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Full-scale dynamic testing of raised floor structures

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Abstract. At the moment there is a rather small piece of the information about the behavior of the raised floor under the seismic impacts, and at the same time the spectrum of such structure application is continuously expanding, that leads to the necessity of the detailed assessment of their characteristics. The research purpose is to determine the resonant frequencies and transfer functions of the raised floor elements and the whole structure at all. The determination of the raised floor structure vibrostability in the frequency range 1 - 30 Hz is determined in the case of the sinusoidal oscillations influence of the basement, too. During the preparatory work the testing platform was constructed, it simulates the full-scale boundary conditions for a raised floor panel installed on the concrete basement in the enclosed room with a tight fit to vertical walls along the contour. Thus, the deformations of the raised floor fragments were neglected because of the racks compliance and joints. Also, the stepwise loading scheme was developed to determine the limiting states and possible destruction of the raised floor elements. As a result of the studies, the oscillation accelerograms of the raised floor fragments were obtained at the given level of seismic impacts; the dependence of the stresses in the raised floor elements on the time at the given level of seismic impact and fixing the defects of the raised floor elements during and after the test series are determined.

1. Introduction

Existing normative documents do not address the issues of the seismic calculation of the raised floor structures [1-3]. Nowadays in the construction standards and regulations of the United States, Australia and the European Union [4-6] the static and dynamic tests are carried out for the following types of loads:

– point load;
– ultimate load, at which structural failure occurs;
– dynamic loading by the moving load.

It should be taken into account that, due to the dynamic loading features caused by the seismic impact, the greatest efforts occur in the transverse (horizontal) directions in the way that the compressed floor racks begin to work as rigid cantilever elements. Also, their own frequency under the load decreases [7], which leads to the entering the earthquake frequency range. Thus, the resonant increase in the amplitudes of the horizontal oscillations appears, which increases the system deformation and leads to the appearance of the significant stresses in the dangerous sections of the racks, at the fasteners. It is important to consider that the most part of the raised floors in the seismically dangerous regions is installed without an appropriate evaluation of strength properties. The seismic stability determination of the raised floor on the basis of the only analytical methodic is extremely difficult and gives the superficial results, because such calculations, as a rule, do not take into account the real non-linear work of the structure material, the calculation models often do not consider the damping properties of both the structure material and the joint elements (in spite of the fact the damping significantly reduces the amplitude of the raised floor resonant oscillations), as well as the mass-inertia characteristics of randomly distributed loads on the floor.

To assess the seismic stability of the raised floor fragments the test methodic was developed that allows determining the characteristics of the stress-strain state of the raised floor structure and its individual elements under dynamic impacts equivalent to seismic. The dynamic tests of the raised floor fragment under different static load levels (4 kN / m^2, 8 kN / m^2, 15 kN / m^2) and various levels of horizontal oscillations (0.2 m / s^2, 0.6 m / s^2, 0.8 m / s^2, 1.0 m / s^2) were conducted. During the test, the accelerations of the raised floor structure elements were recorded, as well as the relative deformation in the racks and stretches.

2. Methods

2.1 Experimental study of raised floor structures

The test bench was designed for tests that simulate the work of the raised floor element structure under the dynamic impact of the alternating loads and accelerations. The testing platform is installed in the reconfigurable frame with the flexible links, chains. The raised floor model was installed for the testing. As the prototypes, the raised floor fragments have dimensions 1.8 * 1.8 meters in the plan, they consisted of 9 plaster panels (600 * 600 mm) supported at 4 corners on the racks of the raised floor. The height of the investigated structure from the basement level was 495mm. The testing platform was designed with a concrete basement on which the raised floor racks were installed and fixed with glue. The gypsum slabs were installed on the racks. The slabs rested against the channels through the shock-absorbing polymer lining with a convex surface to have a better contact with the slab, which fix the braces. This emphasis provided the necessary behavior, close to the behavior in the actual conditions. To the braces, the corners were formed to form the frame of the box, into which sandbags were placed, they ensured the constant uniformly distributed load.

The equivalent seismic impact was created by the horizontal oscillations of the platform with the installed fragment of the raised floor, which were caused by the displacement with the specified frequency and amplitude of the rods of hydrocylinders fixed on the platform basement structure. The hydrocylinder was controlled by the digital controller which was able to monitor and change the parameters of the work during the process. The amount of the vibration acceleration was recalculated into the value of the vibration displacement and was set as the input impact by the hydrocylinders. The control of the given vibration acceleration was carried out with the help of displacement sensors, which are a structural element of the hydrocylinder.

