STUDIES ON IMPACT SOUND INSULATION OF FLOORS

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ABSTRACT

Laboratory and field measurements have been carried out with different floor structures. Special interest is paid to impact sound insulation properties at low frequencies and the effect of heavier impacts. In addition to the tapping machine also footsteps have been used as impacts. The effect of floor coverings or floating floors on the impact sound pressure levels and on the noise levels induced by walking have been studied. The transferability of the improvement effect of floor coverings and floating top floors and the estimation methods for $L'_{n,w}$ are studied, too. Main topics have also been to study will heavier concrete floors fulfil the requirement $L'_{n,w} \leq 53$ dB by using a parquet or a carpet covering alone, and will any low frequency problem occur when using floating top floors.

INTRODUCTION

In 2000 the requirement for $L'_{n,w}$ was tightened in Finland from 58 dB to 53 dB. Former the requirements could be met by choosing a proper soft floor covering, either a carpet or a parquet with a soft underlay, to be used with massive or hollow core concrete slabs. With concrete floors used the new requirements would have led to the use of floating top floors, which were considered to be expensive and risky (moisture, shrinkage etc. problems). Experimental test was carried out to study if heavier and stiffer concrete floors could fulfil the requirements by using soft covering only. According to former studies it is possible to fulfil the recent requirements with lightweight floors, too. However, the lightest floor solutions showed some low frequency problems. There were suspicions that such problems may occur even with multi-layered heavier floors. To study and develop optimal floors, which would meet both the recent sound insulation requirements and the expectations of inhabitants, a national research project "Sound and vibration control of dwelling floors" [1] was started. Low frequency impact sounds was a special topic of interest. The results were considered in the light of the former projects [2, 3, 4].

The reference curve methods and the single numbered values should naturally also describe the sensation received subjectively from the structure. The relation between them is, however, very problematic. During past decades, partly due to the shape of the reference curve the low frequency sound produced mainly from heavy impacts for example, walking on the floors has become predominant. For that reason, it is not even self evident that the tightening the requirement of $L'_{n,w}$ (from a certain good level) would make the floors better from subjective point of view.

TESTS AND TEST ARRANGEMENTS

Different floor structures (wooden, steel, both lightweight and semiweight) have lately been topic of many research projects in Finland [2, 3, 4]. Most recently especially impact sound insulation properties of concrete slabs (Table 1) has also been studied [1] to find out the differences between different type of concrete floors. The improvement effects of floating top floors or coverings are assessed and compared (Table 2). In addition to laboratory measurements sound insulation measurements have for control purposes also been carried out in some field targets. Measurements and rating have been carried out according to ISO standards [5]. In addition to the standard tapping machine tests also walking tests have been carried out. In walking tests a male person (weight 90 kg) walked on the slab without shoes and the sound pressure levels beneath the slab were recorded. Tapping machine measurements have been carried out from the frequency of 20 Hz, because it was interesting to compare the results with those received from walking tests (20 to 1,000 Hz).

Table 1. Concrete floor slabs and other floors in the project [1].

Floor	Code
160 mm thick laboratory concrete slab	**C160**
320 mm hollow core slab (c. 530 kg/m^2)	**H320H**
265 mm hollow core slab (c. 380 kg/m^2)	**H270**
265 mm hollow core slab + 60 mm conc. cast (c. 530 kg/m2)	**H270+60**
composite floor with steel beams + concrete ceiling	**CSB**
wooden floor (with beams)	**W**

Table 2. Floating top floors and coverings on concrete floors (laboratory tests) [1].

Top floor/Covering	Specification	Code
Floating concrete floor	60 mm concrete on 30 mm wool	**CW1**
	60 mm conc. on 30 mm EPS, elasticised polystyrene	**CE**
Floating board floor	Two gypsum boards (2x15) on 30 mm wool	**GW2**
	22 mm gypsum bonded fibre board on 30 mm EPS	**SE**
Lifted floor	three types, not specified her precisely	**IF1, 2 and 3**
	type 3, with parquet (soft underlay)	**IF3P**
Parquet covering	14 mm parquet + soft underlay	**P**
	14 mm parquet + fibreboard underlay	**P2**
Carpet covering	Soft carpet	**C**

RESULTS AND DISCUSSION

Airborne and impact sound insulation

The weighted airborne sound reduction index R_w (or R'_w) and the weighted normalised impact sound pressure level $L_{n,w}$ (or $L'_{n,w}$) of floors both spectrum adaptation terms in laboratory and in the field are presented in Tables 3 and 4. The buildings measured in the field were normal concrete frame buildings (in the field receiving room volume was normally about 25-50 m^3).

