



Optimization of power characteristics of multicomponent low-frequency system of seismic protection of building with reactor plant of VVER-600 type

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ABSTRACT: Basic technical approach to low-frequency seismic isolation of the building is based on application of pneumatic cord shock absorbers of high load-carrying capacity up to 10 MN (vertical isolation) in combination with kinematical supports, ensuring the required motion transformation in horizontal plane. Dynamic power characteristic of the seismic isolation system is substantially nonlinear one. In vicinity of static position of balance in the characteristic there is a section of increased stiffness that creates a zone which is nonsusceptible to the effects, amplitude of which does not surpass the preset level. As to increase the energy dissipation the system is supplied with additional viscous dampers.

Selection of the parameters of dynamic characteristics of elastic and damping elements of the seismic isolation system was carried out when satisfying a series of kinematic limitations, determined by the conditions of functioning of the safety systems and the utility systems (pipelines) which connect the reactor building and adjacent buildings.

1 MAIN REQUIREMENTS

Requirements on seismic safety, which are determined by IAEA standards, to NPS complex as an energetic dangerous object, can be performed in two ways: conventionally, providing provision of necessary seismic stability and seismic strength of building constructions of the NPS facilities, and alternately - due to application of special insulating systems.

It is precisely these levels of seismic loads that can cause one or another structural approaches both to a building part and equipment of NPS complex. Then the cost of antiseismic strengthening of building constructions and equipment becomes rather considerable. According to available data the conventional approach to provision of seismic safety becomes economically inexpedient when safety assurance in conditions of severe seismic effects (more than magnitude 8 per MSK-64 scale).

The use of accident protection devices results in decrease of inertial loads on building constructions and equipment. As such devices in international practice there are used various resin-steel bearings, kinematic bearing, kinematic bearings with spring vibration isolators, etc., overwhelming majority of the seismic insulators proposed is designed for decrease of rate of horizontal seismic oscillations of buildings, as according to available data precisely the horizontal component of earthquake prevails during ground oscillations and it is most dangerous for building constructions and equipment. These factors are not indisputable. Really, among the registered severe earthquakes there are cases of equality of amplitudes (for example, "Los Angeles", 1994) and even of substantial excess of the vertical component relative to the horizontal one (for example, "Gazli", 1976 (fig.1) and "Spitak", 1988).

In case of high seismicity levels in areas of possible NPS construction we offer a technical approach to system of seismic protection, non-critical to seismic effect within the range of rate up to magnitude 10 per MSK-64 scale. A condition of "non-critically", in this instance, assumes the absence of preliminary limitations on location of earthquakes epicentre, frequency composition of seismic oscillations of ground, their duration. The proposed technical approach is based on application of multicomponent low-frequency (0.3 Hz in vertical direction, 0.2 Hz - in horizontal direction) damped system of seismic protection.

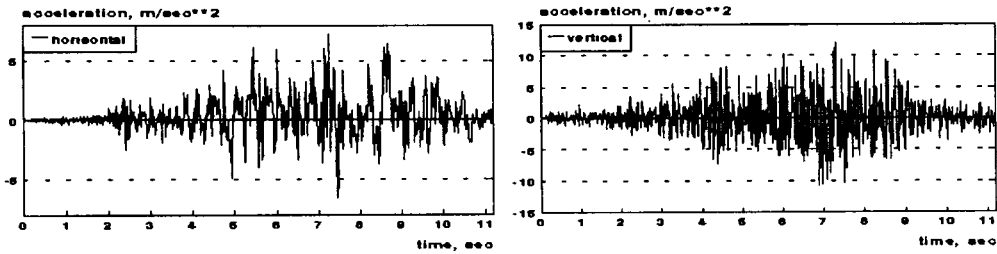


Fig. 1

Stability of setting position of the seismic-isolating unit and its tolerance to various types of external loads of small rate (wind, etc.) is ensured by availability of initial region of increased stiffness in power characteristics of devices.

It is possible to create the system in following versions:

- seismic protection of building of NPS complex as a whole;
- seismic protection of separate unit (units) of NPS building;
- seismic protection of separate NPS building rooms;
- seismic protection of separate groups or elements of equipment.

The suggested system of seismic protection ensures decrease of level of inertial loads on building constructions and equipment up to the values which do not exceed the effect, corresponding to magnitude 7-8 of earthquake according to scale MSK-64 at relative displacement of the seismic-isolating unit of 0.1 m and heeling not exceeding 0.003 Rad.

Thus far seismic protection system engineering had been performed on the detail design level as applied to reactor building of advanced NPS with VVER reactor of average power (general designer is Institute "ATOMENERGOPROJEKT" in St.Petersburg). Reactor building comprises a cylindrical reinforced concrete structure with hemispherical dome-shaped roof, inside of which there is located pressurized unit with steel containment (see fig. 2). Total mass of the building is 75000 tons. To provide the reactor building seismic safety we considered application of multicomponent seismic protection on the basis of pneumocord seismicisolating devices of 1000 tons load-carrying capacity which are stock-produced in Russia (see fig.3).

