BRITISH ACOUSTICAL SOCIETY: SPRING MEETING at Chelsea College
London S.W.3. on Wednesday 25th April to Friday 27th April 1973

VIBRATIONS: SESSION A: STRUCTURAL ANALYSIS AND DAMPING

Paper No. 73VA3

The Internal Damping Capacity of Concrete and its Modification by Polymer Additives

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The problem of vibration transmission by concrete members is of importance when designing buildings and structures in which minimisation of noise and vibration is desired. The paper describes a method of increasing the internal damping, thus decreasing the amplitude of vibration, of concrete specimens. This increase in damping is obtained by the addition of polymer emulsions to the wet concrete mix. The effect the polymer has on the compressive strength of the concrete has been measured and a theoretical model for predicting the damping for a given amount of polymer additive has been proposed.

Several polymers have been used, namely the Revertex products Revinex 29Y40 (Styrene-butadiene latex), Emultex DM1H (Vinyl acetate acrylate emulsion), Emultex 319 (Vinyl acetate with 10% Di-butyl phthalate plasticizer emulsion). Emultex D50 (Vinyl acetate emulsion) and Revertex A3352/1 (all acrylate emulsion). The two polymers which gave the best damping and strength characteristics for 1% addition to the concrete (DM1H and A3352/1) were subsequently chosen for more extensive investigation.

A 1:1:2 concrete mix of sharp sand, cement and coarse aggregate was used throughout the work and the water/cement ratio varied as required.

Previous work has been carried out on the damping of small polymer-modified mortar beams with the polymer added in the form of globules. Results from this work appeared to be encouraging, although the practicability of producing polymer globules for inclusion in a large concrete beam is questionable. It was thus decided to add the polymer in the form of a water-based emulsion with up to 10% by weight of polymer being added to the wet concrete mix.

A resonance technique was used to measure the damping characteristics of rectangular section concrete beams (dimensions approximately 2m x 0.22m x 0.15m) in the frequency range 100 Hz - 2 KHz. This involved supporting the beam at its nodal points to minimise system loss. The sample was vibrated at an antinode of the harmonic of interest, at the frequency of that harmonic, by a vibrator coupled to the sample through a spiral spring to ensure good mechanical contact. A strain gauge was used to monitor the resulting vibration, and subsequent decay, when the exciting spring was withdrawn from contact with the sample.

The log. dec. of the concrete samples was calculated from measurements of the exponential decay curves obtained. This method proved inaccurate for highly damped specimens because of the few cycles involved in the decay. Bandwidth methods were used to determine the log. dec. in such cases.

Initial tests were carried out using 1% and 2% additions of polymer, the results of which are shown in figs. 1 and 2. It can be seen that 1% addition increased the damping of concrete by a factor of approximately two whilst a 2% addition increased the damping by a factor of three. The damping of the 1% set of samples was recorded at various intervals up to one year. After an initial period of rapid decrease in damping, it was found that the damping versus time curves ran approximately parallel to the curve for untreated concrete.

This initial rapid change in damping is thought to be due to the fact that the polymer is hydrophilic. Water is retained for a longer time in the treated concrete and therefore the hydration process is retarded. In the untreated concrete most of the initial hydration is completed at seven days, when the first tests are carried out, and the major part of any excess water has evaporated. Additional hydration then proceeds so as to reduce the damping at a decreasing rate. This condition is thought to be reached at a greater age with the treated concrete depending on the polymer used. Tests have shown that for larger percentages of polymer additives, this effect is even more pronounced.

DM1H and A3352/1 were chosen for more extensive investigation with up to 8% addition to the concrete. Results of the tests are shown in figs 3 and 4. Instead of the expected proportional increase of damping with increase of polymer additive, the results show a 'transition' stage where a very large increase in damping is observed for a small increase in polymer content. This is probably due to a transition between the state where the concrete is the controlling influence in the damping mechanism of the composite to one where the polymer becomes the dominant factor.

Work on post-tensioned prestressed concrete beams has shown no significant decrease in damping over reinforced or unreinforced concretes. Thus polymer treated prestressed beams have similar damping properties to other beams. So far only low stresses have been used and we are currently experimenting with higher stresses.

