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ДИАГНОСТИКА НА СЪСТОЯНИЕТО НА СТОМАНОБЕТОННА ПОДОВА КОНСТРУКЦИЯ – РАБОТЕН ПРИМЕР

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DIAGNOSTICS OF THE CONDITION OF REINFORCED CONCRETE FLOOR STRUCTURE – CASE STUDY

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Abstract:

The paper presents some of the investigative work and test results that were conducted to assess the condition of the reinforced concrete floor structure of the "Tobacco Industry" facility in Leskovac (Serbia). Part of the building was built in the thirties of the twentieth century, and the rest in the period 1958-1960. According to the architectural structure, the building has floors B+GF+4. The main goal of the research work was to come to a conclusion about the state of load-bearing capacity and the state of usability of the structure based on the measured values of the mechanical characteristics and to define the possibility of converting the building into a residential building. Among other things, an examination of the floor slab on the effects of test static and dynamic loading was carried out. The values of global deformations (deflection) and local deformations (dilatation and stresses), as well as the values of dynamic parameters (frequency and damping), were analysed.

Keywords:
assessment of condition, reinforced concrete floor structure, testing, test load

1. INTRODUCTION

As part of the investigative work, during the assessment of the condition of the facility [1], the paper presents a case study of testing the reinforced concrete floor slab on the effects of static and dynamic test loads of the "Tobacco Industry" facility in Leskovac (Serbia). The goal of the investigation was to assess the possibility of converting the building into a residential building. The building was built in two phases, with the northern part built in the 1930’s, and the central and right tracts in the period between 1958-1960. The building has levels B+GF+4. The structural system is a spatial reinforced concrete frame structure and it consists of RC slabs, columns and beams. The external walls are made of bricks with a thickness of 40-55 cm. The interior partition walls, which were made of brick, were removed, as were the layers of the floor

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up to the reinforced concrete slab. The floor slabs are monolithic RC slabs with a thickness of 20 cm. The columns are 60/60 cm and 40/40 cm. The frame beams are 40/60 and 25/35. The foundations are in the form of RC foundation slab 50 cm thick.

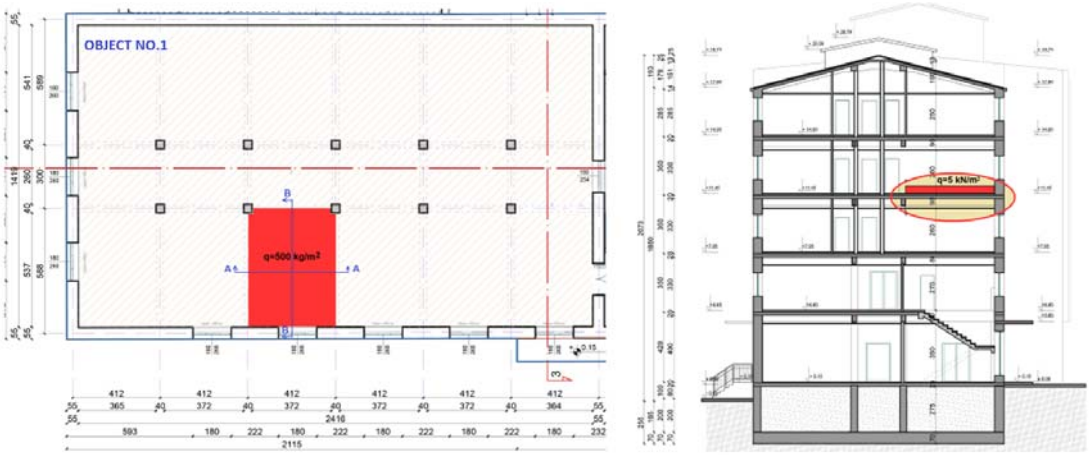

Figure 1. Scheme of test load between the 1st and 2nd floor (left) and cross section 3-3 (right)

For the analysis of the state of the structure, the part of the building with the worst visual characteristics was selected (figure 1), which used to be the dryer of the tobacco industry [1]. There are cracks and exposed reinforcement on the slab, beams and columns. A macroscopic examination revealed that there is a longitudinal crack of opening δ=0.4 mm along the entire length of the shorter span (figure 2) at approximately one third of the span on the surface of the concrete on the slab on the lower side. Damage in the form of stripping of the longitudinal reinforcement ∅19mm and the appearance of cracks in the opening δ=0.6 mm were also observed on the beam in the Y direction (figure 3). In the test area, the reinforcement on the columns at the floor level was also exposed. During the movement of people no increased vibrations on the floor structure were experienced, which causes discomfort to users.