It can be seen that in laboratory the airborne sound insulation of hollow core slabs having weight about 530 kg/m^2 is 2 to 3 dB better than hollow core slab floor having weight about 380 kg/m^2. Respectively, the impact sound insulation is about 1 to 6 dB better (lower $L_{n,w}$). The hollow core slab with a weight 530 kg/m^2 is better than hollow core slab floor having the same weight, but the mass of which has been added by concrete cast. This is evidently due to the greater stiffness of the former. It may be supposed that differences noticed in laboratory tests are of same magnitude in practice, too (in the same circumstances and with same top floor structures or coverings).

In laboratory the weighted airborne sound reduction index (R_w) of hollow core concrete bare floors ($\geq$380 kg/m^2) is greater than 56 dB. According to laboratory and field measurements (see Tables 3 and 4) a parquet covering may impair the airborne sound insulation of a concrete floor

Table 3 .The airborne and impact sound insulation of floors (laboratory tests).

Floor	Floating floor or covering	Code	Sound insulation					
			Airborne sound			Impact sound		
			R_w	C	$C_{50\text{-}3150}$	$L_{n,w}$	C_I	$C_{I,50\text{-}2500}$
C 160	Bare floor	Bare	52	-1	-1	77	-10	-10
	Conc. 60+wool 1	CW1				46	0	2
	Conc. 60+EPS	CE	59	-2	-2	49	0	3
	Gypsumboard+wool 2	GW2	61	-2	-2	52	1	1
	Board+EPS	SE				56	2	2
	Parquet	P	49	0	0	61	0	0
	Carpet	C				59	0	0
	Lifted floor 3	IF3				53	2	2
	former with parquet	IF3P				51	1	2
H320H	Bare floor	Bare	59	-1	-1	78	-14	-14
	Parquet	P				53	0	0
	Carpet	C				50	0	0
H270	Bare floor	Bare	56	-1	-2	82	-13	-13
	Conc. 60 + wool 1	CW1				48	-7	-1
	Conc. 60 + EPS	CE	60	-1	-1	51	-5	-1
	Gypsum boards+wool 2	GW2	63	-2	-3	48	1	3
	Board+EPS	SE				54	1	2
	Parquet	P	53	-2	-2	57	0	0
	Carpet	C				56	-1	-1
	Parquet+soft fibreb.	P2				53	1	1
	Lifted floor 1	IF1	61	-1	-1	57	0	0
	Lifted floor 2	IF2	62	-1	-1	52	-1	0
H270+60	Bare floor	Bare	58	-1	-2	81	-15	-15
	Parquet	P				54	0	0
	Carpet	C				54	-1	-1
CSB	With tongued flooring	T	61	-1	-1	53	2	2
W	Bare floor	Bare	56	-4	-5	61	1	3
	Gypsum boards+wool3	CW3	65	-3	-4	52	1	6
	Former with laminate	CW3+L	65	-3	-4	50	1	10

by about 3 dB and it may cause some problems in practice. However, in former field measurements even 270 mm hollow core slab floors with parquet coverings have usually fulfilled the requirements (in the case of restricted flanking). So it can be estimated that the airborne sound insulation of hollow core concrete slab floors (especially with heavier ones) is in normal cases sufficient in respect to required $R'_w \geq 55$ dB. Former field measurements show that a massive in situ cast concrete floor with thickness at least 200 mm fulfils normally also the requirement. According to former studies R_w (or R'_w) for usually used lightweight floors (with a floating top floor and a resiliently hanged ceiling) is at least 60 dB (greater than the required 55 dB) [2, 3, 4].

Several field measurements show, that with parquet or carpet covered 270 mm thick hollow core slabs (weight about 375 kg/m^2) it is difficult to achieve the $L'_{n,w} \leq 53$ dB in practice. This holds also for a 200 mm thick massive (in situ cast) concrete slabs, although in one control measurement (Table 4) the requirement was occasionally fulfilled. With floating top floors also these bare floors may be used. It can be estimated that with heavier hollow core concrete slabs (mass $\geq$ 500 kg/m^2) or with at least 240 mm thick massive concrete floor the requirement for $L'_{n,w}$ is in normal cases (room volumes $\leq$ 50 m^3) fulfilled by using soft floor coverings. Impact sound insulation in the laboratory and in the field for covered hollow core slabs are much alike, and it seems that they are more dependent on the room volume than on the flanking effects. With the tested wooden floor (with floating top floor part) $L_{n,w}$ is 50 and 52 dB. In former studies with same type of wooden floors $L'_{n,w}$ has been from 40 to 54 dB [2]. According to the former results many wooden floors with resilient ceiling and floating top floor (especially, if mass is at least 150 kg/m^2) meet the requirement $L'_{n,w} \leq 53$ dB [2, 3].

Table 4. The airborne and impact sound insulation of floors (field measurements). (C200 = a 200 mm concrete floor, CW = a composite wood/concrete floor, FF1 and FF2 = floating screed floors, IFS and IFW =lifted floors with wooden or steel beams).

