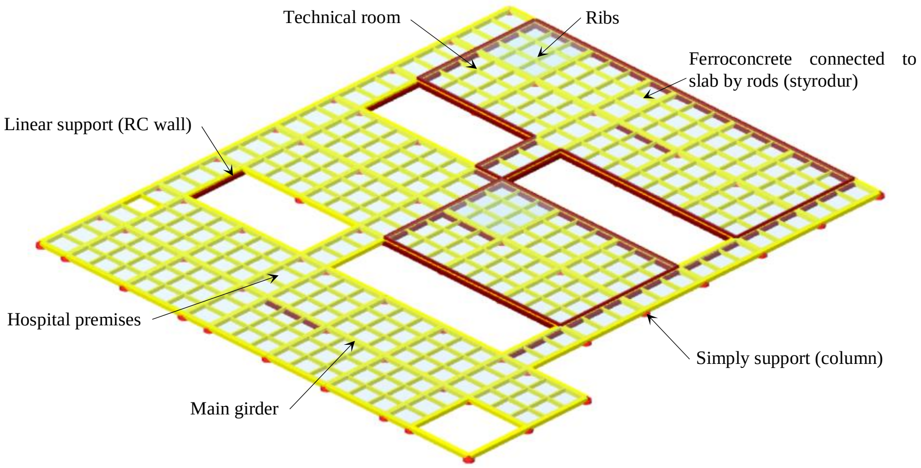

Figure 4. Axonometric view of a mathematical model with realistic modeling of styrodur

Mechanical properties of styrodur, necessary to define stiffness of rods, were tested in the laboratory of Faculty of Civil Engineering and Architecture, University of Nis. Testing was conducted in accordance with standard SRPS G.S2.813:1990. Samples with dimensions of approximately 100 x 100 x 100 mm were exposed to pressure in a hydraulic press with a constant increment of pressure of 0.025 N/mm^2. The aim of the study was to determine the dependence of the styrodur deformation due to compressive stress and determination of compressive stress which leads to deformation of 1 cm. Dependence of styrodur deformation due to compressive stress is shown in Figure 5a. On the basis of the test results the Young's modulus of elasticity of styrodur E = 10.000 kN/m^2 and styrodur compression stiffness c = 25.000 kN/m^3 were defined.

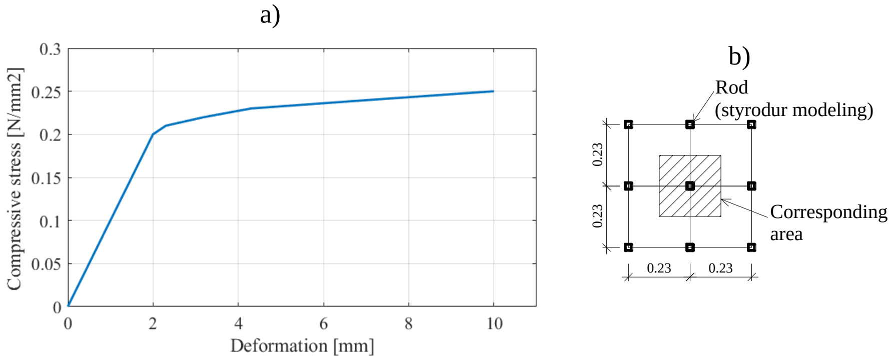

Figure 5. a) Stresse-strain dependence of styrodur; b) Sheme for determination of cross section area of rods

Rods for styrodur modeling were placed at a distance of 0.23 m and 0.30 m, depending on the structure grid. Cross section area A of rod was determined from the condition that the stiffness of the rod has to be equivalent to rigidity of styrodur on the surface which is replaced by rod A_{ra} (Figure 5b):

$$\frac{25000 * A_{ra} * 0.10}{10000 * A} = 1 \quad \rightarrow \quad A = 0.25 A_{ra} \tag{1}$$

Nonlinear analysis was implemented in a maximum of 20 iterations, where the reduction coefficient for one iteration was 0.05 and tolerated stress overdraft in the bars was 0.10 MPa. Such a realistic model of coffered slab with a styrodur and ferroconcrete layers confirmed that RC ribs have sufficient bearing capacity to receive and transmit new design load (Figure 6). It was confirmed that ferroconcrete layer over styrodur layer allows uniform distribution of concentrated loads of the air handling units on coffered slab and there was no concentration of influences in the ribs of the slab.

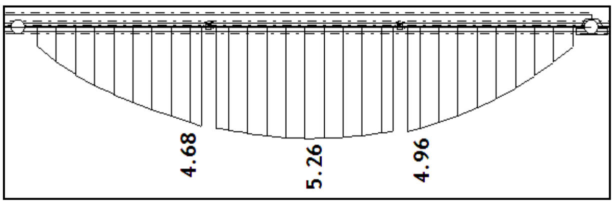

Figure 6. Required reinforcement area in the most loaded rib in real mathematical model

4. CONCLUSION

The paper analyzed the bearing capacity of the coffered slab in the existing building of the New Clinical Center in Nis, due to a newly designed load on the part of the technical room. An analysis in which the styrodur layer and ferroconcrete layer, which will be made over a slab, were treated as a dead load and analysis in which a ferroconcrete layer was modeled

as a plate that was through simple rods, by which was styrodur modeled, connected to the coffered slab were shown.
Based on the performed analysis it can be concluded that ferroconcrete layer over styrodur provides uniform transmission of loads from the air handling units to the coffered slab, which ensures a uniform strain of ribs. Dimensioning slab and RC ribs on the part of the technical facilities required reinforcement were obtained which is less than the adopted reinforcement in the project. Based on that the conclusion was drawn that coffered slab and RC ribs can receive and transmit new design load. Based on the stresses in prestressed ribs and prestressed girders it can be concluded that the stresses are in permissible range and ribs and girders have sufficient capacity to receive and transmit new design load on the part of the technical room. Analysis showed that ferroconcrete layer made over styrodur provided around 50% less required reinforcement in ribs than the case which did not include real behavior of ferroconcrete and styrodur.

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АНАЛИЗА НОСИВОСТИ КАСЕТИРАНЕ ТАВАНИЦЕ НА ОБЈЕКТУ КЛИНИЧКИ ЦЕНТАР У НИШУ

Резиме: *Приказана је анализа носивости касетиране таванице постојећег објекта Клиничког центра Ниш. Услед промене намене простора неопходно је да таваница пренесе концентрисано оптерећење од клима комора. Утврђено је да треба ојачати ребра таванице. Новим решењем је предвиђен слој стиродура и феробетона преко таванице. Механичке карактеристике стиродура, лабораторијски одређене, искоришћене су за моделирање стиродура Винкеровим моделом. Анализом новог решења показано је да није неопходна санација конструкције.*

Кључне речи: *Касетирана таваница, концентисано оптерећење, Винклеров модел стиродура, гранично стање носивости*