DOI: 10.61782/fa.2023.0950

forum acusticum 2023

The influence of dry screed floors on the impact sound pressure level of solid and timber frame ceiling systems

Herbert Muellner [1*] **Maximilian Neusser** [2]
[1] Technologisches Gewerbemuseum TGM, Dep. Acoustics and Building Physics, Vienna, Austria
[2] Technische Universität Wien, Institute of Material Technology, Building Physics, and Building Ecology, Vienna, Austria

Fulfilling the requirements on impact sound insulation in wooden buildings is still a challenge, especially if higher comfort classes are also being considered. In order to meet this challenge, the floor structure is usually designed as a floating cement screed. With regard to avoid the introduction of significant amounts of moisture and accelerating the construction process, the application of floating dry screed versions would be considerably advantageous. In a study, the sound insulation potential of dry screed variants on light weight base floors in timber construction was empirically investigated. The measurements were carried out on a bare timber frame ceiling and on a bare solid timber ceiling (CLT) in a test stand for ceilings according to ISO 10140. The effect and interaction of the dry screed layers, the screed weights, the type and arrangement of the impact sound insulation and the type of filling were compared. The results show how the impact sound insulation potential of the dry screed structures on wooden bare floors can be optimized through a suitable arrangement of the layers and the choice of material. Favorable values can be achieved not only in the classical building acoustics frequency range but for certain variants also in the frequency range below 100 Hz.

Keywords: *Impact sound insulation, wooden building ceiling elements, timber frame elements, CLT-elements*

1. INTRODUCTION

Cement screeds are mainly used in timber construction because they have proven themselves in terms of impact sound insulation performance, costs, and widespread use of workability, also through their wide use in the traditional mineral solid construction technique. The disadvantage of the application of cement screeds is that a lot of moisture is brought into the building, longer drying times delay the progress of construction and this type of product is not in line with the building with wood idea. The present study was therefore intended to show which impact sound insulation performance can be achieved by dry screeds made of the currently common materials in interaction with the bare ceilings often used in the timber construction technique.

2. MEASUREMENT PROCEDURES

For the empirical investigation a representative timber frame ceiling and a 140 mm five-layer cross laminated solid timber ceiling (CLT) were chosen because timber frame and CLT ceilings are the most common elements used in the Austrian building with wood industry.

The measurements were carried out according to ISO 10140-3 [1] with a standard impact machine in a test stand for ceilings according to ISO 10140-5 [2] at the building acoustics laboratory of TGM in Vienna. The size of the ceilings to be tested in this test stand was approx. 18 m^2.
The calculations of the single number quantities (SNQ) for the description of the impact sound insulation of the ceiling constructions were carried out according to ISO 717-2 [3].

2.1 Test specimens

The structure of the two bare ceilings considered in the investigation was given as follows:

2.1.1 Timber frame bare ceiling

The timber frame bare ceiling consisted of 18 mm OSB-boards on top, m' = 10 kg/m^2, 250 mm / 50 mm wooden beams, a = 470 mm, (between them 100 mm glass-wool, 13 kg/m^3). Battens (72 mm / 22 mm), a = 350 mm, rigidly installed perpendicular to the wooden beams and 2 x 12.5 mm gypsum fiber boards (m' = 15.4 kg/m^2 each). Figure 1 shows a schematic representation of the vertical section of the bare timber frame floor described above.

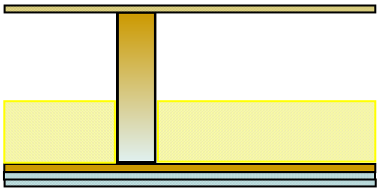

Figure 1. Schematic representation of the vertical section of the bare timber frame ceiling.

