University "St. Cyril and Methodius", Skopje

Institute of Earthquake Engineering and Engineering Seismology

Report IZIIS 2007-44

IN SITU TESTING OF PRESIDENT PALACE IN BAKU, AZERBEJDZAN, BY AMBIENT VIBRATION MEASUREMENTS

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C O N T E N T S

1. INTRODUCTION

For the needs of SERBAZ Company from Baku, Azerbejdzan, experimental in-situ testing of the President Palace in Baku, Azerbejdzan was performed by ambient vibration measurements in August 2007. The ambient vibration measurements for definition of dynamic characteristics: natural frequencies, mode shapes and damping coefficients of the President Palace in Baku before strengthening by DC90 system have been performed. The signal processing of collected data has been performed by means of ARTeMIS computer program which is specially developed for processing of ambient vibration records and has capability of three dimensional presentation of structural dynamic behaviour.

2. OBJECTIVES OF THE TESTING

The objective of the testing was to investigate dynamic behaviour of the building in environmental conditions (wind excitation) based on which the dynamic properties, such as natural frequencies, mode shapes and damping coefficients could be defined. These parameters are strongly related to prediction of seismic behaviour of the structure under earthquake excitation.

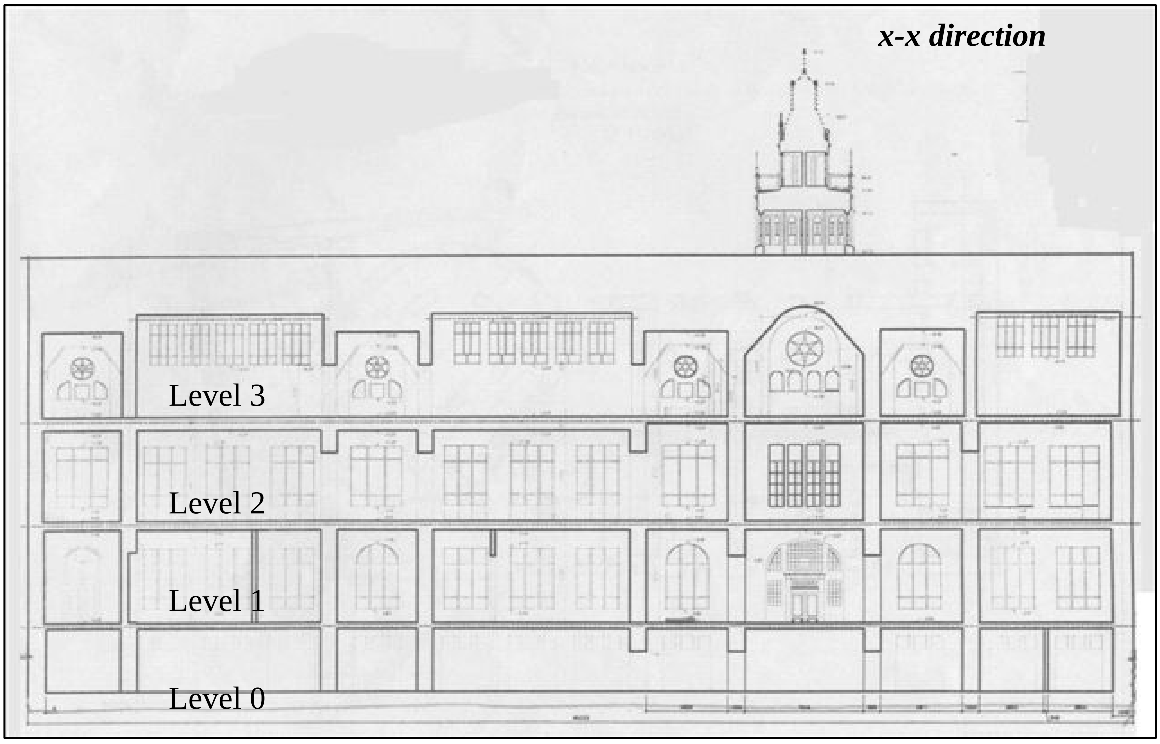
The measurements of dynamic characteristics of building before and after strengthening will give an information about the effect produced by applied strengthening solution in respect to increasing of lateral stiffness as well as damping capacity.

3. DESCRIPTION OF THE PALACE AND POSSITION OF MEASURING POINTS

The building structural system of the building is stone masonry with irregular shape consisting of basement and three levels. Presented in Fig. 1 is the appearance of the building, while on Fig. 2 presented is the enterior of the main entrance. The characteristic vertical sections are presented in Fig. 3.

Fig. 1. The President Palace in Baku

Fig. 2. The main entrance and its interior



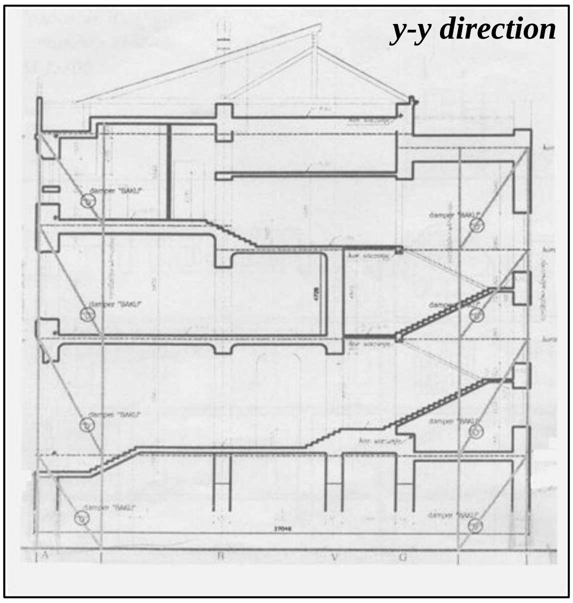


Fig. 3. Vertical cross-sections of the building

The plans of the floors are presented on Figs. 4 and 5 together with the measuring points selected during the measurements. The numeration of points is made by two assignments: the regular number for the measuring point and superscript number for the floor level. For example: 3^1 means point 3 at level 1; 8^3 means point 8 at level 3 etc.