In accordance with the requirements of GOST 30630.0.0-99 [8] and GOST 30630.1.2 - 99 [9], the frequency of external harmonic influence was set in the range 1 - 30 Hz. The tests were carried out in the regime of frequency increasing every 1 Hz of the external impact, with 30 cycles of oscillations being processed at each frequency.

The accelerometers were installed on the concrete basement, racks and slabs of the raised floor to determine the accelerations in orthogonal directions. On the raised floor racks the strain gauges were installed to determine the longitudinal deformation that occurs in the racks.

The purpose of the first test series was to determine the dynamic characteristics of the rigging designed to test the raised floor system to exclude its influence of the dynamic characteristics on the experiment results.

The second test series was an experimental study conducted on the fragments of raised floor No. 1.1, No. 1.2 and No. 2. The raised floor fragments of the series No. 2 differed from the series No. 1 by the stretches fixed to the racks attached to the concrete basement by the anchors.

For the fragment No.1.1, the distributed load q_1 = 4 kN / m^2, for the fragment No. 1.2 the distributed load q_2 = 8 kN / m^2 and for the fragment No. 2 the distributed load q_3 = 15 kN / m^2.

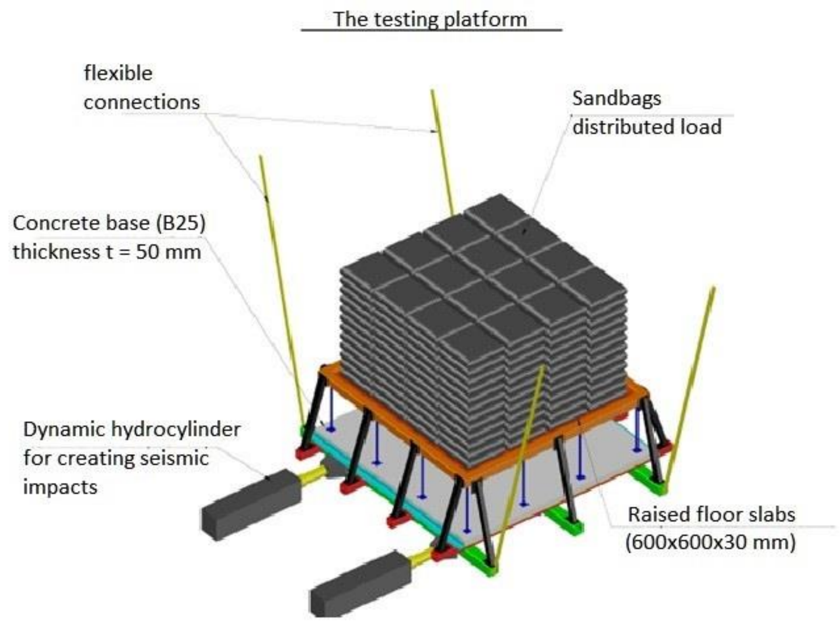

Figure 1. The testing platform scheme

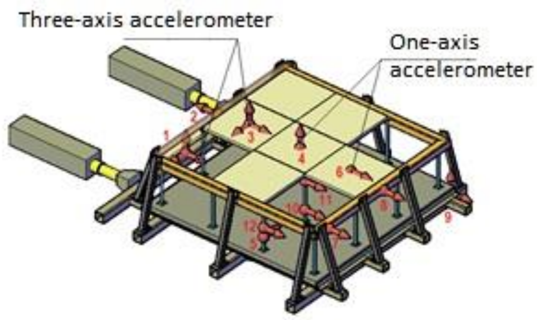

Figure 2. The installation scheme of the accelerometers

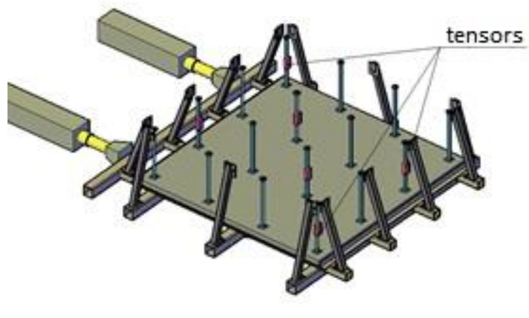

Figure 3. The installation scheme of the tensors

2.2 Test results

The analysis of test results was carried out on the basis of the result comparison of the processed accelerogram records obtained in the characteristic elements of the raised floor. The figures 4 and 5 show the signal spectrograms at the point 3 (accelerometer No. 3, figure 2) of the X direction (along the force application line) with 1.0 m / s^2 acceleration for the raised floor fragments No. 1.1 and No. 2, respectively.