2. TEST PROGRAM AND EXAMINATION RESULTS

The test on the influence of the substitute (test) load was carried out in accordance with the current regulations in Serbia [2]. Measurements were carried out for the effects due to static loading (by phases) and dynamic loading (caused by the movement of people), before and after the application of static loading.

Figure 2. Test load (q_{max}=500 kg/m^2) and a characteristic crack in the RC floor slab

2.1. Examination of static characteristics

A brick blocks were used as a substitute test load during testing for the effects of additional permanent and variable loads [3]. The load was applied in 4 equal steps up to the maximum q=500 kg/m^2 and kept on the structure for 16 hours, after which the load was relieved (also in 4 steps) with the reading of residual values of global and local deformations.

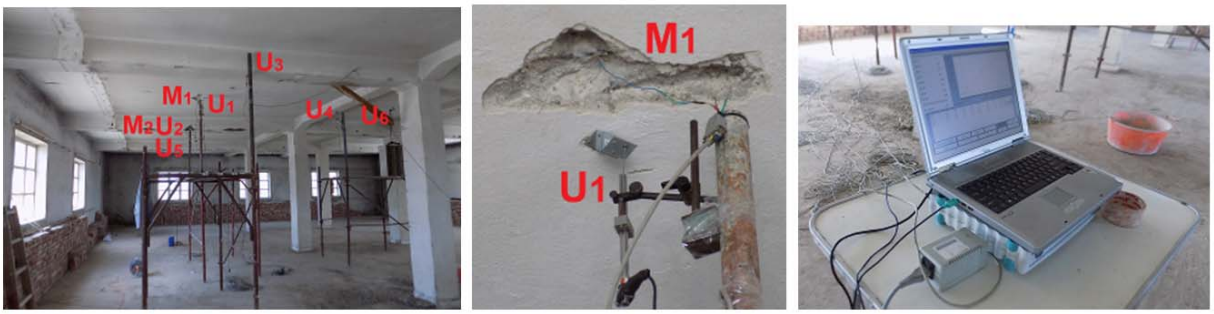

Figure 3. Instruments layout and acquisition system

The layout of the measuring instruments was made in accordance with the principle of banding the sections with instruments (figures 4 and 5).