The measurements have been performed in 43 points in two orthogonal directions: x-x (longitudinal) and y-y (transversal) direction, out of which 7 on level 0 (basement), 12 on level 1, 12 on level 2 and 12 on level 3. Spatial presentation of the reference point at level 3 as well as of all measuring points is given on Fig. 7.

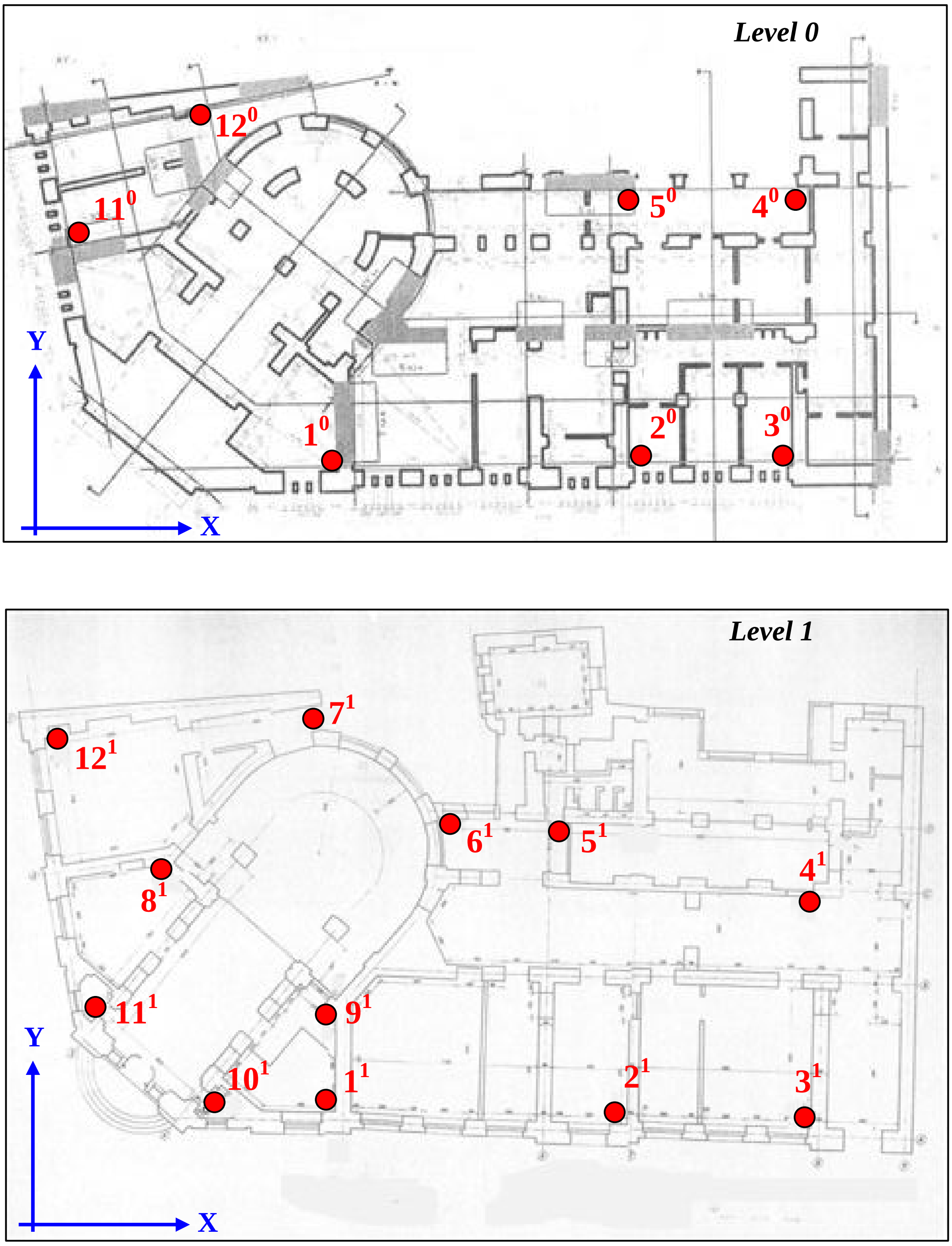


Fig. 4. Distriution of measuring points in plan - level 0 and level 1

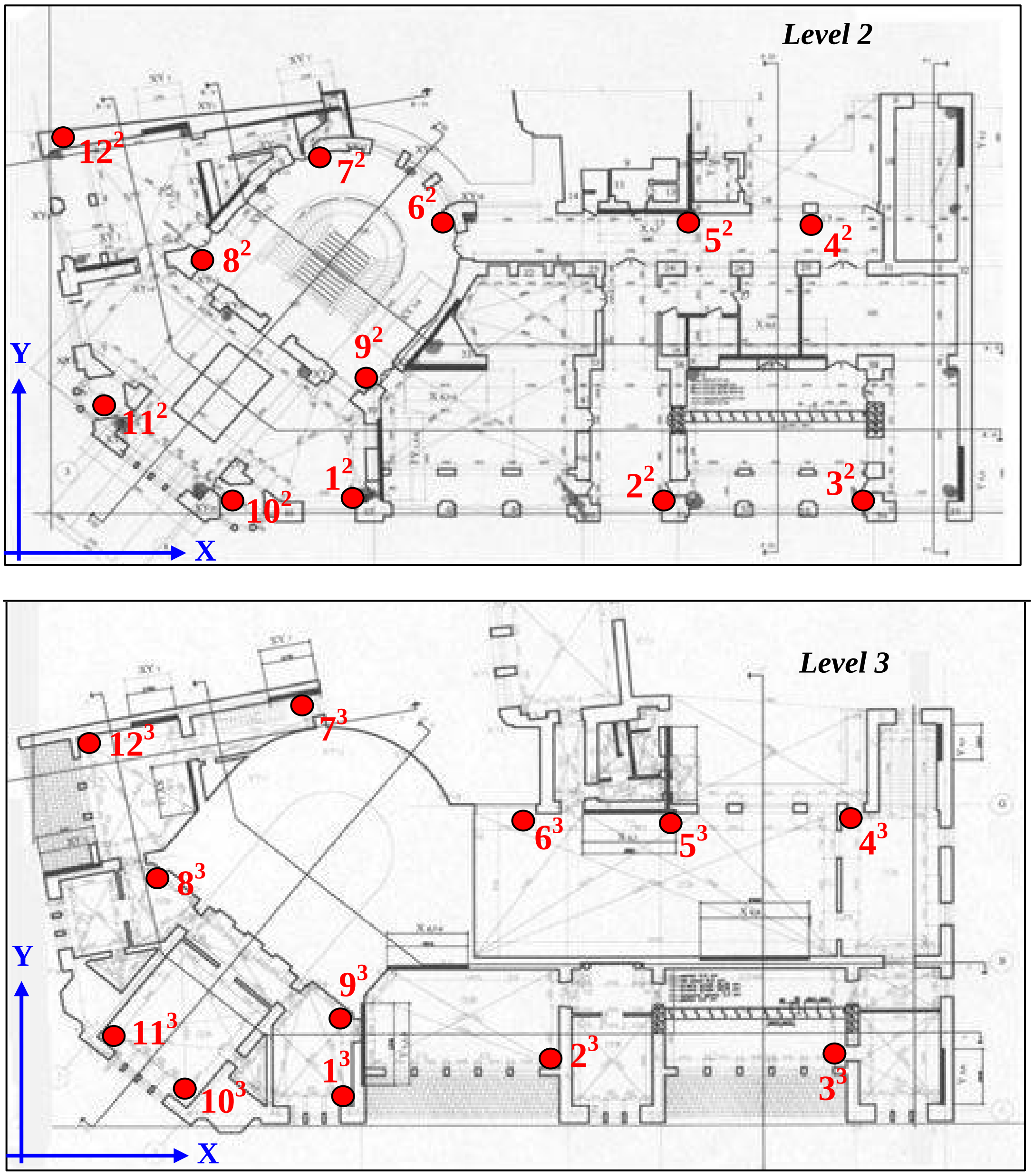


Fig. 5. Distriution of measuring points in plan - level 2 and level 3

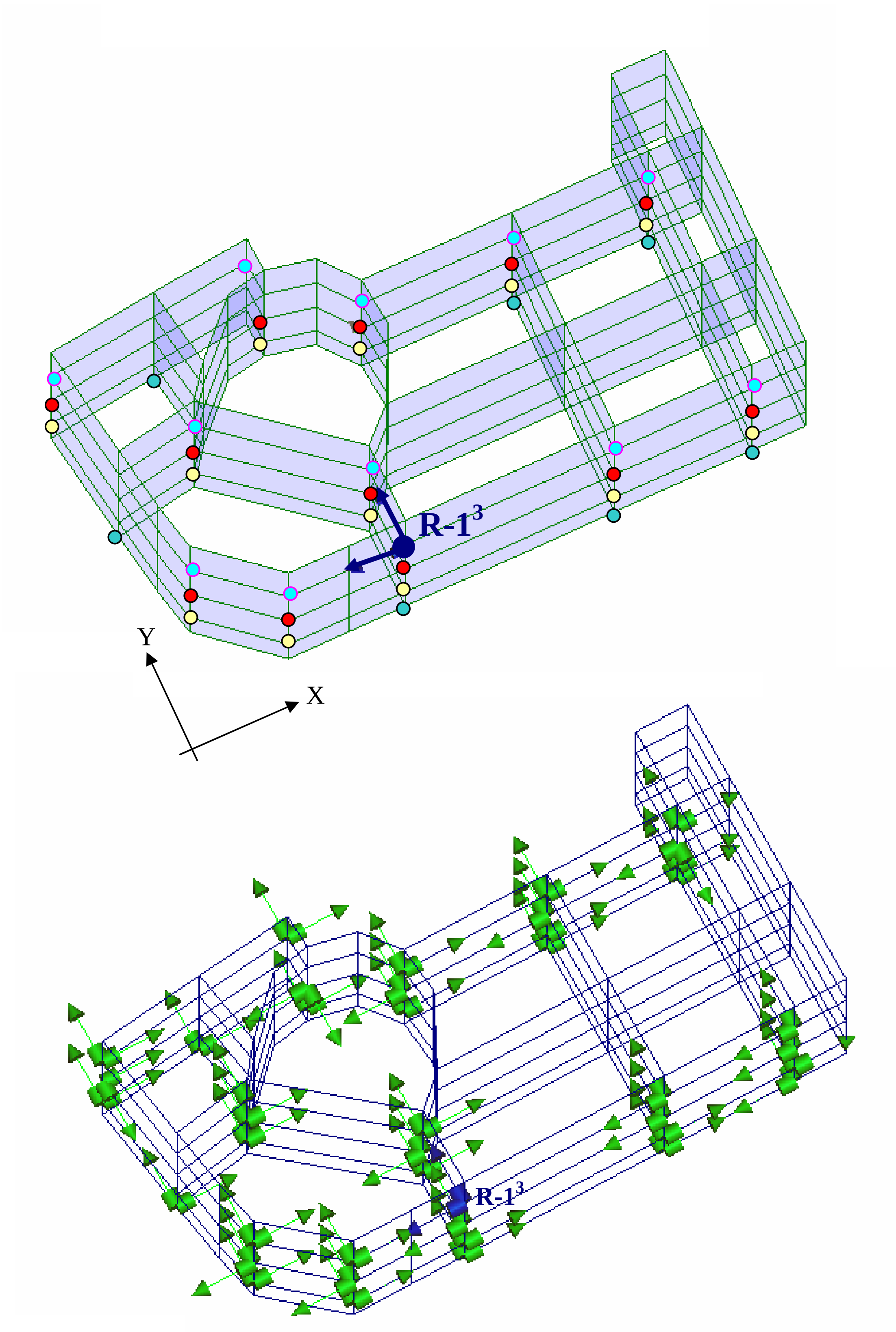


Fig. 6. Spatial presentation of all measuring points on the building together with the reference point R - 1^3 (by ARTeMIS)

4. AMBIENT VIBRATION TESTING PROCEDURE

Dynamic characteristics of the building were obtained by ambient vibration testing method. This is widely applied and popular full-scale testing method for experimental definition of structural dynamic characteristics. It is based on measuring the structural vibrations caused by the ambient, Fig. 7. As ambient forces can be treated the wind, the traffic noise or some other micro-tremor and impulsive forces like wave loading or periodical rotational forces of some automatic machines. The method is very fast and the relatively simple procedure can be performed on a structure in use, without disturbing its normal functioning.

