Buildings, Equipment and Pipe Networks Vibration and Noise Control using SERB – SITON Devices

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Abstract: - Buildings, equipment and pipe networks, herein below called ”structures”, are affected by the dynamic actions of earthquake, shocks and vibrations type, herein below called "excitations". The repeated action of excitations on structures most often lead to important built-up of kinetic and potential energy in structures. This leads to an increase of the amplitude in accelerations and displacements of structures accompanied by the occurrence of damages or destroy. The paper presents the performances of SERB-SITON isolation and telescopic devices used to protect buildings, equipment and pipe networks against dynamic actions. For large-size buildings such as nuclear power plants, old buildings, churches, bridges, etc., SERB-SITON isolation devices with a very small and adjustable stiffness installed under the structure on any horizontal direction, are presented. For reinforced concrete or metal framework buildings such as high buildings, industrial halls, towers, etc., SERB-SITON telescopic devices with controlled stiffness and damping large force inclusively are presented. For equipment and pipe networks, SERB-SITON supports that are capable to overtake large permanent loads with relative displacements on two directions for thermal displacements, and also capable to elastically overtake and damp dynamic actions, are presented. In order to reduce the propagation of the noises and to absorb them, the SERB – SITON panels are presented.

Keywords: - noise control, vibration control, isolation devices, hysteresis, seismic isolation

1. INTRODUCTION

A dynamic action may transfer to a structure a quantity of energy equal or smaller than the excitation energy associated to a vibration cycle, function of the harmonization or de-harmonization of the structure eigen movement with the dynamic action kinetics. The transferred energy may build-up as kinetic and potential energy in the structure, which in point of its dynamic behavior can be over-harmonized, under-harmonized or in resonance with the excitation.
action, the alternatives to accomplish a small seismic response are presented below.

2.1 Solutions to reduce the seismic response of buildings

Alternative 1 – Increase of building damping capacity while also limiting the relative distortions in the linear range of behavior.

The solution consists in the control, limitation and damping of level relative distortions by the installation of elastic devices with damping called “telescopic devices”, in the structure and/or between the structure segments (Figs. 2.1. – 2.3.).

The telescopic devices are usually installed at the building lower levels in central or excentral braces or around the nodes that make up a symmetrical network of braced panels at each level of the building and which are continued vertically with possible reductions symmetrically arranged.

SERB-SITON telescopic devices are capable of overtaking forces ranging between 1000÷5000kN and to limit the level relative distortions to values usually ranging between ± 10 mm to ±20 mm or other values imposed by the building, [4-6].

The devices can be fabricated in a large variety of typo-dimensions, Figs. 2.4.-2.5.

The force-distortion characteristic of the devices is nonlinear type, with strengthening in order to limit the structure distortion and their damping may be accomplished for preset values ranging between 30% and 80% of the elastic energy associated to one cycle.

Force-deformation characteristics may actually be accomplished as per any desired shape, Figs. 2.6. – 2.7.

For building rehabilitation the columns, beams or nodes of the braced panels are strengthened by lining with metal profiles tightened to the reinforced concrete structure and the braces by means of SERB-SITON telescopic devices are arranged as per 1 of the 3 alternatives presented in Figs. 2.1.-2.3.

This alternative may be applied to the construction of new buildings or to the rehabilitation of buildings in a nuclear or classic unit without interrupting the operation.

In case of building strengthening, 5% and 10% of the useful surfaces on a building level is affected by the strengthening solution for a period of 30 and 45 days, the rest of the building being useful without restrictions.

By the application of this alternative the important advantages, compared with the classic strengthening solutions are: necessary materials: 1/10÷1/20; resulted wasted: 1/10÷1/20; strengthening duration: 1/2÷1/4; surfaces of site temporary organization: 1/10÷1/50 of the surface required employing the classic strengthening solution; price: 0.7÷0.9.

Buildings constructed or strengthened by use of SERB SITON method provide a behavior of the building structure in the elastic range during an earthquake.

The control, limitation and damping of the building seismic response is provided by the telescopic devices inserted in the building structure rather than the building damaged structure with plastic hinges as the case with classic solutions.
The advantage of the new building strengthening system developed by SITON have been demonstrated by the rehabilitation of a building made up of reinforced concrete frames, 6 story high in order to make it withstand future violent earthquakes, without damages. Figure 2.8. illustrated pictures of the rehabilitated building employing SERB - SITON method.

