DOI: 10.61782/fa.2025.0461

FORUM ACUSTICUM EURONOISE 2025

IMPROVEMENT OF THE AIRBORNE AND IMPACT SOUND INSULATION OF A TIMBER STUD WALL

Jochen Scheck[1,2*] **Ulrike Schüttler**[3] **Christoph Fichtel**[2] **Berndt Zeitler**[1]
[1] Stuttgart University of Applied Sciences, 70174 Stuttgart, Germany
[2] STEP GmbH, 71364 Winnenden, Germany
[3] IngenieurGruppe Bauen, 76133 Karlsruhe, Germany

ABSTRACT

The airborne and impact sound insulation in wooden buildings is often poor, in particular at low frequencies. For a German manufacturer of prefabricated houses, the sound insulation of a separating wall was investigated and improved in the laboratory. By constructive measures such as using a planning filled with silica sand that provides a high internal damping and the partial separation of the wooden studs a considerable improvement of the airborne sound insulation could be achieved. In a next step the impact sound insulation of a standard wooden stair was successfully optimized by isolation measures at the contacts of stair and wall.

Keywords: *building acoustics, separating wall, laboratory tests, airborne sound insulation, impact sound insulation.*

1. INTRODUCTION

Wooden buildings are gaining popularity, also in Germany. The use of renewable raw materials, lower costs and shorter construction times are advantageous in comparison to heavyweight constructions made of concrete and bricks. However, the airborne and impact sound insulation is often poor, in particular at low frequencies which can cause complaints by inhabitants. The construction of the separating wall in-between residential units plays an important role for the total sound transmission. Within the scope of a master thesis [1], the sound insulation of a separating wall of the German manufacturer Keitel-Haus GmbH was investigated and improved in the laboratory of STEP GmbH.

2. TEST STAND

The airborne and impact sound insulation of the separating wall was measured in the test stand of STEP GmbH that was constructed in 2001 with the main purpose of testing lightweight and heavyweight stairs (Figure 1).

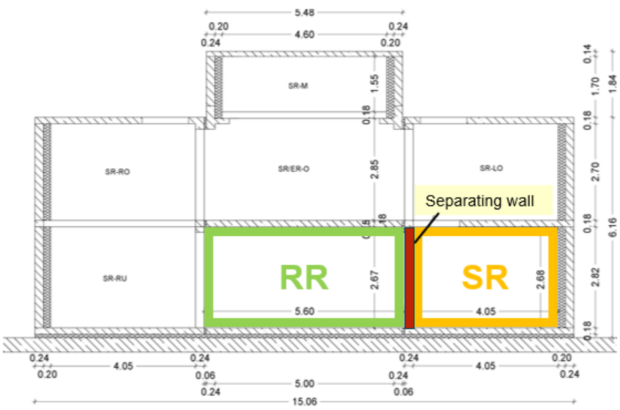

Figure 1. Test stand with sending and receiving room used for the investigations.

The test stand is in accordance with EN ISO 10140-5 [2]. Flanking transmission is avoided by structural linings and the reverberation time in the rooms was conditioned by using absorbers to be within 1s ≤ T ≤ 2s in the frequency range between 50 Hz – 5 kHz.

*__Corresponding author__: jochen.scheck@hft-stuttgart.de

3. BASIC CONSTRUCTION

The frame construction of the timber stud wall consisted of studs, sills and frames with a depth of 200 mm made of wood (Figure 2). The studs were mainly arranged in a grid of 62.5 cm. Individual areas of the wall had a smaller stud spacing for the later planned connection of a staircase. The compartments were filled with mineral wool.

Figure 2. Frame construction of the timber stud wall.

Figure 3 shows the basic construction chosen for the investigations. For this construction, the planking of the timber stud wall consisted of coarse chipboard (OSB) with a thickness of 12 mm and a mass per unit area of 7.4 kg/m^2, which was screwed to the studs, sill and frame. Additionally, gypsum plasterboard fire protection boards (GKF) with a thickness of 12.5 mm and a mass per unit area of 10.2 kg/m^2 [3] were used, which were screwed onto the OSB plate.