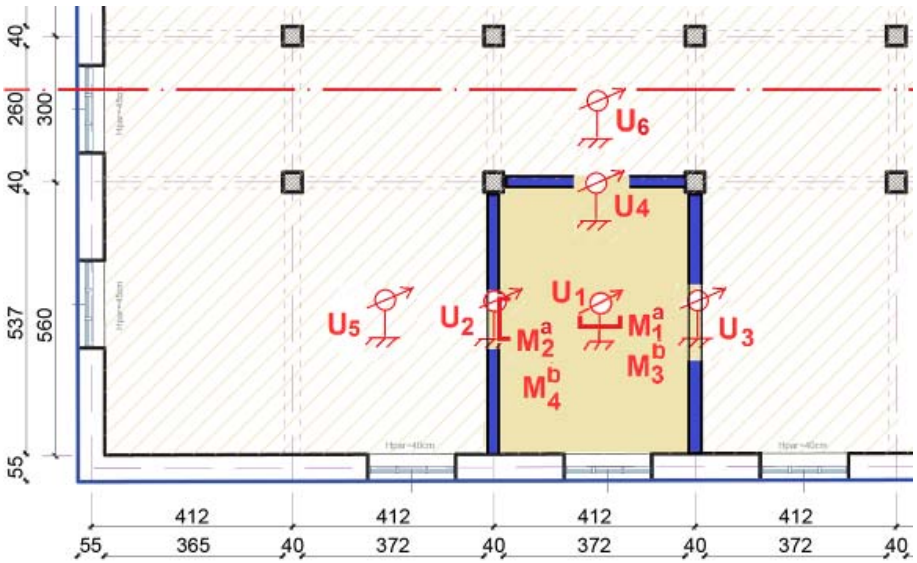

Figure 4. The base of the examined floor structure

Equipment was used to monitor global (general) and local deformations and stresses in characteristic sections where maximum impacts were expected. The measurement sensors are connected to the Spider 8 acquisition system and PC.

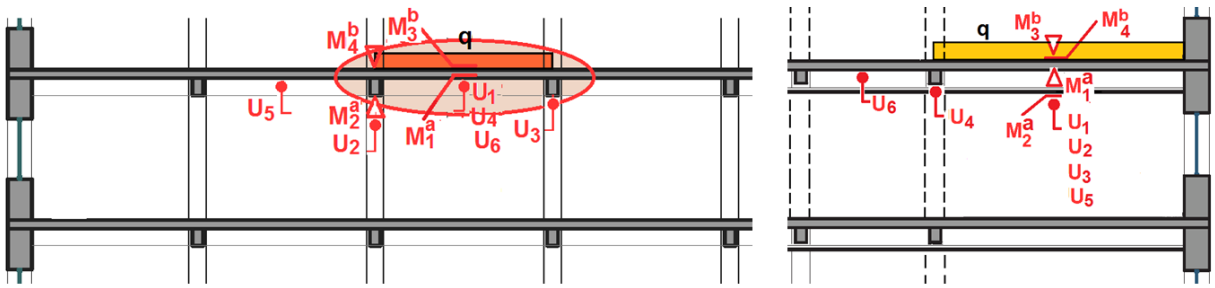

Figure 5. Longitudinal direction A-A (shorter span) and transverse direction B-B (longer span)

By comparing the measured and calculated deflection and stress values, the necessary safety coefficient was established, which is η=1.09 (η>1.0), that is, it was confirmed that the measured values are smaller than the calculated values [3].

