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DETERMINATION OF DYNAMIC CHARACTERISTICS OF RESIDENTIAL FRAME BUILDINGS OF THE SINGLE TYPICAL SERIES IN DIFFERENT GROUND CONDITIONS BY EXPERIMENTAL METHOD

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The article is devoted to the study of the oscillations of buildings of the typical series 111 in various soil conditions using seismic sensors and a logger developed by IGES. By means of microtremor records, spectral analysis was performed, dynamical features of buildings and soils have been determined, and the peculiarities of the joint work of the building and ground have been revealed based on the results.

Keywords: dynamic characteristics, period of vibrations, spectral analysis, Fourier spectrum, mode shapes, buildings of the series 111

Introduction

Testing of the constructions of typical buildings with prefabricated reinforced concrete frame systems and the interaction between soil (ground) and structure is an important scientific-practical task. When implementing anti-seismic measures in building designs it is necessary to take into account the values of periods of natural vibrations of the buildings and structures as well as the values of the dominant vibration periods of the soil so that these values do not match since in the case of seismic effects it will lead to the occurrence of resonance phenomena, as well as the collapse of buildings.

During the 1988 Spitak earthquake, residential 9 story buildings of the typical series 111 with prefabricated reinforced concrete frame systems were subjected to the major collapse in Gyumri. 95% of 133 buildings of this kind erected in Gyumri have not survived and the rest received strong deformations and were later demolished. Meanwhile, none of the 108 buildings of the same type erected in Vanadzor didn’t collapse, nor they didn’t even get serious injuries. The mass destruction of such buildings in Gyumri is explained with a combination of a number of factors [1].

The results of the dynamic tests of these buildings, which were carried out before the Spitak earthquake in 1978-1987 showed that the values of their periods of natural vibrations range from 0.55-0.75 sec. Vibrations of such values of periods have been recorded in Gyumri in 1988 during the December 31 earthquake (aftershock). Immediately after the 1988 Spitak Earthquake, the results of the Japanese researchers, who arrived in the disaster zone, have shown that the values of the dominant vibration periods of the soil in Gyumri range from 0.5 to 0.6 sec, in Spitak 0.2-0.3 seconds and in Vanadzor 0.2-0.4 seconds [12].

After the earthquake, experiments were also carried out on the buildings of different types and the results obtained were even greater. Thus, the values periods of natural vibrations for the buildings of the 111 series were obtained in the range of 0.8-1.2 s [3], which shows that the stiffness of these buildings has significantly decreased.

Since the 1970s, most of the buildings of this series have been erected in a number of cities of Armenia, especially in Yerevan, Gyumri and Vanadzor. The construction of the buildings of the typical series 111 was banned after the earthquake, as the greatest human and material losses were caused by the collapse of these buildings in Gyumri.

Statement of the problem

The aim of the study is to investigate the dynamic features of the behavior of two residential 9 story buildings of the typical series 111 erected on different ground conditions, based on the results obtained from the experiments of microtremor using the super sensitive seismic sensors and the logger developed by the IGES. Its implementation involves the solution of the following tasks:

1. obtain the actual dynamic characteristics of the buildings,
2. investigate the allocation of peak values of natural vibrations’ amplitudes in constructive elements,
3. identify the peculiarities of the joint work of the building and the soil.

One of the most important advantages of microtremor research is that the number of recorded micro-pulses on Earth's surface and buildings and structures is too large, so in a short period of time great information can be obtained for analysis [5,9]. This information allows to solve a number of important scientific and practical issues [6,7,9,10].

The tested buildings are located on different soils: basalt and pebbles, the first building is located in Malatia-Sebastia administrative district and the second is in Shengavit. The building №1 has been erected in 1983 and is located at Babajanyan 23/1 (Fig.1a). The building is a typical 111-point structure with IIS-04 series construction. The building is square with 18.0 × 18.0 m in size (Fig.2a), it has one entrance, basement and overground 9 floors with a height of 29 m (Fig.2b), the height of the floor is 3 m. The basis of the foundation ground is the basalt soil.

