metrotile
LIGHTWEIGHT ROOFING

RAIN IMPACT TESTING REPORT

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TNO report

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Rainfall and impact noise measurements on metal roof tiles

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Contents

1 Introduction

Metrotile Europe designs and manufactures metal roof tiles for the building industry. The trend on the tile market is towards the application of smooth tiles. The current grained tiles have the disadvantage of easy moss growth on the outside of the tile. However, since the introduction of the smooth tile, complaints concerning rainfall and hail noise have been received by the manufacturer. Therefore Metrotile is seeking a tile design with a smooth exterior and yet the same noise emission properties as the conventional grained tile.

Metrotile Europe NV commissioned TNO TPD to conduct rainfall and impact noise measurements on various tile designs in order to investigate which type of noise control measure will be most promising. A special measurement set-up was designed and built for this purpose. It is described in chapter 2. Results are shown in chapter 3 and discussed in chapter 4. Finally conclusions are drawn in chapter 5.

2 Measurement procedure

Rain and hail falling onto a tile have different excitation mechanisms. Raindrops are relatively light non- rigid bodies, whereas hail is a solid body with a higher impedance. Therefore two separate measurement procedures were applied.

2.1 Test roof

A test roof was installed in a reverberant room. The dimensions of the test roof are shown in figure 2.1. The roof was mounted at an angle of 30 degrees. In total 6 prefabricates of 8 tiles were installed on the test roof. The structure was closed by wooden panels. The acoustic quality of this test rig is shown in appendix B. This is of importance in order to be able to clearly distinguish the noise radiation of the tiles in both directions. A fixed microphone was installed inside the test building and a rotating microphone was installed in the reverberant field of the reverberation room, see figure 2.2. The application of a rotating microphone allows averaging over space in the reverberant sound field.

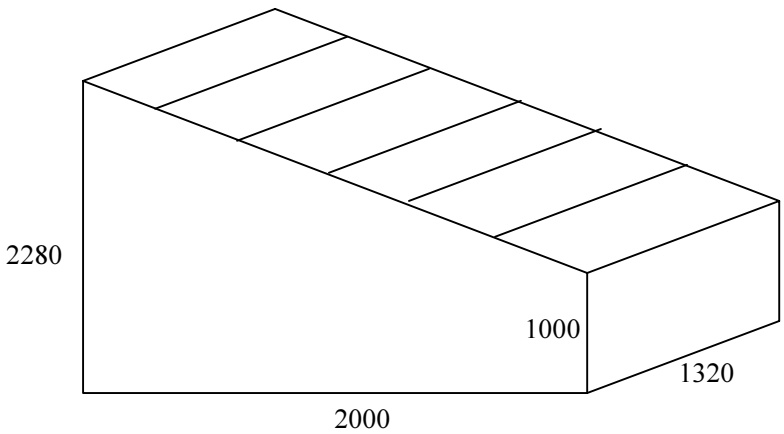


Figure 2.1 – Dimensions of the test structure

Various tile designs were installed on the test rig, see table 2.1. All tested tiles were made of a zinc alloy. The tiles were rigidly installed on the ridges with two screws per prefabricate. This is a representative way of installing Metrotile products in practice. Both rainfall noise and hail noise were measured for the various tile structures.

Table 2.1 Various tested tile designs

Roof tile	Finishing	Thickness [mm]
1	Blank	0.45
2	Blank	0.90
3	Painted	0.45
4	Painted both sides	0.45
5	Felt layer on backside	0.45
6	Double tile	2x0.3
7	Grained	0.45
8	Grained	0.90