Floor	**Cov./Top floor**	**Sound insulation**					
		R'_w	C	$C_{50-3150}$	$L'_{n,w}$	C_I	$C_{I,50-2500}$
C200	Bare				71	-12	-12
	C				49	0	0
	P				51	0	0
	FF1				43	3	5
H270	IFS	61	-2	-2	43	0	2
	IFW	60	-2	-2	49	1	2
H320H	Bare	57	-1	-1	76	-15	-15
	C	57	-1	-1	48	0	1
	P	54	-1	-1	51	-1	0
H320	Bare				80	-15	-15
	C				48	0	0
	P				51	0	0
	FF2				42	2	4
CW	P	60	-2	-3	52	0	2
	C	60	-1	-2	49	0	2

The spectrum adaptation terms for airborne insulation ($C_{50-3150}$) for massive floors vary in laboratory from -3 to 0 dB (the same order in practice). . With a wooden floor the spectrum adaptation terms ($C_{50-3150}$) vary in laboratory from -5 to -3 dB. For concrete floors with floating top floors spectrum adaptation terms for impact sound insulation $C_{I,100-2500}$ are negative or near zero. $C_{I,50-2500}$ vary 1 to 3 dB in laboratory and 1 to 5 dB in practice. With covered concrete floor the both spectrum adaptation terms are near zero. It can be noticed that with some type of floating floors the proportion of low frequencies slightly increases. Generally, the use of any spectrum adaptation terms is not a very meaningful tool for classifying concrete floors or when the acceptability is considered. Former studies show that the spectrum adaptation term C_I ($C_{I,100-2500}$) with wooden floors varies from -2 to 2 dB and $C_{I,50-2500}$ from 0 to 7 dB (average 2.6 dB) in practice [3]. $L'_{n,w} + C_{I,50-2500}$ vary in practice between 47 to 58 dB [3]. It may be stated that a top floor on a wooden floor has only a limited influence on the impact sound insulation at low frequencies.

Reduction of transmitted impact noise (improvement of impact sound insulation)

Weighted reductions of the transmitted impact noise ΔL_w for floor coverings and top floors (according to ISO 140-8 and ISO 717-2 are presented in Table 5. For the sake of comparisons also the "real improvements" (received by substituting the values of $L_{n,w(cov.)}$ from the values of $L_{n,w(noncov.)}$ are presented in the parenthesis. ΔL_w (ISO standards) varied from 15 to 30 dB.

The weighted reductions ΔL_w (calculated with reference floor) vary up to 4 dB depending on the concrete floor type. However, reductions ΔL_w by carpet and parquet coverings are nearly constant. The reductions ΔL by soft floor coverings and parquets (with soft underlay) represent also very well those reductions measured in the field (with small specimens) on hollow core slabs [6]. With many floor coverings the reductions ΔL may be transferred quite reliable from laboratory floor to other concrete floors in practice and predict $L'_{n,w}$ quite reliably.

For a 160 mm thick concrete floor ΔL_w is nearly the same as the "real" reductions. This indicates that for solid concrete floors the shape of the impact sound pressure level curve is very much alike with that of a reference floor and that the prediction for $L_{n,w}$ (or $L'_{n,w}$) could be based on ΔL_w only. For hollow core slabs the respective values differ greatly from each other showing that the "slope" of impact sound pressure level of bare floors differs from that of a reference slab. Thus $L_{n,w}$ (or $L'_{n,w}$) of slab floors cannot be predicted very reliably using directly ΔL_w. For the most accurate estimation one need to transfer the reductions ΔL in third octave bands on bare floor.

Table 5. Weighted reductions ΔL_w by *different top floors and floor coverings on different concrete floors in laboratory (calculated with reference floor). The values received directly from* $L_{n,w(noncov.)}$ - $L_{n,w(cov.)}$ *are presented in the parenthesis*

Top floor or cov. .	**Code**	**Concrete floor type**			
		C160	**H270**	**H320H**	**H270+60**
Concrete+wool	**CW1**	30 (31)	29 (34)		
Concrete+EPS	**CE**	27 (28)	23 (31)		
Gypsumb.+wool	**GW2**	25 (25)	22 (34)		
Boards+EPS	**SE**	20 (21)	16 (28)		
Parquet	**P**	18 (16)	16 (25)	16 (25)	17 (25)
Carpet	**C**	19(18)	19 (26)	19 (28)	19 (25)
Lifted floor	**IF3**	23 (24)			
Former+parquet	**IF3P**	25 (26)			
Lifted floor	**IF1**		15 (25)		
Lifted floor	**IF2**		20 (30)		
Parquet+fibreb.	**P2**		18 (29)		

Walking tests

The measured noise levels in laboratory on concrete floors are presented in Table 6. Tests showed that noise levels are greater in laboratory than in the field. Some other observations:

- footstep noise is in practice from 20 up to 25 dB (A) for the heavy concrete floors, from 25 up to 30 dB (A) for the floors (≥ 150 kg/m^2) and from 30 up to 40 dB (A) for the lightest floors.
- a parquet covering reduces the noise level by 4 to 5 dB in laboratory (probably true in practice)- effect of floating floors on the noise level is minor (some exceptions noticed in practise).
- obviously lifted floors do not increase the total noise level in practice. However they may increase noise levels of low frequencies-i.e. "thumps" may be heard perhaps more clearly.

