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A PRACTICAL METHOD TO INCREASE DAMPING ON INDUSTRIAL MACHINERY USING SAND GRANULAR MATERIAL

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INTRODUCTION

There is frequently a need to reduce sound radiation due to resonant flexural vibrations of stiff panels. This can be achieved by the use of an appropriate damping treatment. Conventionally viscoelastic damping materials are used but such materials are often not ideally suited for use on industrial machinery which often incorporate thick material sections, operate at elevated temperature, be subject to oil or other contamination or rough handling.

Alternative damping treatments are squeeze film and granular infill treatments. The physical mechanisms of squeeze film treatments at work with air and with heavy fluid (for example, oil) are reported in detail in References [1] and [2]. This paper will concentrate on the discussion of granular infill treatments.

Granular material such as sand can be used to fill the cavities of the structure components to increase the damping. It can be useful for high temperature application and it is very cheap to apply. Loss factors approaching 0.1 can be achieved over a broad frequency range.

The following sections will discuss the basic mechanism of the sand granular infill damping treatment at work. Experimental and theoretical results are also compared.

Sand bulk and shear elastic constants measurement

In order to predict the loss factor using sand granular infill treatment, the properties of the sand used have to be known. Figures 1 and 2 show the arrangement used for the sand bulk and shear elastic constants measurement respectively. The experiments have been repeated by varying the hydrostatic pressure. Figures 3 and 4 display the comparison of the measured real and imaginary part of both moduli at a particular hydrostatic pressure. At very low frequencies, the measured results are contaminated by the movement of the concrete block on which the experimental rigs were mounted. Both the moduli increase with frequencies. The moduli are constant at mid-frequencies (100Hz to 2000Hz). At high frequencies (above 2000Hz) resonant and anti-resonant behaviour occurs.

Figures 5 and 6 give the measured real and imaginary part of the moduli versus hydrostatic pressure. The results suggest that the two moduli are the same, giving a Poisson ratio equal to one-eighth. The imaginary part of the moduli increase slower than that of the real part with increasing hydrostatic pressure. This means that the internal loss factor of the sand is higher for low hydrostatic pressure. This is expected because high hydrostatic pressure causes the sand to be tightly packed, the movement between the sand particles is restricted and the losses reduced.

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Sand granular infill damping prediction using two different approaches

In this study, the damping of plates using the sand granular infill treatment is predicted using an impedance approach, in which the response of infinite coupled layers may be predicted by assigning an impedance per unit area to each layer. The excited plate, however, is assumed to have a bending stiffness higher than that of the attached plate. This means that the impedance per unit area of the attached plate is mass controlled, that is, the plate can be seen as equivalent to many small masses which are uncoupled from each other [3].

The loss factor of plates using sand is first predicted using the elastic wave equations of a solid. These include the dilatational and rotational motion in the medium. As an alternative to the exact theory, the loss factor is also predicted using the progressive wave solution to longitudinal vibration of internally damped rod.

This alternative approximate theory is used which does not allow for lateral motion within the sand. The sand layer in these circumstances can be assumed to be "locally reacting" each supporting element of plate has a rod at sand attached.

Figure 7 shows the estimated real and imaginary part of the blocked impedance using the elastic wave equations. The imaginary part at low frequencies is negative and has a 10dB per decade decay slope showing a spring-like characteristic. At high frequencies, the vibrational resonances of the sand cause the imaginary part to change sign. The blocked impedance estimated using the progressive wave solution gives the same trend.

Figure 8 compares the estimated loss factor using the two different approaches. At high frequencies, the predicted values are similar except that the peaks occur at slightly different frequencies. This clearly suggests that the dilatational motion is dominant. At low frequencies, the predicted values are different. The loss factor curve predicted using elastic wave equations gives a decrease at very low frequencies, and once it reaches a minimum, the loss factor increases again. However, the prediction using the progressive wave solution gives a continuing increase in loss factor at the same frequencies.

In order to prove that it is shearing which causes the discrepancies in the result at low frequencies, the flexural wavenumber of the excited plate was deliberately reduced. If the discrepancy was due to shearing, the prediction curve (using the elastic wave equations) at low frequencies should change with varying flexural wavenumber. However, the values at high frequencies should remain the same as the dilatational motion is dominant for both cases. Figure 9 gives the prediction result and the trend is right.