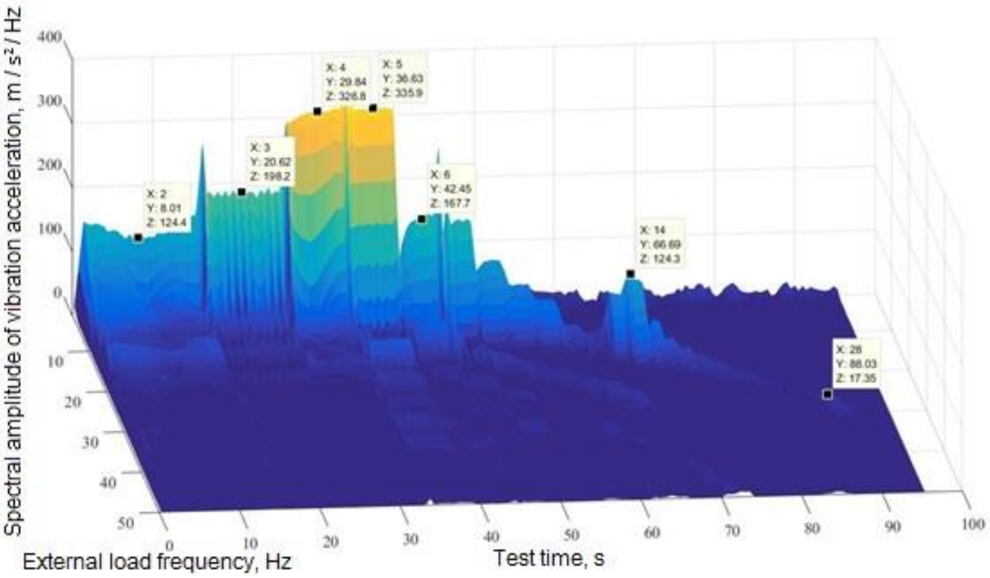

Figure 4. The signal spectrogram at the point 3 (direction X) for No. 1.1 fragment