Table 6. A-weighted total noise level (in dB, 20 to 160 Hz), walking tests in laboratory.

Floor		**Top floor or covering**									
	Bare	**CW1**	**CE**	**GW2**	**SE**	**P**	**C**	**IF1**	**IF2**	**IF3**	**T**
C160	30	32	27	30	27	25	27			30	30
H270	30	31	28	31	29	26	31	39	34		
H320H	25					21	23				
H270+60	28					24					
CSB	-										34
W	42			42		38					

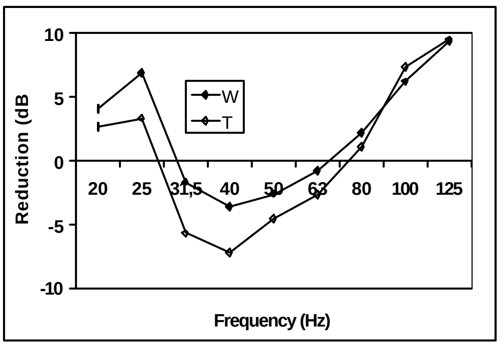

Fig. 1 Av. reduction by a floating concrete floor on resilient wool layer. W = walker and T = tapping machine.

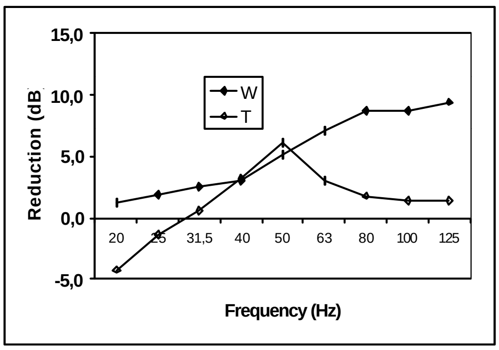

Fig. 2 Av. reduction by a parquet with a soft underlay floors W = walker and T = tapping machine.

Predicting the sound pressure levels caused by footsteps by using the tapping machine

The reductions ΔL by top floors and coatings on concrete floors were measured with a tapping machine and also using walking as an impact. The noticed ΔL in walking tests may be predicted very well by a tapping machine in the case of a hard surface floating concrete top floor (Fig. 1). In the case of parquet and installation top floors the reductions measured by a tapping machine do not very well represent those of walking tests. It can be stated that terms $C_{I,r(50\text{-}2500)}$ assessed according to iso 140-8 and 7717-2 by coverings may be very misleading in respect of walking.

CONCLUSIONS

With a proper floating floor concrete hollow core slabs meet normally the requirements; $R'_w \geq 55$ dB and $L'_{n,w} \leq 53$ dB. Acoustically good carpets and parquets may be used in many cases if the mass of the concrete slab is above 500 kg/m^2 or when the thickness of the in situ cast concrete floor is 240 mm at least. Increase of the floor mass does not lead to such improvements in impact sound insulation as presented in some literal sources. With lightweight floors, in addition a floating top floor and a resilient ceiling construction is usually needed. It is recommended that a lightweight floor should have a weight over 150 kg/m^2.

The frequency dependent reduction of impact sound pressure level ΔL, of many floor coverings is quite independent on the type of the concrete floor. The reduction ΔL measured in a laboratory for a floor covering may be transferred almost onto any desired concrete floor (massive and stiff enough) in practice. The prediction methods for $L'_{n,w}$ should contain also the effect of the volume of the receiving room.

In Finland there are no requirements for the footstep noise. It is recommend that footstep noise in the neighbouring dwelling should remain below 28 dB (A), which is required for appliances. With all studied concrete floors and with wooden or steel floors this limit is fulfilled and the floors are quite acceptable for inhabitants, too. The use of a parquet covering may improve the situation in this respect. However, that could not be evaluated with standard methods 140-8.

Spectrum adaptation terms do not bring out any surplus value when rating concrete floors. The use of the spectrum adaptation term calculated at lower frequencies (calculated from 50 Hz) brings out a noticeable difference between heavy weight and lightweight floors (on the average about 3 dB impairment). On the other hand, extending of the measurements to frequencies 50, 64 and 80 Hz may contain serious problems. The use of a standard tapping machine at low frequencies to describe real heavy impacts may be doubtful.

LITERATURE

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