Sound Insulation of Walls with a new Mortar-Mix System

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Summary
A new clay block walling system developed by the Austrian company Wienerberger called "dryfix®" becomes widely used in Germany, Austria and other European countries. This system replaces the conventional thin layer mortar system by a special PUR-Glue applied partially in stripes on the bricks. The new system has the advantage of a shorter construction period and the application in a lower temperature range (≥ -5°C). The impact on SRI due to the different bonding is investigated. The SRI of four different walls built up in the laboratory was measured for mortar applied in a continuous thin-bed method as well as with the striped dryfix® system. The wave speed was measured on two wall pairs and a modal analysis was carried out on one of this pairs. Small differences in the SRI where detected in the low frequency range for brick walls with high thermal insulation although no significant differences were obtained for the single number quantities.

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1. Introduction

A new clay block walling system called "dryfix®" was developed by the clay block manufacturer Wienerberger. This system is already used in Germany, Austria and other European countries and replaces the conventional mortar-mix by a special PUR-Glue applied partially in stripes on the bricks. The new system has generally the advantage of a shorter construction period and the application in a lower temperature range (≥ -5°C). With bricks that are grounded for having exact size it replaces a widely used 1 mm – 3 mm thin bed mortar system.
The new system is used for conventional brick walls, outer walls with lightweight thermal insulating bricks and heavy partition walls made of hollow bricks filled with concrete.
The transmission coefficient (τ [-]) of walls is widely determined by the mass per unit area (m' [kg/m²]), the bending stiffness or the coincidence frequency (f_c [Hz]) and the loss factor (η_{tot} [-]) of the wall and can for example be calculated according to EN 12354-1 above the critical frequency in equation 1.

$$\tau = \left(\frac{2r_0c_0}{2\pi f m'}\right)^2 \frac{\pi f f_c \sigma^2}{2f\eta_{tot}} \qquad f > f_c \qquad (1)$$

With the new dryfix system the mass per unit area of the wall doesn't change, whereas it was expected that the stiffness of the walls and perhaps also the internal loss factor may be influenced by the type of mortar.
The SRI of four different walls built up in the laboratory was measured for mortar applied in a continuous thin-bed method as well as with the new striped dryfix system. The longitudinal wave speed c_L was measured on two wall pairs to calculate the critical frequency f_c and a modal analysis was carried out on one of this pairs.
Differences in the SRI where detected in the low frequency range for brick walls with high thermal insulation although no significant differences were obtained for the single number quantities.

2. Walls investigated

The horizontal joint of typical brick walls is made of a in average 12 mm thick mortar bed, a 1 - 3 mm thin mortar bed ("thin-bedding" joint) or with the new dryfix system. Thermal insulating bricks are used mostly with a thin layer of mortar to have a lower thermal conductivity of the wall. The 12 mm joint has longer operational hours and brings more humidity in the construction. The vertical joints of the masonry in general have no mortar.
Three types of bricks were investigated separately.

- conventional brick walls
- outer walls with lightweight thermal insulating bricks with or without thermal filling, combined with thick flanges
- heavy partition walls made of hollow bricks filled with concrete

The conventional bricks have small cavities and they are used as load bearing and non-load bearing walls, either between rooms or as space-limiting building elements with a thermal lining added. These walls are in Germany typically 115 mm to 240 mm thick, have a density between 800 kg/m³ to 1400 kg/m³ and behave acoustically like homogeneous elements with a Sound Reduction Index (SRI) expected according to equation 1. The mortar in the horizontal joint is expected to change the flexural stiffness and therefor the SRI of the wall.

Figure 1. Applying dryfix on a quasi homogeneous bricks.

Lightweight thermal insulating bricks with fillings and thick flanges are used as outer walls in a thickness from 300 mm up 490 mm and have a density between 600 to 900 kg/m³. These blocks have a thermal conductivity λ down to 0.07 [W/(m²K)] and are therefore used without additional thermal insulating composite systems. The acoustic performance of these brick walls is determined by a dip in the SRI in the frequency range between 800 Hz and 1600 Hz. This dip is due to resonances of the blocks where inner and outer plane of the individual blocks vibrate 180° out of phase. This resonance is influenced by the stiffness of the mortar and it was found that a thin layer of mortar will decrease the frequency where the resonance occurs and will therefor also decrease the SRI. The mortar in the horizontal joint is expected to change not only the flexural stiffness but although influences the vibration behavior in the frequency range at resonance.