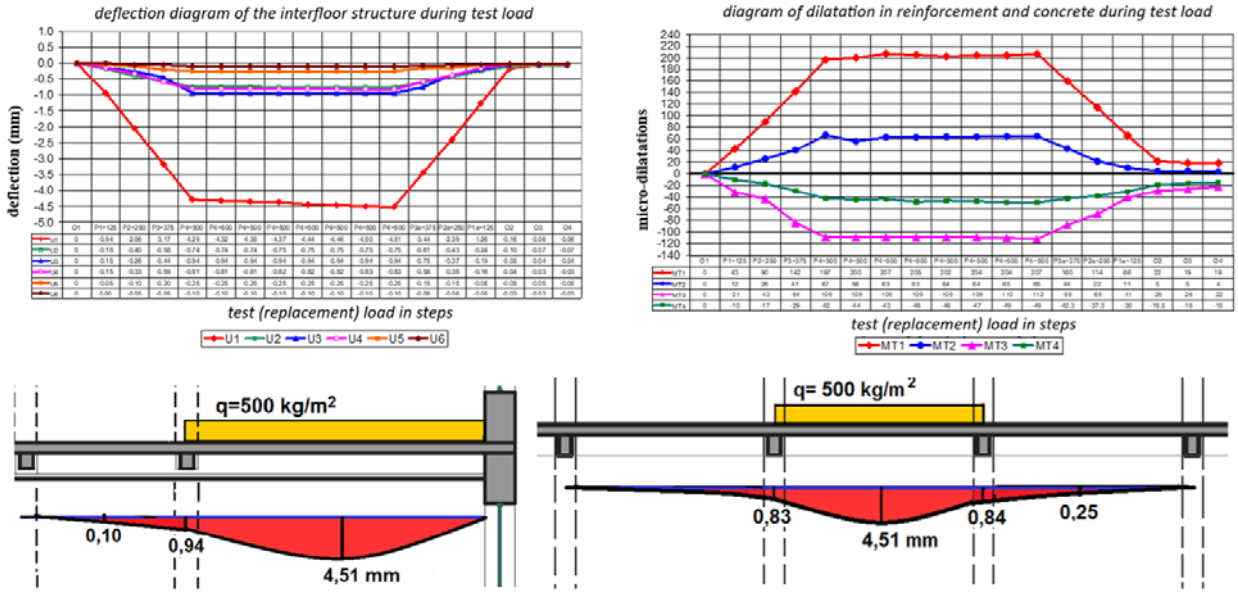

Figure 6. Display of the diagrams of the maximum measured deflections and dilatations of the examined RC floor slab under the test load

The values of residual deformations (deflections) are less than prescribed for reinforced concrete structures and amount to 1.3% of the maximum measured [2], which is significantly less than the allowed 25%.

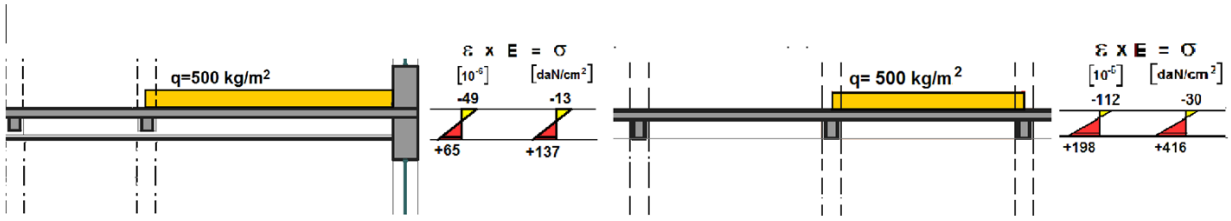

Figure 7. Display of the diagrams of the maximum measured dilatations and stresses in tensioned reinforcement and compressed concrete

2.2. Examination of dynamic characteristics

The dynamic characteristics of the examined RC floor slab were determined by means of displacement transducers (LVDT) and electrical resistance strain gauges ("measuring tapes") placed in half of the span of the RC slab and beams. By dynamic FFT (Fast Fourier Transformation) analysis of vibrations [4] with the help of "Catman" software, characteristic forms were determined, i.e. characteristic natural frequency of vibration. The level of vibration damping is defined by the logarithmic decrement of the damping. The jump of one person in the middle of the span of the slab, as well as the movement of one person in the shorter and longer direction of the slab were used as an exciting dynamic load. The dynamic analysis was carried out first without a test static load, and then with a test static load (an additional mass of 500 kg/m^2) in one field of the floor structure.

The "Spider 8" measuring amplifier (figure 3) connected to a PC was used to record the vibrations, and the signal analysis was done with the licensed program package "Catman". In the

following, characteristic diagrams of records of recorded vibrations (deflections) of the structure and diagrams of dilations in reinforcement and concrete are given with signal analysis.

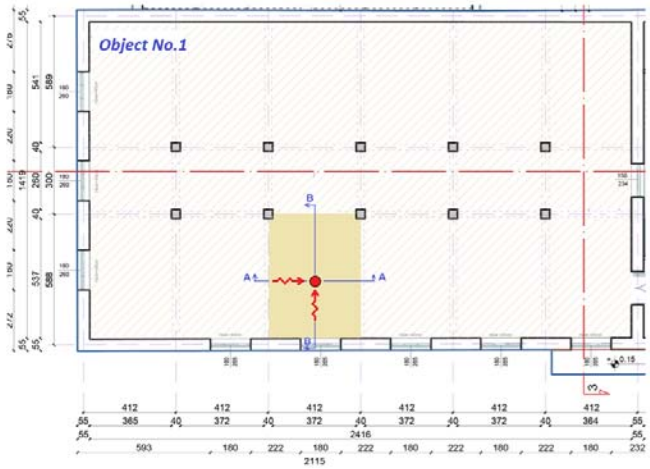

Figure 8. Position of dynamic load on the floor structure

Test programe was designed with 3 main variable loads: one person jumps in half of the slab span, one person crossing in the direction of the shorter span and one person crossing in the direction of longer span. Diagrams of deflection in mid-span, dilatations in reinforcement and concrete are displayed in Figure 9.

