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Optimum control of energy dissipation in support-pendulum seismic isolation system for large NPP equipment

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Abstract

The paper presents the results of theoretical and experimental investigations of support-pendulum seismic isolation (SPSI) system, designed for protection of large NPP equipment against seismic, shock and vibration loads. SPSI is a set of separate supports, the composition of which includes pendulum bars with special fastener assemblies and plastic damper in the form of rod steel elements system.

Full-scale seismic SPSI testing had been conducted on the Russia's largest seismic platform BCC-300. The tested SPSI had three supports, on which a 40-ton mockupup of NPP equipment had been installed. Mockupup size was 4.6×3.7×6.8 m. The testing reproduced three-component load input which corresponds to seismic input, intensity of which exceeded 9 as per the scale MSK-64. Decreasing horizontal accelerations and speeds on the NPP equipment mockupup were approximately 2 times, the amplitude of horizontal displacement had increased on 20% approximately. Relative horizontal displacements of the mockupup were of quick-damped vibrations type that demonstrates the efficiency of using plastic dampers in the form of deformable rods.

The procedure for design and selection of rational damper structural parameters includes searching the optimal parameters of viscous damping for linear dynamic model on the basis of construction of spectral density of seismic input power and selection of for the damper, ensuring damping, equivalent to optimal viscous damping. Purpose-oriented function of optimization is the minimum of dispersion of seismic isolated object accelerations. This experiment had confirmed the correctness of damper structure choice procedure for provision of the required dissipation level.

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Keywords: support-pendulum seismic isolation system, NPP equipment, theoretical and experimental investigations, force characteristic, plastic dampers;

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1. Introduction

Currently in Russia a variety of seismic isolation systems with plastic dampers has been developed (2009). These constructions of seismic isolation systems relate to support or support- pendulum types.

The paper presents the results of theoretical and experimental investigations of support- pendulum seismic isolation (SPSI) system, designed for protection of large NPP equipment against seismic, shock and vibration loads. SPSI consists of a set of separate supports, the composition of which includes pendulum bars with special fastener assemblies and plastic damper in the form of rod steel elements system. SPSI does not incorporate rubber or elastomeric elements which ensures its application in the increased radioactivity zone.

Full-scale seismic SPSI testing had been conducted on the Russia's largest seismic platform BCC-300. The SPSI version under investigation consisted of three supports. 40-ton mockupup of NPP equipment had been installed on these supports. Dimensions of mockupup were 4.6×3.7×6.8 m. The testing reproduced three-component load input which corresponds to seismic input, rate of which exceeded 9 as per the scale MSK-64. Maximum horizontal accelerations of the seismic platform were 9.6 m/s^2, vertical accelerations – 4.6 m/s^2, horizontal speeds and displacements – 0.69 m/s and 0.11 m respectively. These parameters can be considered as extreme for Russian territory. The decreasing horizontal accelerations and speeds on the NPP equipment mockupup were approximately 2 times, the amplitude of horizontal displacement had increased on 20% approximately. Relative horizontal displacements of the mockupup were of quick-damped vibrations type that demonstrates the efficiency of using plastic dampers in the form of deformable rods.

The procedure for design and selection of rational damper structural parameters includes searching the optimal parameters of viscous damping for linear dynamic model on the basis of construction of spectral density of seismic input power and selection of force characteristic for the damper, ensuring damping, equivalent to optimal viscous damping. Purpose-oriented function of optimization is the minimum of dispersion of seismic isolated object accelerations. This experiment had confirmed the correctness of damper structure selection procedure for provision of the required dissipation level.

2. Design analysis

Efficiency of the alternate designs for seismic isolation bearings had been analyzed on the basis of numerous calculations, technological and economical analysis and reliability performance. Consequently for manufacturing and testing of experimental model we had chosen a construction of support-pendulum seismic isolation bearing (SIB), (Fig. 1) as the most promising. Explicitly developments of these seismoisolation systems are considered in works of Belyaev and Rutman et al. (2007, 2008).

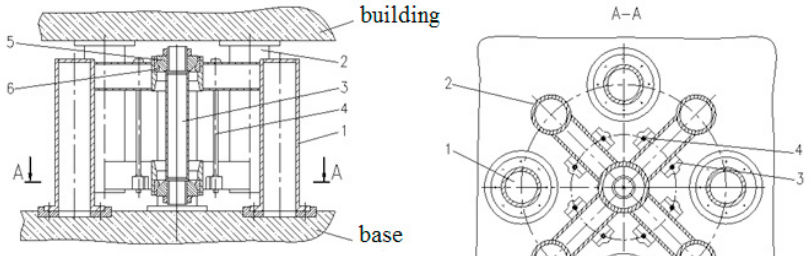

Fig. 1. Support-pendulum bearing with a hinged unit in the form of spherical nut and washer.

In a real SIB construction under study plastic deformable rods had been used as dampers (PD) (Fig. 2). Damping is carried out by deformation of the curvilinear rod stock and necessary PD efforts are selected by means of variation of the following rod stock key parameters: geometries - L , l , R ; diameter - d ; quantity (in this SIB there can be from 4 to 12 rod stock); material.

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