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FLOOR VIBRATIONS AND LOW FREQUENCY SOUND PRESSURE LEVELS USING A RUBBER BALL IMPACT METHOD

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ABSTRACT

A test method using a rubber ball for excitation and an 8- channel FFT system for analysis is used for investigations on different lightweight constructions. The method is intended for a combined testing of impact sound insulation and human induced floor vibrations at low frequencies. The paper mainly deals with research work concerning floor vibrations. Vibration measurements is analysed and compared with numerical calculations using a finite element software program BLAG developed for designing floor constructions.

1 - INTRODUCTION

In Norway wooden floor constructions are very common, also for floors between dwellings. But the general experience is that they do not fulfil people's expectations concerning low frequency impact sound insulation. Common types of timber beam constructions are fairly good concerning the airborne sound insulation, however inhabitants often claim about disturbing vibrations from walking and other normal use of the houses. For the assessment of the quality of lightweight constructions, methods based on the ISO tapping machine and rating methods seems inadequate. An excitation method using a rubber ball is therefor used here. The impact is comparable with an adult jumping, see [1].

2 - EXCITATION METHODS

The impact sound and vibration levels will in general be determined by the dynamic properties of the whole system comprising the plates and beams, the cavities and the receiving room. However, in the lower frequency range, i.e. below 100-150 Hz it may be possible to separate out the effects of the various components combining numerical modelling and narrow band measurements or Fourier transform techniques. Apart from the ISO tapping machine there exist a whole range of suggested excitation methods, for instance drop of a sand ball or sandbag, a falling rubber tyre (JIS-standard) or rubber ball and a live walker. With the sand ball or sandbag excitation method, it is possible to justify the loading with respect to the duration of the impact, but it will be difficult to prevent a static loading after the impact. A rubber tyre or rubber ball will prevent static loading before and after the impact, and it is possible to justify the impact duration and force level. At Norwegian Building research institute we are using a " Japanese " rubber ball type "NF 8", see [2] for research work concerning low frequency sound insulation and vibration measurements of lightweight floor constructions. Equipment is developed to drop the rubber ball preventing rebounds as well as static loading, see figure 1. A drawing of the force in the time domain show a very smooth curve with a duration of the force impulse of about 20 ms, see reference [3]. Experimental investigation shows that the maximum energy in a footfall spectrum occurs between about 20 to 50 Hz, which mostly coincides with the fundamental natural frequency of the ceiling system and with some natural frequencies to the timber beams. The frequency range below 50 Hz should therefore not be excluded in further investigations.

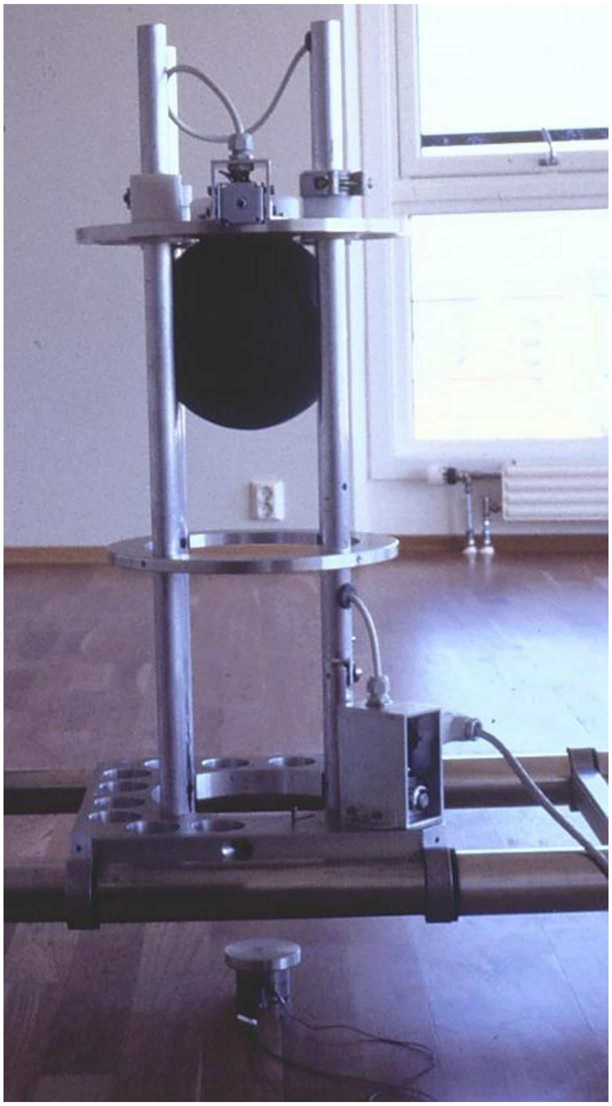

Figure 1: The dropping equipment with rubber ball and transducers.

