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A BEARING STRUCTURE AND FINISHED CONSTRUCTION BEHAVIOR ANALYSIS BASED ON THE FULL-SCALE EXPERIMENTAL RESEARCH

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Abstract. *The paper deals with a brief presentation of a part of the performed experimental tests of the prefabricated reinforced concrete structural system "AMONT"for construction of various types of modern industrial halls. The test results are analyzed for two industrial halls both constructed according to this structural system but in the different phases of construction, tested in the full scale by application of AMBIENT vibration method. From the obtained Fourier spectra for measured ambient vibrations in two orthogonal direction for the structure without walls and the other with façade and filling walls, a significant discrepancy in their natural frequencies has been observed, and some conclusions about the influence of panel walls on dynamic characteristic the frame structure have been drawn out. The paper used some data of the research after the earthquake in Montenegro which took place on 15th of April 1979.*

Key words: *Prefabricated reinforced concrete structure, panel walls, ambient vibrations, Fourier spectrum.*

1. INTRODUCTION

Civil engineering structures consist of a bearing structure and walls and a roof. The walls consist of façade walls and panel walls. In the masonry structures, certain walls are also the bearing structure, and there are also other, panel or partition walls which are normally not the bearing ones.

Dynamic characteristics of the bearing structures and dynamic characteristics of the complete buildings differ. Dynamic characteristics of the complete buildings are dynamic characteristics of the bearing structure plus the characteristics of the walls and other bearing elements, as opposed to the dynamic characteristics of the bearing structure itself. Existence of this difference is best observed by testing a building when only its bearing

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structure is in place and when it is complete. The best test results are achieved by testing the bearing structure and the complete building to the action of forced incitation forces which will, however, not lead to the building damage.

The paper will present the influence of panel walls on the dynamic characteristics of the prefabricated structure AMONT, on the test carried out applying ambient oscillations (for instance, action of the wind).

The dynamic testing of the structure defines its real dynamic characteristics, that is, resonant basic tone frequencies in horizontal and vertical directions, forms of vibrations as well as the appropriate damping coefficients. All these parameters represent the starting point for any mathematic modeling of the structures, and provided that certain analytic research has been previously accomplished, they provide a much more accurate stability analysis than it was possible in the design phase.

2. Skeletal Structure Without Panel Walls

The structural system of a building is represented by the spatial two-storey frame. The desired direction at the level of the first floor is divided into four equal spans of 6m, and at the level of the second floor into two spans of 12 m. A total of 8 such frames was arranged at a distance of 10 m.

The longitudinal beams at the level of the floor slab and at the level of the roof, connect these frames so that the play of the structure in space is ensured.

The roof structure is constructed of prefabricated trapezoidal beams, pre-stressed by adhesion, of 10 m in span, in accordance with the AMONT system. The designed roof cover was to be a trapezoidal sheet-metal, but it was not installed when testing and measuring was conducted.

The floor slab was designed as prefabricated reinforced concrete inversed profiles coated by the monolithization layer (a slab reinforced with ribs) the profiles have 10 m in span, and they are produced and installed in accordance with the AMONT system. At the moment of measuring, only the profiles were in place, while the monolithization layer was not finished yet.

The frames in the orthogonal directions were constructed as prefabricated ones in accordance with the AMONT system. The main beam at the roof level were intended to support the trapezoidal elements. Those were T beams of a constant height T – 90 and the inclinations of around 15°. The main beams at the level of the first floor slab were also T beams of a constant height T – 90 and they support the floor slabs. The secondary beams were installed in longitudinal direction, of a constant height of T – 60 at the level of the roof and T – 70 above the ground floor. The prefabricated columns, of a 50x50 cm cross section are fixed in the foundation pockets. The structure is supported by the foundation footing constructed on the site.

The dynamic characteristics of the bearing structure in the transversal and longitudinal directions were determined by the ambient vibration method. The measuring instruments were placed at the very edge of the roof, and at the floor slab level in the predefined points whose arrangement is presented in the Fig. 1.