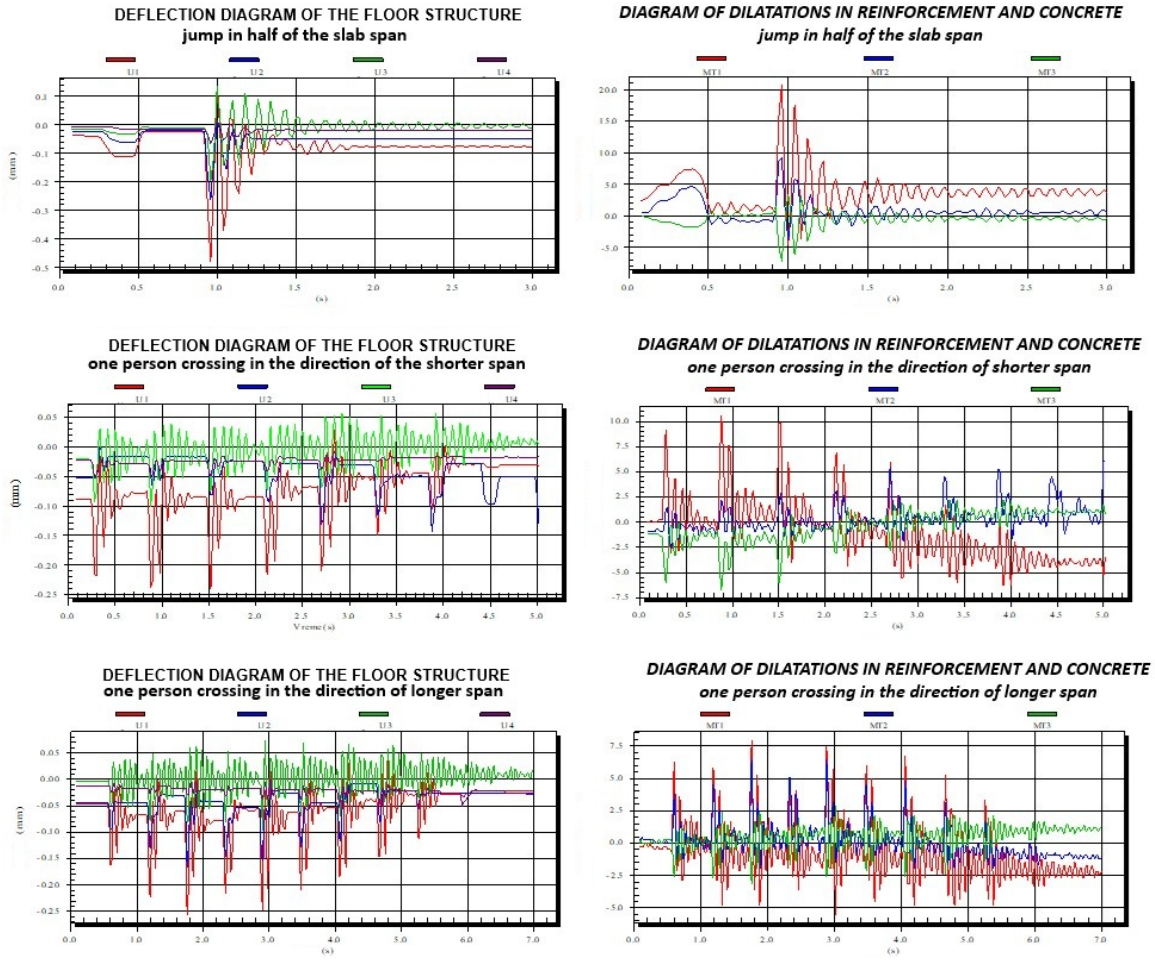

Figure 9. Diagrams of deflections and dilatations in RC floor structure due to test load

In the case of one person jump in half of the slab span characteristic vibration frequency from the deflection diagram of U1 in the half span of the RC slab is f=4,1 Hz (figure 10).