Fig. 1. Views of the a) building №1, b) building №2

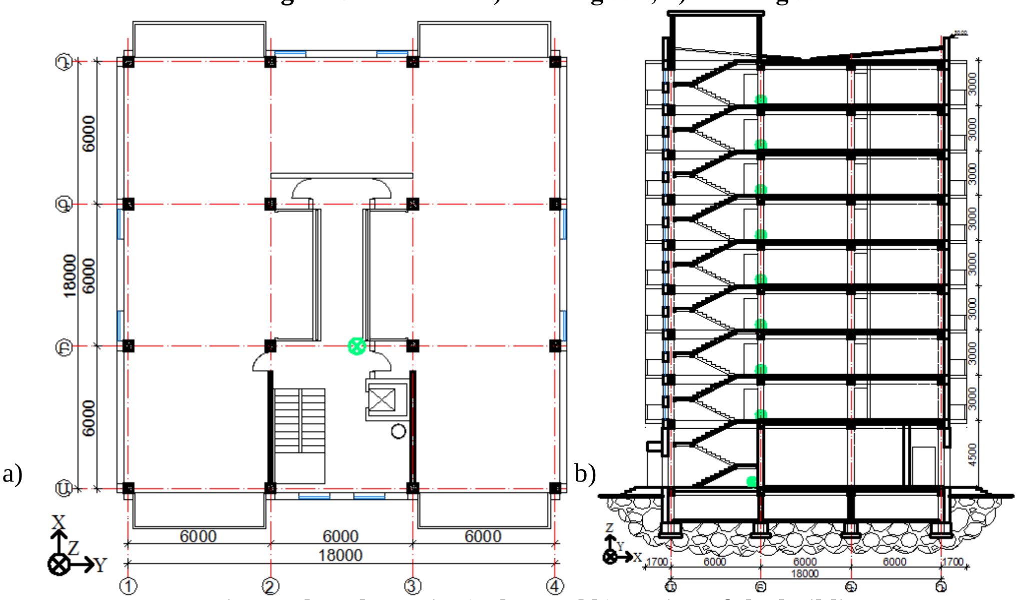

Fig. 2. The schematic a) plan and b) section of the buildings

The building's constructive system is framed. The foundations are isolated spread footings under individual columns from prefabricated reinforced concrete. Columns and beams are from prefabricated reinforced concrete with 400×400 mm and 400×530 mm in size. Shear walls and internal staircase are also prefabricated reinforced concrete. The covers are executed with precast voided floor slabs. The interior walls were installed with masonry of hollow concrete blocks. The roof is terraced/flat with rolling-lamellar waterproof cover and with organized water drainage.

The building №2 was erected in 1976 and is located at Sharur 24/3 (Fig.1b). It is a building of the same 111 series as the building №1. The basis of the foundation ground is the pebbles soil.

Results of the study

Measurements were made by means of a mobile seismic station consisting of three receivers - seismic sensors CM-3 (two horizontal (H) - N-S, E-W and one vertical component (V) – Z), 8 input logger, powered by IGES, with the wireless network that provides connectivity with a laptop [5]. This device (logger) enables online viewing of records that are displayed on the notebook monitor by using specially developed software. The registration frequency is 200 samples per second.

The same experimental works were carried out for these two buildings. Instrumental observations, measurements and microtremor recording were performed on certain sections of buildings (on each floor) and in the surrounding area for the study of the dynamic characteristics of the structure and soils (Fig.3). A spectral analysis was performed based on data from instrumental recordings.

a) b)

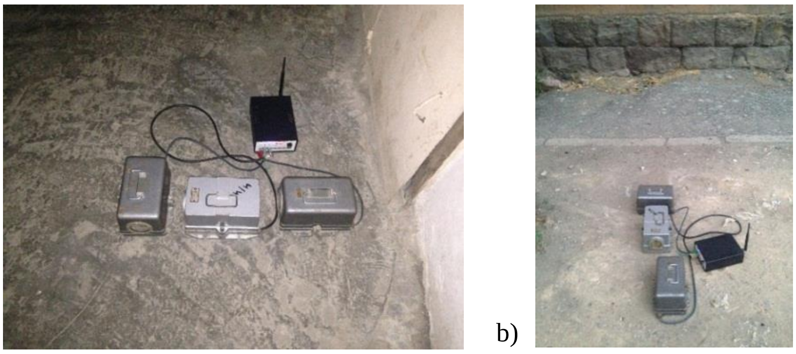

Fig. 3. The location of the seismic sensors a) in the building and b) on the soil