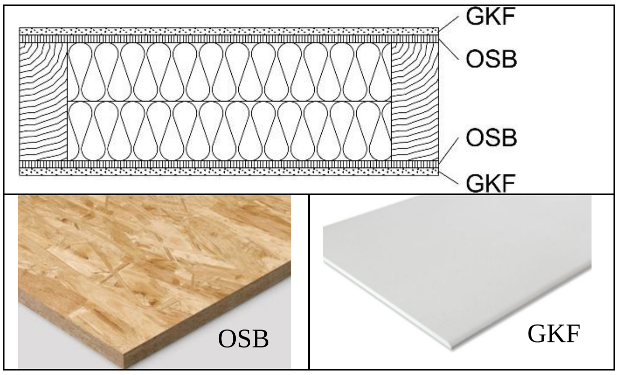

Figure 3. Basic construction of the timber stud wall with OSB and GKF planking.

4. AIRBORNE SOUND INSULATION OF THE BASIC CONSTRUCTION

The airborne sound insulation was determined according to EN ISO 10140-2 [4]:

$$R = L_1 - L_2 + 10\,lg\,S/A \qquad (1)$$

L_1: averaged sound pressure level in sending room [dB]
L_2: averaged sound pressure level in receiving room [dB]
S: wall area [m^2]
A: equivalent absorption area in receiving room [m^2]

The single number value and spectrum adaptation terms were evaluated according to ISO 717-1 [5]. In the following the spectrum adaptation value $C_{50\text{-}5000}$ that accounts for the low frequency sound transmission down to 50 Hz is also given as in [6].

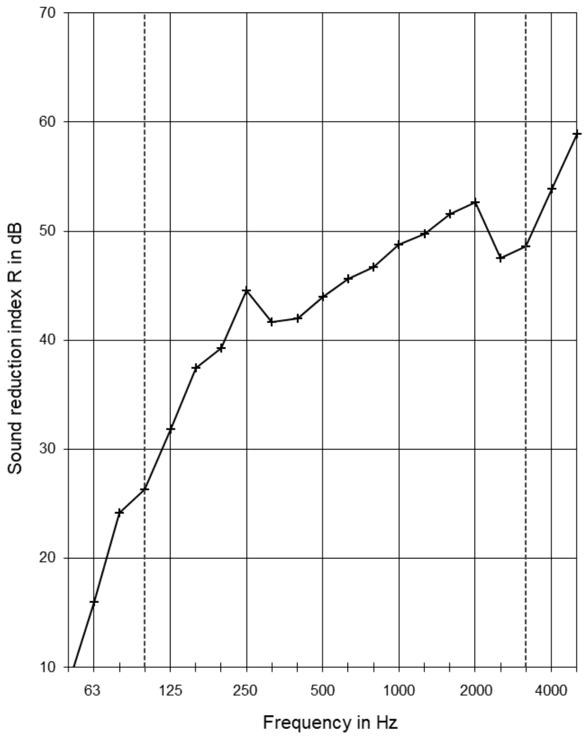

Figure 4. Sound reduction index of the basic construction of the timber stud wall with OSB and GKF cladding; R_w ($C_{50\text{-}5000}$) = 47.8 (-3) dB.

The basic construction achieved a weighted sound reduction index of **R_w ($C_{50\text{-}5000}$) = 47.8 (-3) dB**.

Figure 4 shows the frequency-dependent sound reduction index. Below 200 Hz a strong decrease is visible. An improvement of the sound insulation, particularly in the low-frequency range, was the aim of the design modifications.

5. VARIATION OF THE CLADDING

The cladding of a timber stud wall is known to have a significant influence on the sound reduction index, which is why the optimization of the wall construction was initially started here. In order to improve sound insulation, [6] recommends the use of multi-layer, flexible planking with a high mass per unit area.

Two commercially available additional layers named "Silentboard GKF" [7] and "Phonestar ST Tri" [8] were used. Both layers have a thickness of 12,5 mm and a mass per unit area of 17.5 kg/m^2. They were inserted in-between the OSB and GKF layers, the connection was screwed (Figure 5, Figure 6).