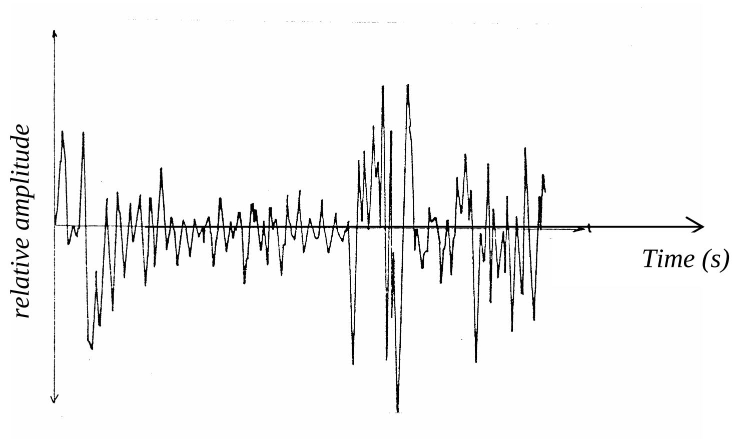


Fig. 7. Time history of vibrations excited by the ambient

The basic assumption used in this method is that the excitation forces are a stationary random process, having an acceptably flat frequency spectrum. In such conditions, the structures will vibrate and their response will contain all their normal modes.

The ambient vibration testing procedure consists of real time recording of the vibrations and processing of the records. The initial test is the dynamic calibration test. During this test all sensors (seismometers) are placed on the same position in the same direction and the signals are recorded simultaneously and Fourier spectra obtained. Resonant frequencies of the structure can be preliminary defined using the dynamic calibration tests, but the final definition of the natural frequencies is possible after obtaining the mode shapes of vibration. After this calibration test, the seismometers are placed at different levels and different points of the structure, but at the same direction, for simultaneous recording. This is necessary for obtaining the mode shapes of vibration. One point is chosen as a reference one, usually at the highest level of the structure. The duration of the recording should be long enough to eliminate the influence of possible non-stochastic excitations which may occur during the test.

5. EQUIPMENT USED FOR THE MEASUREMENTS

For recording of structural vibrations caused by some ambient excitation, a system of seismometers, amplifiers and recorders is used. The seismometer measures the velocity and it has limitations in frequency and amplitude range. The signal from the seismometer through special cables is transmitted to the signal conditioning system which eliminates the effect of higher frequencies. During the ambient vibration measurements of President Palace in Baku, three seismometers *Ranger* type, Kinemetrics product (a), were used and the measured signals were amplified by four channel Signal Conditioner also Kinemetrics product (b). The amplified and filtered signals from the seismometers were than collected by high-speed data acquisition system (c) which transforms the analogue signals to digital. PC and special software for on-line data processing has been used to plot time history and Fourier amplitude spectra of the response at any recorded point (d). Fourier analyzer (e) was also used for quick checking and analyzing of the signals in frequency domain and obtaining the Fourier amplitude spectra (FAS). The equipment used for the measurements is presented on Fig. 8.