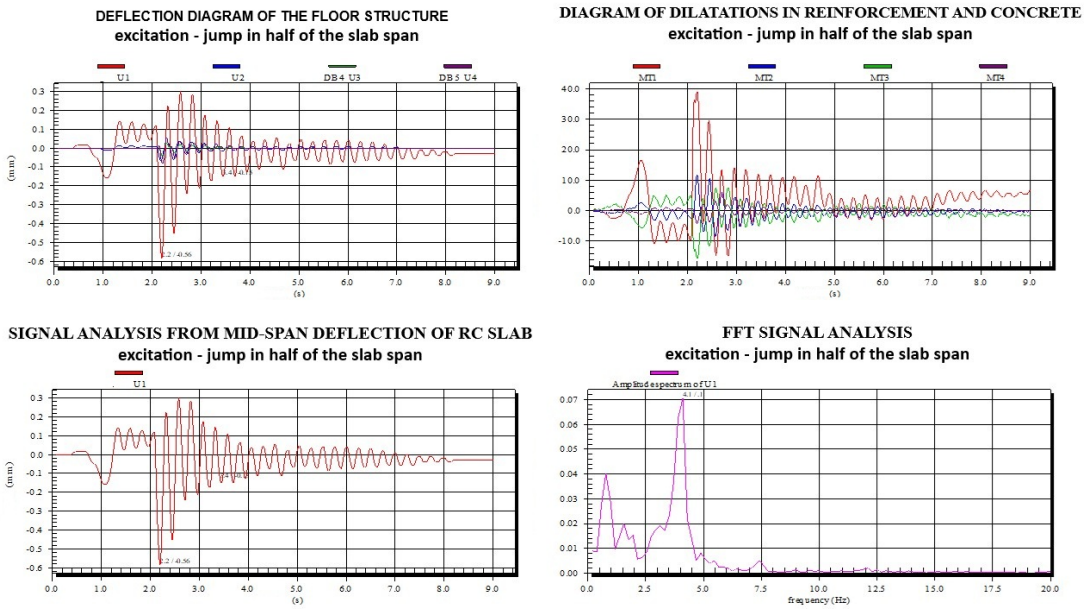

Figure 10 – Diagrams of deflections and dilatations in the floor structure due to dynamic excitation of one person jump in half of the slab span

In the case of one person crossing in the direction of the shorter span characteristic vibration frequency from the deflection diagram of U1 in the half span of the RC slab is f=3,8 Hz (figure 11).

