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MODELING OF VIBRATIONS IN A BUILDING STRUCTURE WITH RUBBER-METAL SUPPORTS

There are presented the experimental results for the layout of the two-storied building made in the scale of 1:10. There is analyzed the influence of the rubber-metal supports in the monolithic construction on the oscillations in its base. The changes in the oscillation frequencies depending on the hardness of used rubber are considered. The experimental results demonstrated the advantages of using less hard rubber.

Keywords: layout, rubber-metal supports, vibrometer, vibration.

Introduction. Bearings, dampers, hydraulic and pneumatic constructions and other devices are used to protect buildings. The vibrations can be caused by an earth seismic wave and by the technogenic vibrations (from the railway, highway, construction machinery). The rubber metal supports are used as seismic protection systems or seismic isolation equipment [1–3]. The detailed scheme of such supports [4] depends on the elastic properties of the rubber including vibration frequencies. Rubber metal supports (RMS) are located under the base of the building columns. As specified in [5, 6] the function of RMS is to perceive on the ground the entire weight of the building and vibration occurrence of horizontal movements. The elastic properties of the rubber allow the movement from the upper support plate to the lower one without damage to the buildings [7–9].

Based on the program complex "Lira" in the articles [1, 3] the effect of the building seismic vibrations is found to be 9.0 (local magnitude) according to the Richter scale with the rubber metal supports application. The calculations showed that the maximum relative horizontal movement towards the top of the building as well as the effect on the construction base elements for the first variant (without

RMS) were bigger comparing with the second variant (with RMS). Comparative analysis of the results was carried out by a linear spectral method. It showed that the application of RMS could be useful in building construction. For the second variant (with RMS) the values of the following parameters in the construction elements were reduced: for the columns of building – 56.5 %; for the building wall – 38.1 %. A relative displacement value of the top of the building was reduced by 45 % in comparison with the first method (without RMS).

Materials and methods. The behaviour of the building was analysed for the different levels of vibration (the change in frequency and vibration amplitude). The building is constructed from the welded square rods and it was set on a rigid base with rubber metal supports; the base has inner linings connection (Figure 1). The model is a tenfold reduced copy real building and it consists of two levels, the distance between the columns is 0.6 m (6 m in real conditions). The height of the first and of the second layers are 0.3 m (3 m in real conditions). The cross-section is a pipe with dimensions 0.03×0.04 m and thickness of 0.003 m. The material is the steel of type 3, the scale is 1:10; the weight of the model is 33 kg.

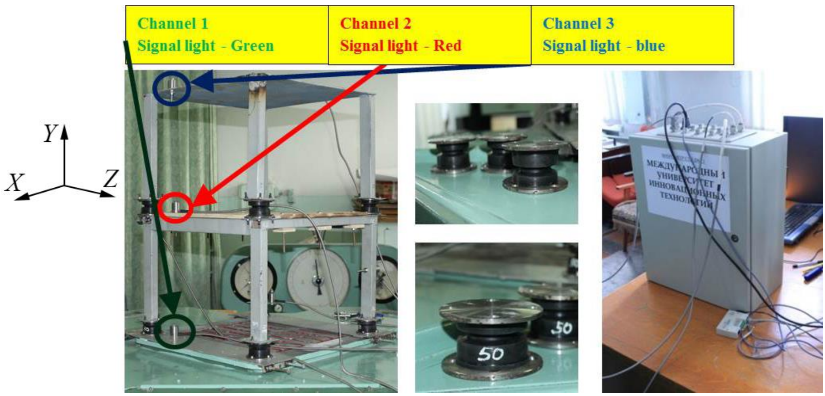

Figure 1 – Layout of the monolithic building, rubber metal supports and STD 2060.1

The material of rubber supports is a mixture of rubber Iv-13 6190 TU 2512-046-00152081-2003. The hardness of RMS rubber elements is 50 and 60 units. In these supports the presence of a rubber layer neck increased the possible movement towards the horizontal direction and the stability of the rubber layer subsidence due to the layout weight. The height recess of the neck is 5mm.

