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Sandwich damping treatment applied to concrete structures

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Introduction

Concentration of sources of noise and vibration into densely populated regions and into buildings of slender construction according to modern practice has shown the need for the introduction into civil engineering of definite methods of vibration damping. This is necessary in particular with prestressed concrete construction in which there is normally hardly any internal damping and the stronger the concrete the less the damping will be.

The slender forms of construction and greater speed ranges of many machines leads to more chances of striking a condition of resonance in a vibrating structure, wherein the exciting forces will be opposed only by the damping forces. Too little damping will mean large amplitudes and much noise.

An idea has been borrowed from the aircraft industry whereby metal panels are damped by making a sandwich consisting of two metal outer skins with a viscoelastic damping layer as the core. Flexural vibrations will induce shear in the core and energy will be dissipated into heat. The rigidity is provided by the metal outer layers. The layers forming the sandwich are bonded together either by vulcanizing or by an adhesive. The damping material in the core should be elastically imperfect to a high degree such that the strain will lag behind the applied stress. The material is referred to as being viscoelastic when the stress-strain law has the properties of an ellipse. The damping property of the viscoelastic material can then be specified by a loss factor, being the ratio of the quadrature to the in-phase moduli of elasticity. The stress-strain law can be defined by the loss factor and one of the moduli of elasticity. These quantities are often dependent upon temperature, frequency and strain.

Application of the sandwich damping technique to concrete structures requires a damping material which will adhere readily to the concrete and onto which further wet concrete can be poured to complete the sandwich. It should not be so costly as to make a construction in concrete uneconomic. Such a material has been found in the form of a bitumen reinforced with rubber latex. Bitumen adheres readily to a concrete surface provided it has been cleaned of salts and other impurities. The rubber latex makes a lattice and prevents flow. The shear strength and loss factor will depend upon the state of the bitumen. High values for the loss factor can be achieved compared with plastic materials for which a loss factor of unity is usually a maximum according to Oberst & Schommer (1965). The in-phase shear modulus and the loss factor have been measured for a particular type of bitumen-rubber latex mixture made by Evode Ltd and referred to as Evoseal 202. Some of the results are shown in figure 1 to an abscissa of shear strain for two different frequencies. The loss factor is substantially greater than unity and fairly constant, whereas the modulus of elasticity varies with strain and frequency.

The damping of the foundations for a railway

The Barbican redevelopment in the City of London has entailed the realinement of the Moorgate–King's Cross line carrying diesel main line trains out of Moorgate Station and the Metropolitan line of the London Transport underground system. The realinement railways run close to the proposed concert hall, school of music and the theatre. Several blocks of flats are being built over the railway. Some of the reasons for the realinement and the problems arising from this have been described by Clayden (1966). Ground vibrations have been attenuated by carrying the railways on prestressed concrete bridges supported at intervals of 35 ft. on rubber blocks. The length of each railway supported in this manner is about 1000 ft. and a concrete box has been constructed around and over it to contain the airborne noise. The reasons for this form of construction and the over-all attenuation of ground vibrations achieved have been given by Grootenhuis (1967).

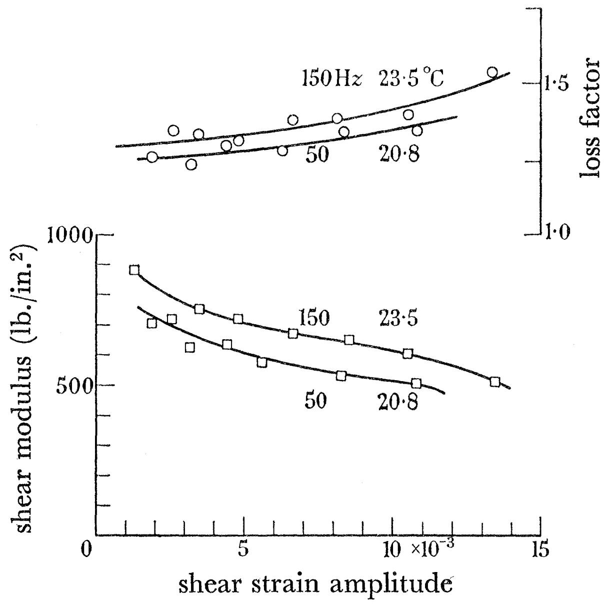

Figure 1. Evoseal 202: variation of shear modulus and loss factor with strain at constant temperatures and frequencies.

The bridge deck itself, being continuous for the whole length of the suspended section, would vibrate like a sounding board unless damping was built into it. Resonances of the bridge deck would greatly reduce the attenuation achieved across the rubber blocks and jeopardize the success of the entire installation. The bridge deck had to be made with prestressed concrete beams for reasons of economy and little internal damping would have been expected. The sandwich damping technique was proposed using the bitumen-rubber latex mixture referred to earlier. The sandwich could not be made symmetric as the load-carrying beams forming the lower layer had to span 35 ft. A longitudinal section of part of the bridge deck is shown in figure 2. The damping material was laid on the top of the beams which had been surrounded with in-fill concrete. The top layer of reinforced concrete of lesser proportions was laid subsequently on the damping material. The ballast, sleepers and rails were laid thereafter.

