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Seismic protection of bridges by the viscoelastic technique

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ABSTRACT: A range of special dampers has been created for seismic protection of bridge structures. These devices are based on the technique of compression of viscoelastic fluids. Such devices have been in use in Italy and France and have given satisfaction. Moreover, recent experimental simulations show the efficiency of these shock absorbers on a bridge undergoing severe dynamic movements.
In normal time, they allow thermal expansion of the bridge deck and, in case of earthquakes, isolate it, dissipate a large part of the energy, and set it in motion to prevent it from impacting the bridge abutments.

1 INTRODUCTION

The first dampers based on this technique for the particular application of preventing earthquake damage to bridges have been developped ten years ago for Italian sites, but this technique remained quite unknown. The protection of bridges and the studies associated to it has made great progress recently and the international demand for new techniques is important. Thus this paper which exposes the technique of compression of viscoelastic fluids.

2 VISCOELASTIC DAMPERS

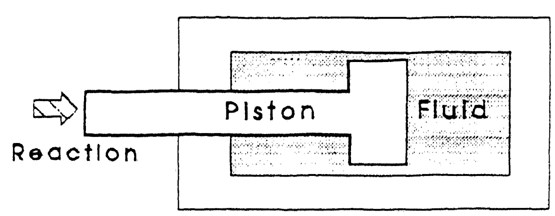
The originality of the technique employed - which is fully patended - rests on the hydrostatic compression of viscoelastic elastomers through appropriate mechanical designs. These elastomers are specially formulated silicones obtained by the synthesis of silicon/organic compounds. They appear as rubbers which are polycondensates of very high molecular weight.

2.1 Fundamental Principle

The fundamental principle of operation is based on the appropriate use of two properties exhibited by this series of elastomers.

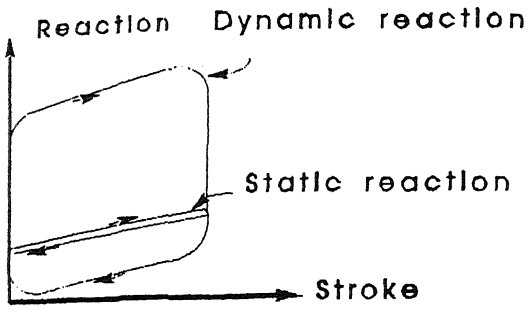
1. Viscosity : it varies from 10 million to 20 million cSt and is due to the "pasty" characteristic of the elastomer. This condition generates very high viscous friction, far higher than that occuring in normal liquids (which ranges from 50 to 500 cSt). This viscosity determines the <u>damping</u> function.

2. Compressibility : when the fluid is subjected to compression (a decrease in volume) its pressure increases very significantly. A fifteen percent reduction in volume (compression) results in a presure increase of 4,000 bars. The compressibility of the elastomer determines the extent of the <u>spring</u> function.



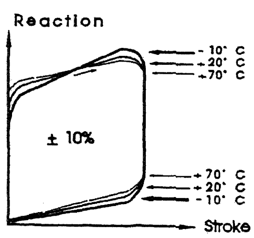
2.2 Consequences

1. Advantages : the most significant advantage obviously



results from the fact that a single device can provide both energy dissipation and energy storage in appropriate proportions to those required to solve the problem. This eliminates the need for traditional mechanisms or external power supplies in the case of shock absorbers, or pre-loading devices in the case of springs. Thus these devices are effective, simple in basic concept and maintenance free.

2. Influence of temperature : the elastomers used do not alter in their fundamental state between -50°C and +250°C. It is one of the particular characteristics of silicone compounds.
A change in temperature affects only viscosity and pressure. An increase in the temperature of the fluid results in a reduced viscosity and a reduction in temperature an increase in viscosity. In the case of a shock absorber the characteristics of viscosity change and pressure change act in opposite directions and substantially offset each other over a temperature range of -10°C to +60°C.



3. Ageing : silicone fluids are completely stable with respect to time insuring no change of characteristics. Experience over 25 years has shown no change in physical properties over such a period.

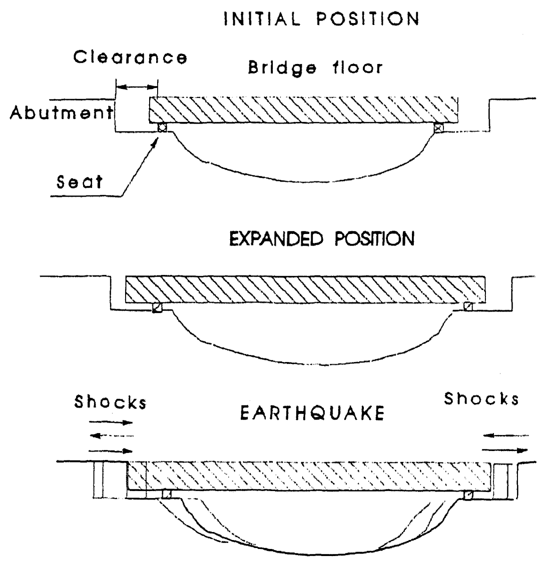
4. Flexibility : the very wide range of shock absorbing problems to be solved has led to the development of a great variety of shock absorbing components and systems. The ability to produce a wide variety of force/stroke diagrams allows the solution of a wide range of application problems. By changing the geometry of the component parts of the shock absorber and by selecting the most appropriate fluid it is possible to emphasize the "spring" function or the "damping" function.

