About the possibility of simulating spatial oscillations of buildings

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Abstract. The experimental research of the form of behavior of structures and constructions under the effect of seismic load is of big practical interest. The most reliable way of experimental research of seismic effect is the instrumental observation of the form of behavior of an actual structure, construction or their model during a major earthquake. The result of experimental research of the possibility of simulating two-component seismic load with the utilization of systems of directional vibration machines is given in this work. The principle of the method of simulating the seismic load is that for vibration excitation in two mutual-perpendicular directions on the floors of the 9,6 and 3 floors of the model (in the places of onset of maximal shifting for the according mode) 6 directional oscillating machines were installed. The first three oscillating machines were exciting vibrations in the transverse direction and the other three in the longitudinal direction of the building (since the first three modes of vibrations are quintessential for multistory buildings). Each of the vibrators excited oscillations in a specific mode. It is demonstrated that with simultaneous effect of machines in two mutual-perpendicular directions, the duty cycle of the vibrations does not change. This allows for simulating the seismic load on the building in each direction separately.

1. Introduction

Despite the considerable success of the domestic and foreign research in the field of earthquake-proof construction, the problem of preserving buildings and constructions during major earthquakes is far from full resolution. The complexity of the problem of seismic effect on buildings and constructions leads to the utilization of a variety of approaches to this issue.

The most rational representation of the actual seismic effect can be achieved through experimental research, the accuracy of which largely depends on the method of simulating the seismic load. Currently utilized methods of vibration excitations in the foundation of the experimental constructions through the utilization of a specially assembled vibration machine, directional underground detonation or a seismic platform with programmable control are related with major technical and organizational difficulties. In this connection, the development of new and improvement of existing ways of experimental reproduction of the seismic effect on buildings and constructions are appearing as actual problems to the resolution of which this work is dedicated.

During the vibrations of high-rise buildings, the examination of their reactions to the application of the higher mode of vibration has a practical cause regarding the improvement of their seismic effect calculation. The articles about this problem for instance [1, 2,3,4,5,6,7,8,9] are generally theoretical. Here are presented the results of experimental research of the deformed state of the model of a high-rise building under the impact of higher mode of vibrations evoked by complex dynamic load of a seismic type excited by a system of vibration machines in one or two mutual-perpendicular directions.

2. Methods

When an earthquake happens, the construction undergoes vibrations in three mutual-perpendicular directions and enters a complex mode of deformation. The two horizontal constituents of the vibration which themselves undergo complex vibrations in individual directions are the most dangerous.

For the determination of the influence of spatial vibrations on the deformation state of the elements of the framework, special experiments were carried out regarding the technique of creation of complex seismic type dynamic loads on a model of a nine-story steel framework which is 6 times smaller than the original[10,11,12,13,14,15,16].

With this goal in mind a special experimental facility was assembled [17], which allowed for the implementation of complex seismic type vibrations in the models of the constructions by overlapping several modes of self-induced vibrations in one and two mutual-perpendicular directions.

The facility consists of a model of a steel framework of a nine-story building, reinforced floor, 6 directional oscillating machines, equipment structures for the engines of the oscillating machines, console, measuring outfit and other fixtures (see Figure 1)