Separate experiments were conducted with a single 35 ft. prestressed beam, without the damping treatment and then with the damping and upper concrete layers added. The beam was supported at the ends on rollers and a weight of about $\frac{1}{2}$ ton was suspended from it at mid-span. A sudden release of this weight set the beam into free vibrations just as if

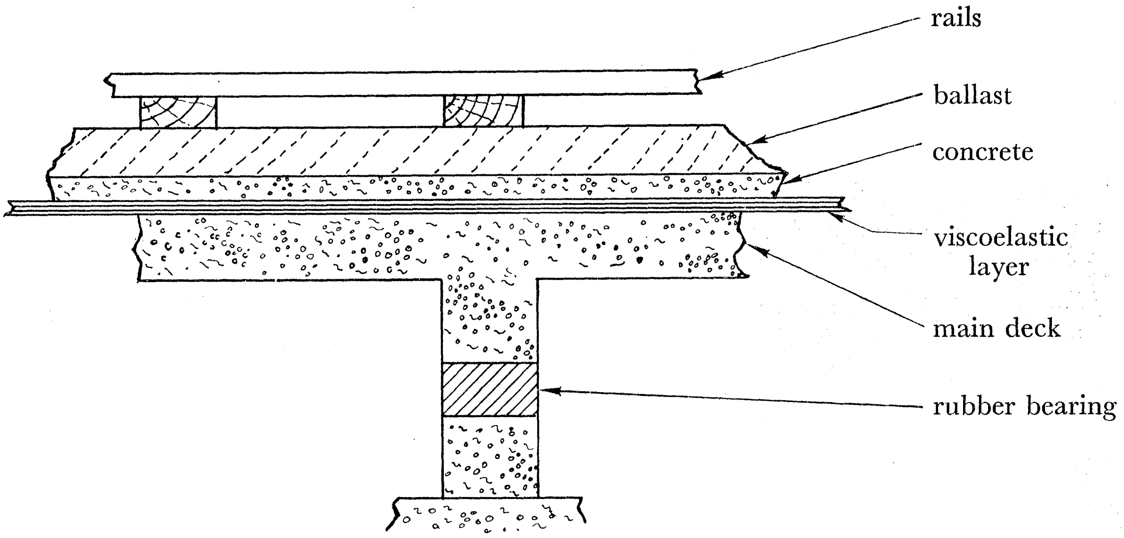

FIGURE 2. Damping treatment of main deck.

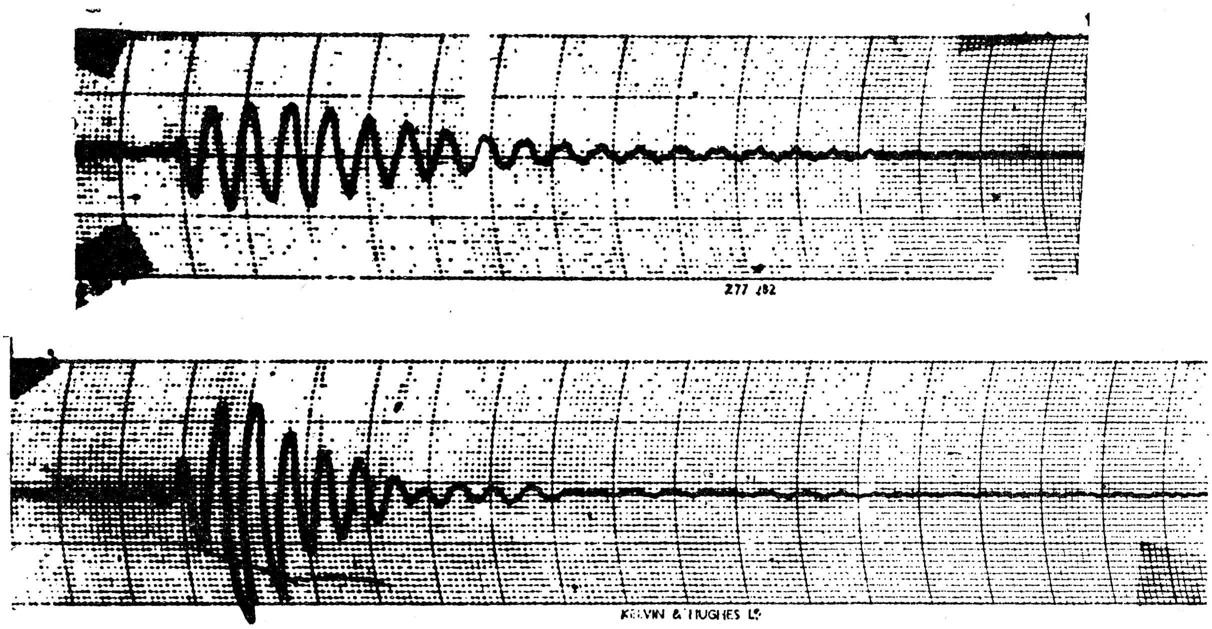

FIGURE 3. Records of the free vibration of a test beam. Upper record, undamped beam; lower record, beam with damping treatment.