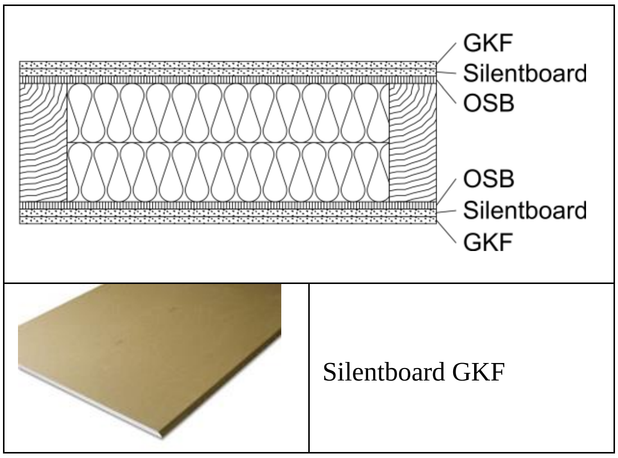

Figure 5. Timber stud wall with an additional layer "Silentboard GKF" [7], a gypsum board recommended for exceptional sound insulation in drywalling.

In Figure 7 are compared the sound reduction indices of the basic construction and with the additional layers.
With the Silentboard a weighted sound reduction index of $\mathbf{R_w}$ **($\mathbf{C_{50\text{-}5000}}$) = 50.6 (-1) dB** and thus an improvement of the basic construction by ΔR_w = 2,8 dB is achieved.

With the Phonestar a weighted sound reduction index of $\mathbf{R_w}$ **($\mathbf{C_{50\text{-}5000}}$) = 55,7 (-3)** and thus an improvement of the basic construction by ΔR_w = 7.9 dB is achieved.

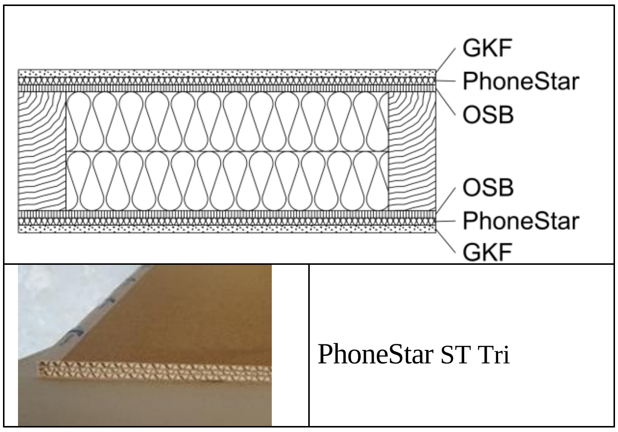

Figure 6. Timber stud wall with an additional layer "PhoneStar ST Tri" [8], a three-layer corrugated board filled with fine, loose quartz sand.

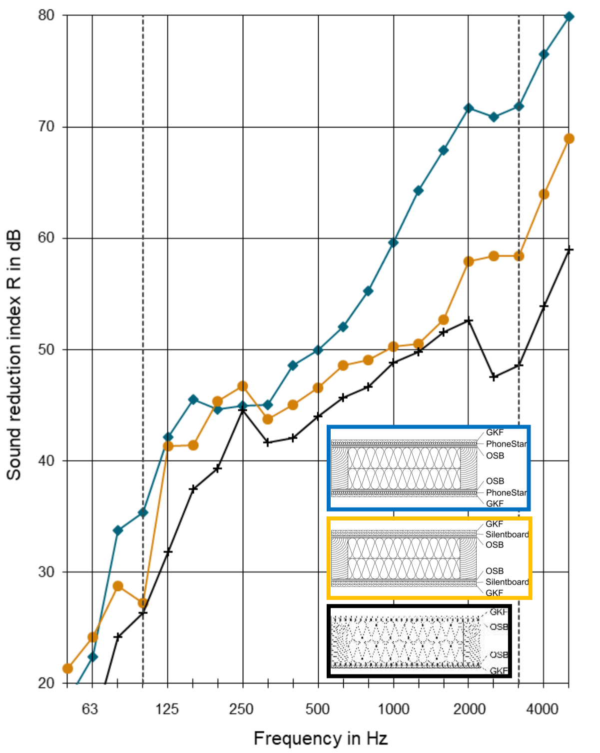

Figure 7. Sound reduction index of the wall with different claddings:

Table 1: Single number values for the frequency spectra in figure 7.

