DEVICE FOR SEISMIC PROTECTION OF BUILDINGS

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1. INTRODUCTION

Seismic insulation is one of the most progressive types of seismic protection. Seismic insulation is understood as applying special devices for reducing of inertial seismic loads acting on a building.
The first seismic insulation units were developed by M.Viskondini (roller supports) in 1925. A lot of variants of constructive performance of seismic insulation systems (SIS) have been proposed since then: buildings with flexible lower parts, foundation supports of different types (suspended, sliding and so on). The most practical application of the SIS was found, in which resilient, elasto-frictional, viscous and other supports had been placed between the foundation, resting on the ground, and the foundation plate of the building [1], [2].
The Special Engineering Design Office has been developing for a long time protection systems of engineering objects from emergency loads, in particular, from powerful blast effects on engineering structures. The works in that field of technical equipment have shown possibility of practically absolute protection of people and equipment from strong seismic effects generated by blasts. The constructions, shown lower, can, to our opinion, significantly more effectively solve problems of seismic protection, comparing to the existing SIS.

2. RESILIENT SEISMIC INSULATION UNITS

The Special Mechanical Engineering Design Office has developed, manufactured and tested a shock-absorber unit (SAU) of large load capacity. The SAU (Patent of RF N 2029155) represents a block of number of pneumatic shock-absorbers (PSA), concentrically mounted round the guiding cylinder. The upper parts of the PSA are connected with the stationary upper flange, the PSA foundation is connected with the lower flange (Fig.2.1). The SAU can have from 2 to 6 PSA.
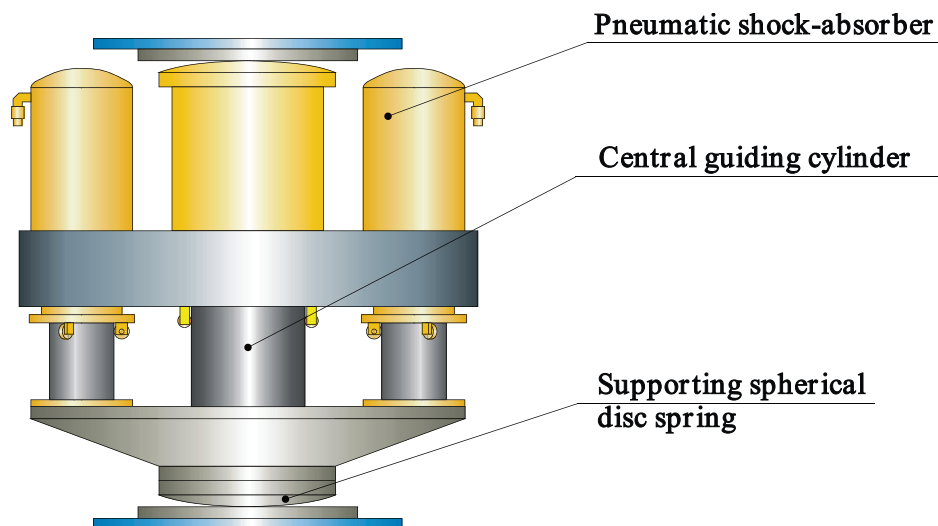

Figure 2.1. Shock-absorber unit
(Golden Medal of International Exhibition "Brussels-Eurika '95)

The main part of the PSA is a rubber-cord envelope. Safety and durability of the PSA is provided by way of connecting the rubber-cord envelope (RCE) to the metallic construction of the shock-absorber and also by the arrangement and the shock-absorber cavity ampulization technology. Rationality and safety of such construction has been proved by failureless operation of the PSA during 15-18 years. The main and constructional parameters of the PSA and the SAU are shown in Tables 1, 2.

