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Seismic testing of models and fragments of seismic isolated structures of NPS buildings

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ABSTRACT: The modern practice in Russia shows the feasibility of simulation of the real non-stationary effect of seismic waves on large constructions with the aid of underground explosions. This report states the bases of original methodology and results of model and full-scale seismic testing on 3-component seismic platforms (load-carrying capacity up to 500 t). For simulation of loads and shakes of elements of structures of seismic isolated buildings on the structure of the stands the technology of buried underground explosions was used.

1 INTRODUCTION

Bench and proving ground investigations of seismic stability of structures and systems are among the most important and expensive components when creating a trouble-free nuclear power objects. Specialists from different countries carry out such investigations i essentially with the aid of seismic platforms, the largest of which (dimensions of test table 15x15 m) successfully operates in Japan. Special problems when designing and testing large-sized and large-capacity objects are connected with necessity to reproduce a multicomponent (in a general way) motion of seismic platform which corresponds with high-intense (up to magnitude 10 as per MSK-64 scale and more) vibrations of NPS buildings foundations at earthquake and especially with the vibrations of high buildings marks under these conditions. The expediency to preserve a real substantially non-stationary nature of seismic effect of earthquakes in this case is to be specially noted.

Quantity of seismic platforms which are used at present in Russia and enable to reproduce non-stationary processes of high-intense seismic and shock loading is rather limited, and their load-carrying capacity is relatively low (less than 30-50 tf). A unique position among test facilities occupies the complex of seismic explosive stands of Research and test center (RTC), which is intended for check of seismic and shock stability of large-sized fragments of building constructions and equipment of special structures.

2 BASIC SPECIFICATIONS OF SEISMIC TEST COMPLEX

Existing RTC seismic test complex includes a series of facilities which are grouped in one place on the opened site near the city of Vyborg. The main characteristics of mass and overall dimensions of the facilities - soil seismic explosive stands are presented in the table 1.

Operation of the facilities is based on original technology which had been ubder investigation for more than 20 years.

The main element of this stands is a supporting steel structure, installed on a layer of sandy soil on the rock, and a movable test table which is cross-connected with the structure with the help of transforming members. The building fragments and the equipment under test are either sited on the table or, if necessary, they are suspended to the portals of the stand.

Table 1

Stand Brand	Rated load-capacity, tf	Dimensions*) of test table	
		length, m	width, m
VSS-300	300	30.0	14.0
VSS-100	100	16.0	8.0
VSS-40 (2 stands)	40	7.6	4.7
VSS-20	20	5.6	5.6

*) Dimensions of the object under testing are not limited by the height.

At the end of 1994 a special facility VSS-500-VOK was incorporated into the complex structure, the facility is designed for testing the seismic isolated structures of nuclear power objects. It includes a rectangular steel fragment of building with dimension 22x6x7 m and mass 400 tf, which is supported with the aid of removable seismic insulators on movable bearings. The bearings are located on a layer of sandy soil similarly to the supporting structure of the stands.

The motion of supporting structure of stands and bearings of the facility VSS-500-VOK is carried out due to explosions in the ground under the bottom and/or sidewise. The monitoting of parameters of the test table space motion is produced by way of selection of location of the charges and their values, as well as of the characteristics of transforming elements and the parameters of initial displacement of the test table.

3 PARAMETERS OF BENCH EFFECTS

On each of facilities the realization of three main modes of testings is ensured:

"shock-seismic" mode, reproducing the shakes of building constructions and fixing units of equipment at the effect of nearby industrial explosions, for example;

"severe-seismic" mode, simulating, among the other things, seismic vibration on high (12.0 m and higher) marks of buildings and structures, as well as in accordance with similarity laws of real structures models;

"soft-seismic" mode, simulating the ground and foundations motions under the conditions of earthquakes of various rate.

In this case the motion of support blocks of an object under study in conformity with testings purposes has type of space, flat or one-dimensional non-stationary vibrations. The limits of changes of characteristic peak values, reproduced on the load applications stands in the frequency range [0; 200 Hz] are presented in the table 2.

Besides the observance of amplitude-time limitations in ranges, specified in the table 2, in the processes realized there is ensured the performance of requirements to amplitude-frequency composition of vibrations of test table of the stand, for example, filling of standard spectrum or special prescribed spectra. The fig. 1-3 show the typical experimental reaction spectra for testing conditions, here too several domestic and foreign standard spectra are given for comparison purpose.