The vibration was simulated using a shaker equipped with three electric motors of 400 W power and a countertop size of 0.55×0.55 m dimension. The recordings of building vibration were performed for the *X*, *Y* and *Z* axes respectively. The *Y*-axis is for the vertical vibration, the *X* and *Z*-axes – for vibrations in the horizontal plane. The oscillation amplitude was set between 0.008 and 0.04 m. The panel frequency was changed by a motor rotation control in the range of 0 to 200 Hz.

The frequency vibrations of the model were set at the station of technical diagnostics STD 2060.1 type produced in Russia. The station is the device with two signal transmitters' modules for controlling and signaling the technical condition of the unit for a period of 0.4 seconds by comparing the signals received from six channels.

The rubber-metal supports were under a static load from the construction weight. The vibrations distribution from the bottom to the top of the construction with supports was stopped due to the natural oscillations of the rubber layer. Figure 1 shows the RMS located under the columns (4 pcs.) between the connections of the first and the second levels of the building model. The software Vibroscope was used to measure the frequency of vibrations in relation to time.

Results and discussion. The signals of the sensors were located at all levels of the building layout as shown in figure 1. At the first level (the color of recorded signals is green) the sensor is located on the shaker for measuring the vibration frequency. At the second level (the color of recorded signals is red) the sensor is installed in the inner lining of the connection between the first and second levels of the building model. The third level (the color of recorded signals is blue) – the sensor is fixed on the upper floor, at the top level of the layout.

The channel 1, the green light lines, is installed on the countertop and showed its vibration frequency on the graph. The channel 2, the red light lines, measures the oscillations at the top of the layout first-level which shows the difference between the vibration frequencies of the construction protected by rubber-metal supports and without them. The channel 3, the blue light lines, measures the vibrations at the top of the layout second-level and displays the difference between the oscillation frequency of the first and the second levels of the model and therefore vibration frequency when using the RMS in the inter-layer connection. For the experiment, the sensors were located at different levels of the RMS-supported model for the oscillation frequency difference detection. The channel 4, the gray light lines, is fixed on the basis of the column in the area of RMS location (already next to it) and measures the oscillations after the RMS fixing. The channel 5, the pink light lines, shows the vibrations in the middle of the column and their distribution from level to level of the layout. The channel 6, the turquoise light lines, measures the vibrations in the inter-layer connection area before attaching to RMS (in contrast to the channel 2). The oscillation frequency-time dependencies were recorded by graphs using the special software. The figure 6 demonstrates the received six multicolored curves corresponding to the described channels. The oscillation frequencies excited by the vibrostand increase gradually that corresponds to the timeline and it is shown in figure 1.

The figures 2–4 show the difference between the frequencies of the layout oscillations in case of using rubber-metal supports. Figure 2 shows that the maximum oscillation frequency on the tabletop reaches 7 Hz; on the first level top – 3 Hz. So, the usage of one rubber-metal support allowed to decrease oscillations frequencies by 4 Hz. The differences in frequencies between the countertops and upper level of layout (the second level) is equal to 4.5 Hz for the case of two RMS in the base of the construction (figure 5).

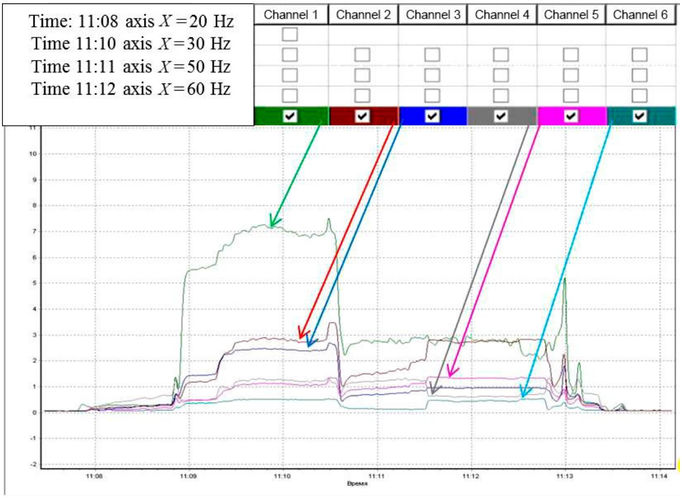

Figure 2 – The frequency-time dependence for the X axis for the oscillation amplitude equal to 16 mm for the case of RMS base