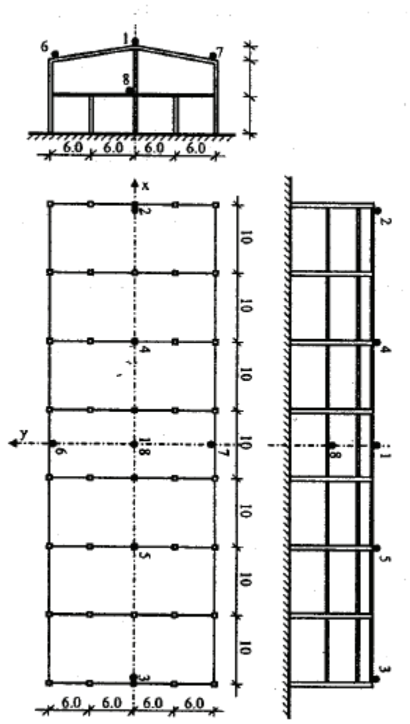

Fig. 1 Arrangement of measuring points for a two storey structure without walls

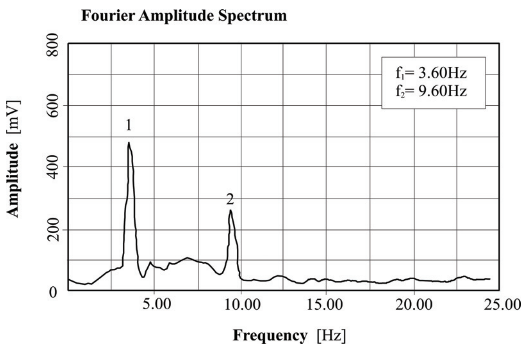

Fig. 2 Fourier amplitude spectrum for measuring of ambient vibrations, in the transversal direction of the skeletal structure without the panel walls

The dominant and resonant frequencies for two orthogonal directions were determined on the basis of the Fourier amplitudes.

Observing the behavior of the structure during measuring, and taking into account the structural system itself, it was concluded that in dynamic terms, the structure behaves approximately as a system with two degrees of freedom, in the observed directions.

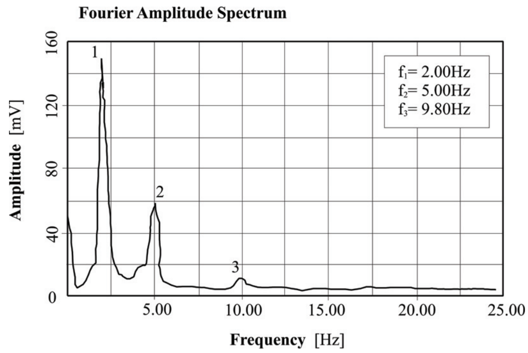

Fig. 3 Fourier amplitude spectrum for measuring of ambient vibrations, in the longitudinal direction of the skeletal structure without the panel walls

The measured values of the resonant periods are slightly higher than those which might be encountered in the available literature for such a type of the structure. This can be explained by the fact that the structure has not been completed, because the walls which may significantly augment rigidity of the structure (they can reduce the oscillation period, in the initial phase of the structural response) are missing.

3. Skeletal Structure With Panel Walls

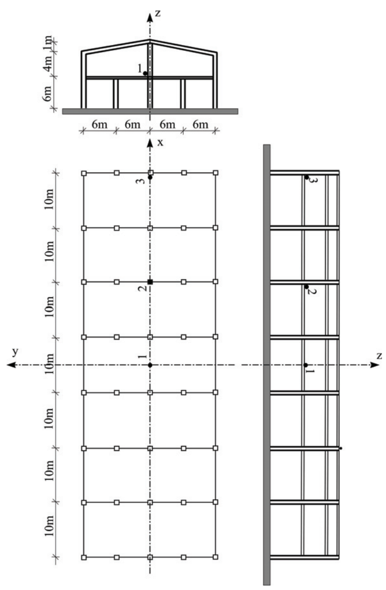

Fig. 4 Arrangement of measuring points for a two-storey structure with panel walls

The structure of this building is the same as the one previously described, but the building in this case has been completed, with façade and panels walls. The measuring instruments were arranged as displayed in Fig. 4, and the obtained test results were presented in Fig. 5 and 6 (both for transversal and longitudinal directions).