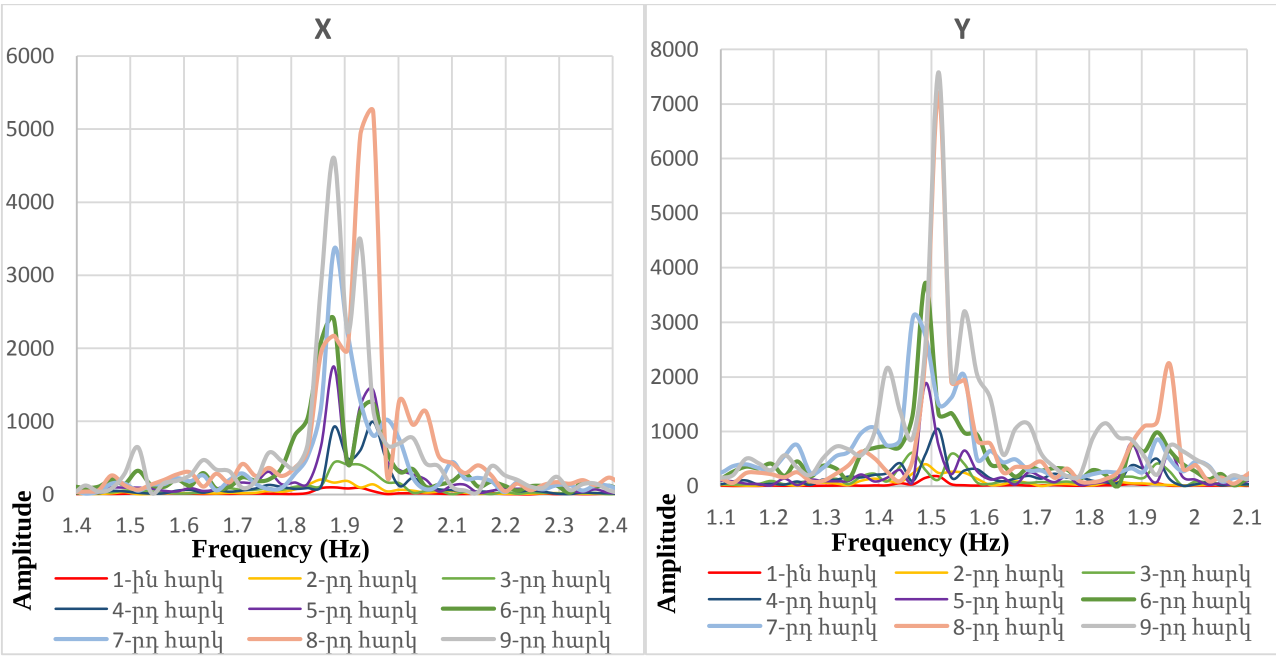

Fig. 4. Comparison of Fourier spectra of components X and Y of all floors of Building №1