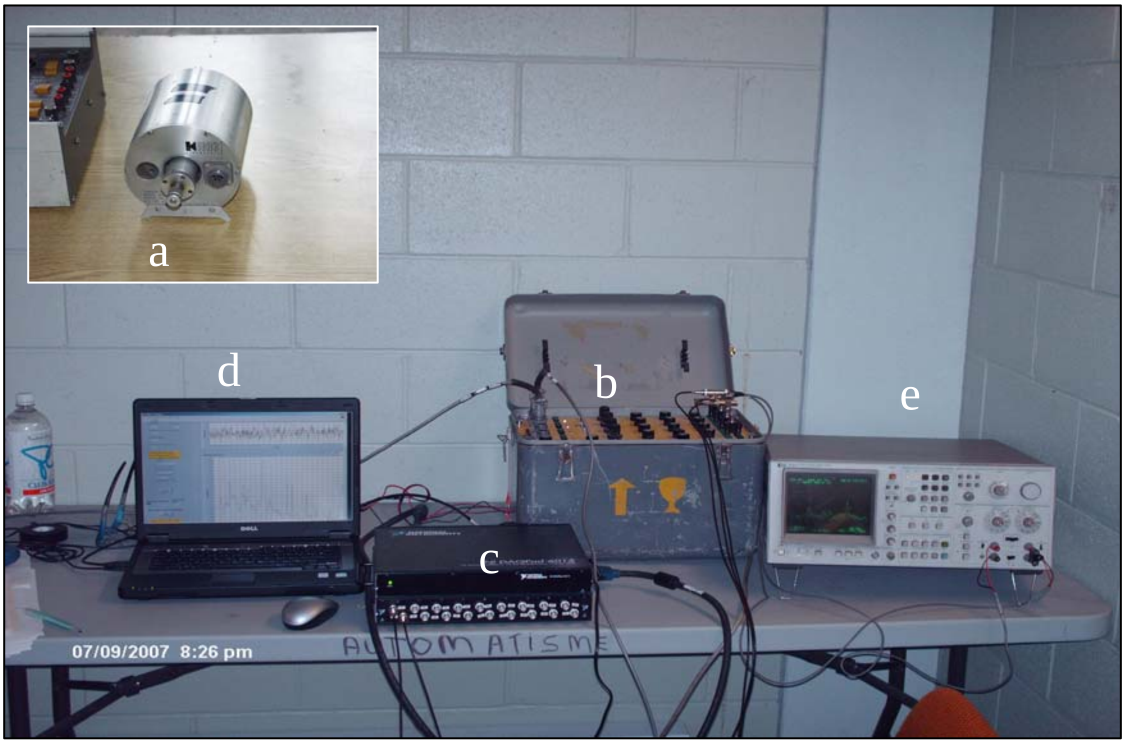


Fig. 8. Equipment for ambient vibration measurements

For post-processing and analysis of the recorded vibrations in all measuring points ARTeMIS software was used. This software is based on the Peak Picking technique and Frequency Domain decomposition and has possibilities for good graphical presentation of the obtained data.

6. EXPERIMENTAL RESULTS

During the experimental testing of the President Palace recorded ambient vibrations in longitudinal and transversal direction were analyzed in frequency domain up to 25 Hz. A total number of 87 tests has been performed, including the dynamic calibration tests at the reference point on level 3. During the data acquisition process, 20 averages have been considered. The time duration of each particular record was 100 seconds and the sampling frequency was 200 samples/sec.

Fourier amplitude spectra (FAS) were obtained for each particular point. Presented on Fig. 9 are the FAS recorded at the reference point 1^3 at level 3, for direction x-x and for direction y-y, respectively. The first resonant frequency is the dominating one, but it can be noticed that beside it there are few more dominating frequencies on the spectra.