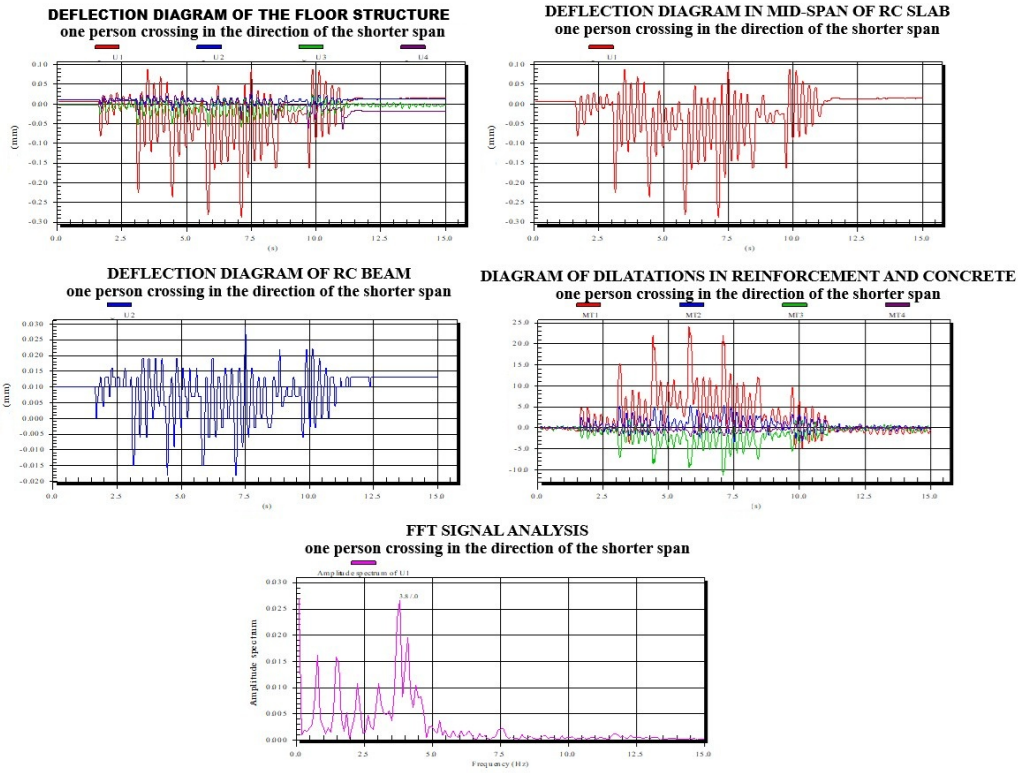

Figure 11. Diagrams of deflections and dilatations in the floor structure due to dynamic excitation of one person crossing in the direction of the shorter span

In the case of one person crossing in the direction of the longer span characteristic vibration frequency from the deflection diagram of U1 in the half span of the RC slab is f=4,1 Hz (figure 12).

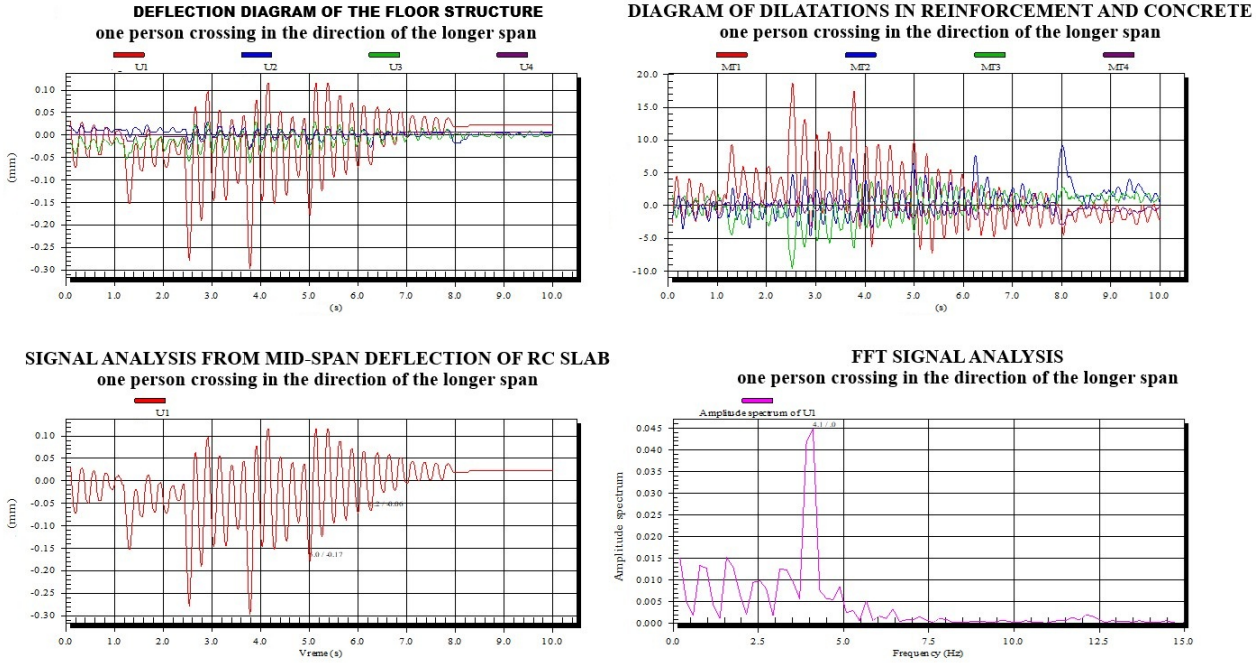

Figure 12. Diagrams of deflections and dilatations in RC floor structure due to dynamic excitation of one person crossing in the direction of the longer span

Analyzing the response diagram of the structure to dynamic actions, it was established that with the increase in the mass of the structure, there is a decrease in the vibration frequency and logarithmic decrement. The obtained values are outside the limit of unfavorable frequency f=2 Hz, so the movement of people will not lead to the appearance of resonance or shaking in the final state of the reconstructed floor structure. Increasing the amplitude and the duration of vibrations does not affect the usability of the structure and does not cause discomfort to the users.