Figures 10 and 11 display the measured and predicted loss factor calculated using the progressive wave solution. The agreement is good both at low and high frequencies. This clearly demonstrates that shearing is not as important as suggested by the elastic wave equations. The dilatational motion is dominant at both the low and high frequencies.

It is noticed that the measured loss factors at high frequencies are smooth. However, the predicted values show the resonance peaks. A possible explanation for this phenomenon is that the wavespeed and therefore the wavelength in the sand is related to the bulk modulus. If the bulk modulus decreases due to a decrease in static pressure with the approach to a free surface, the wavespeed will accordingly decrease and the damping effect will therefore increase. This however, requires further study.

Figure 12 shows the predicted loss factor by increasing the internal sand loss factor from 0.22 to 0.5 in the computation. This has the same effect as increasing the sand layer thickness. As can be seen, the loss factor increases and the loss factor curve is smoothed.

CONCLUSIONS

Experimental and theoretical investigation of the sand granular infill damping treatment on plates have been carried out and the agreement is good. At low frequencies, the sand behaves as a spring. The dilatational motion is dominant at both the low and high frequencies. Shearing motion in sand is not important for predictions.

REFERENCES

[1] L.C. Chow and R.J. Pinnington, "On the prediction of loss factors due to squeeze film damping mechanisms", ISVR Technical Report No.130, University of Southampton, 1985.

[2] L.C. Chow and R.J. Pinningon, "On the prediction of oil layer damping on plates", ISVR Technical Report, No.137, University of Southampton, 1986.

[3] L.C. Chow and R.J. Pinnington, "On the prediction of the loss factors of plates using sand granular material", ISVR Technical Report No. 141, University of Southampton, 1986.