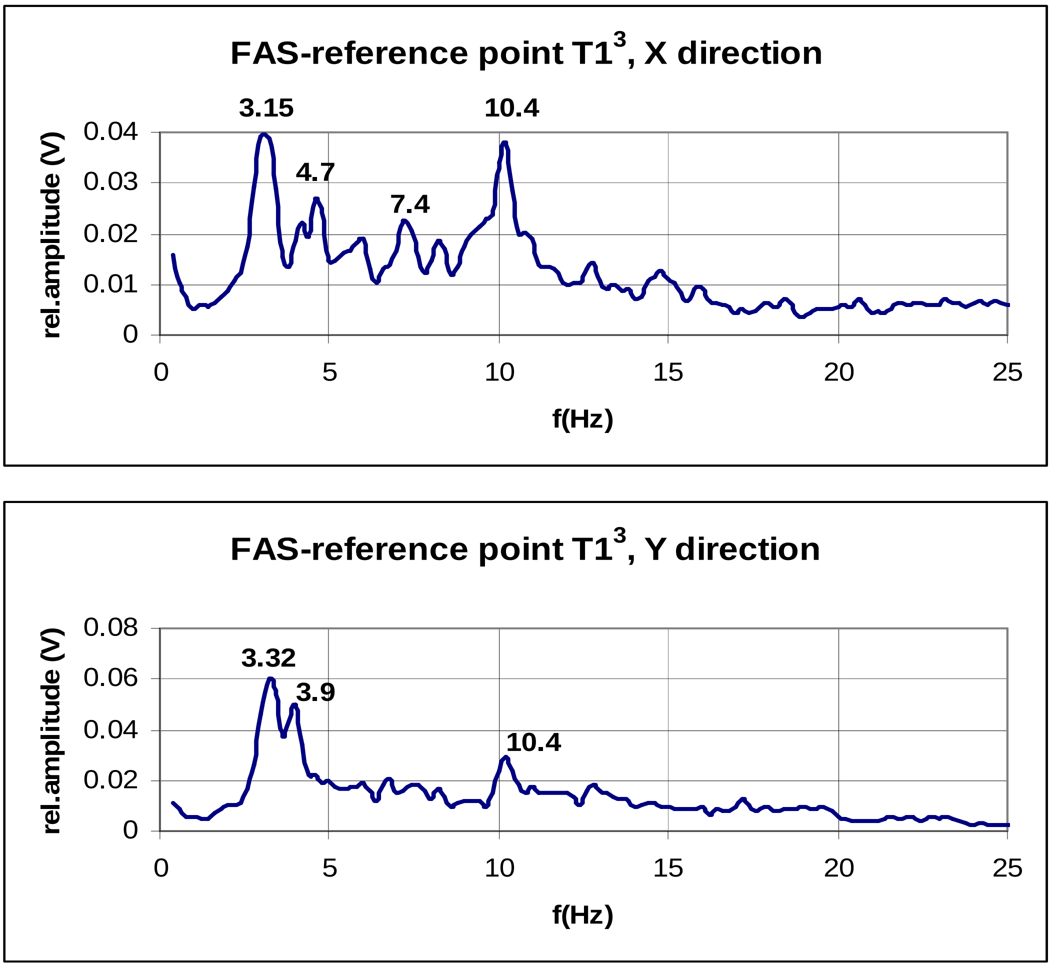


Fig. 9. Fourier Amplitude Spectra recorded at reference point R-1^3

As mentioned before for post-processing of the signals ARTeMIS software was used. Peak picking of the dominant frequencies by ARTeMIS software is presented on Fig. 10, while in Table 1 given are the values of these frequencies as well as the corresponding damping coefficients.

The frequency of 3.15Hz is the first resonant frequency of the building in longitudinal (x-x) direction, while the frequency of 3.32Hz is the first resonant frequency in transversal (y-y) direction. The first torsional frequency is 3.9Hz. The mode shapes of vibration of the building at particular dominant frequencies are presented on Figs. 11 and 12, while the *avi* simulations are given as separate appendix. Considering the obtained spectra as well as the mode shapes of vibration it is obvious that spatial vibrations are dominant for the structure and the torsional influence is prevailing during vibration.

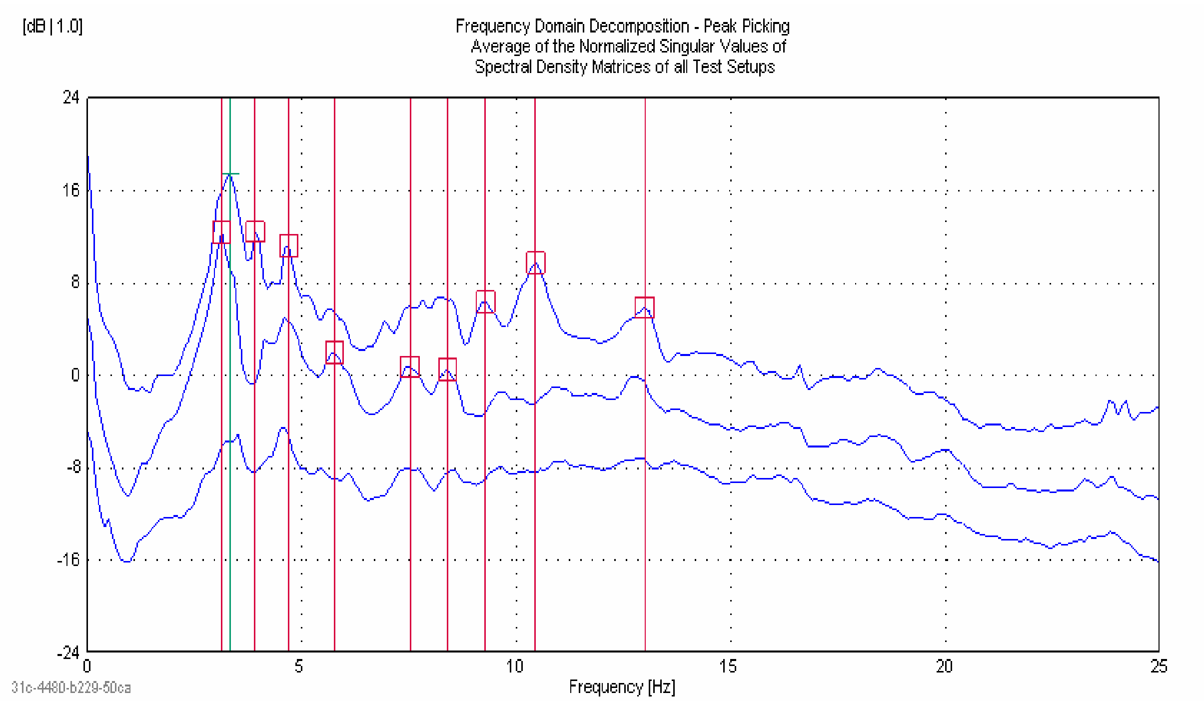


Fig. 10. Peak Picking of the dominant frequencies of the President Palace in Baku

Table 1. Dominant frequencies of the building

mode	frequency (Hz)	damping (%)
Mode 1	3.15	2.4
Mode 2	3.32	3.6
Mode 3	3.9	3.6
Mode 4	4.7	2.1
Mode 5	5.7	1.7
Mode 6	7.42	1.4
Mode 7	8.4	1.3
Mode 8	9.28	1.7
Mode 9	10.45	2.4
Mode 10	13.0	1.1