Alternative 2 – building seismic isolation

The most efficient solution to reduce seismic loads on buildings is “to cut off the transfer of the seismic action from the ground to the building by isolating the building. In this case, the loads on the structures may be reduced tens of times function of the dynamic characteristic of the isolation systems, compared with the kinetic characteristics of the dynamic action.

For the isolation system to be efficient it is necessary that the system should satisfy the following requirements:
- the eigen vibration period $T_i$ of the supra-structure – isolation device assembly should be about three times greater than the eigen vibration period $T_r$ of the supra-structure embedded at the isolation level and respectively three times greater than the corner period $T_c$ in the ground response spectrum;
- the isolation devices should provide the overtaking of permanent loads with no distortion on vertical, over which tensile and compression dynamic loads overlap also providing a sufficient displacement on horizontal plane;

SERB SITON isolation system is a non-linear system which can provide very large vibration periods, with large capacity of reverting to initial position and rather small relative damping lest the seismic action should be transferred from the ground to the building via the damping forces.

Limitation of site displacements to reset values as well as the revert to the initial balanced position are provided by non-linear elements with the stiffness increasing with the displacement increase, making part of the isolation device.

SERB-SITON type isolation system is made by mechanical devices which do not include safety components that may be negatively affected by ageing and sometimes radiations, humidity or temperature. They are capable to overtake permanent loads, up to 5000KN over which tensile and compression dynamic loads of ±1500 KN are overloaded and which are also allowing translations in horizontal plane, usually up to ±300 mm. Figures 2.9. – 2.10 show 3 alternatives of isolation devices developed by SITON.
In order to evaluate the insulating system’s efficiency, a case study was conducted for the NPP Cernavoda detritiation building. Fig. 2.11 presents the analyzed insulating system and the horizontal hysteresis diagram of the insulating system.

An analysis was conducted for a site specific design accelerating diagram and for a sinusoidal accelerating diagram with a maximum ground acceleration on two perpendicular directions on a horizontal plan of 0.3 g, values of 50% higher than the design basis acceleration for DBE.

Following the numeric analysis performed for the rolling insulators on plain surfaces, a seismic acceleration was obtained which operates over the insulating system of 0.3g, the response in acceleration is of 0.02g, according to Fig. 2.12, and the response in relative movements between insulated infrastructure and supra-structure is of maximum 10mm, as in Fig. 2.13.

2.2 Noise absorbent SERB Panels

Fig. 2.14. Prototype of noise absorbent curved panels  
Fig. 2.15. Prototype of noise absorbent curved panels

Fig. 2.16. Noise level in the rear of various profile panels
Noise absorbent SERB Panels (fig.2.14, 2.15, 2.16, 2.17) have a large capacity to absorb and damp noises coming in the front or rear of the panels. A throughout noise in the whole frequency range which has 100 dB inside panel, is damped down to 45 dB at a distance of 30 m from the panel. The value corresponds to a 632 time decrease of the noise amplitude. At 1 m away from the panel, the noise intensity is 63 dB outside the panel and 70 dB inside the panel back to noise source.

2.3 Reduction of the dynamic response of equipments and piping network using SERB-SITON devices.

For equipments and piping network, the seismic loads, shocks and vibrations have a larger percentage in load groups than in constructions, [2]. Moreover, in many cases, the qualifying solutions for equipments and piping network for dynamic charge-discharge are in contradiction with their qualifying solutions for charges resulting from thermal expansions, their application being possible by imposing the extra-requirements for the devices used.

Usually, the devices for the reduction of the dynamic response, which for equipment and ducts are called bolsters, must also allow movements in thermal expansion (which besides the takeover and damping of dynamic actions are large because of temperature variations).

SERB-SITON bolsters may absorb the elasticity with pre-settled rigidity, permanent charges (usually from self weight), allow movement in thermal expansions on a direction or in a plan with elastic reactions or constant dynamic charges that they absorb. Depending on the percentage of the dynamic charge, in the group of charges and its cinematic characteristics, a few bolster (devices) options are presented below.

**Alternative 1 – Bolster for heavy equipment support, which undergoes shocks and vibrations.**

Usually, heavy equipments are placed on bolsters with horizontal action limiting device. In Fig. 2.18, the cassette bolster type for large loads is presented and in Fig. 2.19, the individual bolster type for large capacities. These bolsters have a non-linear and asymmetric conduct with large absorption. Insulation of heavy equipment like mould hammers lead to the obtaining of a 98% insulation.
Alternative 3 - For the catch of the pipes and columns to which vibration and thermal expansion movements are imposed in pre-established values for certain directions, the bolsters in Figs. 2.23. – 2.24. are developed. The thermal expansion movement or seismic movements of catch points can be made with constant or elastic reactive forces of pre-established values.