OSB + GKF	R_w $(C_{50\text{-}5000})$ = 47.8 (-3) dB
OSB + Silentboard + GKF	R_w $(C_{50\text{-}5000})$ = 50,6 (-1) dB
OSB + Phonestar + GKF	R_w $(C_{50\text{-}5000})$ = 55,7 (-3) dB

The performance of the Phonestar is clearly better. At low frequencies up to 200 Hz the improvement is about 10 dB. Above 250 Hz the increase of the sound insulation is much steeper than with the Silentboard. It is assumed that this is mainly due to high internal damping caused by the loose sand in the panels. Due to the better performance PhoneStar ST Tri was used for the further investigations.

6. SEPARATION OF THE WOODEN STUDS

The planking of the two sides of the wall is coupled via studs, sills and frames. According to [6], improvements in sound insulation can be achieved by separating the two wall shells. In order to achieve a solution that is as practical as possible, the studs were separated, while the sill and frame remained continuous (Figure 8). In this way, complete decoupling of the two wall shells is not achieved, but the wall can be manufactured, transported and assembled in one piece. This meets the prefabricated house industry's desire for a high degree of prefabrication. As before, the wall with separate studs was cladded with OSB, PhoneStar ST Tri and GKF (Figure 9).

Figure 8. Timber stud wall with separated studs and continuous sill and frame.

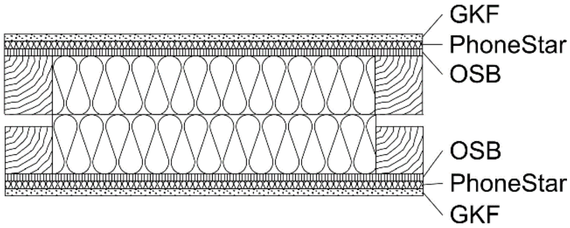

Figure 9. Timber stud wall with separated studs and cladding with OSB, Phonestar ST Tri and GKF.

In Figure 10 are compared the sound reduction indices of the basic construction, with the additional layer Silentboard and without and with separated studs.

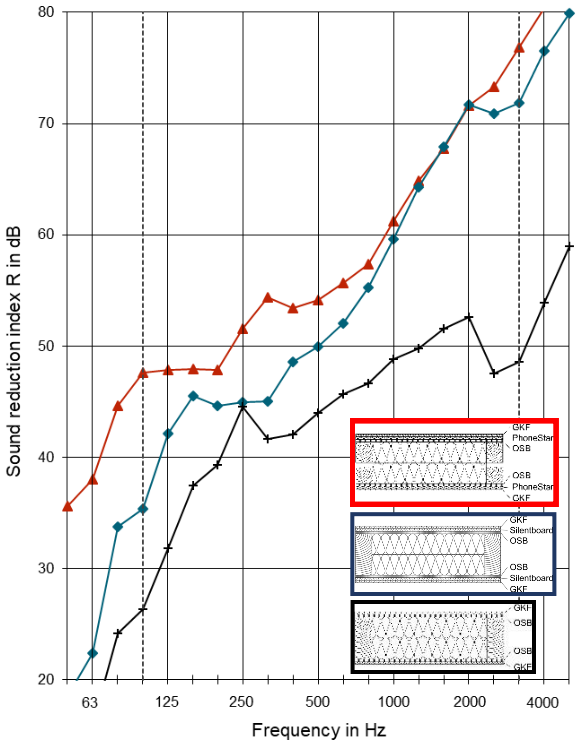

Figure 10. Sound reduction index of the wall with different claddings:

The separation of the studs leads to a significant improvement of the sound insulation below 1 kHz and especially in the low frequency range where the improvement of the previous construction is about 10 dB.