3 SEISMIC PROTECTION OF BRIDGES

Protection of bridges calls for specific techniques. The bridge floor must be isolated whilst a part of the energy is dissipated, and it must be set in motion so that it never gets out of its seats.

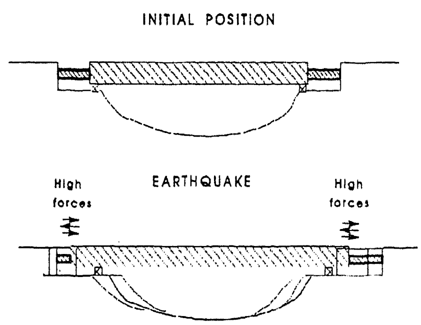
3.1 Bridge-ground coupling

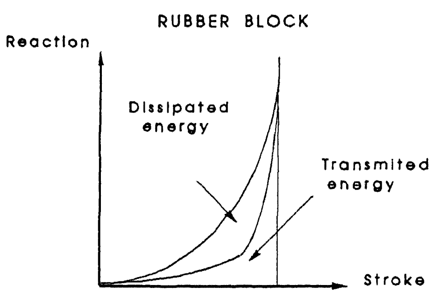
1. No bridge ground coupling : in the absence of a resilient interface between the bridge and its abutments, thermal expansion may force the bridge floor up against the abutment. In the event of a shock-producing earth tremor the bridge may be damaged and may leave its seats.



2. High stiffness coupling : alternatively a high stiffness interface (for example rubber

blocks) would have the disadvantage that as the bridge floor expands due to thermal expansion, the rubber blocks would transmit high forces to the abutments which would require additional strengthening of the bridge floor. In the event of an earthquake the rubber blocks dissipate only a small part of the energy and yet transmit very high forces. The bridge floor therefore experiences almost all of the earthquake energy and may be damaged.

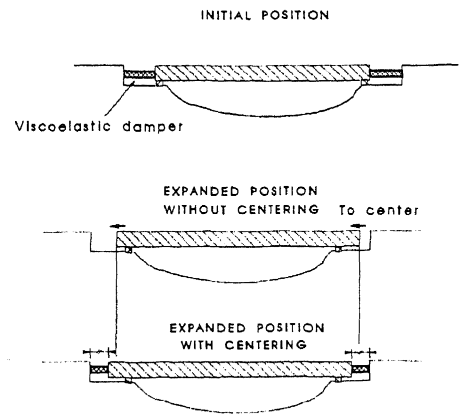




3.2 Viscoelastic protection

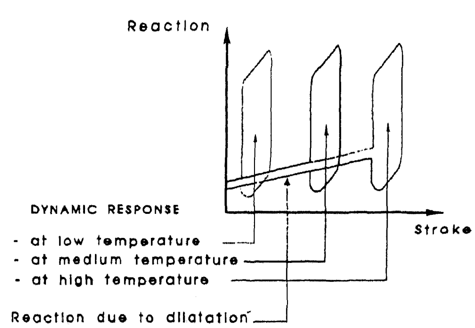
The functionning of the viscoelastic dampers is the following : they dissipate a large part of the energy, use the remainder to set in motion the bridge floor, and, in normal time, allow thermal expansion.

1. Static centering of the bridge floor : under normal conditions the static expansions and contractions of the bridge caused by temperature changes are easily absorbed by the stroke of the dampers. The damper generate only sufficient force to keep the bridge floor from coming into direct contact with the abutments, that is, they centre the expanded bridge.



2. Brutal accelerations : in the case of a violent acceleration due to a seismic shock the shock absorbers dissipate a large part of the total energy and set in motion the bridge floor so that the floor is not impacted by the abutments. The bridge structure is therefore isolated from shocks and absorbs only a part of the energy transmitted by the earthquake.

3. Response time : in the event of a severe acceleration the shock absorber instantaneously changes from its "static" mode of operation to a "dynamic" mode ; there is no loss of stroke in the shock absorber as it converts to its shock absorbing mode whatever the position of the shock absorber due to thermal expansion or contractions. The shock absorber is thus able to absorb the energy of the earth tremor and set the bridge in motion without any loss of time.



4. Bridge on piles : in the case

of a bridge supported by piles, the shock absorbers are located on these piles and act in the same way as those used on bridges supported by abutments. They also have similar dimensions and force characteristics.

4 EXPERIMENTAL SIMULATIONS

4.1 The Commissariat à l'Energie Atomique

An experiment at a one thousandth scale of a bridge undergoing an earthquake has been led at the French state institution "Commissariat à l'Energie Atomique". The CEA has special equipment which allows earthquake simulations to be carried out. The main shaking table is the largest in Europe having dimensions of 20' x 20'. It is therefore Europe's most important experimental test facility that has been used to simulate the effects of an earthquake on a viscoelastic damper protected bridge.