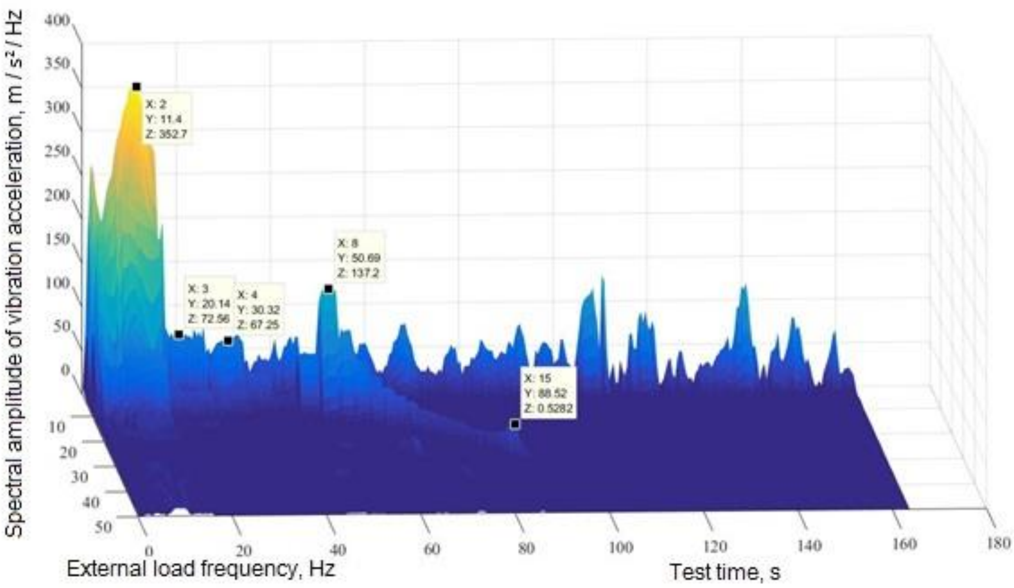

Figure 5. The signal spectrogram at the point 3 (direction X) for No. 2 fragment

The spectrograms (Figures 4-5) show a characteristic burst corresponding to the current disturbance frequency (the frequency with which the hydrocylinders move the bearing surface of the test platform). In linear oscillatory systems, which include the elements of the tested raised floor in the zone of the reversible deformations (elastic deformations), the frequency of the forced oscillations of the system coincides with the frequency of the external load. In this case, the spectrogram shows the characteristic bursts of vibration acceleration at the time of the changing of the oscillation mode, which are not taken into account when we analyze the raised floor structures operation. Such bursts are often impulsive, which is noted by the several harmonic components in the spectrum at the time of the impact.

The largest oscillation amplitudes, recorded by the test results (at the constant amplitude of the external load in the range 1 - 30 Hz) correspond to the resonant frequencies of the horizontal raised floor oscillations.

The resonances at the frequencies 2, 3, 4, 5, 6, 14 Hz are noted in the spectrum of horizontal oscillations of the raised floor fragment No. 1.1. In this case, the amplitude of the forced oscillations of the raised floor fragment No. 1.1 is maximal at the frequency of 5 Hz.

The resonances at the frequencies of 2, 3, 4, 6, 12 Hz are noted in the spectrum of horizontal oscillations of the raised floor fragment No. 1.2. In this case, the amplitude of the forced oscillations of the raised floor fragment No. 1.2 is maximal at the frequency of 4 Hz.

The resonances at the frequencies 2, 3, 4, 7, 8, 9 Hz are noted in the spectrum of horizontal oscillations of the raised floor fragment No. 2. In this case, the amplitude of the forced oscillations of the raised floor fragment No. 2 is maximal at the frequency of 2 Hz.

The comparative analysis of the test results shows that with the distributed load increase from 4 kN / m^2 to 15 kN / m^2 on the floor surface, the lowest natural frequency of the horizontal oscillations decreases from 5 to 2 Hz. The nature of the decline is shown in figure 6. It can be noted that a decrease in the frequency of natural oscillations has a weakly pronounced nonlinear character. The presented dependence makes it possible to determine the frequency of the proper horizontal oscillations of the raised-floor fragments for any other intermediate values of the load applied to it.

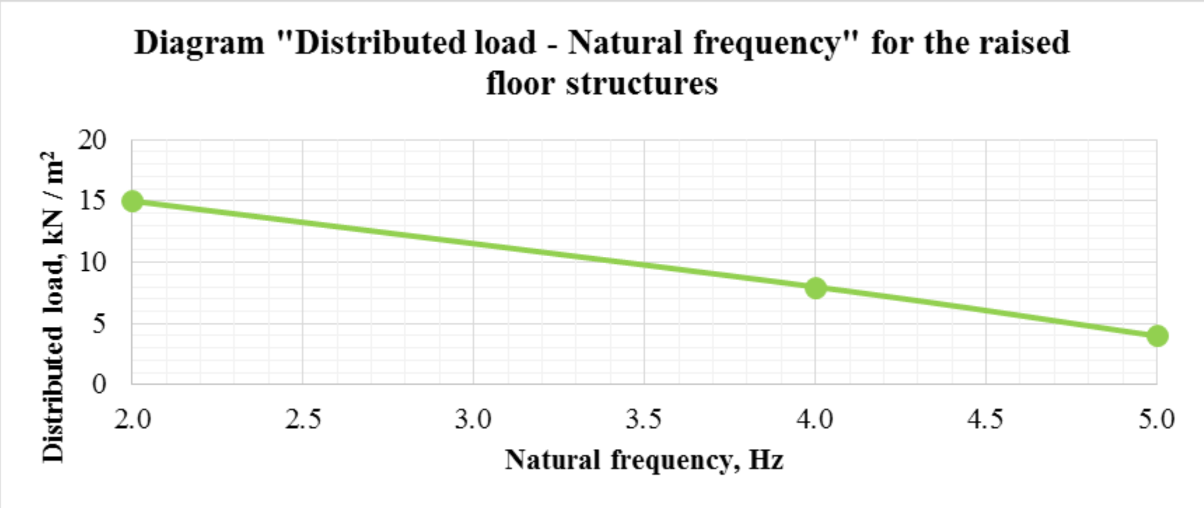

Figure 6. The dependence of the natural oscillation frequency on the applied load