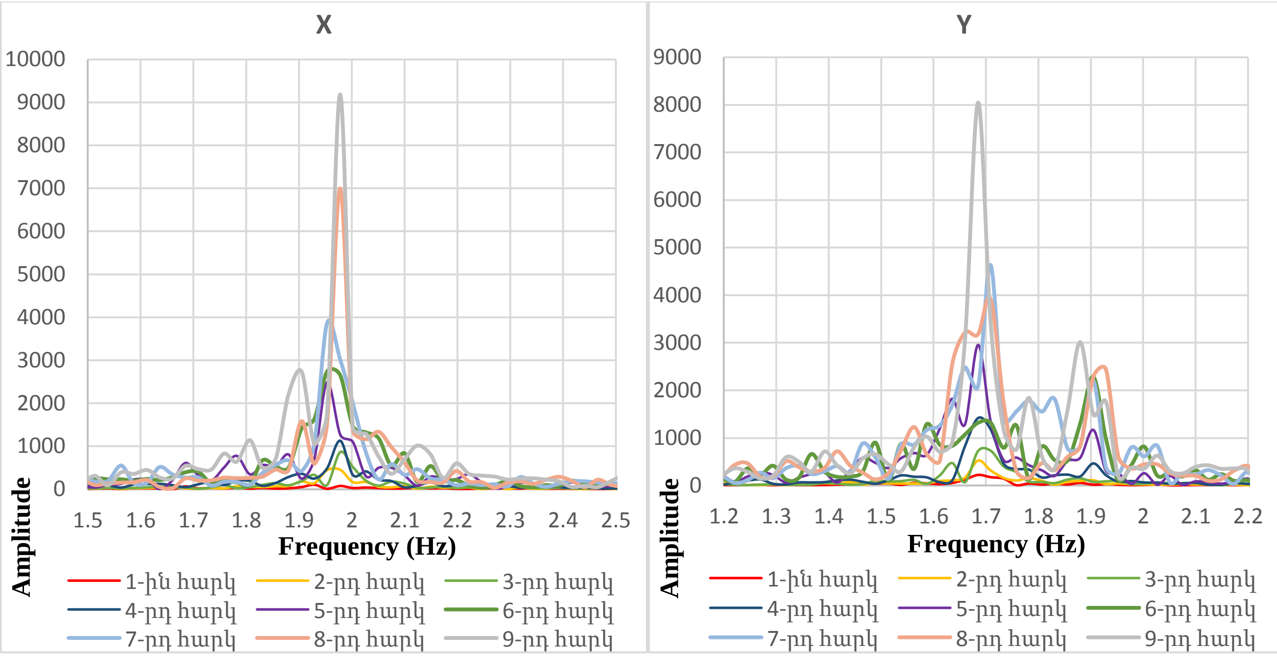

Fig. 5. Comparison of Fourier spectra of components X and Y of all floors of Building №2

Experimental values of buildings, including amplitudes of buildings vibrations in two vertical horizontals and one vertical directions are given in Table 1 and Table 2.

Table 1

	The building №1								
	X			Y			Z		
Floor	Frequency (Hz)	Amplit.	Period (sec)	Frequency (Hz)	Amplit.	Period (sec)	Frequency (Hz)	Amplit.	Period (sec)
soil	8.253	320.22	0.121	8.253	1093	0.121	8.253	940.15	0.121
1	1.88	95.04	0.532	1.514	178.22	0.661	1.88	99.74	0.532
2	1.856	203.61	0.539	1.489	404.43	0.672	1.489	42.28	0.672
3	1.88	437.24	0.532	1.465	611.72	0.683	1.929	74.69	0.518
4	1.953	997.63	0.512	1.514	1045	0.661	1.929	112.28	0.518
5	1.88	1749	0.532	1.489	1879	0.672	1.953	55.94	0.512
6	1.88	2385	0.532	1.489	3727	0.672	1.514	118.11	0.661
7	1.88	3360	0.532	1.465	3086	0.683	1.465	107.5	0.683
8	1.88	5229	0.532	1.514	7214	0.661	1.514	307.97	0.661
9	1.88	4602	0.532	1.514	7580	0.661	1.514	330.785	0.661
average	**1.885**	**-**	**0.530**	**1.495**	**-**	**0.669**	**1.687**	**-**	**0.602**

Table 2

	The building №2								
	X			Y			Z		
Floor	Frequency (Hz)	Amplit.	Period (sec)	Frequency (Hz)	Amplit.	Period (sec)	Frequency (Hz)	Amplit.	Period (sec)
soil	1.978	68.71	0.506	1.685	49.86	0.593	1.978	72.66	0.506
1	1.929	104.59	0.518	1.685	222.5	0.593	1.978	91.61	0.506
2	1.978	452.87	0.506	1.685	525.28	0.593	1.685	96.34	0.593
3	1.978	863.41	0.506	1.685	726.47	0.593	1.685	116.92	0.593
4	1.978	1129	0.506	1.685	1418	0.593	1.709	134.7	0.585
5	1.953	2486	0.512	1.685	2955	0.593	1.685	281.41	0.593
6	1.953	2736	0.512	1.905	2284	0.525	1.978	98.46	0.506
7	1.953	3857	0.512	1.709	4633	0.585	1.709	336.25	0.585
8	1.978	6996	0.506	1.709	3914	0.585	1.929	143.53	0.518
9	1.978	9184	0.506	1.685	8047	0.593	1.978	325.46	0.506
average	**1.964**	**-**	**0.509**	**1.715**	**-**	**0.584**	**1.815**	**-**	**0.554**

Analysis of the data obtained for building №1 shows that the average values of the building's periods of natural vibrations: in the direction of X equals 0.53 sec (frequency: 1.885 Hz); in the direction of Y equals 0.669 seconds (frequency: 1.495 Hz) and the Z-direction diffraction is great, with the peak obtained at 1.514 Hz, i.e. 0.661 sec. Comparing with the calculated values of the first form of the horizontal vibrations T_1 in the normative document [2]:

- for reinforced concrete frame with shear wall structural system buildings:

$$T_1 = 0.06n = 0.06 \times 9 = 0.54 \text{ (sec)}$$

it turns out that the periods of natural vibrations of the building in the X direction are approximately equal to the normative value, with a slight difference. The average value of the logarithmic decrements of the building's natural vibrations' basic tone in the direction of X is 0.128, in the direction Y is 0.109, and in the direction of Z is 0.101.