With the separated studs a weighted sound reduction index of **R_w $(C_{50\text{-}5000})$ = 60,4 (-1) dB** and thus an improvement of the basic construction by ΔR_w = 12.6 dB is achieved. According to the German standard DIN 4109-5 the “increased” requirement in multi-family houses is $R_w \geq 56$ dB. This value is met by far even when the spectrum adaptation term is added. In a building of course flanking transmission has to be taken into account. Calculations and a measurement in a real building [1] indicate that with this wall construction and so far used flanking element constructions the targeted value is still met with safety.

Table 2: Single number values for the frequency spectra in figure 10.

OSB + GKF	R_w ($C_{50\text{-}5000}$) = 47.8 (-3) dB
OSB + Phonestar + GKF	R_w ($C_{50\text{-}5000}$) = 55,7 (-3) dB
OSB + Phonestar + GKF; separated studs	R_w ($C_{50\text{-}5000}$) = 60,4 (-1) dB

7. IMPACT SOUND INSULATION

On the optimized wall construction with OSB, PhoneStar ST Tri and GKF cladding on both sides and with separated studs (Figure 9) a quarter-spiral wooden staircase with stringboard was installed in the test stand (Figure 11). A side wall was also added here, which was bolted to the partition wall. In the original state, the stair stringboard was rigidly bolted to the partition and side wall and had no distance to them.

Figure 11. Wooden staircase with stringboard connected to the optimized wall construction with separated studs (Figure 9) and optimized corner support.

Based on this standard construction used so far, the screw connections to the wall were loosened and the staircase was moved away from the wall. Statically, a corner support was then required, which was screwed to the side wall, as shown in Figure 11. In addition, an elastomer isolating element was placed under the corner support to decouple the stair string board and rubber sleeves were used to decouple the screws for connecting the stair to the corner support.

The impact sound insulation was determined according to EN ISO 10140-3 [9]:

$$L_n = L_i + 10\,lg\,A/A_0 \tag{1}$$

L_i: averaged sound pressure level in receiving room [dB]
A: equivalent absorption area in receiving room [m²]
A_0: reference absorption area, $A_0 = 10$ m²

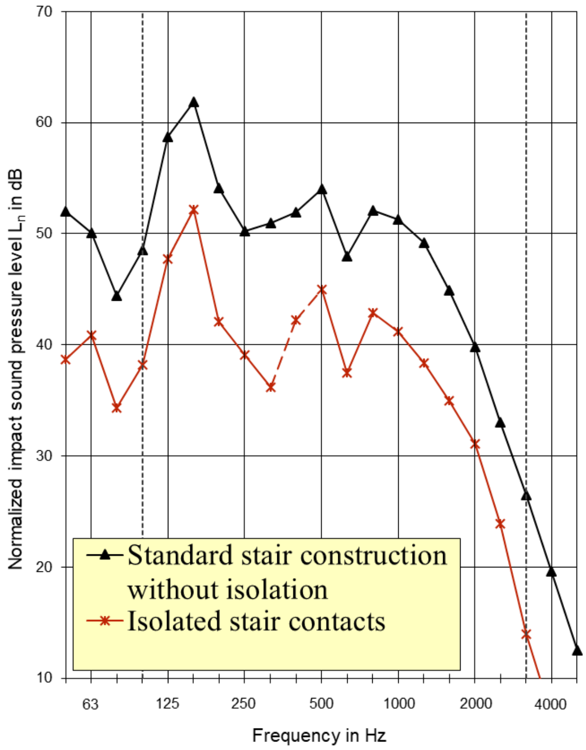

Figure 12. Normalized impact sound pressure level of the stair attached to the optimized wall:

The single number value and spectrum adaptation terms were evaluated according to ISO 717-2 [10]. In the following the spectrum adaptation value $C_{I,50\text{-}2500}$ that accounts for the low frequency sound transmission down to 50 Hz is also given as in [6].

Table 3: Single number values for the frequency spectra in figure 12.