Accurately speaking, we can use the following regression formula for approximate frequency estimation of the horizontal oscillations of the raised-floor fragments f_{hor}, Hz, under the uniformly distributed load q, kN / m^2:

$$f_{hor} = -0.00274 \cdot q + 6.134 .$$

The estimate of the rigidity change of the raised floor structure, depending on the different loading levels (4, 8, 15 kN / m^2) and the initiation of the additional anti-seismic elements (stretch marks) is performed on the basis of the accelerometer record comparison of the forced oscillations of the racks according to the accelerometer data set at the point 10 (accelerometer No. 10, figure 2) along the application line of the driving force.

The frequency spectrogram composition for the rack differs from the similar data for the raised floor slab.

The resonances at the frequencies 2, 3, 4, 5, 6, 13, 18 Hz are noted in the horizontal oscillation spectrum of the racks of the raised floor No. 1.1. In this case, the amplitude of the forced oscillations of the racks of the raised floor No. 1.1 is maximal at the frequency of 4 Hz. The resonances at the frequencies of 2, 3, 4, 12, 30, 34 Hz are noted in the horizontal oscillation spectrum of the racks of the raised floor No. 1.2. At the same time, the forced oscillation amplitude of the racks of the raised floor No. 1.2 is maximal at the frequency of 3 Hz. In the horizontal oscillation spectrum of the racks of the raised floor No. 2 resonances are observed at the frequencies of 4, 19, 23 Hz. Thus, the amplitude of the forced oscillations of the racks of the raised floor No. 2 is maximal at the frequency of 23 Hz.

The essential difference between the resonant vibration frequencies of the rack from the raised floor panel is associated with other stiffness and transfer characteristics between the tool basement and the floor. So the essential differences in the frequencies of the forced oscillations are noted for the fragment of the raised floor No. 2, in which the struts are strengthened in the longitudinal and transverse directions by the braces. In this regard, the shear rigidity of such construction is increased that is noted in the increase in the oscillation frequencies from 4 to 23 Hz. In this case, the significant bursts in the frequency range 17-25 Hz at the driving force frequency of 2-4 Hz is associated with the design features of the fastener attachments to the racks. Due to the sliding contact between the connecting slab (with respect to the two stretch marks) and rack the connection is spun that results in frequent strikes against the slab, which cause the occurrence of frequency components in the range of 17-25 Hz. At the same time, there is an increase in the deformability of such compound.

2.3 Test result conclusions

1. The analysis of existing domestic and foreign normative and technical documents, as well as the results of experimental studies of the dynamic characteristics of the raised floor structures for use in conditions of the seismic impacts, has been carried out.

2. Based on the provisions of the leading domestic normative and technical documents GOST 30630.0.0-99 [8] and GOST 30546.1-98 [10], as well as their analysis, the methodic of the performing dynamic tests of the raised floor structures has been developed.

3. The dynamic testing stand for raised floor fragments simulating the horizontal seismic impacts was developed.

4. The dynamic tests of the raised floor fragment under the different static load levels (4 kN / m^2, 8 kN / m^2, 15 kN / m^2) and different levels of the horizontal oscillations (0.2 m / s^2, 0.6 m / s^2, 0. 8 m / s^2, 1.0 m / s^2) were conducted. During the test, the accelerations of the raised floor structure elements were recorded, as well as the relative deformation in the racks and stretches.

5. The analysis of the test results indicates that the presented structure of the raised floor No. 1.1 and No. 1.2 for specified static loading levels and absence of gaps between the raised floor slabs and the test platform frame, the gap between the raised floor slabs, which is not more than 0.5 mm, is seismic resistant in case of the dynamic impact with the acceleration amplitude up to 1.0 m / s^2.

The structure of raised floor No. 2 for given levels of static loading and certain gap between the raised floor slabs and test platform frame is not more than 10 mm, the gap between the raised floor slabs, which is not more than 0.5 mm, is seismically resistant under the dynamic impact with the acceleration amplitude up to 1.0 m / s^2.

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