Table 1

SPECIFICATIONS			UNITS OF MEASUREMENT	MEANING				
				PSA-1	PSA-2	PSA-3	PSA-4	PSA-5
Load capacity			T	5…40			25…150	
Effective RCE diameter			mm	300			575	
Working stroke	Vertically		mm	±200	±450	±540	±200	±350
	Horizontally		mm	250	350	400	300	500
Dimensions		A	mm	1535	2150	2380	1700	2500
		B	mm	∅460	∅460	∅460	∅780	∅780
Shock-absorber mass			Kg	540	610	700	1170	2000
Working gas			-	Nitrogen or air				
Nominal pressure			MPa	1.0…6.2				
Operation temperature			^{0}C	5…35				
Storage temperature			^{0}C	±50				
Guaranteed service life			years	20				

Table 2

SPECIFICATIONS		UNITS OF MEASUREMENT	OPTION OF REALIZATION				
			SAU-2	SAU-3	SAU-4	SAU-5	SAU-6
Number of pneumatic shock-absorbers		pcs	2	3	4	5	6
Nominal load capacity		T	Up to 300	Up to450	Up to600	Up to750	Up to 900
Guiding apparatus mass		mm	Up to1500	Up to2300	Up to3000	Up to3500	Up to2000
Working stroke	Vertically	mm	±200				
	Horizontally	Mm	~300				
Working gas		-	Nitrogen or air				
Guaranteed service life		years	20				

The SAU, being an element of the SIS, provides:
- stable steady position of the seismoinsulated object in the   initial state;
- relative movement (under earthquake) of the seismoinsulated   object vertically and horizontally in any direction in the   limits of the working strokes;
- automatic return of the object to the initial position after an   earthquake.
The protected object rests upon the upper movable part of the guiding cylinder of the SAU. In its turn, the lower part of the SAU is rested on the foundation plate, mounted on the ground. A set of the SAU of the same type, mounted by the above-mentioned method, is a constructive realization of the SIS (Fig.2.2).

Figure 2.2. Shock-proof object with shock-absorber units.

Efficiency of such SIS has been proved as theoretically, so experimentally. (During tests of structure fragments at the seismoexplosive stands, a glass of water, put in a fragment, was not spilt).
It is recommended to use the SAU with PSA-1,...PSA-3 for seismic protection of structures with mass up to 800 tons. The SAU with PSA-4, PSA-5 is for buildings of mass 1000...100000 tons and more.
If there are any significant residual non-uniform shifts of the ground under the building foundation after an eartgquake, the SAU provides possibility of its leveling. The leveling is implemented by gas pumping to the cavities of the rubber-cord envelopes.

3. PLASTIC SEISMIC INSULATION UNITS

An effective SIS can also be created on the base of the elasto-plastic shock-absorbers developed by the KBSM. The principle feature of these shock-absorbers is the circumstance that they create spatial protection of the object. Godograph of maximum forces of resistance of such shock-absorbers is a curve or a surface. (Numerous elasto-plastic shock-absorbers, has been proposed and used up to present time are single-component. In other words, the resistance force acts along single axis). Part of the elastic energy in the elasto-plastic shock-absorber is small. Basically, it disperses mechanical energy i.e. it is essentially a damping device. Therefore, the considered further three-component elasto-plastic shock-absorbers are actually three-dimensional plastic dampers (3D PD).
The 3D PD constructions are developed as a spatial combination of rods and planes, manufactured from plastic steels. Many types of 3D PD were developed. As an example we shall see some of them. A skittle-band damper is shown in Fig.3.1. Horizontal movement of the plane 1 relative to the plane 2 (Fig.3.1) is created by forming plastic hinges in the grooves of A and B. (The 3DPD is transformed into "a skittle" with plastic hinges). Vertical movement of the plane 1 relative to the plane 2 is implemented by way of "rolling" the band C. The 3DPD is shown in Fig.3.26 made of curvilinear rods of continuous round cross-section. Movement of the plane 1 relative to the plane 2, as in vertical, so in horizontal directions is provided by bending and torsion of these rods.
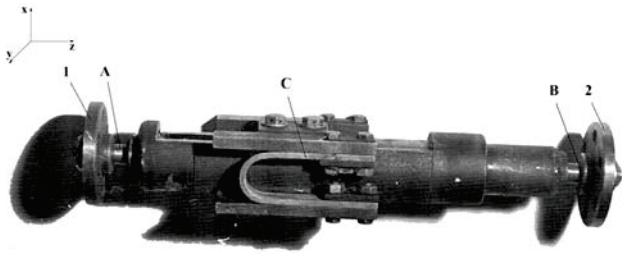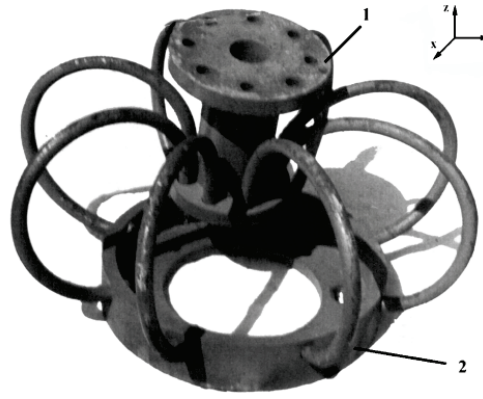
Figure 3.1. A skittle-band damper