it had received an impact. These vibrations were measured with a velocity transducer attached to the beam and two typical records are shown in figure 3. The upper record was obtained with an undamped beam with some in-fill concrete added to it. The amount of damping in the beam and at the supports can be expressed by the logarithmic decrement of the decaying vibrations which is 0·10 for this record. The lower record was obtained with the same beam with the addition of a $\frac{1}{4}$ in. thick layer of bitumen-rubber latex and a

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6 in. thick layer of reinforced concrete as the outer backing layer of the damped sandwich. The logarithmic decrements for this record has increased to 0·45. The frequency of vibration for each record was about 16 Hz and the maximum amplitude about 0·005 in. The lower record shows clearly the slow build-up of the response after the impact which is typical of a heavily damped system.

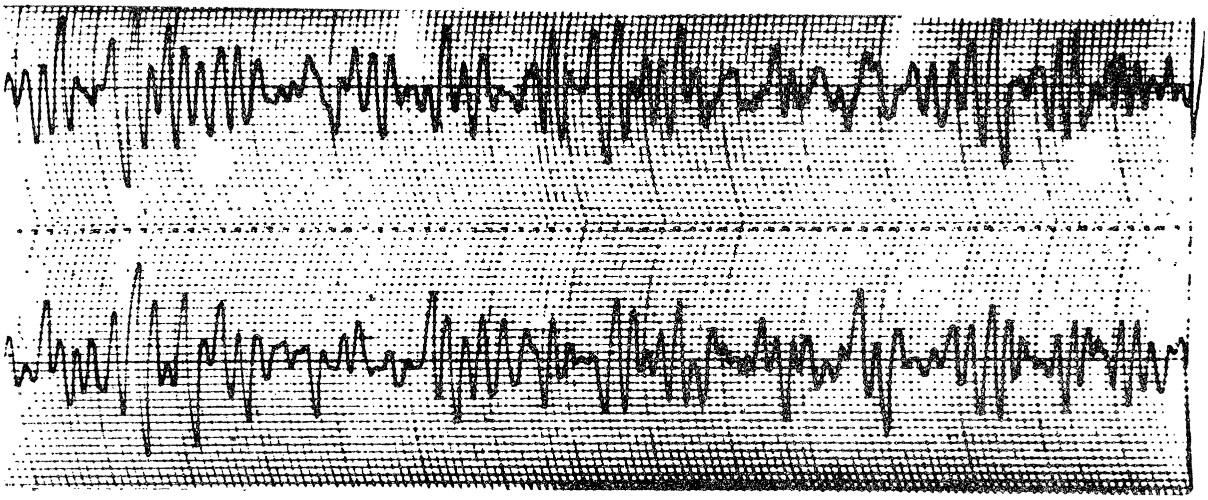

FIGURE 4. Velocity of motion of the deck due to a diesel train. Upper record, transducer on cross-beam; lower record, transducer at mid-span.

A further proof of the effectiveness of the damping treatment has been obtained by measuring the vibrations of the bridge deck when a diesel train was passing over it. Two identical vibration transducers were attached to the deck, one at mid-span and the other at one of the support cross-beams over a rubber block. Any build-up of vibrations due to resonances within the bridge deck would give a larger output from the transducer at midspan. A typical record is shown in figure 4, and although the wave form is somewhat complex there is no evidence of any build-up in vibration levels.

CONCLUSION

The sandwich damping technique developed initially for reducing resonant vibrations in panels in aircraft and missiles can be applied to concrete structures. The first large-scale application for the damping of the bridge deck of the suspended railway sections on the Barbican redevelopment site has demonstrated its feasability and effectiveness.

This form of damping treatment can be applied to other types of bridges and to concrete floors supporting sources of vibration as well as sensitive instruments.

Another application would be placing a damping layer between a concrete floor and the finish screed or other hard top surface. Much of the noise and annoyance caused by footsteps in corridors could then be eliminated. The high value of the loss factor of bitumen-rubber latex mixture makes this a promising material.

The structural design for the railway realinement was carried out by Messrs Ove Arup and Partners, to the requirements of the London Transport Board. The experimental work was done with the help of Messrs Ove Arup and Partners.

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