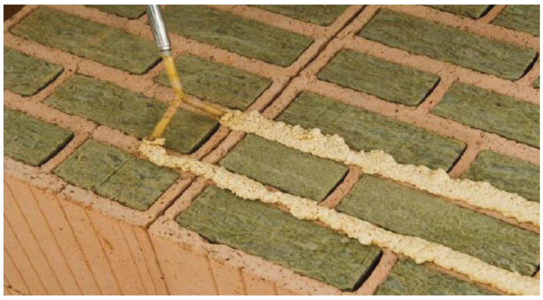

Figure 2. Applying dryfix on a thermal insulating bricks.

The third type of bricks are used as partition walls between dwellings. They have a thickness of 175 mm to 300 mm and are filled with concrete. The individual bricks are bonded together during setup with a thin layer of mortar or with the dryfix system. Later the compound of the bricks is set by the concrete filled with. The stiffness of these walls is mainly reached by the stiffness of the filling with concrete and therefore the impact of mortar on SRI is expected to be negligible and is not investigated.

Figure 3. Brick to be filled with concrete used for partition walls.

3. Measurement results

3.1. Conventional bricks

The SRI of four conventional brick walls (see figure 1) was measured in the laboratory according to ISO 10140 series. A 115 mm thick wall (ρ ≈ 800 kg/m³) and a 175 mm thick wall (ρ ≈ 1200 kg/m³) were both built up with thin-bedding mortar and with the dryfix system.

In the following figure 4 the measured SRI for the four walls is shown.

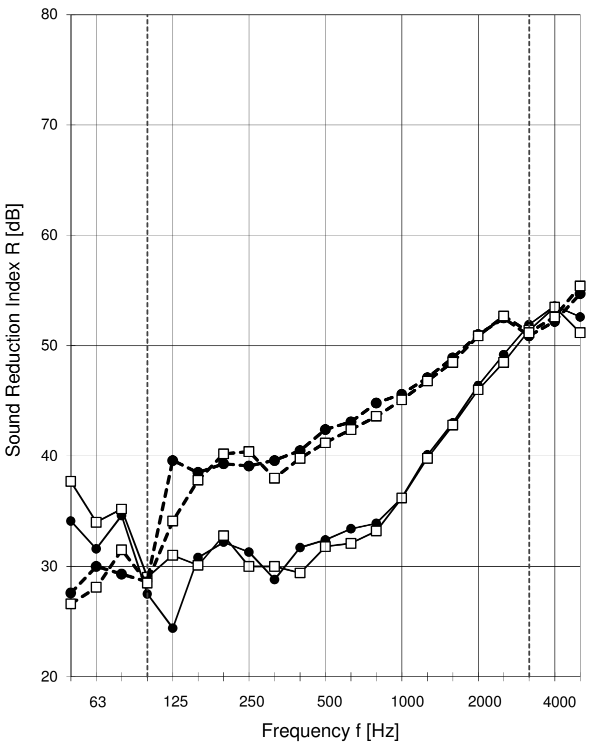

Figure 4: SRI of a 115 mm brick wall (solid lines) and of a 175 mm brick wall (dotted lines) where the horizontal joints are made of thin-bedding mortar (dots) and dryfix (squares).

The SRI of the walls with equal thickness show a similar trend and no significant difference due to the different mortar systems can be detected in the SRI curves.

For all the walls applies that in the low frequency range the SRI is rather low (approx..30 dB for the 115 mm wall and 35 dB for the 175 mm wall) with a rather large spread. The critical frequency for the two walls is expected (e.g. for a longitudinal wave speed of c_L = 1700 m/s) in the third octave bands of 315 Hz for the 115 mm and 200 Hz for the 175 mm brick wall. Although, no clear dip in the SRI due to these critical frequencies is visible, a clear increase in SRI can be seen above the critical frequencies. The increase in SRI is constant for approximately two octave bands, with a higher gradient for the thinner wall. At 5 kHz for the 115 mm wall and at 3.15 kHz for the 175 mm wall small dips appear in the SRI. These dips may be assigned to resonances due to the thickness of the walls, where half a longitudinal wavelength match the thickness of the wall (this is the case for c_L = 1100 m/s).