4. APPLICATION AND CHARACTERISTICS

The new technology developed by SITON has been applied by now in classic and nuclear objectives as follows:
- in 2003, the isolation of vibration shocks and seismic actions of a forging hammer located in IUS Brasov-Romania, [3], and having the weight of 360kN which, as per the initial foundation solution, the shocks generated by the hemmer blow were transferred to the near-by building (300 m and 800 m distance) and were resulting in the vibration of the building floors by a speed up to 52 mm/sec exceeding by 3,5 times the allowable limit of 15 mm/sec. After having installed SERB-SITON isolation devices, the value of the building floor vibration speed was reduced down to 6,75 mm/sec;
- also in 2003, the isolation against shocks, vibrations and seismic actions of pressurized air inlet and outlet pipes to the forging hammer.
- in 2005 a similar work with the one in 2003 for another forging hammer. The new solution was more performant meaning that the values of the building floor vibration speed was reduced to 0.085mm/sec from 52mm/sec. The isolation rate experimentally determined is 89%;
- Between 2005-2006 the strengthening, extension and rehabilitation of an old reinforced concrete framework building in order to withstand violent earthquakes with a 0.29g. Strengthening was done by inserting a small number of panels braced by SERB type telescopic devices. SERB device are controlling, limiting and damping the relative level displacements of the building. The columns and beams of the building have not been strengthened, except those pertaining to the placed panels which have been lined with metal profiles;
- In 2006, installation of a SERB-SITON type of support on the pipe 1056 located in Drobeta-Turnu Severin Factory-Romania. After the installation the amplitude of the pipe vibrations was reduced 6 times;
- In 2007, the isolation of the electric and I&C panels associated to the H2S compensators in GS3 section in ROMAG PROD against shocks and vibrations and seismic movements by the use of SERB type sliding supports. After the installation of the seismic isolation devices in the cabinets, the serial components inside the cabinet could be also installed but without verifying the behavior of the cabinet during an earthquake because the seismic acceleration transferred to the cabinet by the isolating;
- In 2008, seismic qualification of COLD-BOX columns for the radioactive tritium separation located in the Cryogenic Research (ICSI) in Ramnicu-Valcea, Romania. The seismic qualification consisted of the installation of 4 SERB supports on each column for to control, limit and damp the swinging movement of the columns during an earthquake;
- In 2009, the isolation of the electric and I&C panels associated to the H2S compensators in GS4 section ROMAG PROD against shocks and vibrations by the use of SERB type rolling supports;

5. CONCLUSIONS

The nonlinear method developed by SITON was checked on physical models, on prototypes on a 1/1 scale and by certain applications in classical and nuclear industry.
This method can be successfully applied to the rehabilitation or construction of objectives, because it possesses the following advantages over the current methods:

- Reduces the seismic response of constructions through the enlargement of damping capacity, including at small and medium deformations as well as through the control and limitation of relative level deformations to small values so as the structure of the building remains in the linear behavior range. Seismic energy is taken over and damped by these devices on a hysteretic cycle;
- The structural element of the construction do not reach local overload which may lead to their degrading and to the appearance of plastic articulations including in case of a violent earthquake, and the construction in functional after an earthquake;
- The control and limitation of level movements is performed with SERB-SITON mechanical devices, which can be installed either in central and ex-central bracing, or around the nodes of a panel or at the interface between building parts;
- The typical SERB-SITON telescopic devices can take over axial force of stretch and compression up to 1500 kN and can damp the seismic energy on a cycle up to 80% of a seismic energy on a cycle. The SERB-SITON isolator devices can take over compression load up to 5000kN and tension load up to 1500kN;
- The consolidation of the constructions can be made without the evacuation of the inhabitants and the time needed for the consolidation is reduces two or three times more than the classic method and the price is lowered with approx. 10-30%;
- The devices for equipment and piping network can be used to isolate these and/or to the reduction of the relative movement; These can take over the movements in thermal expansions with the elastic or constant reaction force;
- The SERB-SITON mechanical devices work efficiently at low speeds as well as high vibrating speed which allows their use without any restrictions, both in case of fast surface earthquakes and slow earthquakes like the intermediary ones or the earthquakes on unconsolidated soft soils;
- The devices are not affected by the aging phenomenon and can be installed including in areas with high radiation flux;
- The devices are safe, cheap, have a low weight and are easy to install unlike the hydraulic absorbers or other devices existent on the market.

REFERENCES