Figure 2 shows an early stage of the installation of the timber frame ceiling in the test stand according to ISO 10140-5

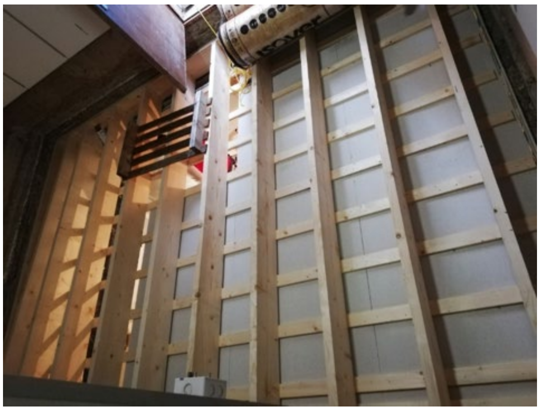

Figure 2. Installation of the bare timber frame floor in the test stand.

2.1.2 Solid timber bare ceiling

The solid timber bare ceiling consisted of 140 mm CLT elements.

Figure 3 shows the section of the 140 mm CLT ceiling slab.

Figure 3. Vertical section of the bare 140 mm CLT ceiling, approx. 69 kg/m^2.

Figure 4 shows the almost final stage of the installation of the CLT bare ceiling in the test stand according to 10140-5

Figure 4. Installation of the bare timber frame ceiling in the test stand.

2.1.3 Variation of the dry screed components

The top layer of the dry screed variants was always made of 2 x 10 mm gypsum fiber boards (both together 25 kg/m^2).

The impact sound insulation slab materials and thus the dynamic stiffness *s*' (measured according to EN 29052-1 [4]) of the insulation material layers were varied. The properties of the materials used are listed in table 1 below.
The impact sound insulation was tested in the situations without and with additional load (material used c.f. table 2) installed between the uppermost layer of the dry screed and the impact sound insulation slabs.
Additionally, versions with different fillings (table 3) between the bare ceiling and the impact sound insulation layer were tested.

Table 1. Impact sound insulation material and properties.

Material	thickness mm	*s*' / MN/m^3	density ρ / kg/m^3
Polystyrene	25	62	16
Woodfibre	30	50	140
Rock-wool	30	40	188
Glass-wool	30	8.2	90

Table 2. Additional load between top layer of the dry screed and impact sound insulation slab.

Material	thickness / mm	area density m'/ kg/m^2
2 x 18 mm gypsum fiber board elements (1000 mm x 600 mm)	36	44
Granite slabs (600 mm x 600 mm)	30	78

Table 3. Filling between impact sound insulation slab and bare ceiling construction.

Material	thickness mm	area density m' / kg/m^2
Perlite	80	10
Cellulose pellets	80	40
Basalt grit (bounded)	80	125
Grit (loose)	80	148

2.2 Results

Regarding the explanations according to [5, 6], the single-number quantity combination of the weighted normalized impact sound pressure level $L_{n,w}$ and the spectrum adaptation term $C_{I,50\text{-}2500}$ ($L_{n,w} + C_{I,50\text{-}2500}$) is considered to be the characterization with the best correlation for the description of the impact sound insulation of ceiling constructions in timber construction technique in connection with the perception of the transmitted walking sound in the receiving room. For the characterization of the impact sound insulation performance of timber ceiling elements it is considered as the most appropriate characterization by a SNQ [6, 7]. Thus, the following descriptions of the impact sound insulation performance of the examined ceilings, the traditional weighted normalized impact sound pressure level $L_{n,w}$ as well as the SNQ-combination of weighted normalized impact sound pressure level $L_{n,w}$ and spectrum adaptation term $C_{I,50\text{-}2500}$ are shown.

2.2.1 Timber frame ceiling

The weighted normalized impact sound pressure level $L_{n,w}$ and the combined single number quantity of $L_{n,w}$ + spectrum adaption term $C_{I,50\text{-}2500}$ of the bare timber frame ceiling is shown in table 4 below.

Table 4. Impact sound insulation values of the timber frame bare ceiling.

	$L_{n,w}$ / dB	$L_{n,w} + C_{I,50\text{-}2500}$ / dB
Timber frame bare ceiling	75	75

The first step was to investigate the effect on the impact sound pressure level due to the properties of different impact sound insulation materials. The results are listed in table 5 below.

Table 5. Dry screed on bare timber frame ceiling with different material of the impact sound insulation slabs.