A measurement of the longitudinal wave speed was performed on all the four walls in vertical and horizontal direction. The longitudinal wave speed c_L is measured from the time of flight Δt of an impulse (F in Figure 5) travelling across a distance Δx measured by two accelerometers placed (approx. 2 m) apart. The time of flight was evaluated using the onset of the impulse appearing in the time signal of the two accelerometers. For the excitation of the impulse, a hammer blow on the frame of the wall in line with the accelerometers is used.

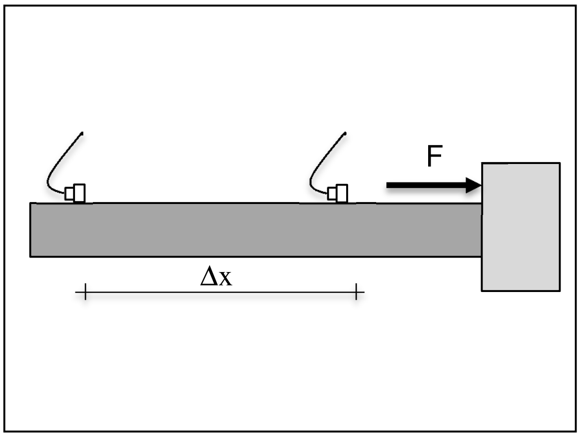

Figure 5. Measurement setup for the longitudinal wave speed of a wall (grey) when measuring the time of flight of a longitudinal wave between two accelerometers The impulse is generated by a hammer blow (F).