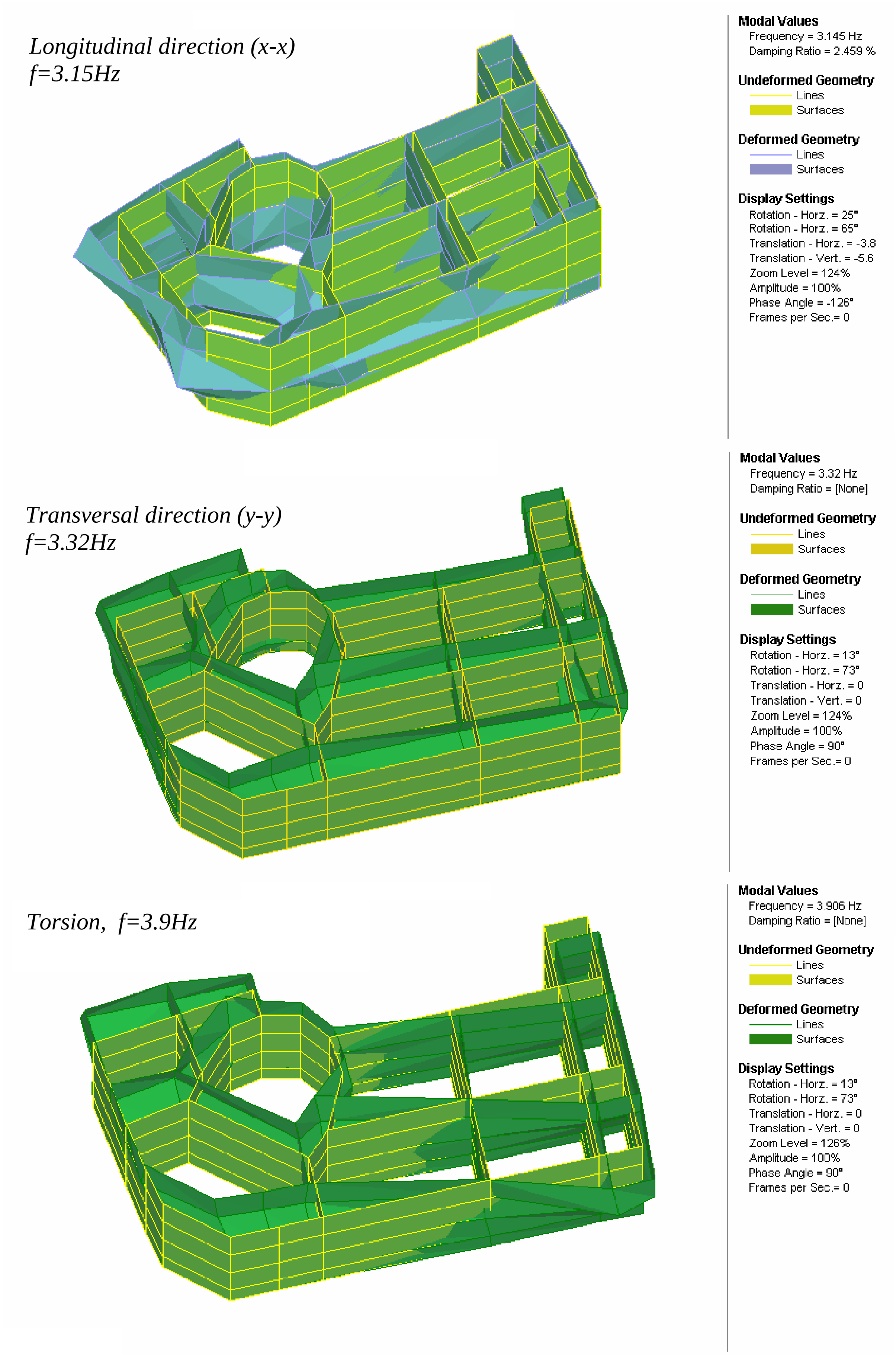
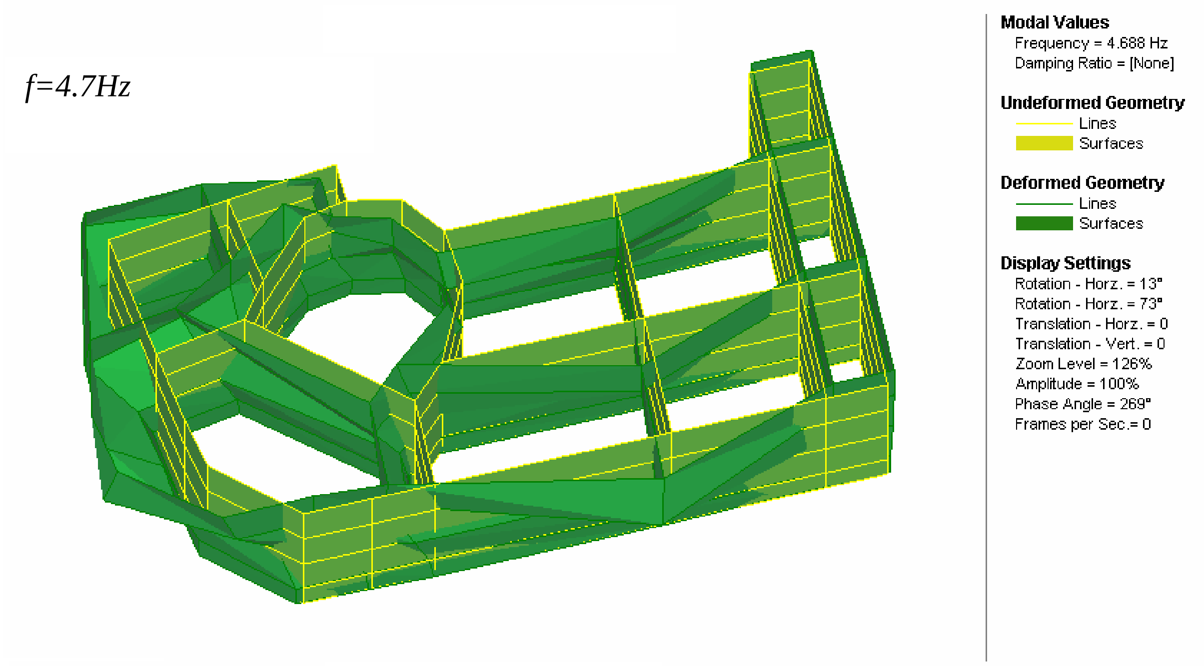
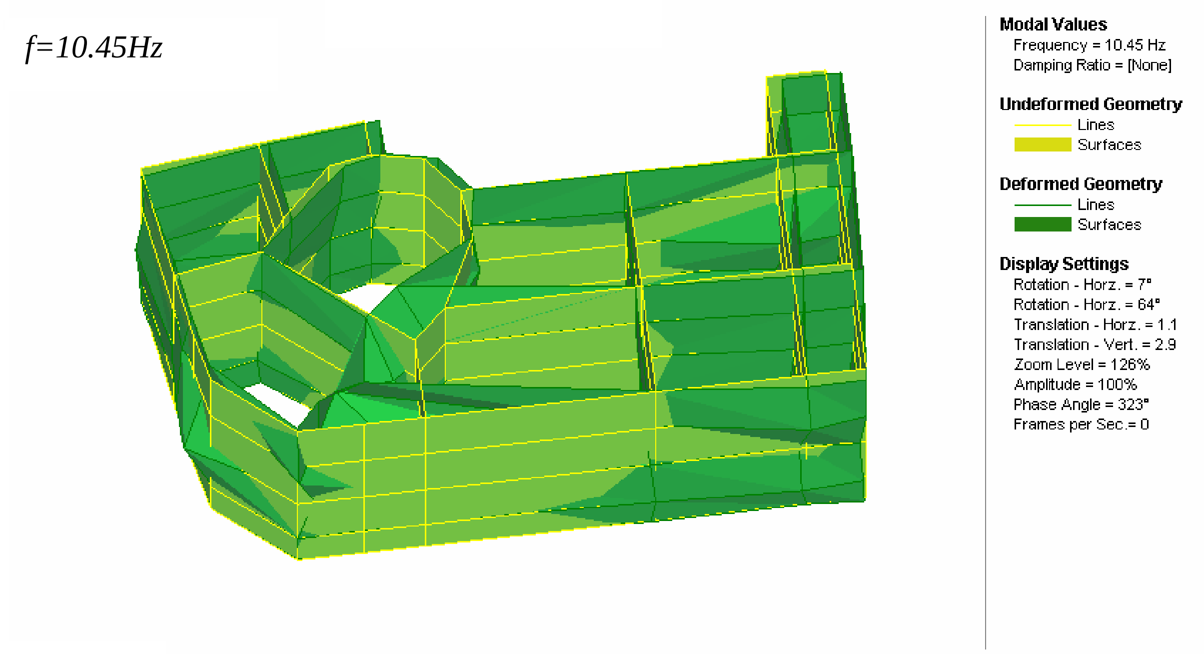