Material	s' / MN/m^3	$L_{n,w}$ / dB	$L_{n,w} + C_{I,50\text{-}2500}$ / dB
Woodfibre	50	66	69
Rock-wool	40	63	67
Glass-wool	8.2	62	66

For increasing the mass of the screed, additional load was installed by applying either 2 x 18 mm gypsum fiber board elements or 30 mm granite slabs between uppermost screed layer and the glass-wool impact sound insulation. The results regarding the influence are shown in table 6.

Table 6. Dry screed on bare timber frame ceiling with different additional load between dry screed gypsum boards and the glass wool impact sound insulation slabs (s' = 8.2 MN/m^3).

Material	additional load m' / kg/m^2	$L_{n,w}$ / dB	$L_{n,w} + C_{I,50\text{-}2500}$ / dB
Gypsum-fiber boards	44	55	60
Granite slab	78	53	57

The influence on the impact sound insulation performance of the fill between impact sound insulation slabs and bare ceiling is listed in table 7 below.

Table 7. Dry screed on bare timber frame ceiling with different material of fill between rock wool impact sound insulation slabs (s' = 40 MN/m^3) and bare ceiling.

Material (approx. 80 mm)	m' / kg/m^2	$L_{n,w}$ / dB	$L_{n,w} + C_{I,50\text{-}2500}$ / dB
without	-	63	67
Perlite	10	59	62
Cellulose pellets	40	57	61
Basalt	125	54	60
Grit	148	54	59

2.2.2 CLT bare ceiling

The weighted normalized impact sound pressure level $L_{n,w}$ and the combined single number quantity of $L_{n,w}$ + spectrum adaption term $C_{I,50\text{-}2500}$ of the bare CLT ceiling is shown in table 8 below.

Table 8. Impact sound insulation values of the 140 mm CLT bare ceiling.

	$L_{n,w}$ / dB	$L_{n,w} + C_{I,50\text{-}2500}$ / dB
140 mm CLT	90	90 (84)

The effect on the impact sound pressure level depending on the dynamic stiffness properties of the different impact sound insulation materials used between uppermost screed-layer and bare ceiling is shown by the SNQs $L_{n,w}$ and $L_{n,w} + C_{I,50\text{-}2500}$ in table 9.

Table 9. Dry screed on 140 mm CLT bare ceiling with different materials of the impact sound insulation slabs.

Material	s' / MN/m^3	$L_{n,w}$ / dB	$L_{n,w} + C_{I,50\text{-}2500}$ / dB
Polystyrene	62	68	68
Woodfibre	50	65	67
Rock-wool	40	62	65
Glass-wool	8.2	59	64

Table 10 shows the impact sound insulation performance if additional load by gypsum fiber board elements is installed between uppermost screed-layer and the impact sound insulation-slabs.

Table 10. Dry screed on 140 mm CLT bare ceiling with additional load of gypsum fiber board elements (m' = 44 kg/m^2) between dry screed gypsum boards and impact sound insulation slabs.

Material	s' / MN/m^3	$L_{n,w}$ / dB	$L_{n,w} + C_{I,50\text{-}2500}$ / dB
Polystyrene	62	61	63
Woodfibre	50	58	62
Rock-wool	40	59	61
Glass-wool	8.2	53	59

Table 11 shows the results, if the dry screed consisting of 2 x 10 mm gypsum fiber boards and different impact sound insulation material is applied on bounded basalt grit onto the bare ceiling.

Table 11. Dry screed on 140 mm CLT bare ceiling with additional fill of bounded basalt grit between impact sound insulation slabs and bare ceiling.

Material	s' / MN/m^3	$L_{n,w}$ / dB	$L_{n,w} + C_{I,50\text{-}2500}$ / dB
Woodfibre	50	53	58
Rock-wool	40	52	60
Glass-wool	8.2	46	55

For the variations with fill of bounded basalt grit and either additional load of 2 x 18 mm gypsum fiber board elements or 30 mm granite slabs the sound insulation performance is listed in table 12 and 13 below.

