The acoustic role of glass wool in double-leaf lightweight walls

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Chapter 1

Fundamentals

1-1 How does a fibrous product improve the acoustic performance of a wall ?

The reason why a double-leaf partition gives better sound insulation when its cavity is filled with a fibrous product is known. Many theoretical and experimental studies have been performed to investigate the effects of porous-mineral wool products in walls.
From these studies we can draw the conclusion that there are three basic reasons why the *sound reduction index* (R) or *Sound Transmission Loss* (STL) of a double-leaf wall improves when glass wool is used in the cavity.

1. The resonance frequency of the mass-spring-mass system is shifted to a lower value.
2. The glass wool dampens sound waves transmitted through the wall.
3. The glass wool dampens lateral standing sound waves in the cavity of the wall.

Each one of these reasons is discussed in more detail in the following paragraphs.

1-1.1 Shift of resonance frequency

All double walls have a resonance frequency caused by the **mass-spring-mass system.**
At this frequency, the Sound Transmission Loss of the wall decreases.
For most partitions, this resonance occurs at a frequency below 200 Hz. The frequency at which this resonance occurs is dependant on the mass per unit area of the leaf material and the stiffness of the spring, which is the air space. The mass is usually provided by gypsum wallboard on both sides. The stiffness of the spring is given by the distance between the leaves and the dynamic properties of the enclosed air.
When glass wool rolls or batts are placed in the cavity between the leaves, the mass-air-mass / *mass-spring-mass* resonance frequency shifts lower, which causes an increase of the overall sound insulation properties of the wall.
The shift of the resonance of the mass-spring-mass system to a lower frequency is caused by the reduced *dynamic stiffness* of the cavity /spring filled with glass wool.

Figure **1.1** shows in principle the transmission loss for a lightweight cavity wall with and without glass wool.

Glass wool rolls and batts are very effective at causing the resonance frequency of lightweight cavity walls to shift lower, resulting in higher sound insulation.

1-1.2 Damping of sound waves

In double-leaf lightweight walls, sound is transmitted from one leaf to the other via the cavity.
As the sound waves pass through a fibrous material, friction occurs between the sound wave and the surface of the individual fibres of the insulation product. This friction causes some of the sound field energy to be converted into heat. With the conversion of acoustic energy into heat, there is less sound energy transmitted through the wall.
The thicker the insulation product, the more the energy of the sound field is converted into heat, resulting in an increase of the sound insulation.(Fig **1.2**)

The best acoustic performing construction is obtained when the cavity is filled with a damping material.
Glass wool rolls and batts will give the most economical way of maximising acoustic performance.

1-1.3 Lateral damping

In the air cavity between the two leaves of a lightweight partition, resonance of lateral sound waves occurs. These resonant frequencies are the result of standing waves due to the wall dimensions and the distance between the studs inside the wall.
At the resonance frequencies, the Sound Reduction Index or Sound Transmission Loss of a wall decreases.
When the cavity is filled with a damping material, hence glass wool, these lateral standing sound waves are reduced due to the conversion of acoustical energy into heat. generated by friction.

Converting sound energy into heat energy causes the damping of both lateral standing waves inside the cavity and of sound waves transmitted via the cavity across the wall.

Figure **1.3** shows the difference in amplitude of standing waves inside a wall cavity with and without acoustic insulation.

Filling the cavity with glass wool rolls or batts reduces the negative influence of standing waves and results in the best overall acoustic performance.

1-2 Practical performances of lightweight walls

1-2.1 *German study*

1-2.11 Influence of the damping material

Based on the knowledge that the surface mass always has a positive impact on the transmission loss of single-leaf separating partitions (as does the leaf mass of cavity walls), building experts have long believed that this advantage will also apply to the density of the filling material. Studies on the role of the filling material as a damper in the air cavity led to the conclusion that a higher density did not help to improve the performance of the whole system.
In fact if the density - and therefore stiffness – is to high and the filling material is in contact with both leaves, it negatively influences the acoustical performance of the wall.
For a long time it was also believed that a material with higher *air flow resistivity* (**r** in kPa.s /m2, former Rayls / cm) would improve the performances of walls.
Many tests were carried out in Germany in the 70's to evaluate the influence of the air flow resistivity of the filling material on the sound insulation of walls.
The results show that the air flow resistivity has a positive impact on the sound reduction index, *but no additional improvement is achieved when the* **r** *-value is higher then 5 kPa.s /m^2*, which corresponds to that of **lightweight glasswool rolls and batts.**

Figures **1.4** and **1.5** show the behaviour of different mineral wools as damping materials.
Figure **1.4** shows the influence of a complete filling, figure **1.5** of a half filling.
With respect to the reproducibility of transmission loss measurements, both graphs show identical results for materials with airflow resistivity varying between 6 and 25 kPa.s/m^2.

The two figures are also good examples of the **non-impact of the density** which may vary from 12 to 70 kg/m^3 with reference to the range of the air flow resistivity of the mineral wool products presently applied.