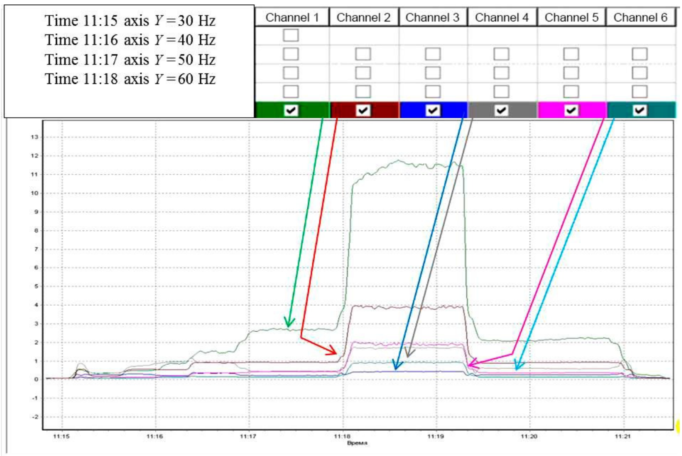

Figure 3 – The frequency-time dependence for the Y axis for the oscillation amplitude equal to 16 mm for the case of RMS base

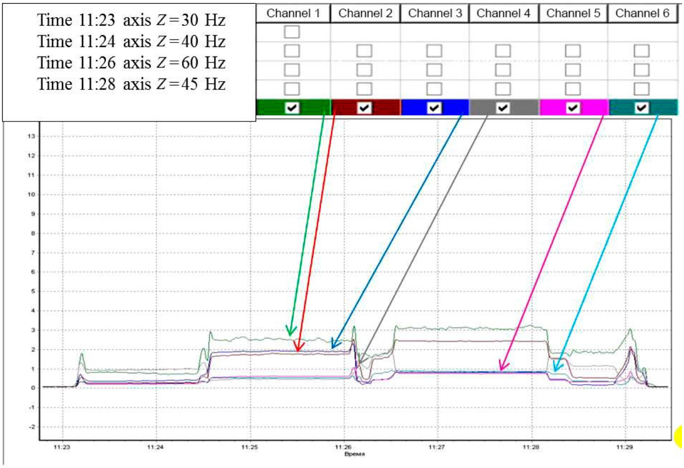

Figure 4 – The frequency-time dependence for the Z axis for the oscillation amplitude equal to 16 mm for the case of RMS base

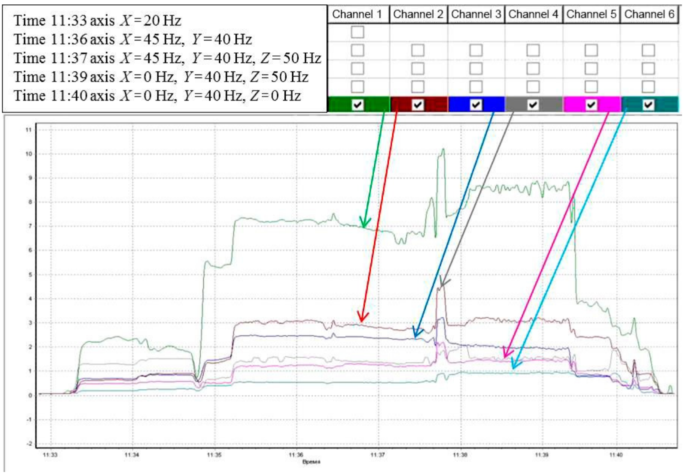

Figure 5 – The frequency-time dependence for the X, Y, Z axes for the oscillation amplitude equal to 16 mm for the case of two RMS in the layout base

Rubber with high hardness provides the construction stability for the non significant amplitudes and frequencies of vibrations. Softer rubber shows very good resistance to vibrations with large amplitudes and frequencies. However, it may lose its stability under a prolonged static load. The frequencies of oscillations excited by the shaker gradually increase along X, Y, Z axes relating to time as shown in Figures 6, 7 and 8 respectively.