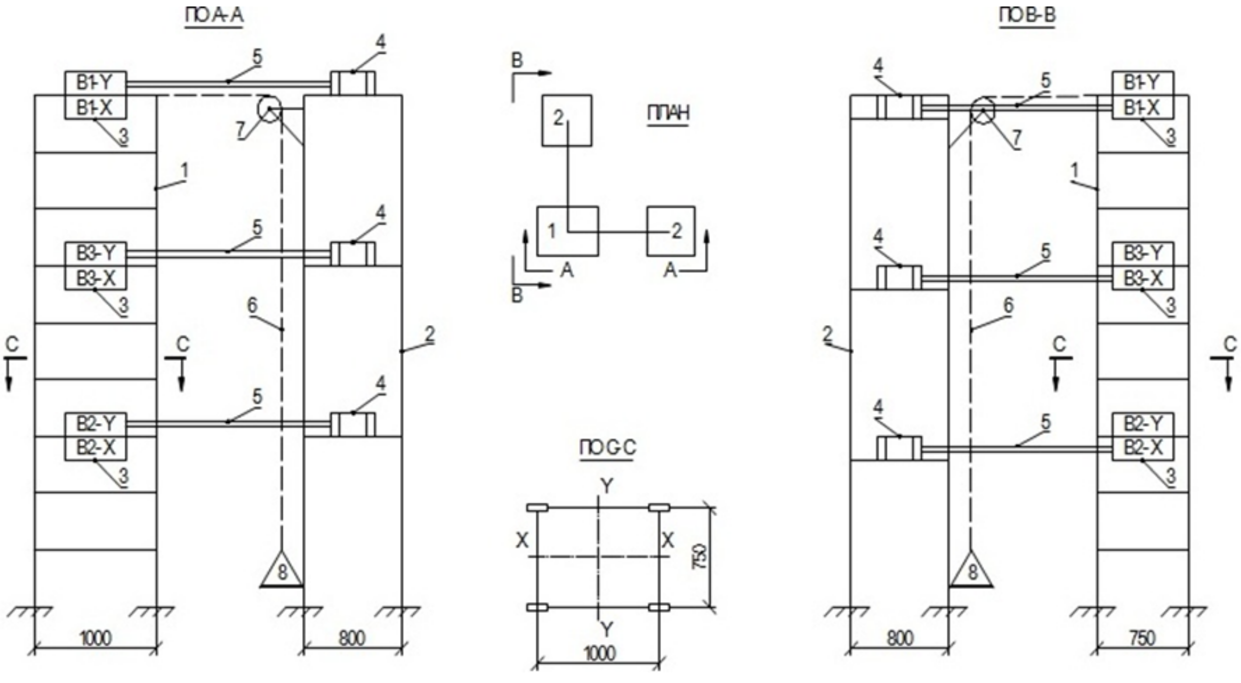

Figure 1. Construction arrangement of the facility
1 – model, 2 – equipment structures for the engines, 3 – oscillating machines, 4 – engine, 5 – flexible shaft, 6 – cable, 7 – block, 8 – load platform

IOP Conf. Series: Materials Science and Engineering **365** (2018) 042042 doi:10.1088/1757-899X/365/4/042042

Oscillating machines were placed on the 3rd, 6th and 9th floors of the model. The mounting locations of the oscillating machines are aligned with the maximum ordinate, the deflection curve of the relevant mode of vibrations, what allowed for efficient utilization of force capabilities of the oscillating machines.

Each of the three oscillating machines is used for the creation of resonance oscillations only of one mode of self-oscillation of the test subject construction.

This way the oscillation machines B1-Y, B2-Y, B3-Y, installed above the floor of the model (see Fig.1) excited resonant vibrations of the I, II and III modes along the Y-axis and oscillation machines B1-X, B2-X, B3-X installed below the floors excited similar vibrations along the X-axis.

Direct current motors installed on separate equipment structures powered the oscillating machines. The rotation from the motors was transmitted to the oscillating machines by the means of a flexible shaft. This allowed for exclusion of the influence of the vibrations of the motors on the results of the test on the model. The vibrations on the floors were recorded with the type CM-3 seismometers, situated in the directions of the main axes X and Y of the model.

Experiments were carried out by the following method. With the smooth change of the rotary speed of specific vibrators, the model was put into resonant mode vibrations of the I, II and III modes in a single direction. The process was recorded and registered by the console of the oscillating machine. Analogously the resonant vibrations of the model in the other direction were recorded and registered. After that, with the simultaneous activation of the oscillating machines, the model received resonant vibrations of the different modes in two mutual-perpendicular directions. The same method was used to achieve the simultaneous effect of several oscillation machines in every main direction exciting vibrations in different harmonics.

Different combinations of modes of vibrations excited in two mutual-perpendicular directions were examined.

3. Results

Figures 2a and 2b represent the lines of rebound deflections in the main mode with monaxonic (full line) and diaxonic (dotted line) vibrations of the model in the directions of the main axes X and Y. It is safe to say that the relevant shifts of the storeys of the model with monaxonic and diaxonic vibrations both in longitudinal and transverse directions practically does not change.

Figures 2c and 2d represent the orthographic epures of the maximal shifts of the points of the model when overlapping the first, second and third modes of vibrations, when the building vibrates in direction of X or Y (full lines) and when the vibrations are spatial (dotted lines) with the same components of overlapping. Here as in the previous case, the shifts of the model in the directions of X or Y stayed nearly the same both with the planar and spatial vibrations.