4 SEISMIC TESTINGS

Complex of facilities is equipped with a system of control, collection, primary processing and analysis of the results of experiment. A control system ensures the programmatic explosion of explosive charges. A specialized instrumental and computing complex permits to register kinematic parameters (accelerations, speeds, displacements) and deformation of the structures of the objects under investigation in

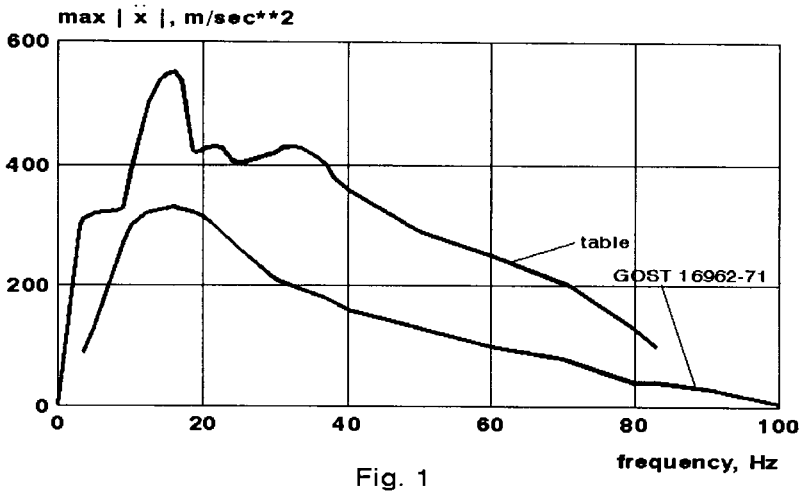

Fig. 1

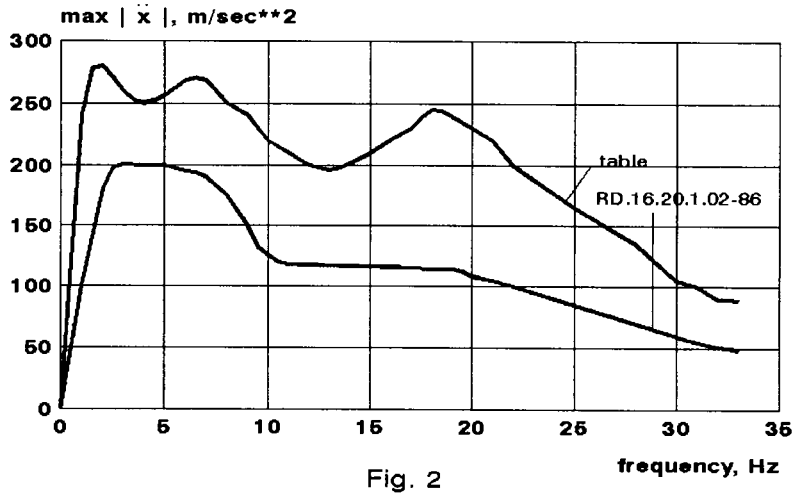

Fig. 2

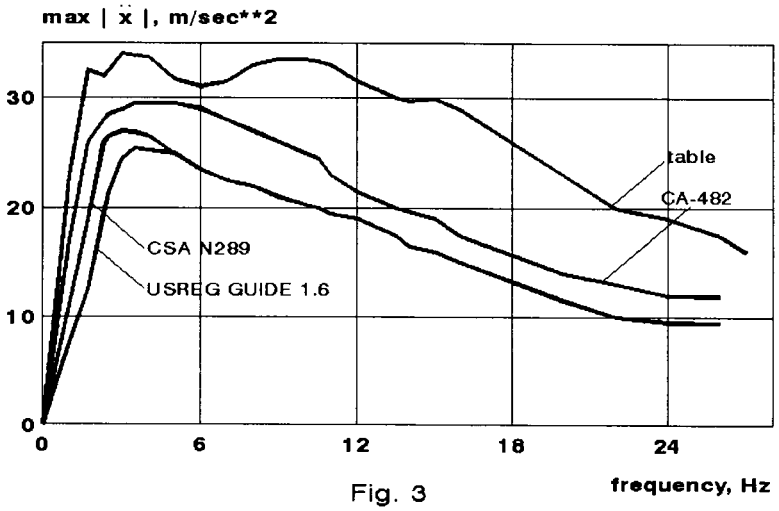

Fig. 3

Table 2

Type of loading mode	Accelerations (g) about the axes		Speeds (m/s) about the axes		Displacements (m) about the axes		Durations of loading, s
	oz	ox(oy)	oz	ox(oy)	oz	ox(oy)	
Shock-seismic	+30/ −10	±40	+3/ −1	±3	+0.5/ −0.2	±0.5	to 1.0
Severe-seismic	±10	±10	±2	±2	±0.5	±0.5	to 5.0
Soft-seismic	±2	±2	±1	±1	±0.7	±1.0	to 30.0

real time and to conduct automatic processing of experimental data with simultaneous amplitude-frequency analysis. The systems ensure visual and graphical display of received data and storing them in a database.

Bench facilities function both separately and jointly, for example if it is necessary to determine the seismic stability of long-size (50-70 m and longer) objects. On the facilities of the complex, among the other things, testings of full-scale fragment of a multicomponent low-frequency seismic protection system of NPS reactor building with VVER-640 had been carried out, these testings were logical completion of experimental investigations of large-scale (1:7.5) model of seismic isolated building which were performed earlier on this complex.

5 CONCLUSION

Seismic explosive technology of seismic testings permits to expand substantially (in comparison with seismic platforms which have mechanical drive) the possibilities to reproduce the parameters of effects of severe earthquakes, especially for high buildings marks.

The efficiency of the technology in question, including the economical efficiency, is confirmed during the testings of a new type of seismic protection for NPS reactor building with VVER-640.