1-2.12 Influence of the filling thickness

The performance of double-leaf partition walls is considerably dependant on - although not sufficiently realised - the thickness with which the cavity is filled with mineral wool.

Figure **1.6** shows the important impact which mineral wool filling has on the acoustic performance of a partition wall with an 80 mm cavity depth. A 25% filling of the cavity thickness improves the weighted sound transmission index Rw by 5 dB. Successive filling with more mineral wool leads to further clear improvements of performance.
Total filling of the cavity thickness improves the weighted sound reduction index by 16 dB.
The improvement of lightweight partition walls by doubling the mass per unit area of the leaves normally lies between 4 and 6 dB. In comparison the improvement achieved by doubling the amount of cavity damping from half to full filling has the same order of magnitude, but is far less expensive.

1-2.2 *Other practical studies*

Studies in France and Sweden have recently confirmed the findings of the German study regarding the use of lightweight glass wool and the need to fill the cavity entirely.
The ***French study*** covered a partition specially designed to test the performances of a lightweight glass wool roll developed in the late 80's for this specific application.
Figures **1.7** and **1.8** re-cap the values obtained in an acoustics laboratory, which once again confirms the satisfactory results brought by a lightweight glass wool with a sufficient air flow resistivity ($r \sim 5$ kPa.s/m^2) and the performance gains achieved by progressive filling of the air cavity.
A large ***Swedish study*** of the impact on acoustic performances of filling the air cavity of lightweight partitions was performed in 1997. It consists of more than 130 measurements of 12 types of partitions with part or total filling with glass wool in densities of 12.5 to 26 kg/m^3, and stone wool in density 35 kg/m^3
Below are the results of our examination of 2 examples of steel stud partitions filled with stone wool in comparison with the lightest glass wool tested.
The results of the Swedish study, corroborate the previous ones.

- single steel stud partition
  - 2 leaves of 12.5 mm gypsum board
  - 45 mm cavity / studs
  - 2 leaves of 12.5 mm gypsum board

Damping material	Amount of filling	Rw (dB)
Lightweight glass wool $r \sim 5$ kPa.s/m^2	fully filled 45 mm	**47**
	over filled 70 mm	**48**
Stone wool $r > 5$ kPa.s/m^2	fully filled 45 mm	**46**
	over filled 70 mm	**44**

- double steel stud partition
  - 2 leaves of 12.5 mm gypsum board
  - cavity 150 mm / studs 70 mm
  - 2 leaves of 12.5 mm gypsum board

Damping material	Amount of filling	Rw (dB)
Lightweight glass wool $r \sim 5$ kPa.s/m^2	fully filled 150 mm	**62**
	over filled 170 mm	**62**
Stone wool $r > 5$kPa.s/m^2	fully filled 150 mm	**61**
	over filled 170 mm	**58**

As stated in1-2.11, it is also confirmed that over-filling the cavity might deteriorate the sound reduction index, the more so as the density of the damping material is high, hence increasing the coupling between the leaves.

1-3 Conclusions

1 Many factors influence the Sound Transmission Loss or Sound Reduction Index of a wall, these are:

a. Type of studs or joists used in the construction.
Flexible metal studs are better than solid wood studs.
Single wood studs walls should be used with resilient channels to reduce the solid contacts between the leaves and studs which favour sound transmission
b. The amount and type of acoustic glass wool insulation used inside a cavity wall.
c. Workmanship in building the wall is very important. Careful attention to construction details must be observed. Air leaks, which are sound leaks, can greatly reduce the acoustic effectiveness of a wall.

2 Acoustic insulation lowers the mass-air-mass resonance frequency of a double-leaf wall; this causes an increase in the sound reduction index of the wall. This effect is the major contributor to the improved acoustic performance of a double-leaf lightweight wall. Depending on the type and spacing of the studs used in a double-leaf wall, the single number rating (STC or R_w) can increase by 6 to 12 points.

3 Cavity resonance in a double wall is greatly attenuated or reduced by acoustic insulation in the space between the two leaves. It is imperative that this cavity is completely filled with low density glass wool in order to achieve the maximum benefit from the insulation.

4 Sound energy in a wall is reduced when it passes through the acoustic insulation due to friction with the fibres in the insulation. This loss of sound energy results in higher Sound Reduction Index or Sound Transmission Loss values. The thicker the insulation, the more the sound is reduced.
Increasing the density of the insulation above that achieving an air flow resistivity of $r \sim 5$ kPa.s/m^2 does not improve the acoustic performance of the double-leaf wall.

5 Total filling of the cavity with lightweight glasswool rolls or batts is the most economic way to achieve high sound insulation values compared with larger cavities or extra layers of gypsum board.

**Hence, we can summarise CHAPTER 1 by stating that not filling cavities of lightweight walls with an adapted glass wool (r ~ 5 kPa.s/m2)
means not taking advantage of the most economical way of maximising acoustic performance.**

6 The same principles apply to wall linings on heavy single-leaf walls, floors with wooden or steel joists, roofs with wood rafters, façades with sheet metal cladding, etc..