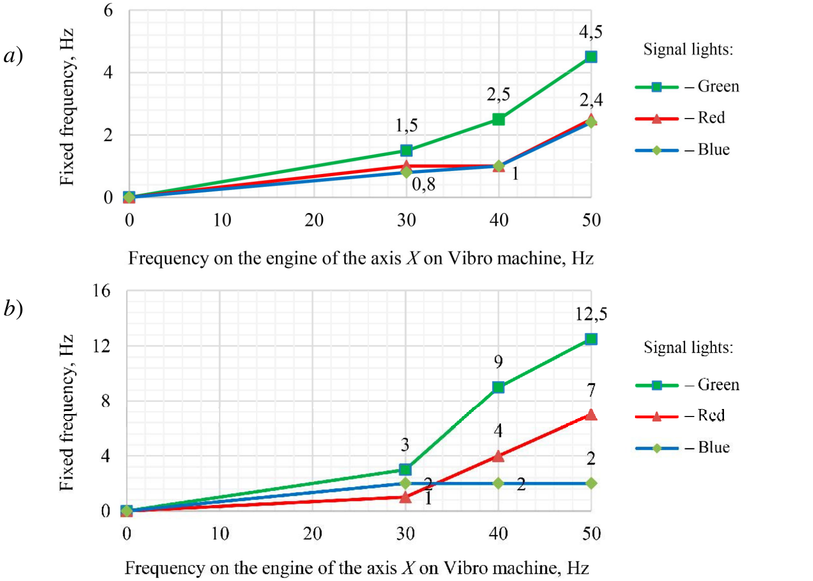

Figure 6 – Sensors' vibrations frequency in X direction for the case of using RMS with rubber hardness equal to 50 (*a*), 60 (*b*)

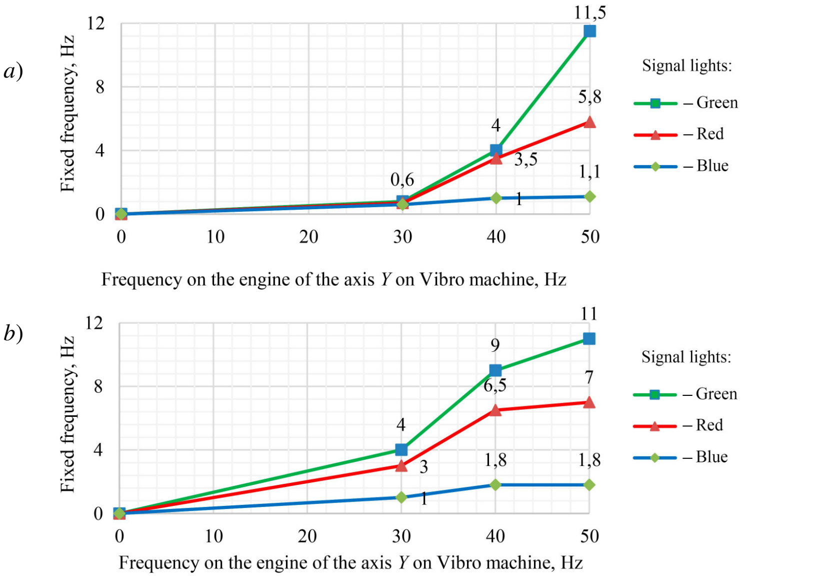

Figure 7 – Sensors' vibrations frequency in Y direction for the case of using RMS with rubber hardness equal to 50 (*a*), 60 (*b*)