Table 1: Values of measured dynamic factors

	UNLOADED STRUCTURE		LOADED STRUCTURE (q=500 kg/m^2)	
EXCITATION	frequency f (Hz)	logarithmic decrement δ	frequency f (Hz)	logarithmic decrement δ
jump in half of the slab span	f=11,3 Hz	δ=0,392	f=4,1 Hz	δ=0,365
one person crossing in the direction of the shorter span	f=11,3 Hz	δ=0,282	f=3,8 Hz	δ=0,234
one person crossing in the direction of the longer span	f=11,3 Hz	δ=0,318	f=4,1 Hz	δ=0,208

3. COMPUTATIONAL MODEL

In order to predict structural behaviour prior to determine testing programe, computational model was developed in software Tower 8 by Radimpex, Serbia. In 3D model one story was designed (figure 13), with main elements of RC slab, beams and columns as supports.

Too much test load and slab my suffer from structural damage, yet small load will results in unmeasurable values of deflections. So designed test load was firstly inputed through several load intensities, in order to gain optimal results in slab deflection. Finally, optimal test load was chosen for further investigation.

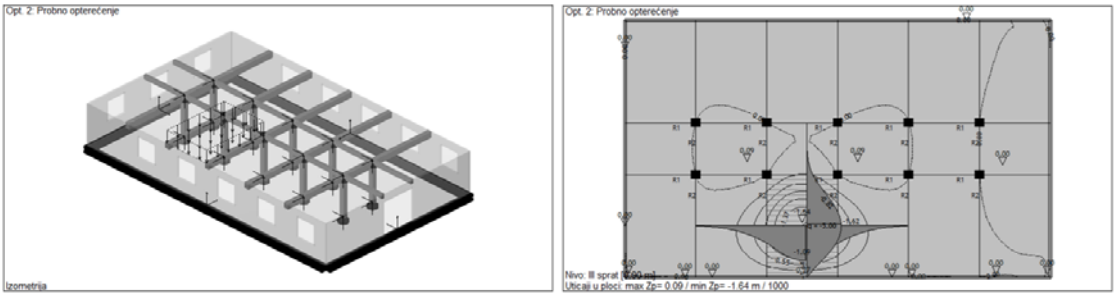

Figure 13. Computational model and deflection values of the part of the structure under investigation

4. CONCLUSIONS ON THE STATE OF THE RC FLOOR STRUCTURE

By analyzing the results obtained by measuring the static and dynamic characteristics of the RC floor structure during the test load test, it was established that the structure:

1) has the required global safety coefficient of η=1.09;

2) has the necessary elasticity (1.3% of the maximum measured);

3) has maximum cracks of δ=0.4 mm, which is greater than the permitted δ=0.3 mm, but that their propagation did not occur during the test load;

4) is an appearance of baring of the reinforcement on the beams and columns, which can be rehabilitated by repair. The subsequent strength of concrete at a pressure of 20 MPa was determined using the sclerometry method.

It is concluded that in this particular case, there is a possibility of repurposing the building into a commercial and residential one, given that it has preserved its load-bearing capacity and usability. It is necessary to proceed with repairs, and after a detailed computational analysis in the seismic sense, probably also with constructive repairs.

There is an increasing need for repurposing old buildings, given that they occupy attractive locations in cities, and in addition, they often represent cultural and historical monuments. In view of the most common lack of any documentation, investigative work on the assessment of the condition is necessary, and the method of testing the structure with a test load is necessary in most cases, as the safest.

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