3 - VIBRATION MEASUREMENTS AND ANALYSIS

In the laboratory, measurements have been carried out for a total of 8 floor constructions. The investigated floor constructions are based on three main principles. Cross-section of the different constructions is shown in table 1. Experimental investigations are based on simultaneously measured force level, acceleration levels at 3 different positions and sound pressure levels in the receiving room at 4 different positions. Different excitation points have been used including the weakest point above a beam i.e. in middle of the span with. The measurements always include acceleration levels at the excitation point. Excitation and measurements at positions between the beams have not consistently been carried out. From the 8 channel OROS FFT-system the collected data have been stored and later on converted to Matlab format for analysis and presentation. For the floor vibration purpose, the time series have been analysed in the following way:

Band pass filtering in the frequency range 2−500 Hz for control and transfer function purposes, and in the frequency range 5−40 Hz for adaptation to the calculation procedure in BLAG, see [4], *transforming* the acceleration level measurements *to velocity* in the time domain using FFT and IFFT routines, *calculation of maximum velocity level* from this impulse response, *calculation of maximum and integrated force function*, *calculation of measured maximum impulse velocity response*, and *calculation of loss factor* for each observed resonance based on the transfer function. Some results from the measurement and analysis are presented in table 1. Values for the loss factor are based on average values for all equal resonance frequencies.

	Beam and simple plate	Beam, transverse stiffeners and floating floor	Beam, plate, additional mass and floating floor
* Beam web not perforated			
Span width 7,02 m	OS – A *	OS – E	OS – H
h'$_{\text{max}}$ [mm/s/Ns]	31	27	44
f_1 [Hz]	12.5	11.9	9.4
η [%]	9	8	4
Span width 4,6+2,42 m	OS – B * / OS – C	OS – D	OS – G
h'$_{\text{max}}$ [mm/s/Ns]	34 / 36	28	49
f_1 [Hz]	23.8 / 23.8	19.7	23.1
η	9 / 8	6	4

Table 1: Cross-section of the different floor constructions and some results from the measurements and analysis.

4 - FEM CALCULATIONS USING BLAG

A design guide for springiness and human-induced floor vibrations was established some years ago, see reference [4]. The design procedure deals with calculation and control of deformations, maximum initial impulse velocity response, h'$_{\text{max}}$ and velocity related to continuous load. This paper deals with the impulse velocity response as a model for experimental investigations and for independent calculations. In conjunction with the h' $_{\text{max}}$ criterion, it is the initial vertical vibration velocity due to an idealised (unit) vertical force impulse which is to be limited – and calculated at the " weakest point ". Only contributions at frequencies $f < 40$ Hz are taken into consideration, and the design method do not apply for constructions for which the lowest resonance frequency $f_1 < 8$ Hz. The term " weakest point " refers to the point where h'$_{\text{max}}$ assumes its greatest value (often at mid span towards one of the short sides of the floor).

*Beam web not perfor. c/c 300 mm	Beam c/c 600 mm and simple plate	Beam and transverse stiffeners	Beam and plate with additional mass
Flexural stiffness: D_x D_y [Nm^2/m]	$3{,}3\times10^6$ * / $3{,}2\times10^6$ $2{,}1\times10^{3}$	$2{,}8\times10^6$ $5{,}7\times10^4$	$3{,}2\times10^6$ $4{,}2\times10^3$
Weight [kg/m^2]	23	35	75
Span width 7,02 m	OS – A *	OS – E	OS – H
h'$_{\text{max}}$ [mm/s/Ns]	42	20	(22)
f_1 [Hz]	12,1	9,1	6,6
Span width 4,6+2,42 m	OS – B * / OS – C	OS – D	OS – G
h'$_{\text{max}}$ [mm/s/Ns]	38 / 41	21	27
f_1 [Hz]	36,0 / 35,4	26,9	19,6

Table 2: Input and output values from the BLAG calculations.

Research results show that people tolerate a much higher initial vibration velocity if the vibration is rapidly damped. From [4] the damping coefficient σ_0 is considered to be an important parameter, where $\sigma_0 = f_1 \cdot /2\left[s^{-1}\right]$. Table 2 shows important input parameters and essential results from the BLAG calculations. Attempts have been made to choose realistic values for the material parameters.

5 - COMPARISON AND COMMENTS

The calculations show natural frequencies both lower, equal and higher than the measured one. Some of the discrepancies are large, especially for the double span-with situation. One reason for this is probably some uncertainties related to the " choice " of frequencies in the transfer function. Another important reason for the discrepancies, is that the measured construction do not act as an ideal double-span construction caused by a light construction without loads at the supports. For the construction with additional mass, the lowest calculated natural frequency is below the limit specified in the calculation method and also below the measured values. In this case, the values for the calculated impulse velocity response is not valid (given in parenthesis in table 2). For the constructions with top floor plate fixed to the beams, the calculated impulse velocity responses are a bit higher than the measured one. For the construction with a floating top floor solution, the measured impulse velocity responses are higher than the calculated one. Except for the construction with additional mass, the calculated responses are in reasonable agreement with the measured ones. For independent analysis (or control purposes), the maximum impulse velocity responses will also be determined from measurements with the rubber ball falling directly on the floor. The calculated loss factors (from measurements) are considerable higher than assumed values from [4]. The results also show great differences between the constructions, but not between the single and double span-width of the same construction. The reason for this is not clear.

From [4] a preliminary proposal for classification of the response of a floor construction to an impact load is presented. Input parameters for this classification is the maximum impulse velocity response and the damping coefficient. In this case assumed values are used for the damping coefficients. With some deviations between calculated and measured natural frequencies and impulse responses, it becomes some deviations in the classifications. Generally the constructions will be classified as "intrusive" or "uncertain", except the calculation of the " stiffened " and " simple plate " constructions with mid-span support.

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