It was found that there was a marked decrease in compressive strength of polymer treated concretes depending on the type and amount of polymer addition. This decrease is thought to be due to the way in which the polymer modifies the hydration process. The polymer, being hydrophilic, tends to retain excess water which would normally (a) react with the cement, forming a cement gel and (b) evaporate by capillary action through the pores of the hydration products. It is thus desirable to cure the modified concrete at a low relative humidity to obtain optimum strength at early ages. Results of compressive tests on 150 mm concrete cubes cured under ambient laboratory conditions are shown in fig. 5.

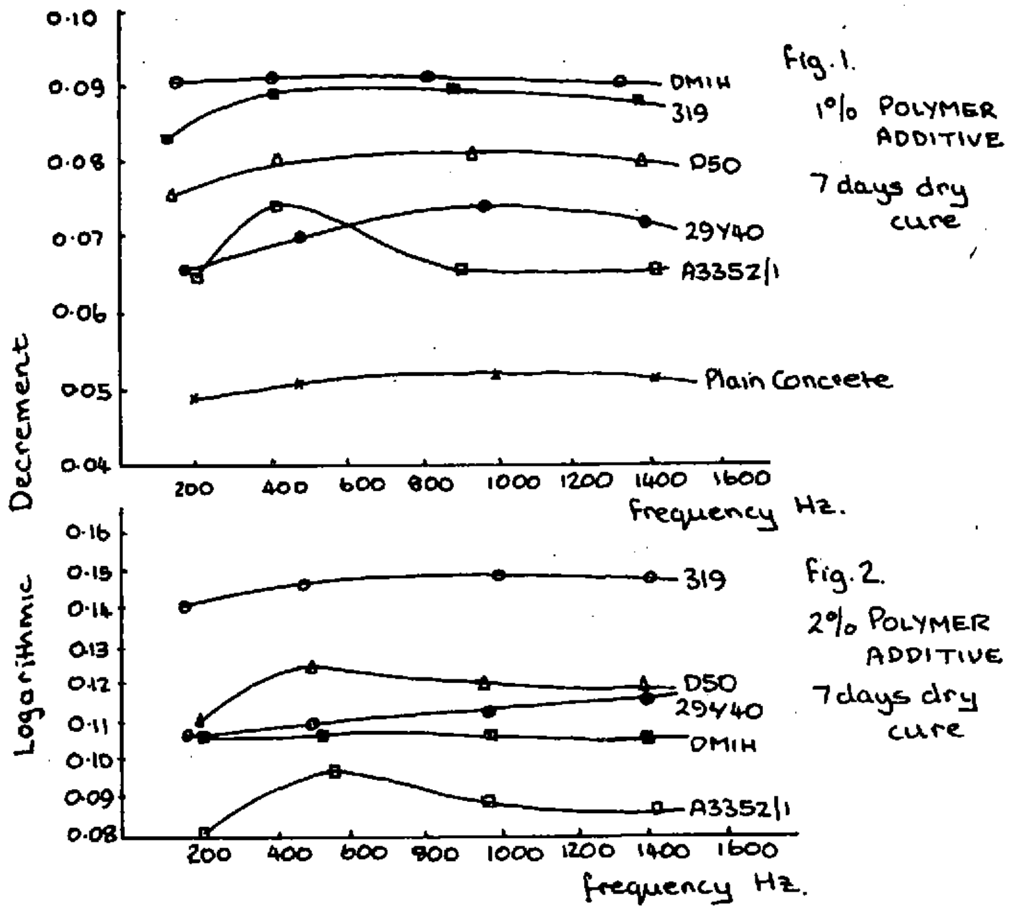
The mechanical system formed by the addition of polymer to concrete has a marked effect on both the compressive strength and damping of the concrete-polymer system so formed. A model considering the complete system to be formed by successive layers of polymer and concrete has been formulated and it is hoped that this together with measurements of the mechanical properties of the polymers, will enable the damping and strength of concrete treated with varying amounts of polymer to be predicted.

CONCLUSIONS

The internal damping of concrete specimens increases significantly when polymer is added to the mix. However, decreases in compressive strength of the modified concrete have been observed.

Other authors have shown that, under controlled curing conditions, certain polymers may increase the compressive strength of concrete when added to the mix. Thus, it is believed that, with a suitable polymer as additive, useful increases in the internal damping of concrete can be obtained without significant decrease in compressive strength.

ACKNOWLEDGMENT. This work is supported by the Science Research Council. We are grateful to Revertex Ltd., for the provision of the polymers.