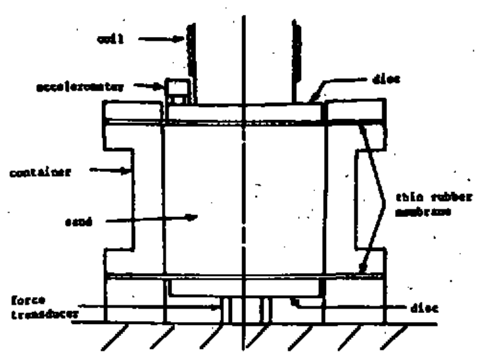


FIGURE 1

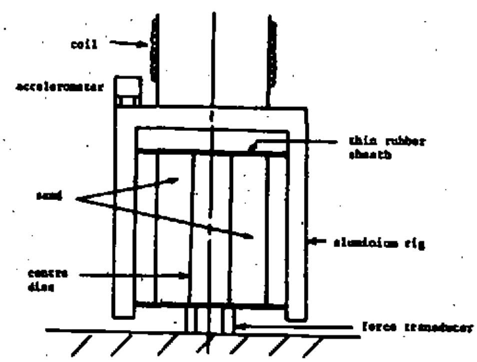


FIGURE 2

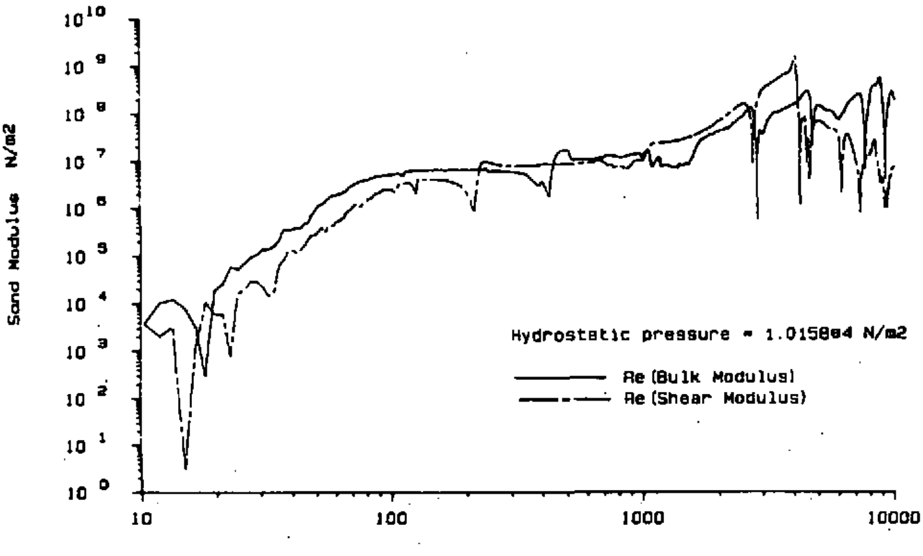
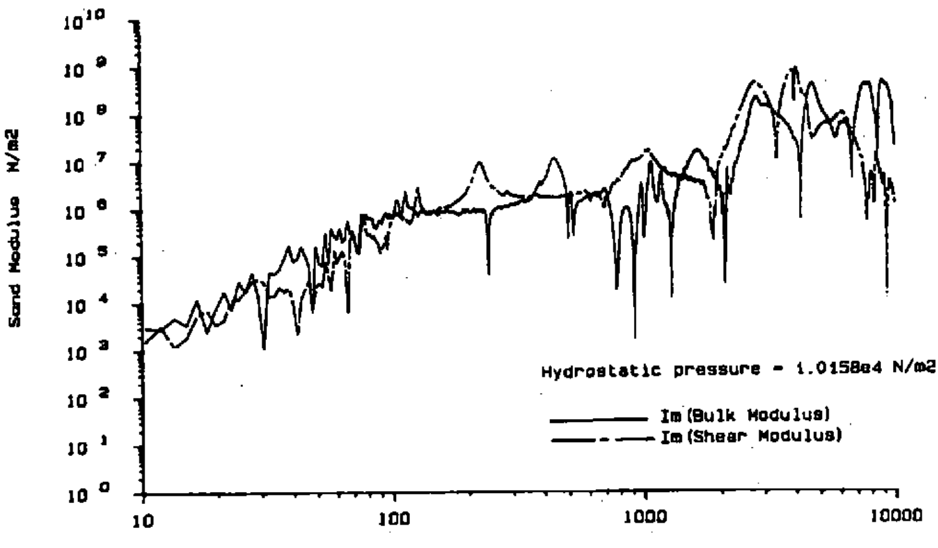


FIGURE 3



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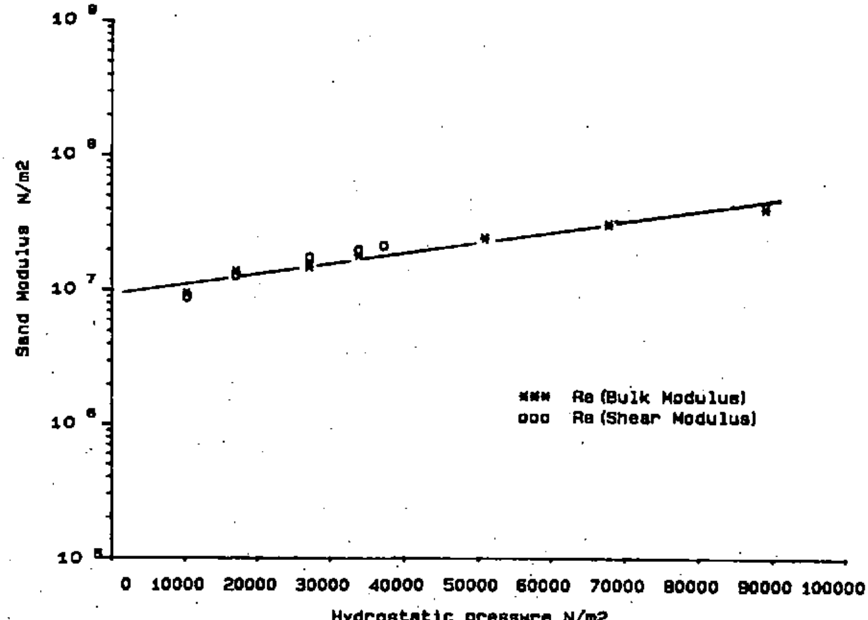