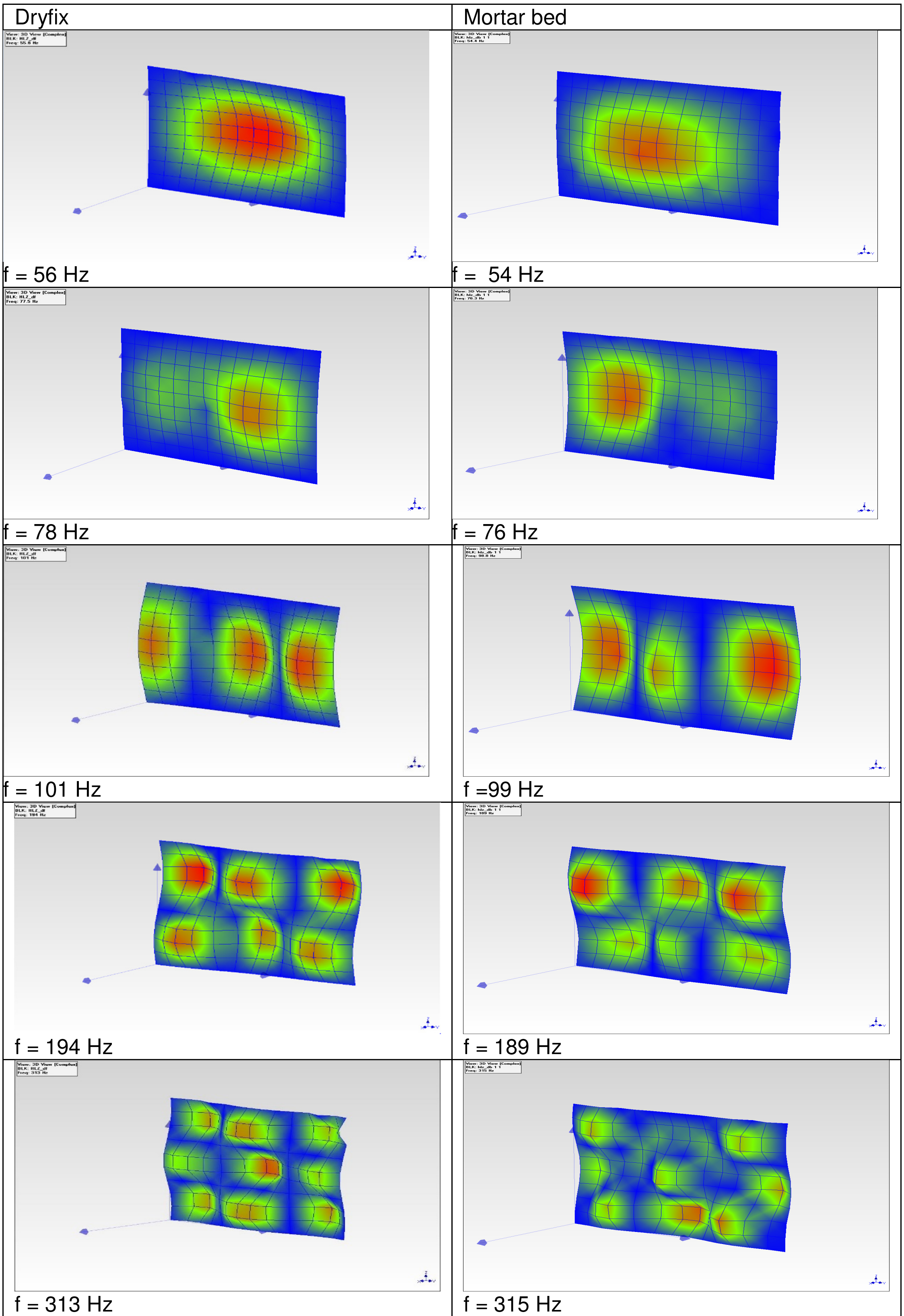

Figure 6. Measured mode shapes of two 115 mm brick walls. Left colum: new mortar system dryfix. Right colum: 1 mm mortar bed.

In table 1 the measured longitudinal wave speed for the walls with the different mortar types are shown for horizontal and vertical direction. The resulting coincidence frequency was calculated from these values according to eq. 2 and an effective coincidence frequency f_{ceff} was calculated from the geometric mean of the horizontal and vertical results.

$$f_c = \frac{c_0^2\sqrt{3}}{\pi h c_L} \quad (2)$$

		Horizontal		Vertikal		
	t	cL	fc	cL	fc	fc eff
	[mm]	[m/s]	[Hz]	[m/s]	[Hz]	[Hz]
1a (DB)	115	1707	324.7	2438	227.3	271.7
1b (DF)	115	1937	286.1	2185	253.6	269.4
2a (DB)	175	1336	272.6	2503	145.5	199.2
2b (DF)	175	1384	263.1	2296	158.6	204.3

Table I. Measured longitudinal wave speeds and calculated coincidence frequencies of two walls with thin-bedding mortar (DB) and with dryfix (DF).

The longitudinal wave speed for the vertical direction is much higher than in horizontal direction. This seems due to the fact, that there is no mortar in the vertical joints and therefore the longitudinal wave speed and the stiffness of the wall in horizontal direction are lowered.
Smaller differences are found between the two mortar systems: in vertical direction, the longitudinal wave speed of the dryfix system is slightly lower.
Considering the coincidence frequency, one observes differences in horizontal and vertical directions of e.g. 227 Hz to 324 Hz for the 115 mm mortar mix wall and a range of 145 Hz to 272 Hz for the 175 mm wall. This spread of the measured coincidence frequencies can be found as a plateau in the SRI of these walls in figure 4. This plateau tends to result in a rather unusual shape of the SRI in the mid frequency range.
Measurements of the loss factor show no significant differences between the two mortar systems.
The two 115 mm walls are investigated using experimental modal analysis. The partitions were setup inside a test stand for measuring sound insulation according to ISO 10140-2 (2.75 m height and 4.14 m width). The grid had a spacing of approximately 25 cm and on the 140 points transfer functions were measured using a fixed accelerometer and a moving impulse hammer.
In figure 5 some of the first mode shapes for the two walls are shown. The mode shapes and the corresponding resonance frequencies are very similar. Therefore it is suggested, that the vibrational behaviour in the low frequency range will not change due to the kind of mortar used.

3.2 Thermal insulating bricks with filling

The SRI of four thermal insulating walls (see figure 2) was measured too. A 365 mm and a 425 mm thick wall (ρ ≈ 650 kg/m³) were both build up with thin-bedding mortar and with the dryfix system. In the following graph, the measured SRI for the four walls is shown.