The value of the dominant vibration periods of the soil is 0.121 sec (frequency: 8.253 Hz) in the direction of all the components, with a striking peak. The value of the logarithmic decrements in the direction of all the components equals 0.009. As seen from the values obtained, the period of natural vibrations of the building essentially differs from the dominant vibration periods of the soil more than 1.5 times, therefore, the condition of the point 7.1.8 of “ՀՀՇՆ II-2.02–2006” normative document [2] is satisfied.

Analysis of the data obtained for building №2 shows that the average values of the building's periods of natural vibrations: in the direction of X equals 0.509 sec (frequency: 1.964 Hz); in the direction of Y equals 0.584 seconds (frequency: 1.715 Hz) and the Z-direction diffraction is great, with the peak obtained at 1.978 Hz, i.e. 0.506 sec. Comparing with the calculated values of the first form of the horizontal vibrations T_1 in the normative document [2]: $T_1 = 0.54$ (sec) it turns out that the periods of natural vibrations of the building in the X direction are approximately equal to the normative value, with a slight difference. The average value of the logarithmic decrements of the building's natural vibrations basic tone in the direction of X is 0.084, in the direction Y is 0.113, and in the direction of Z is 0.09.

The Fourier spectrum has been constructed in the direction of all the components of the soil microtremor data processing of this location and there are no bright peaks in the spectrum, but many peaks with small amplitudes. The values of the basic tone’s period coincide with the values of periods the building vibrations in the X and Y directions. It can be regarded as a tone transmitted from the building vibrations. By the way, the amplitudes of these frequencies are higher than the amplitude of the second tone frequencies. The values of the second tone’s periods are within the range of 0.125-0.135 sec, which is also well expressed in the spectra of Z of the building vibrations. Here are the peculiarities of the joint work of the building and the ground.

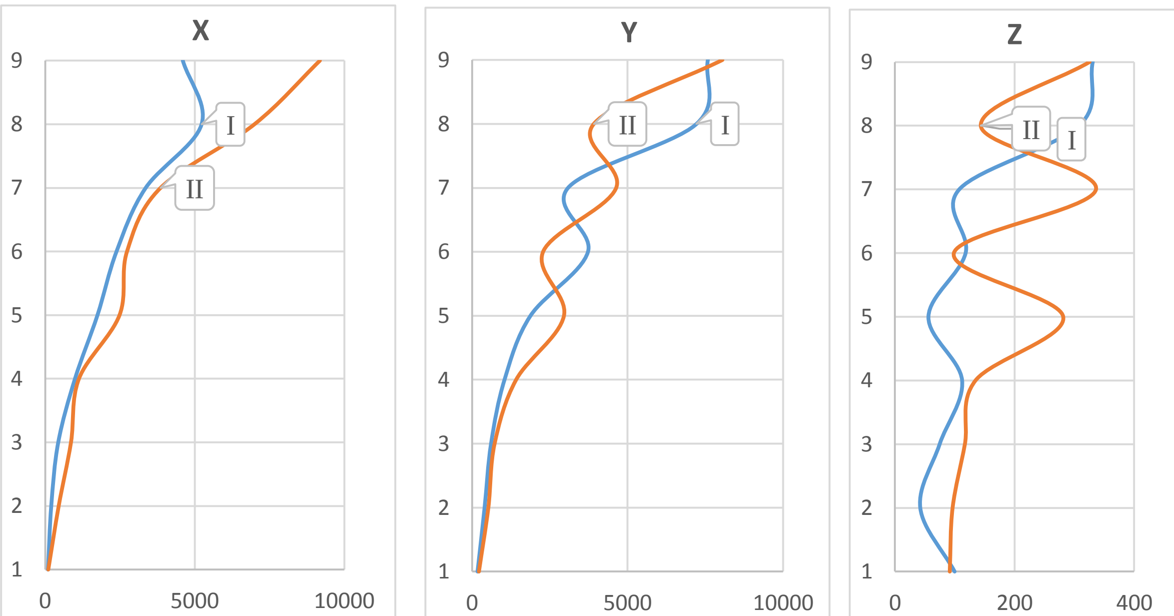

Fig. 6. Diagrams of allocation of peak values of natural vibrations' amplitudes to the floors (I - Building №1, II - Building №2)

The allocation of peak values of natural vibrations' amplitudes in constructive elements has been investigated. From the diagrams, it is clear that the buildings up to the 4th floor have a look of the first mode shapes of vibrations, and in the upper floors, there are several shapes of mode, even 4 forms.