FIGURE 5

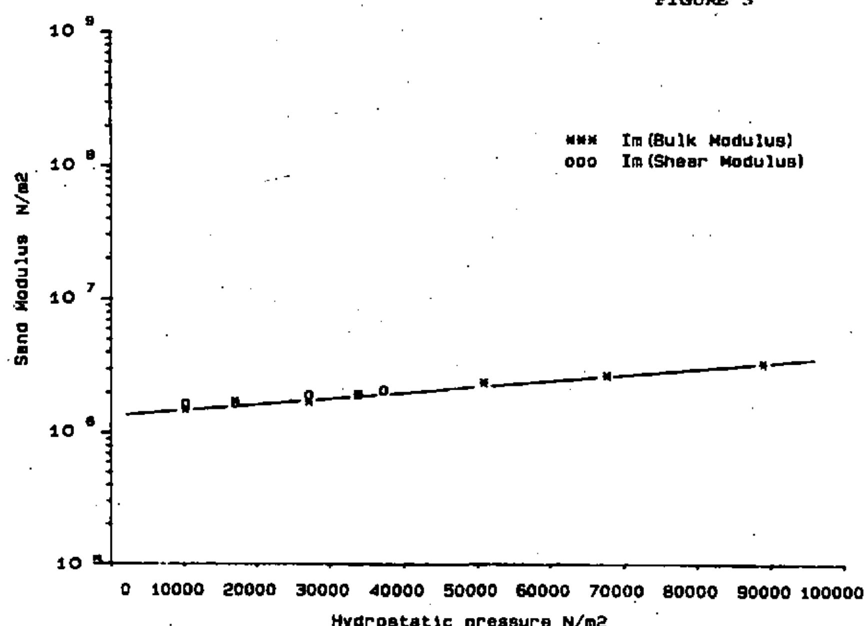

FIGURE 6

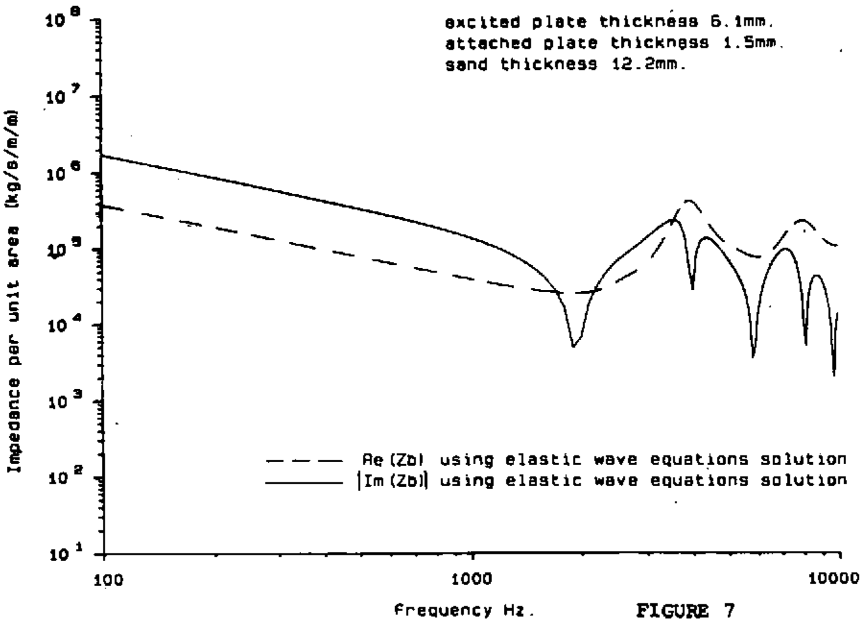

FIGURE 7