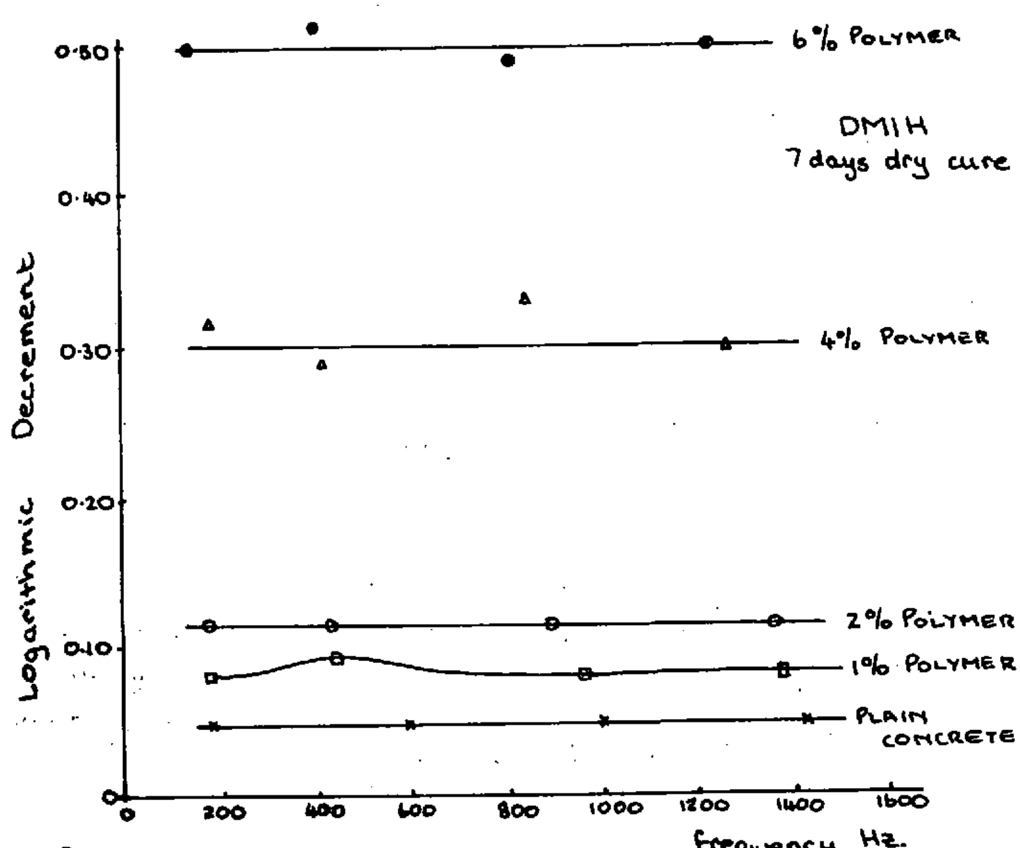
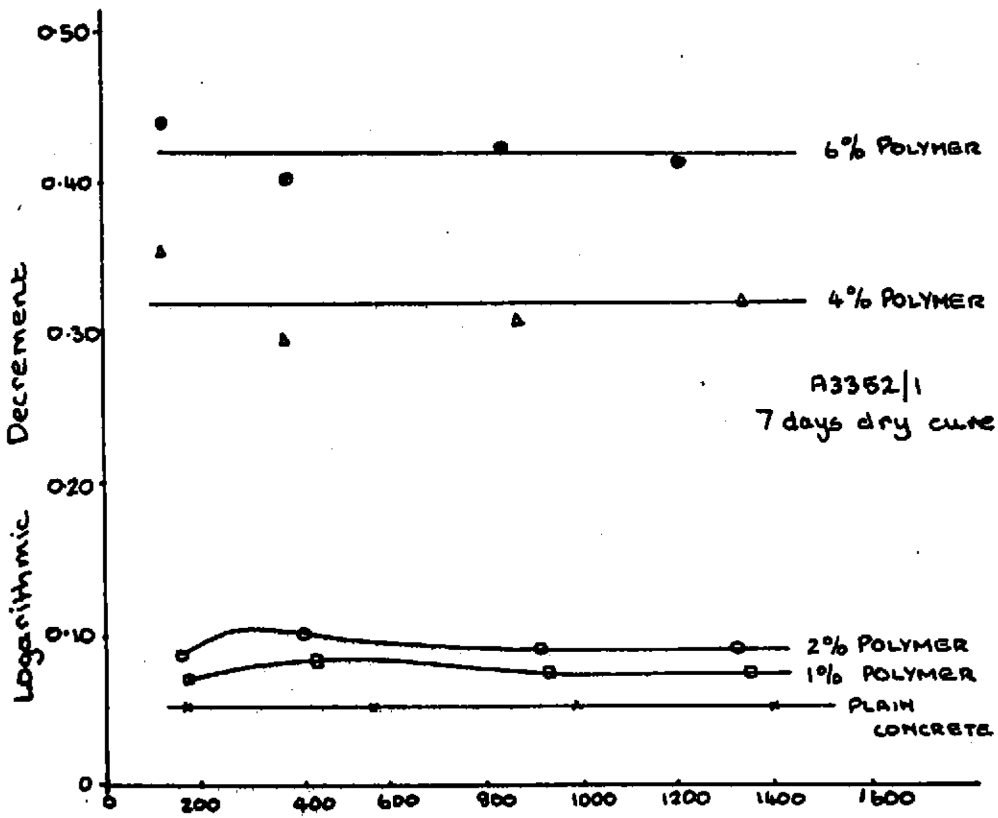