Table 12. Dry screed on 140 mm CLT bare ceiling with bounded basalt grit (m' = 125 kg/m^2) and additional load of gypsum fiber boards (m' = 44 kg/m^2) between dry screed gypsum boards and impact sound insulation slabs.

Material	s' / MN/m^3	$L_{n,w}$ / dB	$L_{n,w} + C_{I,50\text{-}2500}$ / dB
Woodfibre	50	48	54
Rock-wool	40	49	54
Glass-wool	8.2	42	52

Table 13. Dry screed on 140 mm CLT bare floor with loose grit (*m'* = 148 kg/m^2) and additional load of granite slabs (*m'* = 78 kg/m^2) between dry screed gypsum boards and impact sound insulation slabs.

Material	*s'* / MN/m^3	$L_{n,w}$ / dB	$L_{n,w} + C_{I,50-2500}$ / dB
Glass-wool	8.2	41	50

2.2.3 Further optimization

Further optimizations were realized by applying a suspended ceiling. The constructions including the suspended layer are described below.

The timber frame ceiling construction consisted of a dry screed of 2 x 10 mm gypsum fiber boards without and with additional load of 2 x 18 mm gypsum fiber boards (*m'* = 44 kg/m^2), 30 mm impact sound insulation slabs (rock-wool, *s'* = 40 MN/m^3) on 80 mm bounded basalt grit, (*m'* = 125 kg/m^2), on 18 mm OSB-boards, 250 mm / 50 mm wooden beams, a = 470 mm, (between them 100 mm glass-wool, 13 kg/m^3), instead of rigid installed battens suspended battens (60 mm / 40 mm), a = 500 mm, installed perpendicular to the wooden beams and 2 x 12.5 mm gypsum fiber boards (each *m'* = 15.4 kg/m^2). The impact sound insulation performance results are listed in table 14.

Table 14. Dry screed on timber frame ceiling construction with suspended 2 x 12.5 mm gypsum boards (GFBs).

Timber frame ceiling	impact sound insulation *s'* / MN/m^3	$L_{n,w}$ / dB	$L_{n,w} + C_{I,50-2500}$ dB
bare, suspended GFBs	-	62	65
without additional load	40	41	53
with additional load, *m'* = 44 kg/m^2	40	39	51

The CLT ceiling construction consisted of a dry screed of 2 x 10 mm gypsum fiber boards, additional load of 30 mm granite slabs beneath the gypsum fiber boards, 30 mm glass-wool impact sound insulation slabs (*s'* = 8.2 MN/m^3) on 80 mm grit (loose), *m'* = 148 kg/m^2, on 140 mm CLT with suspended battens (by approx. 5 mm, 60 mm / 40 mm), a = 500 mm, and 12.5 mm gypsum fiber board, 15.4 kg/m^2, (without mineral-wool inside the gap). The impact sound insulation SNQs are listed in table 15 below.

Table 15. Dry screed on CLT-ceiling construction with suspended 1 x 12.5 mm gypsum board (GFB).

CLT ceiling	impact sound insulation s' / MN/m^3	$L_{n,w}$ / dB	$L_{n,w} + C_{I,50-2500}$ / dB
suspended GFB, with additional load, m' = 44 kg/m^2	8.2	39	49

3. SUMMARY

The obligatory impact sound insulation requirement in Austria still refers to the classical weighted standardized impact sound pressure level $L_{nT,w}$ only. The spectrum adaptation term $C_{I,50-2500}$ can be applied additionally to the weighted standardized impact sound pressure level $L_{nT,w}$ to consider the voluntarily applicable requirement according to ÖNORM B 8115-5 [8] for the description of the impact sound insulation of the so called comfort classes, but also for the basic impact sound insulation requirement. In the following table 16 the requirements according to the 5 impact sound insulation classes A - E of ÖNORM B 8115-5 are listed. The option $L_{nT,w} \leq 48$ dB of class C is identical with the obligatory requirement which is currently applied in Austria. Class B and A are comfort classes with increased impact sound insulation requirements as shown in table 16. The categories D and E are classes with lower requirements can only be applied within the same apartment unit.

Table 16. Impact sound insulation categories A - E according to ÖNORM B 8115-5 [8].