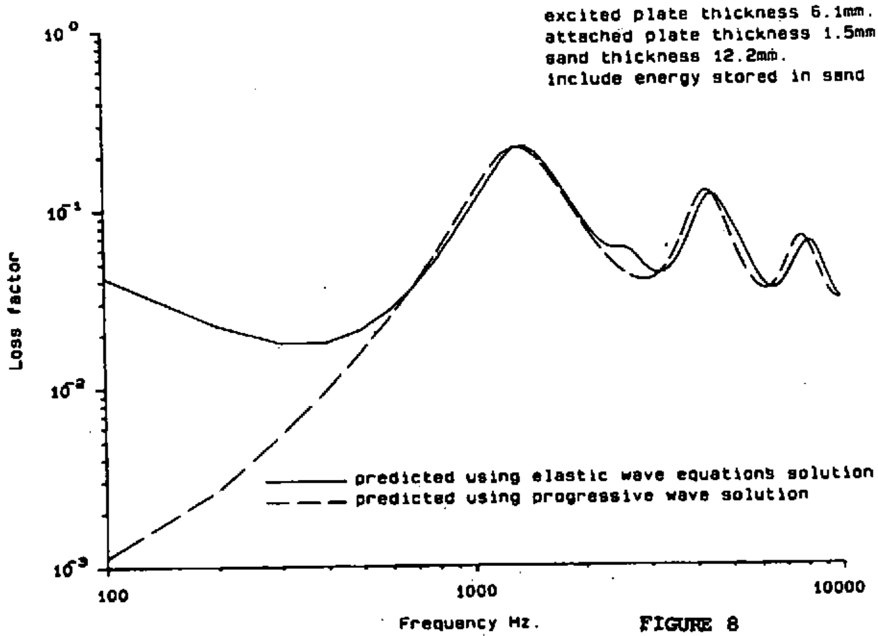

FIGURE 8

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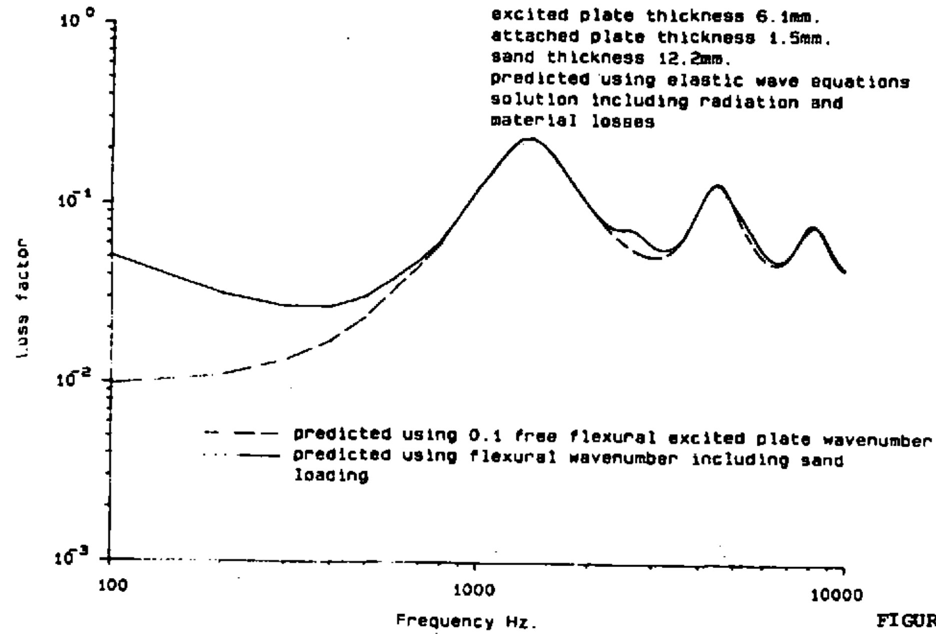