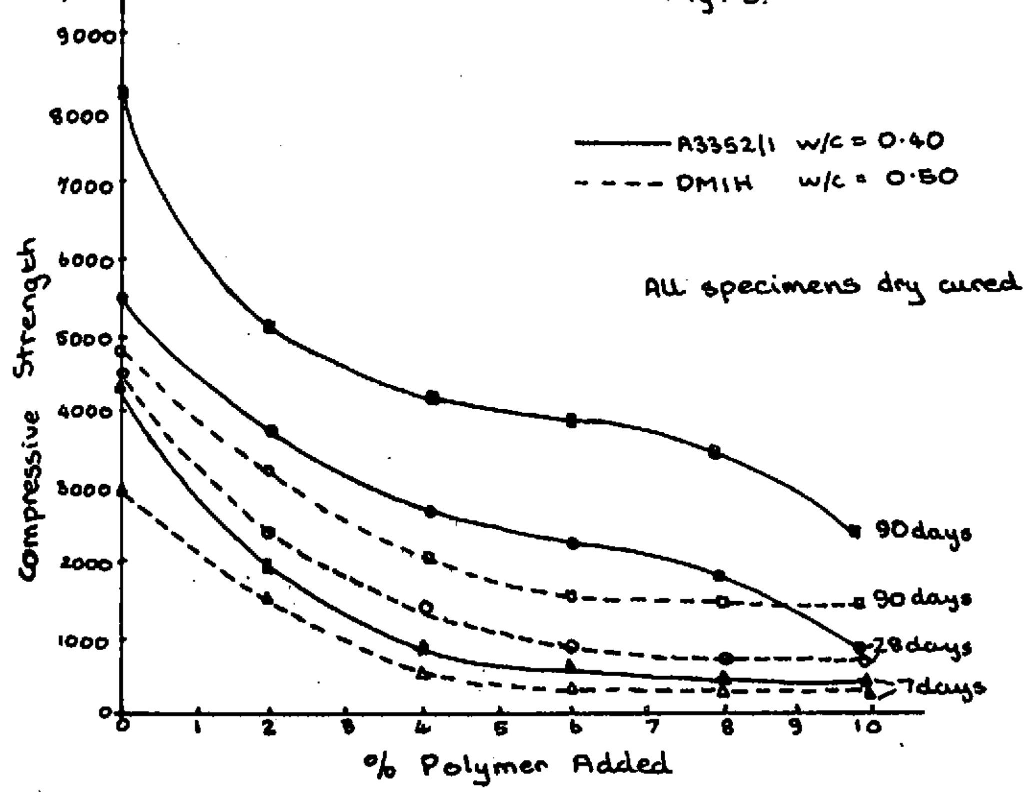
Fig. 3.



0.50
0.40
0.30
0.20
0.10
0
Logarithmic Decrement
6% POLYMER
4% POLYMER
A3352/1
7 days dry cure
2% POLYMER
1% POLYMER
PLAIN CONCRETE
0
200
400
600
800
1000
1200
1400
1600
Frequency Hz.

Fig. 4.

Fig. 5.



p.s.i.
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Compressive Strength
A3352/1 w/c = 0.40
DMIH w/c = 0.50
All specimens dry cured
90 days
90 days
28 days
7 days
0
1
2
3
4
5
6
7
8
9
10
% Polymer Added