MEASUREMENT OF LOSS FACTOR IN FLOORS

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Introduction

The vibration generated by machinery and transmitted to building structures is sometimes a cause for concern. Unacceptable noise and vibration levels and occasionally even structural damage can occur, particurlarly in modern light weight structures. In order to reduce vibration transmission the designer requires information about the nature of the excitation and the dynamic characteristics of both the machine and building structure.

A parameter that controls the resonance response level and therefore has a great influence on vibration transmission is structural damping. Although various articles on damping mechanisms in built up structures have been published [eg 1, 2, 3] it is still very difficult to quantitatively estimate the amount of damping present in a structure at the design stage. Numerous practical investigations of building vibration characteristics have been reported and some of these contain data on damping in long span floors [4] and walls [5].

The object of this investigation was to obtain data on point mobility (velocity/force ratio) and total loss factor for some common types of floor, particularly in workshops where there were machine tools and other equipment standing on the floor. For comparison, a free concrete slab (floor 1), a newly constructed, unfurnished office building (floor 4), and an experimental floating floor (floor 11) were also measured.

Measurement method

Choice of measurement method was based on simplicity, transportability, and not least availability of instrumentation. An electrodynamic vibration exciter was coupled to a force transducer positioned on the floor and an accelerometer was placed as close to the excitation point as possible. The upper frequency limit for point mobility measurement was therefore governed by the transducer separation, and was typically about 2000 Hz.

For heavy floors, with a surface weight of over 100 kg/m^2, a specially modified vibration exciter was used. This had a reinforced suspension system that could support a static load equal to its own mass of 25 kg. The exciter was positioned upside down standing with its own weight loading the force transducer against the floor. A special non-magnetic guide held the exciter in a vertical position without affecting its motion.

For light floors, under 100 kg/m^2, the force trancducer was screwed to the floor and an unmodified exciter suspended above it. This arrangement was used in order to reduce the effects of mass loading at the excitation point.

The floors were excited with band pass filtered white noise in three bands up to 1600 Hz. Force and acceleration signals were recorded for about 8 points on each floor. An FFT analyser was used to evaluate point mobility and estimate average loss factor for the major resonances within each frequency band.

When resonance peaks were not visible in the mobility diagrams the damping was determined by stopping the excitation suddenly and measuring reverberation time from the decaying floor acceleration level. When the decay time was short a FM taperecorder was used for time transposition.

Measurement accuracy

The accuracy of damping estimated from resonances in the mobility diagrams depends on frequency resolution, digital analysis errors, and measurement system errors. The probable error based on the standard deviation of measurements at several points on each floor was ± 10%. Repeatability of results measured independently at the same point on the same floor lay well within the limits described in ISO standard 140/II-1978 (E).

The accuracy of damping measured from decay time is largely governed by interpretation of the decay curve and speed variations in the taperecorder. For a typical reverberation time of 1 second this gives on error of ± 15%. For very lightly damped floors ($\eta < 0.01$) the loss factor may be overestimated due to damping associated with the exciter.

Classification of floor types and results

The classification is primarily made with respect to material and surface weight, and is shown together with the results in Table 1. Loss factor shows large variations from 0.01 to 0.6 depending on frequency, floor type and construction. At low frequency (under 50 Hz) the damping appears to be most dependent on the boundary conditions. Floors with loose connections along the edges or along the supporting beams had the largest loss factors. At higher frequency (over 50 Hz), floors with surface damping (eg concrete on hardcore, or chipboard on mineral wool) had the largest loss factors. The concrete floors with free spans in general had the lowest loss factors, and the concrete slabs on the ground and wooden floors on average had 2-3 times more damping.

References

[1] Ungar, E.E. The status of engineering knowledge concerning the damping of built-up structures. JSV 26(1), 141-154, 1973.

[2] Beards, C.F. & Williams, J.L. The damping of structural vibration by rotational slip in points. JSV 53(3), 333-340, 1977.

[3] Mead, D.J. Prediction of the structural damping of a vibrating stiffened plate. AGARD-CP-277, 2.1-2.15, 1979.

[4] Fahy, F.J. & Westcott, M.E.. Measurement of floor mobility at low frequencies in some buildings with long floor spans. JSV 57(1) 101-129, 1978.

[5] Craik, R.J.M. The measurement of structural damping. Proceedings IOA Autumn Conference, 37-39, 1980.

HEAVY FLOORS (> 100 kg/m²)	Thickness	Floor construction	Loss factor η, in frequency bands		
			5-50 Hz	50-400 Hz	400-1600 Hz
1. Concrete, on a free span	14 cm	slab, point supported an corners	0.026	0.026	0.015*
2.	12 cm	floor cast onto walls	0.090		
3.	20 cm	floor and walls cast together	0.14*	0.031*	0.009*
4a.	20 cm	girders, columns & floor cast together	0.16*	0.082	
4b. Concrete, over a beam	20 cm	-"-	0.086	0.094	
4c. Concrete, over a column	20 cm	-"-		0.046	
5. Concrete, on the ground	13 cm	10 cm slab & 3 cm screed on 30 cm hardcore	0.10	0.38	
6.	13 cm	10 cm slab & 3 cm screed on 20 cm hardcore	0.23*	0.14*	0.039*
7. Floating concrete floor	4 cm	4 cm slab on 3 cm polystyrene	0.64*	0.087*	0.022*

LIGHT FLOORS (< 100 kg/m²)	Thickness	floor construction	Loss factor η, in frequency bands		
			5-50 Hz	50-400 Hz	400-1600 Hz
8. Wood floor on beams	1 1/2"	boards on 2" x 5" beams on brick pillars	0.29*	0.11*	0.059*
9. Wood floor on joists	1 1/4"	boards on 2" x 3" joists on concrete elements	0.67*	0.13*	0.051*
10.	1 1/4"	boards on 2" x 3" joists on concrete slab	0.23*	0.047*	0.013*
11. Floating wooden floor	22 mm	chipboard on 3 cm mineralwool on wood floor	0.21*	0.40*	

Table 1. Loss factor measured for some floor constructions.
Results are the average for several measurement points on each floor.
(* measured using reverberation time)