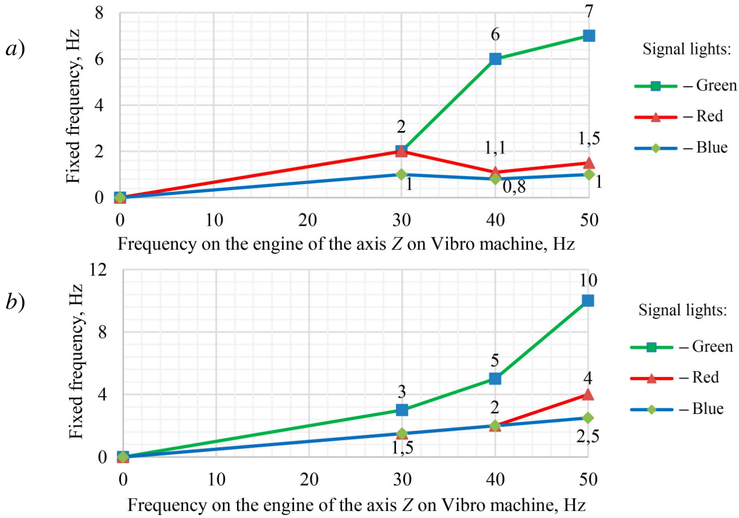

Figure 8 – Sensors' vibrations frequency in *Z* direction for the case of using RMS with rubber hardness equal to 50 (*a*), 60 (*b*)

Rubber metal supports with hardness of 60 Shore A units, the oscillation frequency reached 12.5 Hz at the countertop, the top of the first level of the building layout was under fluctuations of 7 Hz frequency. The difference indicates the presence of rubber-metal supports effect on vibrations. The oscillation frequency of countertop and the top level of the layout (the second level) reached 2 Hz for the two RMS between the source and the object of vibrations. There were recorded different fluctuations for the rubber with hardness of 50 Shore units. The sensor mounted in the shaker had a frequency of 4.5 Hz. The oscillation frequency at the top of the first and the second layout level obtained 2.4 Hz. Fluctuations occurred only in the horizontal *X*-axis where a maximum oscillation frequency excited by the shaker was 50 Hz. In the Figure 7 the oscillations occurred only in the vertical Y-axis.

The oscillation frequency was 11.5 Hz on a vibrating table, on the top of the first level and at the top of the second level there was recorded 5.8 Hz and 1.1 Hz for rubber with hardness of 50 Shore units. For the rubber with hardness of 60 Shore units, the values were slightly different. On the shaker the vibration frequency was 11 Hz, on the top of the layout first level it was 7 Hz and at the top of the layout it reached 1.8 Hz. These oscillation frequencies appeared when the frequency of oscillation was excited at 50 Hz by the shaker. It should be noted that vibrations in the vertical axis of the frequency vibrations with rubber hardness of 50 and 60 units showed no visible difference. The case of *X* and *Z* distribution of vibrations had the same horizontal directions of oscillations in the layout of the building. This suggests that rubber metal supports with lower hardness are suitable for the vibrations damping due to the fact that these elements have their own vibration frequency comparing with the harder ones.

Conclusion. The experimental results show the effectiveness of using rubber metal supports for vibration damping in order to protect buildings. Due to the natural vibration of RMS it can reduce the effects of the object frequency vibration caused by an external source. The elastic energy of the oscillations damping in the RMS rubber layer and the metal elements were considered for creating and loading the layout with the corresponding weight. The time of oscillation influence on the object was in the range of 60–90 minutes from the start of vibrations. The better way to decrease the frequencies of the construction vibrations is to use softer rubber elements in the rubber-metal supports.

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МОДЕЛИРОВАНИЕ КОЛЕБАНИЙ СТРОИТЕЛЬНОЙ КОНСТРУКЦИИ С РЕЗИНОМЕТАЛЛИЧЕСКИМИ ОПОРАМИ

Приведены результаты экспериментов, в которых на макете двухэтажного здания, выполненного в масштабе 1:10, анализировалось влияние резинометаллических опор в составе монолитной конструкции здания на колебания, возникающие в его основании. Рассмотрено изменение частоты колебаний в зависимости от твёрдости использованной резины. Результаты экспериментов продемонстрировали преимущества использования резины с меньшей твердостью.

Ключевые слова: макет, резинометаллические опоры, виброметр, колебания.

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