Impact sound insulation categories A - C					
applied SNQ	A	B	C	D	E
$L_{nT,w} + C_{I,50\text{-}2500}$ / dB	48	53	58	-	-
or					
$L_{nT,w}$ / dB	38	43	48	≤53	>53
f_0 / Hz	31	50	80	-	-

Especially with regard to the building acoustic comfort of multi-storey wooden buildings, the impact sound insulation SNQs with the spectrum adaptation term $C_{I,50\text{-}2500}$ should be taken into account if long-term success of the building with wood construction method is the aim.

The results of the investigation show the potential and the quantitative extent of the effect on the sound insulation performance of the different applied measures. Certain measures combined can lead to sound insulation values of the ceiling constructions which could meet the impact sound insulation requirements if appropriately applied.

Timber frame ceilings with suspended soffit of gypsum fiber boards and dry screed with moderate additional load (additional gypsum fiber board elements) and fill of $m' \geq$ 125 kg/m^2 on the bare ceiling can achieve considerable impact sound insulation values even if the spectrum adaption term $C_{I,50\text{-}2500}$ is regarded ($L_{n,w}$ = 39 dB, $L_{n,w} + C_{I,50\text{-}2500}$ = 51 dB and $L_{n,w}$ = 41 dB, $L_{n,w} + C_{I,50\text{-}2500}$ = 53 dB, c.f. table 14). In principle the same applies to the CLT ceiling also even without additional suspended gypsum fiber board ($L_{n,w}$ = 42 dB, $L_{n,w} + C_{I,50\text{-}2500}$ = 52 dB and $L_{n,w}$ = 41 dB, $L_{n,w} + C_{I,50\text{-}2500}$ = 50 dB, without suspended GFB, c.f. table 12 and table 13. With suspended gypsum fiber board the SNQs achieve $L_{n,w}$ = 39 dB, $L_{n,w} + C_{I,50\text{-}2500}$ = 49 dB, c.f. table 15).

4. ACKNOWLEDGMENTS

The authors acknowledge the support of all project partners of the research project “Schall.Holz.Bau II”. The project was funded by the "NÖ Wirtschafts- und Tourismusfonds" in the funding track "Kooperation" under the number WST3-F2- 525823/007-2018.

Project partners:

ELK Fertighaus GmbH
Fuchs Metalltechnik GmbH
Fermacell GmbH
Ing. Johann Graf Zimmerei- und Holzbau Ges.m.b.H
Isocell GmbH
Schmid Schrauben Hainfeld GmbH
Stauss Perlite GmbH
Stora Enso Wood Products GmbH
Sonnenklee GmbH
Vinzenz Harrer GmbH

5. REFERENCES

[1] ISO 10140-3:2010, Acoustics — Laboratory measurement of sound insulation of building elements — Part 3: Measurement of impact sound insulation.

[2] ISO 10140-5:2010, Acoustics — Laboratory measurement of sound insulation of building elements — Part 5: Requirements for test facilities and equipment.

[3] ISO 717-2:2013, Acoustics — Rating of sound insulation in buildings and of building elements — Part 2: Impact sound insulation.

[4] EN 29052-1:1992, Acoustics - Determination of dynamic stiffness - Part 1: Materials used under floating floors in dwellings.

[5] A. Rabold, U. Schanda, J. Hessinger, „Korrelation zwischen Geher und Norm-Hammerwerk bei der Trittschallübertragung“, Proc. DAGA, (Düsseldorf, Germany), pp. 399-400, 2011.

[6] M. Späh, K. Hagberg, O. Bartlomé, “Subjective and objective evaluation of impact noise sources in wooden buildings”, *Building Acoustics*, vol. 20(3), pp. 193–214, 2013.

[7] W. Scholl, J. Lang, V. Wittstock, “Rating of Sound Insulation at Present and in Future: The Revision of ISO 717”, *Acta Acustica united with Acustica*, 97, pp. 686-698, 2011.

[8] ÖNORM B 8115-5:2021, Sound insulation and room acoustics in building construction - Part 5: Classification.