According to the obtained Fourier spectra for measuring ambient vibrations in two orthogonal directions for the structure without walls, and for the other with façade and panel walls, significant differences in their own frequencies can be observed. In the transversal direction, the measured frequencies of the first tone are f_l=2.60 Hz for a building without walls (Fig. 2) and f_l=3.60 for the building with walls (Fig. 3), that is, the frequency of oscillations in the second case is 38,46% higher than in the first case.

In the longitudinal direction, the measured frequencies are f_l=2.0 Hz for a building without walls (Fig. 5) and f_l=2.80 for the building with walls (Fig. 6). The difference in this case amounts to 40% (not displayed in the figure). As for the damping coefficient β for the longitudinal direction it is β_l = 0,033 and β_l=0,069 for the buildings with and without walls, respectively, which is, for the buildings in question within the usual range.

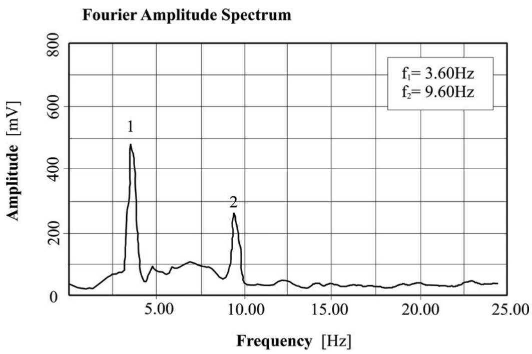

Fig. 5 Fourier amplitude spectrum for measured ambient vibrations, for transversal direction of the skeletal structure with panel walls.

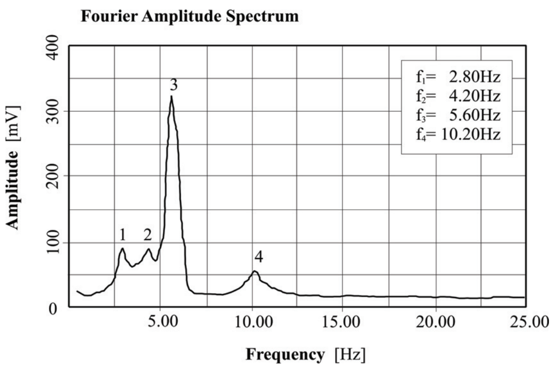

Fig. 6 Fourier amplitude spectrum for measured ambient vibrations, for longitudinal direction of the skeletal structure with panel walls.

4. Some Data About Research After The Montenegro Earthquake

After the earthquake in Montenegro that occurred on 15th of April 1979, its effects on the structures were analyzed in the following locations: Bar, Ulcinj, Sutomore, Petrovac, Budva, Kotor, Tivat, and Herceg Novi. On the mentioned territory data were collected from the characteristic structures, such as: demolished structures, damaged structures, and the structures where structural damage was minimal or there was no damage at all.

In terms of the type and purpose of the structures, diverse structures were included in the analysis, and of various number of storeys as well. From the aspect of structural systems, efforts were made to include all the existing structural systems in the certain areas, starting form traditional masonry and stone structures, to the multi-storey masonry buildings, mixed-type and frame systems, systems with reinforced concrete diaphragms, as well as prefabricated large-panelled systems. Regarding the specific influence the local soil conditions have, in the selection process of the characteristics structures a special attention was paid to the foundation conditions.

Lacking the complete technical documents on the structures and relying on the inspection of the situation on the damaged structures, only the visible damage can be assessed. Very often it cannot provide a truthful picture about the behavior of the structures and about the actual bearing capacity and stability of structures. Yet, it is necessary to investigate in detail the damages or destruction of certain characteristic modern structures.