FIGURE 9

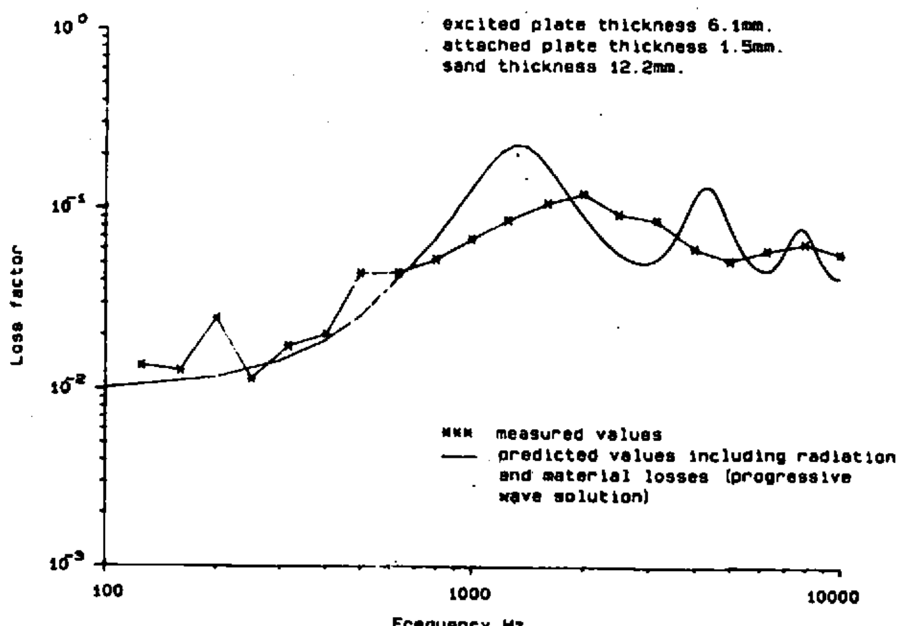

FIGURE 10

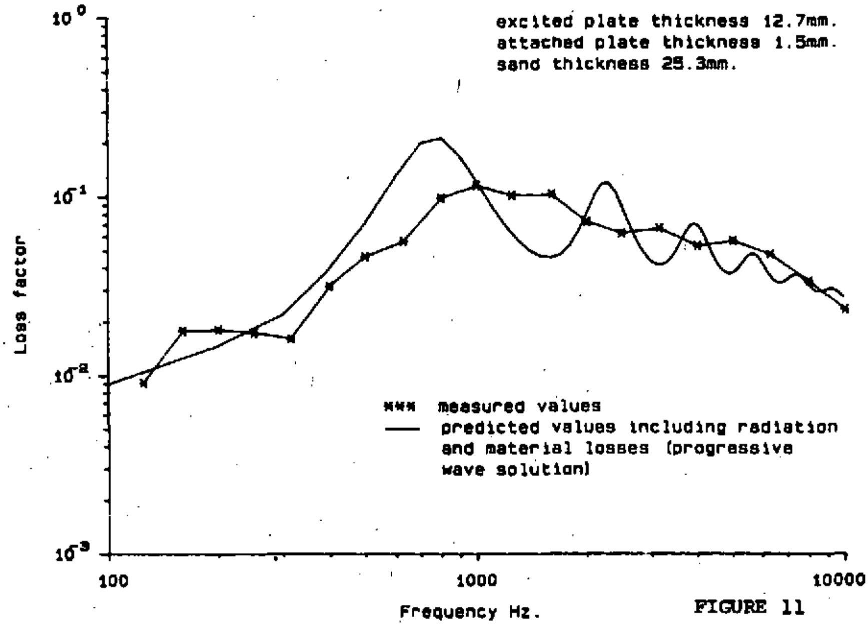

FIGURE 11

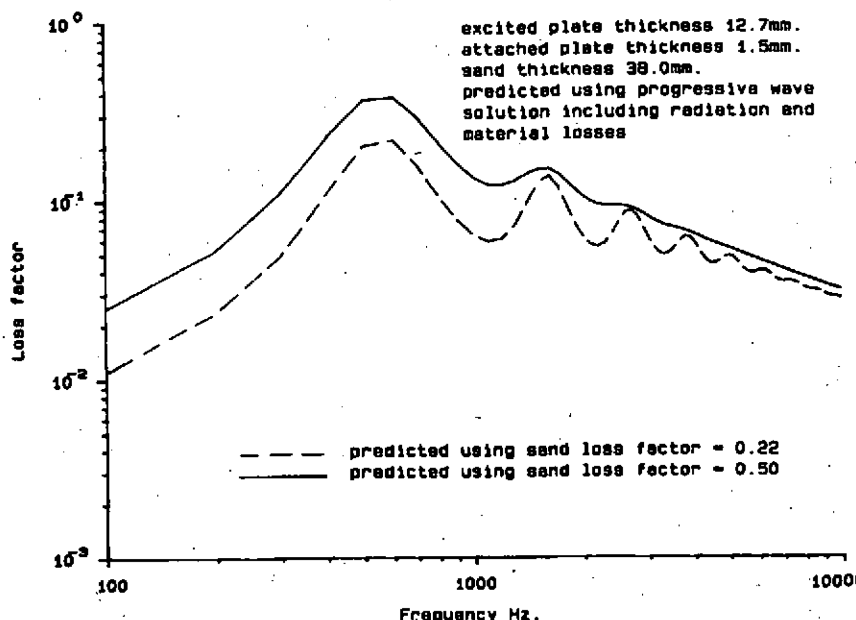

FIGURE 12