Fig. 11. Mode shapes of vibration at resonant frequencies


f=4.7Hz
Modal Values
Frequency = 4.688 Hz
Damping Ratio = [None]
Undeformed Geometry
Lines
Surfaces
Deformed Geometry
Lines
Surfaces
Display Settings
Rotation - Horz. = 13°
Rotation - Horz. = 73°
Translation - Horz. = 0
Translation - Vert. = 0
Zoom Level = 126%
Amplitude = 100%
Phase Angle = 269°
Frames per Sec.= 0


f=10.45Hz
Modal Values
Frequency = 10.45 Hz
Damping Ratio = [None]
Undeformed Geometry
Lines
Surfaces
Deformed Geometry
Lines
Surfaces
Display Settings
Rotation - Horz. = 7°
Rotation - Horz. = 64°
Translation - Horz. = 1.1
Translation - Vert. = 2.9
Zoom Level = 126%
Amplitude = 100%
Phase Angle = 323°
Frames per Sec.= 0

7. CONCLUSIONS

- The dynamic testing of the President Palace in Baku, Azerbejdzan been performed by means of ambient vibration method in August 2007, before its strengthening by DC90 system;
- The measurements have been performed in two orthogonal directions;
- Total of 87 tests have been performed giving the comprehensive experimental data related to dynamic properties of the structure.
- The investigated frequency range was from 0-25 Hz.
- The dominating natural frequencies for the structure are the following:

  - First natural frequency for vibration in longitudinal direction is 3.15Hz;

  - First natural frequency for vibration in transversal direction is 3.32Hz;

  - First natural frequency for torsional vibration is 3.9Hz;

  - Dominant frequencies of higher modes are: 4.7Hz, 5.7Hz, 7.6Hz, 8.4Hz, 9.28Hz, 10.45Hz and 13.0Hz;

- The damping coefficients are in range 1.5 to 3.7% of critical damping and these values are lower than ussualy expexted for masonry structures;
- Considering the shapes of vibrations, except for vibration in the first mode for transversal direction, it is obvious that the structure is vibrating in complex way with significant torsional effects. Considering the iregular geometry and plan of the building this effects are expected;
- The comparison of measured dynamic characteristics of building before and after strengthening by DC90 system will give an information about the effect produced by applied strengthening solution in respect to increasing of lateral stiffness as well as damping capacity.
- Obtained experimental data represent a good and comprehensive base for further numerical modelling of the seismic response of the building.