Analysis of the soil movement registration was carried out in full compliance with the procedure of the strong earthquake processing data developed in IZIIS, Skopje.

With the aid of this analysis of the accelerograph recordings, the corrected data of the recorded velocity, acceleration and displacement of the soil, spectrum of reactions of relative velocity, absolute acceleration, relative displacement, pseudo-relative speed and Fourier amplitude spectrum were obtained.

The response-spectra show maximum values of response, including: displacements, velocities, accelerations, interior forces, stresses and dynamic coefficient of structures with one degree of freedom of movement under the action of certain load. The Response spectra are drawn for the damping of: 0, 2, 5, 10 and 20 % of the critical damping. For the damage of structures resulting from earthquakes, usually the curves with damping values of 5% of the critical one are used. The abscise of the diagram presents time in seconds, whereas the ordinate presents parameters for which the spectrum is drawn. The higher the damping, the higher the values, as it can be seen in the figure 8, which is a recording of the earthquake in Petrovac.

In Fig. 7, the time course of horizontal acceleration, velocity and soil displacement during earthquake in Montenegro, on 15th of April 1979, recorded in Petrovac, NS, can be seen.

$_{\max} a = -441 \, {}^{cm}\!/_{s^2}, \quad _{\max} \upsilon = -40.4 \, {}^{cm}\!/_{s}, \quad _{\max} u = -10.6 cm$

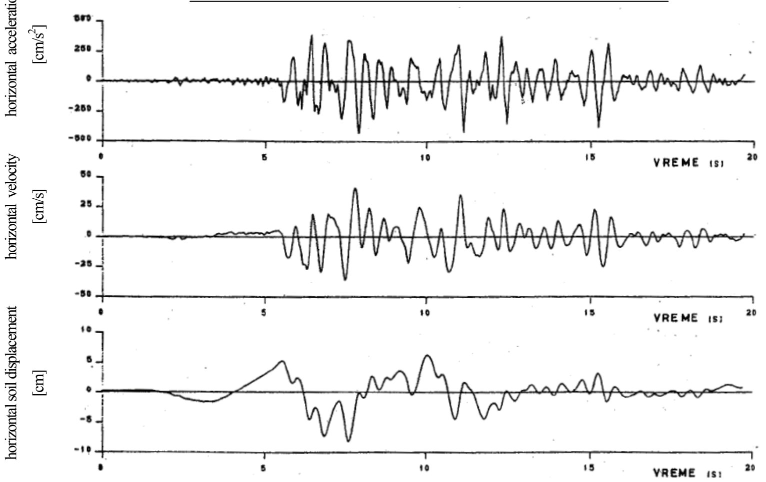

Fig. 7 Time course of horizontal acceleration, velocity and soil displacement during earthquake in Montenegro, on 15th of April 1979, recorded in Petrovac, NS