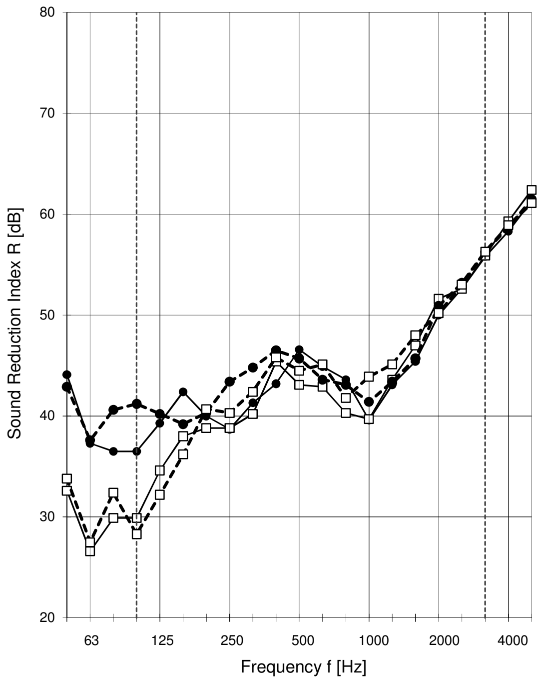

Figure 7: SRI of a 365 mm brick wall (solid lines) and of a 425 mm brick wall (dotted lines) where the horizontal joints are made of thin bedding mortar (dots) and dryfix (squares).

The SRI of all the walls have a typical shape for thermal insulating brick walls. A clear dip in the SRI at 800 Hz - 1 kHz indicates that in this frequency range, the individual bricks vibrate [2] and the SRI is reduced. The depth and the frequency of this dip are influenced by the thickness and the kind of mortar [3]. In this case, there is no systematic difference due to the mortar in the SRI in this frequency range.

The SRI in the frequency range below 160 Hz changes due to the kind of mortar. The dryfix walls (squares in figure 5) have a SRI, which is up to 10 dB lower indicting that the bending stiffness of the dryfix wall is lower than of the wall with mortar. This result for the thermal insulating walls is in contrast to the results for conventional brick walls.

An explanation was rapidly found: the new dryfix system does not cover the complete area of the bricks. As indicated in figure 2 the glue is applied in two double stripes on the inner and outer flanges of the bricks respectively. The proportional area where the dryfix glue is applied therefor gets smaller when the thickness of the brick increases and is for the thermal insulating bricks much smaller than for the conventional bricks. With the much smaller contact or gluing area of the bricks the stiffness of the wall itself decreases and a lower SRI is expected.
Similar to the results for the conventional bricks the loss factor of the thermal insulating bricks show no significant differences due to the different mortar systems.

4. Conclusions

The new dryfix system replaces the widely used thin bed mortar system partially. The new system allows a quick gluing of the horizontal joints of the bricks and is applicable at low temperatures too. The influence of the mortar system on acoustic properties was investigated on conventional and thermal insulating brick walls.
The loss factor of the walls was not changed systematically by the tested mortar systems.
For the conventional brick walls the longitudinal wave speed in vertical direction decreased slightly with the new dryfix system. Due to the fact that there is no mortar in the vertical joints, the horizontal and vertical wave speed differ quite a lot. This leads to a strong anisotropic system, indicating two coincidence frequencies that give a plateau in the SRI around these frequencies. However, no significant differences in the SRI are found between the two mortar systems on the conventional bricks with a thickness of 115 mm and 175 mm.
For the thermal insulting brick walls with a thickness of 365 mm and 425 mm the SRI decreased with the new dryfix system in the frequency range below 160 Hz. However, no change was observed at higher frequencies not even in the frequency range where the resonances of the bricks cause a dip in the SRI. Therefore no significant differences for the weighted sound reduction index R_w were observed.
The reason for the different SRI of brick walls with the new dryfix system is probably not found in the material itself but in the area where the dryfix system is applied. In contrast to the thin layer mortar the new system is not applied over the whole area of the bricks: with the new system the glue is applied in two double stripes. Therefore, the percentage of glued area reduces with increasing thickness of the wall. With the reduced gluing area the stiffness of the wall and thus the SRI is changed.

Acknowledgement

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