Figure 3.2. A curvilinear rod shock-absorber

The following are easily provided by choice of the 3DPD material elements, their cross-sections and the spatial configuration:
- standardized level of load passed to the protected object;
- capacity for work of the 3DPD under the given number of loading cycles.
The 3DPD almost always allow to solve a difficult for other similar devices problem – in strict dimensions to create a very compact system of protection of an object from spatial intensive shock/ vibrational effects. In its turn, the 3DPD compactness increases permissible displacements (relative to the moving foundation) of the protected object that, as it is known, sharply grows the protective properties of the system.

Having the above-mentioned special properties, the 3DPD fully saves all the positive properties of single-directed plastic dampers:
- stability of characteristics under outer conditions changes (temperature, humidity and so on);
- long service life do not requiring maintenance;
- simplicity and low cost of manufacturing;
- reliability in operation.

However, the SIS designing on the base of the 3DPD requires conducting of special calculations. Without these calculations the 3DPD application can be non-effective and even erroneous. The principle information for preliminary estimation of the SIS efficiency is the surface parameters of the 3DPD flow. The decision of that problem is not difficult in some cases. Thus, for the skittle-band 3DPD (Fig.3.1.) it is a cylinder. However, for the 3DPD, shown in Fig.3.2., the flow surface calculation by traditional methods is highly difficult. Therefore, a special calculation method was developed – a method of pseudo-rigidities [3]. The Special Mechanical Engineering Design Office has a set of softwares allowing to receive the decision of the seismic protection problem taking into account all the factors influencing the dynamic process. They are: effects of hardening and cyclic recurrence of loading, accounting of elastic properties of the 3DPD, geometric nonlinearity and so on [4].

The experiments have shown sufficient accuracy of these calculation techniques (Fig.3.3.).
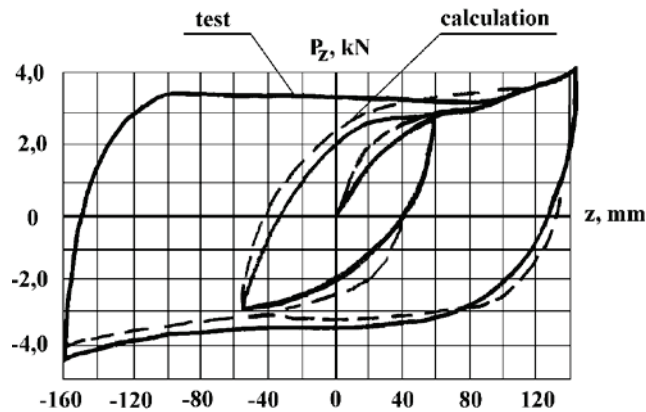

Figure 3.3. Comparison of results from calculation and experiment.

Materials used in the 3DPD were experimentally proved for effect of temperature, rapid and long term loading. Thus, the 3DPD have gone a full cycle of theoretical and experimental work-off and also have been checked in the process of operation.

Small load capacity and presence of residual shifts of the protected object after an earthquake does not allow to recommend these elements for creation of the SIS structure in the whole.

It is extremely effective to apply these devices as the SIS elements for protection of the NPPs facilities equipment and other industrial objects.

4. CONCLUSION

New designing and constructional solutions of the seismic insulation problem are proposed. They are based on the use of the original SIS elements, performed on the base of long time existing (in the other field of technical equipment)units, safety and durability of which have been proved by long term service (more than 20 years).

LITERATURE:

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