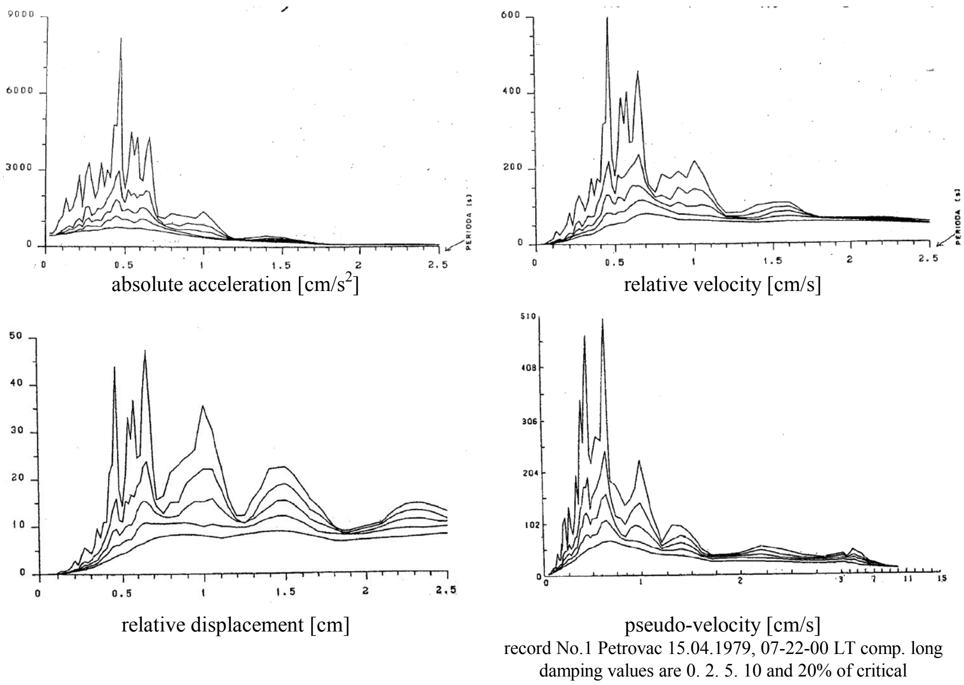

Fig. 8 Spectra of absolute acceleration, relative velocity, relative displacement and pseudo-velocity, recorded in Petrovac, NS Damping is 0, 2, 5 10 and 20% of the critical one.

5. CONCLUSIONS

On the basis of the results of the conducted research of dynamic characteristics of prefabricated reinforced concrete structures of industrial halls constructed in the "AMONT"system, applying the experimental method with ambient vibrations, very useful conclusions were obtained, regarding the influence of panel walls and other elements of completed buildings on the structural response. From the obtained Fourier spectra of measured ambient vibrations, in two orthogonal directions for two industrial halls, both constructed in the "AMONT"structural system, but in different construction phases, one in without walls and one with façade and panel walls, a significant difference in their own frequencies was observed.

Increase of rigidity of a frame structure due to the panel walls should not be neglected in determining the seismic forces design in the initial phase of the earthquake. Regarding the fact that after the initial phase the walls crack and detach from the structure, their rigidity cannot be taken into design with any reliable certainty. In calculation of maximum structural displacements due to the action of seismic forces it is necessary to take into account the previous facts. Reduction of initial rigidity due to cracking of panel walls can significantly increase horizontal displacement of structures. In this case it is necessary to make structural calculations according to the Theory of the Second Order, that is, it is necessary to introduce the influence of the so-called P-δ effect into the calculation; this means that the geometrical non-linearity of the structure should be analyzed.

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ANALIZA PONAŠANJA NOSEĆE KONSTRUKCIJE I ZAVRŠENOG OBJEKTA NA OSNOVU EKSPERIMENTALNIH ISPITIVANJA U PRIRODNOJ VELIČINI

Slavko Zdravković, Dragan Zlatkov, Biljana Mladenović, Tomislav Igić, Nikola Stojić

U radu je ukratko dat prikaz dela sprovedenih eksperimentalnih ispitivanja montažnog armiranobetonskog sistema "AMONT"za izgradnju različitih tipova modernih industriskih hala. Analizirani su rezultati ispitivanja dve industrijske hale, obe izvedene u tom konstruktivnom sistemu ali u različitoj fazi izgradnje, u prirodnoj veličini primenom metode ambijent vibracija. Iz dobijenih Furijeovih spektara za merene ambijent vibracije u dva ortogonalna pravca za konstrukciju bez zidova i istovetnu konstrukciju sa fasadnim i zidovima ispune, uočena je značajan razlika u njihovim sopstvenim frekfencama i izvedeni su zaključci o uticaju zidova ispune na dinamičke karakteristike te ramovske konstrukcije.

Ključne reči: *Montažna armiranobetonska konstrukcija, zidovi ispune, ambijent vibracije, Furijeov spektar*