Conclusion

- Dynamic behavioral peculiarities of two 9 story buildings of the same 111 series with different soil conditions were studied by field tests, 56 spectra of microtremor recordings were developed and analyzed.
- The actual dynamics characteristics of the basic tone of these buildings and their foundations, their natural vibrations of the buildings and the logarithmic decrements' values according to X, Y, Z components that can be used to assess the technical condition of the buildings and their material passport.
- Although the plan of the buildings looks like a square, however, the Y-direction values of the periods are greater (not so large) than that of X. This can be explained by the existence of the shear walls.
- The peculiarities of the joint work of the building and the ground have been investigated. It has been found that in the case of basalt soil, the average value of the periods of natural vibrations of the building is greater than the building erected on pebbles soil.
- Comparing the results of the two buildings, we can conclude that there are no resonance phenomena in buildings of 111 series erected on basalt soils, but in the case of more fragile ground, the probability of this phenomenon increases.
- In the future, an attempt will be made to detect the actual dynamic characteristics of similar buildings erected on other soil conditions and to identify the values of their periods of natural vibrations in the fragile soils.

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ՏԱՐԲԵՐ ԳՐՈՒՆՏԱՅԻՆ ՊԱՅՄԱՆՆԵՐՈՒՄ ԳՏՆՎՈՂ ՄԻԵՎՆՈՒՅՆ ՏԻՊԱՅԻՆ ՍԵՐԻԱՅԻ ԲՆԱԿԵԼԻ ԿԱՐԿԱՍԱՅԻՆ ՇԵՆՔԵՐԻ ԴԻՆԱՄԻԿ ԲՆՈՒԹԱԳՐԵՐԻ ՈՐՈՇՈՒՄԸ ՓՈՐՁԱՐԱՐԱԿԱՆ ԵՂԱՆԱԿՈՎ

Հ.Յ. Հայրապետյան

ՀՀ ԳԱԱ Ա.Նազարովի անվ. Երկրաֆիզիկայի և ինժեներային սեյսմաբանության ինստիտուտ, Գյումրի

Հոդվածը նվիրված է տարբեր գրունտային պայմաններում գտնվող տիպային 111 սերիայի 2 շենքերի տատանումների առանձնահատկությունների ուսումնասիրման խնդրին, ԵԻՍԻ-ի կողմից հատուկ մշակված սեյսմիկ տվիչների և գրանցող սարքի միջոցով։ Միկրոսեյսմների գրանցումների միջոցով կատարվել է սպեկտրալ վերլուծություն, որոշվել են շենքերի և գրունտների դինամիկական վարքի առանձնահատկությունները և ստացված արդյունքներով բացահայտվել են շենքերի և գրունտների համատեղ աշխատանքի առանձնահատկությունները:

Բանալի բառեր. դինամիկական բնութագրեր, տատանումների պարբերություն, սպեկտրալ վերլուծություն, Ֆուրյեի սպեկտր, տատանման ձևեր, 111 սերիայի շենքեր

ОПРЕДЕЛЕНИЕ ДИНАМИЧЕСКИХ ХАРАКТЕРИСТИК ЖИЛЫХ КАРКАСНЫХ ЗДАНИЙ ОДИНАКОВОЙ ТИПОВОЙ СЕРИИ В РАЗЛИЧНЫХ ГРУНТОВЫХ УСЛОВИЯХ ЭКСПЕРИМЕНТАЛЬНЫМ СПОСОБОМ

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Статья посвящена вопросу изучения колебаний зданий типовой серий 111 в различных грунтовых условиях с помощью сейсмических датчиков и регистратора, разработанными ИГИС. Средством записей микросейм был выполнен спектральный анализ, были определены динамически особенности зданий и грунтов, по полученным результатам выявлены особенности совместной работы здания и грунта.

Ключевые слова: динамические характеристики, период колебаний, спектральный анализ, спектр Фурье, формы колебаний, здания 111 серии