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The Effect of Polymer Additives on the Internal Damping of Cement Mortar Beams

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INTRODUCTION

Vibration studies of concrete and cement mortar have shown that there is a need for structures of this material to have a higher internal damping. Materials so modified would result in amplitudes and decay times of resonant structural vibrations being reduced. Flanking transmission would also be attenuated. Methods of increasing the internal damping appear to have been confined to the application of layers of high damping material to the exterior of the concrete, or to the use of a separate layer within the structure (Randell and Ward 1965, Grootenhuis 1967). Among the difficulties encountered when using this technique are the economic considerations of placing the high damping layer. This paper describes an alternative approach in which damping can be "built" into the structure in the form of a suitable polymer used as an additive to the cement mix.

PREPARATION OF SPECIMENS

Beam specimens consisting of pure mortar and mortar plus a controlled content of polymer were prepared and stored as recommended in BS 1881 (1952). The polymers used were:

1) Acrylonitrile butadiene,
2) Acrylonitrile butadiene plus polyvinyl chloride,
3) Polyvinyl acetate (Vinyl Products type N9125) unplasticised.

Where possible polymer was added to the mix in the form of an emulsion. For the first two groups of polymer, however, this type of addition had a detrimental effect on the hydration and curing times of the mortar.

STRUCTURE OF POLYMER/MORTAR MIX

The first type of polymer emulsion appeared to be distributed throughout the mortar as a lattice which could be considered as two subgroups:

a) Spherical globules,
b) Thin cylindrical chains

To overcome difficulties experienced when using acrylonitrile butadiene emulsion, and to enable study of subgroup (a), solid spherical globules were manufactured from the emulsion, and added to the cement mix as an aggregate.

GEOMETRY OF SPECIMENS

If the polymer was thoroughly dispersed throughout the mortar, small specimens of such materials could be considered macroscopically homogeneous. For this reason, and because of conclusions reached by Cole and Spooner (1965), small beam specimens (50 x 5 x 1.5cm.) were used, thus facilitating convenient handling and allowing easy excitation and detection of flexure by PZT/5 piezoelectric type strain transducers.

DAMPING MEASUREMENTS

The methods for examining the variation of internal damping with frequency were those of free decay and determination of bandwidth for various flexural partials of a beam specimen. Where possible the logarithmic decrement of the specimen was automatically and rapidly evaluated from the partials decay by employing a specially designed decay measuring apparatus (Mason and Leventhall 1969). The simplified experimental arrangement is shown in Fig. 1. This enabled the damping associated with at least the first 18 flexural partials of the beam specimen to be determined. That is, the logarithmic decrement in the range 0.01 to 0.20 for frequencies from 150Hz to 20kHz could be determined from a single sized specimen at a constant excitation strain of about 10^{-5}.

SUPPORT SYSTEM

To obtain meaningful values for the internal vibration damping of a material, additional external damping arising from constraints placed on the specimen by the supporting system must ideally be eliminated. Of several support systems investigated by the present authors, that shown in Fig. 2, produced the closest approximation to a free-free configuration for a flexing beam specimen.

THEORETICAL CONSIDERATIONS

A theoretical study has been conducted of the stress transfer that occurs between the mortar and polymer. It is assumed that this produces a deformation of polymer which results in strain energy being dissipated. The work of Southwell (1926) and Goodier (1933) has been extended and, including bulk changes which were found to occur, the value of damping of a specimen due to an addition of polymer in globule form has been expressed in terms of the elastic constants and geometry of the mortar and polymer at a given partial resonance. The elastic constants of the polymers used, which were required for the evaluation of the above theory, were determined by conventional methods.

RESULTS FROM MORTAR/POLYMER BEAMS

The first graph of Fig. 3 shows the variation with frequency of the logarithmic decrement of beams containing different concentrations of acrylonitrile butadiene globules. Also shown in the second graph is the variation in damping for the first beam partial given by various concentrations of these globules. Included on this plot is the variation predicted by the theory which has been outlined above.

A similar set of graphs (Fig. 4) is shown for a wet cure set of beams containing polyvinyl acetate emulsion. For a five per cent addition of this polymer the internal damping had increased to nearly six times that of the pure specimen.

DISCUSSION

The literature shows that the mechanical properties of cement mortar may be improved by the addition of a polymer (e.g. Cherkinsky 1960). However, it is generally accepted that such additives produce specimens with a compressive strength inferior to that obtained from equivalent specimens of pure mortar. Further investigation of a variety of polymer types and blends is required in order to select an optimum material with which a small percentage addition will make it possible to achieve considerable improvements in damping whilst maintaining compressive strength at an acceptable level.