Standard stair configuration without isolation	$L_{n,w}$ ($C_{I,50\text{-}2500}$) = 51.2 (0) dB
Optimized stair configuration with isolated wall contact	$L_{n,w}$ ($C_{I,50\text{-}2500}$) = 41.2 (0) dB

The results for the two stair configurations are shown in Figure 12.
The isolation of the stair leads to a significant improvement of the normalized impact sound pressure level in the whole frequency range and especially in the low frequency range where the improvement is about 10 dB. For the non-isolated stair a weighted normalized impact sound pressure level of **$L_{n,w}$ ($C_{I,50\text{-}2500}$) = 51.2 (0) dB** is obtained.
With the isolated stair contacts a weighted normalized impact sound pressure level of **$L_{n,w}$ ($C_{I,50\text{-}2500}$) = 41.2 (0) dB** and thus an improvement by $\Delta L_{n,w}$ = 10 dB is achieved. According to the German standard DIN 4109-5 the "increased" requirement in multi-family houses is $L_{n,w} \leq 47$ dB. This value is met by far even when the spectrum adaptation term is added. Again, in a building situation flanking transmission has to be considered but it is unlikely that this will dramatically worsen the laboratory value.

8. SUMMARY

The airborne sound insulation of a timber stud wall was to be determined and optimized by constructive measures, for which measurements were carried out in a test stand. Starting from a basic wall construction and a weighted sound reduction of R_w ($C_{50\text{-}5000}$) = 47.8 (-3) dB the final value achieved was R_w ($C_{50\text{-}5000}$) = 60,4 (-1) dB. The significant improvement was obtained by adding an additional cladding - a three-layer corrugated board filled with fine, loose quartz sand - and a separation of the wall studs.
In a second step the impact sound insulation of a standard wooden staircase attached to the optimized wall was improved by isolation measures at the stair-wall contacts from $L_{n,w}$ ($C_{I,50\text{-}2500}$) = 51.2 (0) dB to $L_{n,w}$ ($C_{I,50\text{-}2500}$) = 41.2 (0) dB. The constructive modifications are highly effective in the low frequency range that is mainly problematic in wooden buildings.

9. ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support by the manufacturer Keitel-Haus GmbH.

10. REFERENCES

[1] Schüttler, U. Untersuchung der Luft- und Trittschalldämmung von Holzständerwänden im Prüfstand. Masterarbeit KIT, Karlsruhe, 2023.

[2] ISO 10140-5:2021: Acoustics - Laboratory measurement of sound insulation of building elements - Part 5: Requirements for test facilities and equipment.

[3] Knauf Gips KG. Feuerschutzplatte Knauf Piano GKF. Wirtschaftliche Gipsplatte für Brand- und Schallschutzsysteme im Trockenbau. K713E.de Technisches Blatt. 03/2023.

[4] ISO 10140-3:2021: Acoustics - Laboratory measurement of sound insulation of building elements - Part 2: Measurement of airborne sound insulation.

[5] ISO 717-1:2020: Acoustics - Rating of sound insulation in buildings and of building elements - Part 1: Airborne sound insulation.

[6] Blödt, A.; Rabold, A.; Halstenberg, M.; Ecker, T.; Huber, A.; Huissel, L.; Löffler, S.; Scheuerpflug, M. Schallschutz im Holzbau – Grundlagen und Vorbemessung. holzbau handbuch, REIHE 3, TEIL 3, FOLGE 1. Holzbau Deutschland-Institut e.V., 2019.

[7] Knauf Gips KG. Knauf Silentboard-Systeme. Schallschutz mit hochwertigem Trockenbau. SIB01.de Technische Broschüre. 01/2018.

[8] Wolf Bavaria GmbH. PhoneStar ST Tri. Technische Daten. 01.10.2020.

[9] ISO 10140-3:2021: Acoustics - Laboratory measurement of sound insulation of building elements - Part 3: Measurement of impact sound insulation.

[10] ISO 717-2:2020: Acoustics - Rating of sound insulation in buildings and of building elements - Part 2: Impact sound insulation.