4.2 The testing installation.

A bridge floor, represented by a 20 ton mass, rests on wheels on the shaking table. Fixed blocks bolted to the table represent the side abutments. The shock absorbers, to scale, are connected to the side abutments and the bridge floor on both ends of the bridge.

4.3 The experiment.

The shaking table is moved along a unidirectional horizontal signal identical to the North-South El Centro earthquake accelerogram, with accelerations up to five times the accelerations actually measured in that case. All relative and absolute displacements, speeds, accelerations and forces are recorded.

4.4 Results.

The analysis of the experimental results shows that for substantial accelerations and displacements of the shaking table the accelerations experienced by the bridge floor are reduced by fifty percent and the displacement of the bridge is controlled so that it never bumps up against the side abutments. The bridge has therefore been effectively set in motion and protected.

5 REFERENCES

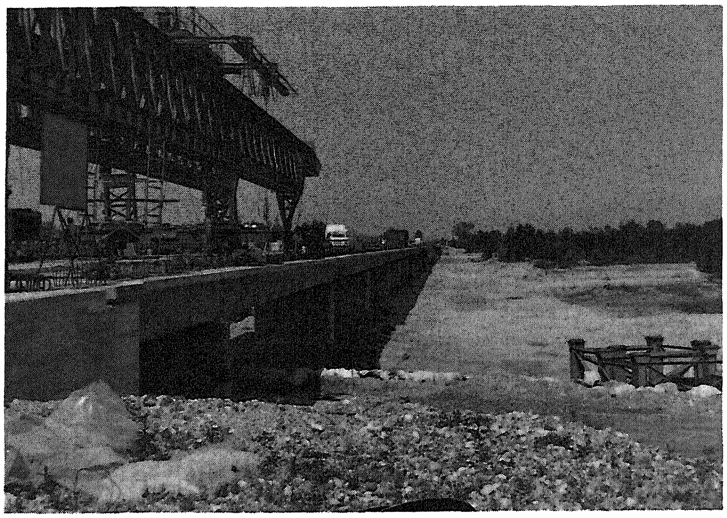
Viscoelastic shock absorbers presently protect highway bridges in six locations in Italy and one in France. The length of the bridge floor varies from 400 feet to more than a mile. Each site has its own characteristics and the disposition and the properties of the dampers vary as shown on the following table.

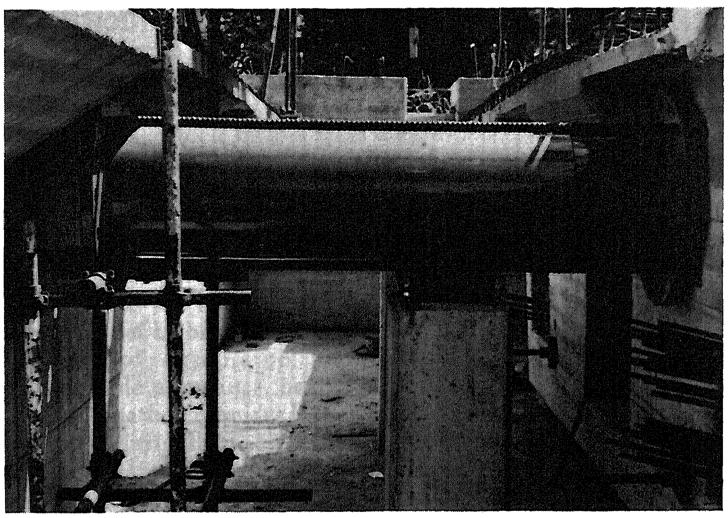
Name	Location	Year	length of bridge (m)	Layout of the shock absorbers
Viaduc de Reveston	Le Var - Bouches du Rhône (France)	1991	1 x 377	bridge floor
Tagliamento	Road "Pontebbana" Udine (North Italy)	1988	1 x 1027	
ICLA	Naples	1988	1 x 210	
Meschio	Vittorio Veneto/ Pian di Vedola (A27)	1989	2 x 210	
Restello	Vittorio Veneto/ Pian di Vedola (A27)	1989	2 x 2100	
San Cesareo	Fiano Romano / San Cesareo (Rome)	1987	600 + 120	
Prenestino	Fiano Romano / San Cesareo (Rome)	1987	1 x 300	

6 EXAMPLE OF ACHIEVEMENT

In Italy, at Udine, a one-kilometer bridge with a floor weight of 25,000 tons is protected by two shock absorbers on each abutment. Each one rests on a small concrete pillar, and is bolted to the bridge on one end, and to the abutment on the other end.
The general characteristics of these shock absorbers are a 500 ton maximal force, a 2,000 kJ dissipated energy, a 500 mm stroke, a weight of 2 tons and a total length of 2 m.

General view of the one kilometer ICOP bridge in Udine (Italy).
Two shock absorbers are located at each end, between the bridge floor (a 25 000 ton mass) and the abutments.





View of one of the shock absorber