SPRING-DAMPER SYSTEMS FOR THE SUPPORT OF STRUCTURES TO PREVENT EARTHQUAKE DAMAGE

G. Hüffmann [I]

SUMMARY

The idea of isolation of structures from earthquake attack by means of spring-dashpot system is presented. The superiority of this system over the other vibration isolation systems such as rubber pads is explained.

It is emphasized that the spring system itself may cause serious problems, however, with the addition of viscous dampers the response is reduced to acceptable limits. Finally, it is concluded that spring-dashpot system, although more expensive than the other earthquake isolation systems, provides protection not only for the structure itself, but also for the equipment installed in the structure, thus reducing the overall cost significantly.

GENERAL

The use of elastic support for protection against earthquakes has been discussed for some years by a number of writers. Their basic conclusion has been that protection is necessary for only the horizontal but not the vertical components of the earthquake. However, several cases are known in which structures have been destroyed specifically by the vertical component of the earthquake. Moreover, in the case of a nuclear power plant the equipment inside and the piping system must be protected from both the horizontal and vertical components. Experts are also aware that the theory which holds that vertical components of an earthquake are always smaller than the horizontal is not always valid.

The present discussion would of course be unnecessary if it were technically feasible to separate the structure from the vibrating ground. But since it is impossible to create complete separation of a nuclear power plant from the ground by hanging it from a balloon for instance, the elastic support concept remains the best possible solution for protecting a massive rigid system.

ELASTIC SUPPORTS

Elements with quite different properties may be involved in establishing an elastic support. The use of rubber elements to support the structures and reactors in nuclear power stations is quite well-known today. Such elements are horizontally very flexible but nearly rigid vertically. It has been already suggested above that this is by no means an ideal solution, although of course a system vertically flexible and horizontally rigid would be even less satisfactory.

The ideal solution would be a spring-support system combining high flexibility in both vertical and horizontal directions. The helical springs could be such a solution; but model tests have shown that a structure may jump off the bearings if no damping is added to the coil springs which, unlike rubber elements, have almost no damping inherent in the material.

A new spring-dashpot system based on helical springs and viscodampers combines the advantages of a spring-support system with the efficiency of both systems, providing protection not only for a structure itself but also for the equipment installed in the structure, thus resulting in considerable cost saving.

The mathematical response of a system supported by springs and dashpots to earthquake input is given in another paper by Tezcan et.al. Here a movie film will show the different seismic response of a reactor model, first as supported by rubber elements, then by vertically and horizontally highly flexible springs without dampers, and finally as supported by a combined spring-dashpot system. The superiority of the latter system is quite convincing.

[I] Dr. G. Hüffmann, GERB Vibration Isolation Ltd./Germany

TECHNICAL CHARACTERISTICS

Helical springs may be designed for vertical natural periods of about T = 0.70 sec to 0.85 sec. The horizontal stiffness of the springs will be about 50 percent of the vertical. Depending on the distribution of the springs, the natural period of rocking around the lower rolling center will be in this case about T = 2 sec. High damping will reduce to acceptable limits the horizontal amplitudes of the spring-supported system caused by rocking. The film shows the effect of different degrees of damping and a way to optimize the spring-dashpot system. Usually 20% to 30% of critical damping may be achieved by the new dashpot system for the major modes of vibration, while the damping effect of the rubber supported system is limited to 3% to 8% of critical damping.

Helical spring elements with high load capacities up to 1300 kN have long been in use for example, for the support of turbine foundations. Elements for load capacities up to 4500 kN have already been designed. Tests are shown to determine the vertical and horizontal spring constants of a single spring and a 1300 kN element. Also shown are tests of the dashpot system giving an idea of the damping resistance of such a system. The damping resistance is nearly proportional to velocity. Damping resistances of 1000 kN.s/m per element have been measured and values up to 1500 kN.s/m per element are possible. The dashpots are working in all directions with nearly the same effectiveness, which is not limited to certain amplitudes.

Since the spring elements are prestressable their replacement is very simple. They can be compressed while in position, then removed and later replaced in the same way. Adjustment and alignment at any time also causes no problem, for example after unequal settlement following an earthquake. Neither springs nor dampers will lose or change their properties with time.

SPRING-DASHPOTS ALREADY IN USE

Spring-dashpot systems have already been used in the past in seismic areas for earthquake protection of the machine foundations such as large turbine foundations. In these cases the natural periods of vibration have been about T = 0.30 sec vertically and about T = 0.55 sec for rocking.

In a quite heavily seismic area in Taiwan, with natural periods similar to those mentioned above, a diesel generator station with 9 units, the weight of each machine plus the foundation being about 9000 kN, has been in operation on a spring-dashpot system for the last ten years. Difficulties were encountered only at first, before the dashpots had been mounted. Horizontal amplitudes of 40 mm and more on the machine floor level have been measured during earthquakes, which occur there several times a year. Once the dashpots had been installed the situation improved decisively, and no further disturbing or excessive amplitudes have been measured since.

CONCLUSIONS

While in these cases earthquake protection has been combined with normal vibration isolation of the equipment, since then spring-dashpot systems have been designed for the vibration isolation of the support of an entire reactor building. The highest natural periods of vibration in the case of reactor buildings isolated by spring-dashpot system are usually T = 0.70 sec for vertical and T = 2 sec for rocking motions as mentioned above.

The spring-dashpot system itself may be more expensive than the other elastic support systems but, the higher saving of costs of the structure itself and also the further protection of installations inside the structure will more than offset the extra cost for springs and dampers.