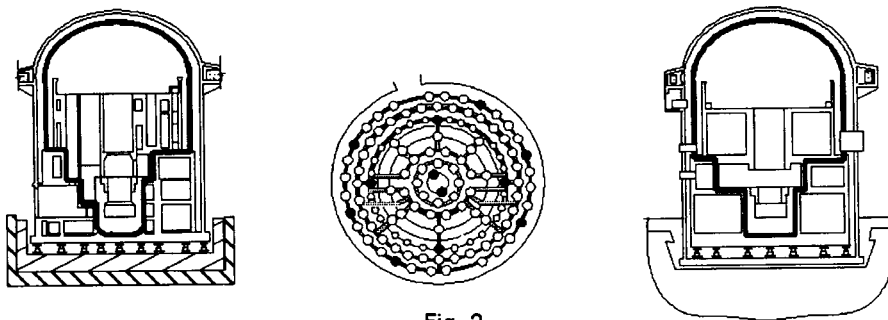


Fig. 2

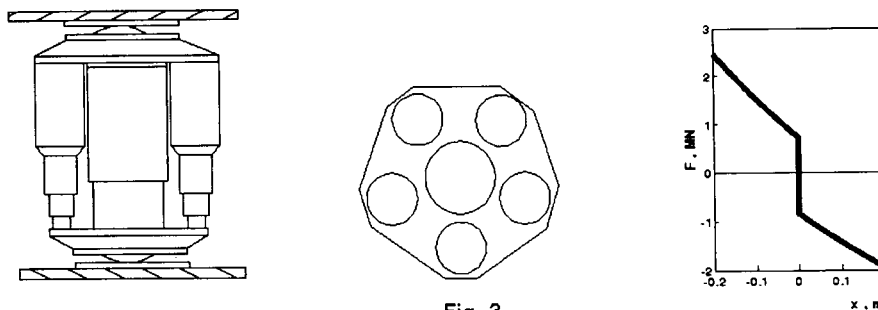


Fig. 3

Seismic-isolating bearings are located in a specially equipped basement under supporting structure elements of the whole building. A height of the gap between the upper and the lower basement plates is 3.5 m. The devices are capsulized and do not require permanent monitoring and additional feeding. More than 20 years of failure-free operation of the similar devices in conditions of various dynamic loads confirm their high reliability.

2 DESIGN ANALYSIS

According to the design estimations, conducted by dynamic finiteelement analysis of reaction of system "soil - basement plate - seismic protection system - reactor building" on analog and synthesized seismic effects, which are characteristic for various types of soils (stress-strain modulus of soil varied from 30 MPa to 200 MPa), seismic protection application results in considerable decrease of inertial loads at the building height (see fig. 4).

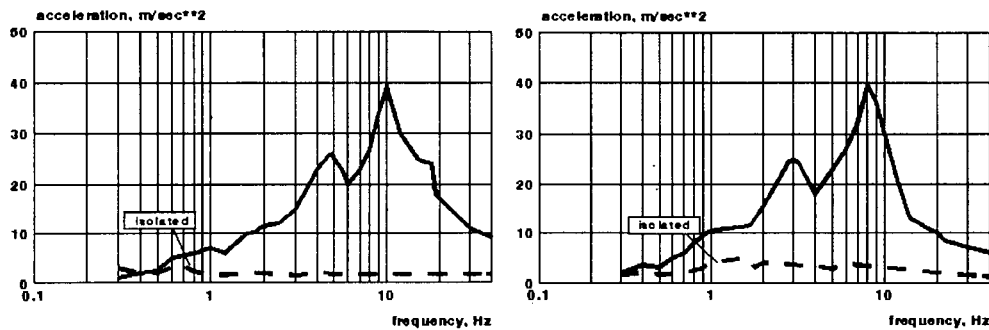


Fig. 4

The calculation results are presented in the table 1.

Table 1
Coefficients of slackening of dynamic loads on specific marks of reactor building

Mark, m	-4.5	0.0	4.5	10.5	16.0	23.5	28.0
The vertical	3-5	3-6	4-8	4-10	5-15	6-22	8-30
The horizont	3-4	3-8	5-10	5-15	6-20	8-30	10-40

The calculations had shown, that the most effective system from the standpoint of parameters optimization (relative displacements, absolute acceleration and angular turn of the structure), is a system of depreciation which consists of elastic elements (spherical-ended pneumatic shockabsorbers) and dampers. We had produced calculations with various types of damping. The best one among the considered is the version of square-law damping with limitation of the force which is equal (in horizontal direction) to 10% from the weight of the isolating structure, in this case the damping, making up only 4%, is sufficient in vertical direction, that fact can be explained by difference in parameters of kinematic disturbance in vertical and horizontal directions.

We had conducted additional calculations of the estimation of the influence of damping on determining the output parameters of the dampers system (horizontal displacement and angular turn). When the damping increases to 15-20% of the force of weight the horizontal displacement practically does not alter and takes on a value 6 sm. At reduction of horizontal damping to 5% the increase of horizontal displacement is up to 10 sm.

3 EXPERIMENTAL TEST DATA

For evaluation of serviceability of the seismic protection system, verification of the accepted structural model, justification of the choice of elastic and dissipative characteristics of devices and optimization of the accepted structural approach there had been conducted large-scale (1:7.5) testings of a seismic-isolated reactor building and a fragment of a seismic protection system with the use of standard bearings on an explosive seismic platform. The testing results are presented in table 2.

Table 2
Results of reactor building model testings

Pickup Installation place	Orientation of the pickup	Amplitude of the process	
		effect 1	effect 2
Stand	Vertically	11.3	4.0
	Horizontally	6.04	3.8
Basement of the model	Vertically	2.35	2.13
	Horizontally	0.9	0.8
Upper shear of the model	Vertically	1.86	1.93
	Horizontally	0.85	0.75

4 CONCLUSION

Competitiveness of the proposed technical approach of the seismic protection system is ensured by the following:

- designers of the system have wide experience (more than 30 years of earthquake shock protection of large-sized objects;
- technological preparedness of technical solutions of elements of the system;
- advanced software for calculation of all modes of seismic protection system operation, choice and justification of efficiency of the technical approach;
- methodical preparedness of all modes of functioning of seismic protection system (installation, filling, replacement of separate devices, normal operation, modes of specific dynamic effects);
- experimental verification of efficiency of the proposed technical approach of seismic protection system.