IOP Conf. Series: Materials Science and Engineering **365** (2018) 042042 doi:10.1088/1757-899X/365/4/042042

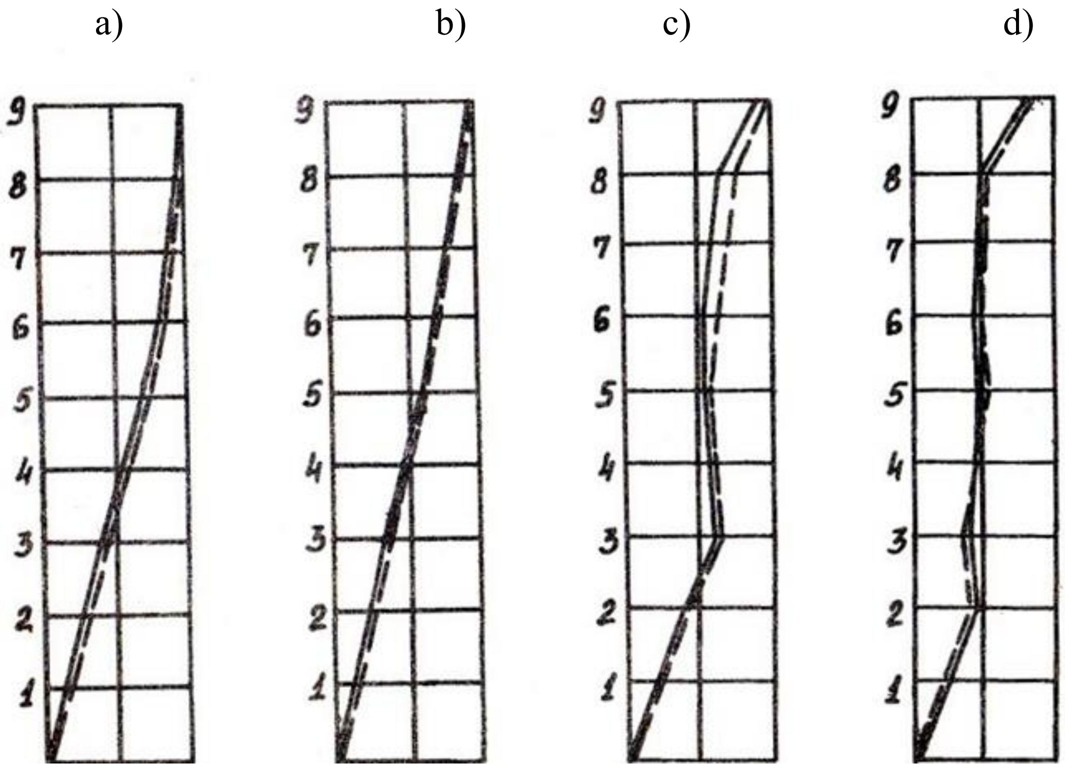

Figure 2. Maximal shifts of the points of the model with monaxonic (full lines) and diaxonic (dotted lines) vibrations

The frequency of forced vibrations of different modes with monaxonic and diaxonic vibrations also stayed the same (see the table below)

Table 1

Vibrations along axes	Frequencies of vibrations in Hz with modes		
	I	II	III
X-X	3.85	12.05	21.75
X-X and Y-Y	3.85 2.70	12.05 8.05	21.75 15.40
Y-Y	2.70	8.05	15.40

4. Discussion

A method of producing complex dynamic load of a seismic type utilizing several concurrent vibration machines, installed on the construction and exciting resonance vibration on individual forms of self-induced vibrations was developed.

The results of the experimental research presented above provide for the simulation of two-component seismic load with the use of a system of directional vibration machines.

the influence of spatial oscillation of the construction on the deformed state of the elements of the framework was examined;

the facility and method of experimentation of actual constructions and their models were developed.

5. Conclusions

This way the practical possibility of producing complex dynamic load of a seismic type in a construction utilizing a system of vibration machines either in one or simultaneously in two main mutual-perpendicular directions of the construction was proven;

The results of the experimental research indicate that the duty cycles of the vibrators and the parameters of the excited vibrations experience slight changes when they are experiencing the simultaneous effect of oscillation machines in two mutual-perpendicular directions, meaning that vibrations in mutual-perpendicular do not influence each other.

This allows for simulating the seismic loads on structures in each of the directions separately.

The suggested method is applicable for testing of either actual buildings and constructions or their models

Acknowledgments

I would like to express my special gratitude to my science advisor academician of the National Academy of Sciences of Republic of Armenia, head of the department of structural mechanics, Doctor of Engineering, Professor Hachiyan E.E. for the provision of the technological basis of the experiments.

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