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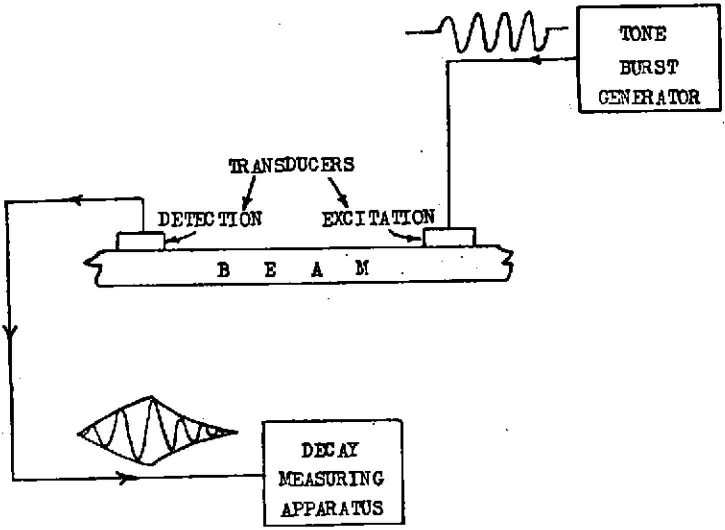

Fig.1. Simplified Diagram of Experimental Arrangement.

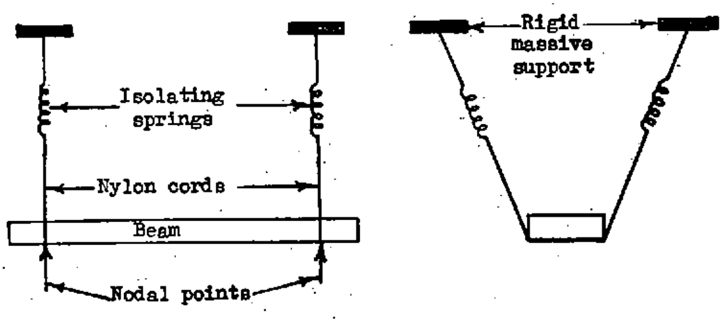

Fig.2. The Free-Free Support System.

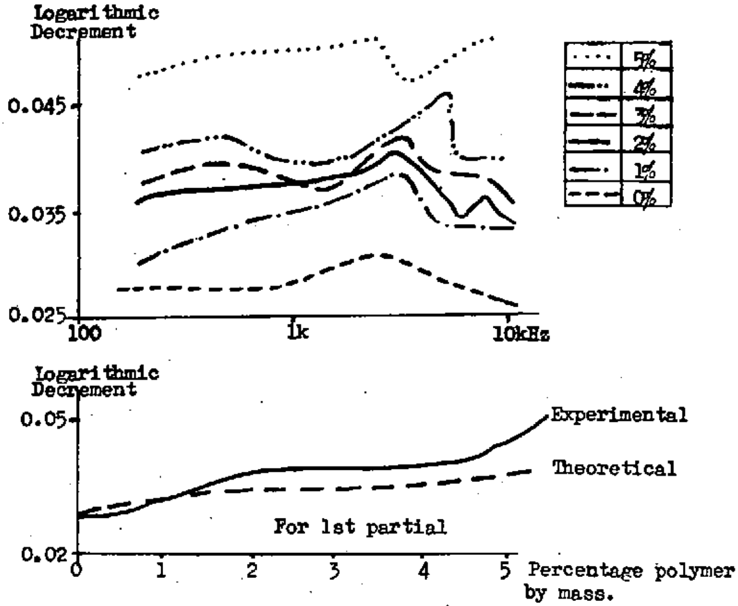

Fig. 3. Results for Specimens Containing Acrylonitrile Butadiene Globules.

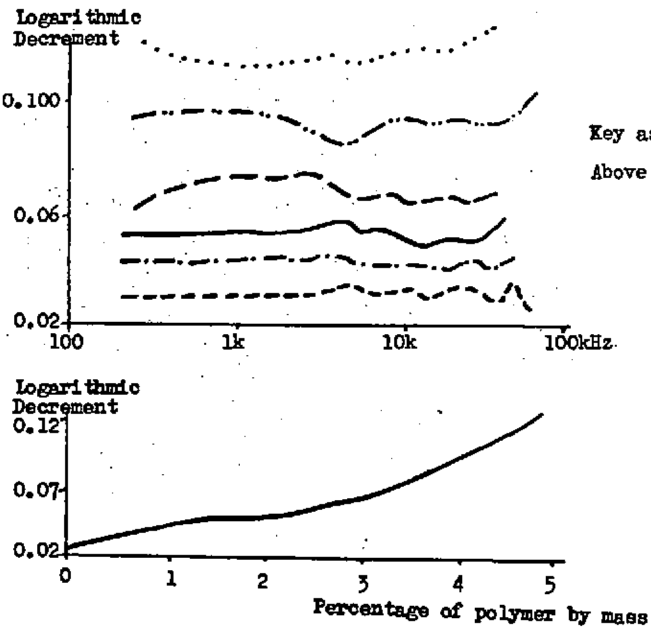

Fig. 4. Results for Specimens Containing Polyvinyl Acetate.