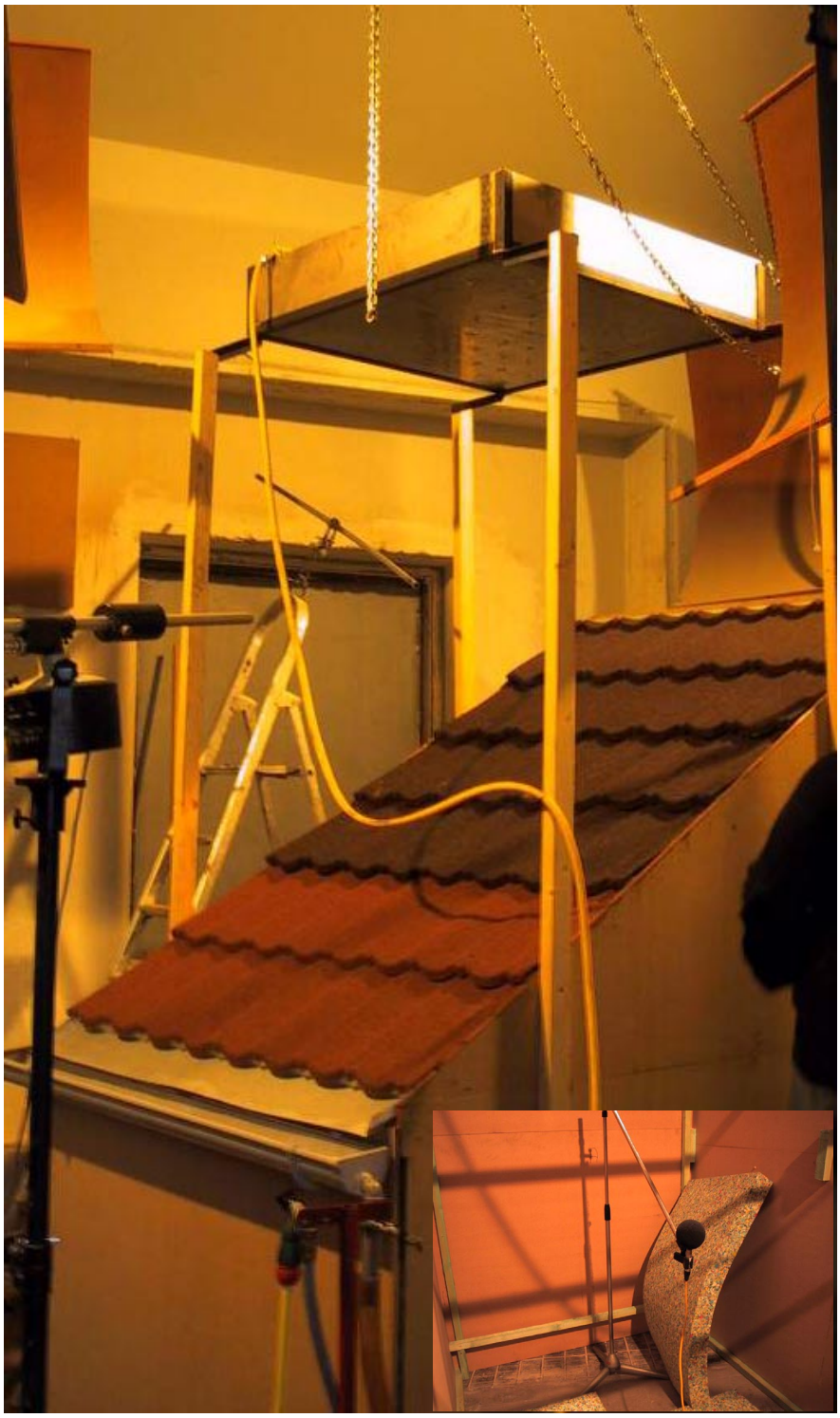


Figure 2.2 – Overview of the test set-up. The inset shows the microphone inside the test building. Above the structure the artificial raindrop generator can be seen.

2.2 Rainfall noise

For the rainfall noise test the procedure as described in ISO 140-18 (in preparation) [1] is used. Artificial raindrops ware generated by a tank with perforated base, producing *heavy rain* according to IEC Standard 60721-2-2. Figure 2.3 shows an overview of the rain tank. The in total 64 perforations on the tank base were distributed over 1 m^2. In this way the roof is uniformly excited by raindrops. The diameter of the perforations are 1 mm and the base plate thickness was 1 mm. During all noise measurements a water column of about 10 cm was present in the tank.

The equivalent A-weighted sound pressure level is measured both inside the test roof (fixed microphone position) and outside the roof in the reverberation room (rotating microphone). The noise is averaged during 64 s, which equals one rotation of the microphone.

2.3 Hail noise

Hail noise is not standardized yet. TNO TPD simulated hail impact excitation on the roof tiles by dropping a metal marble (weight 7g) from a fixed position at 0.5 m above the tile surface. The maximum sound pressure level (L_{Amax}) inside the test rig with integration time FAST (125 ms) was measured. Each impact test was repeated 10 times to check reproducibility.

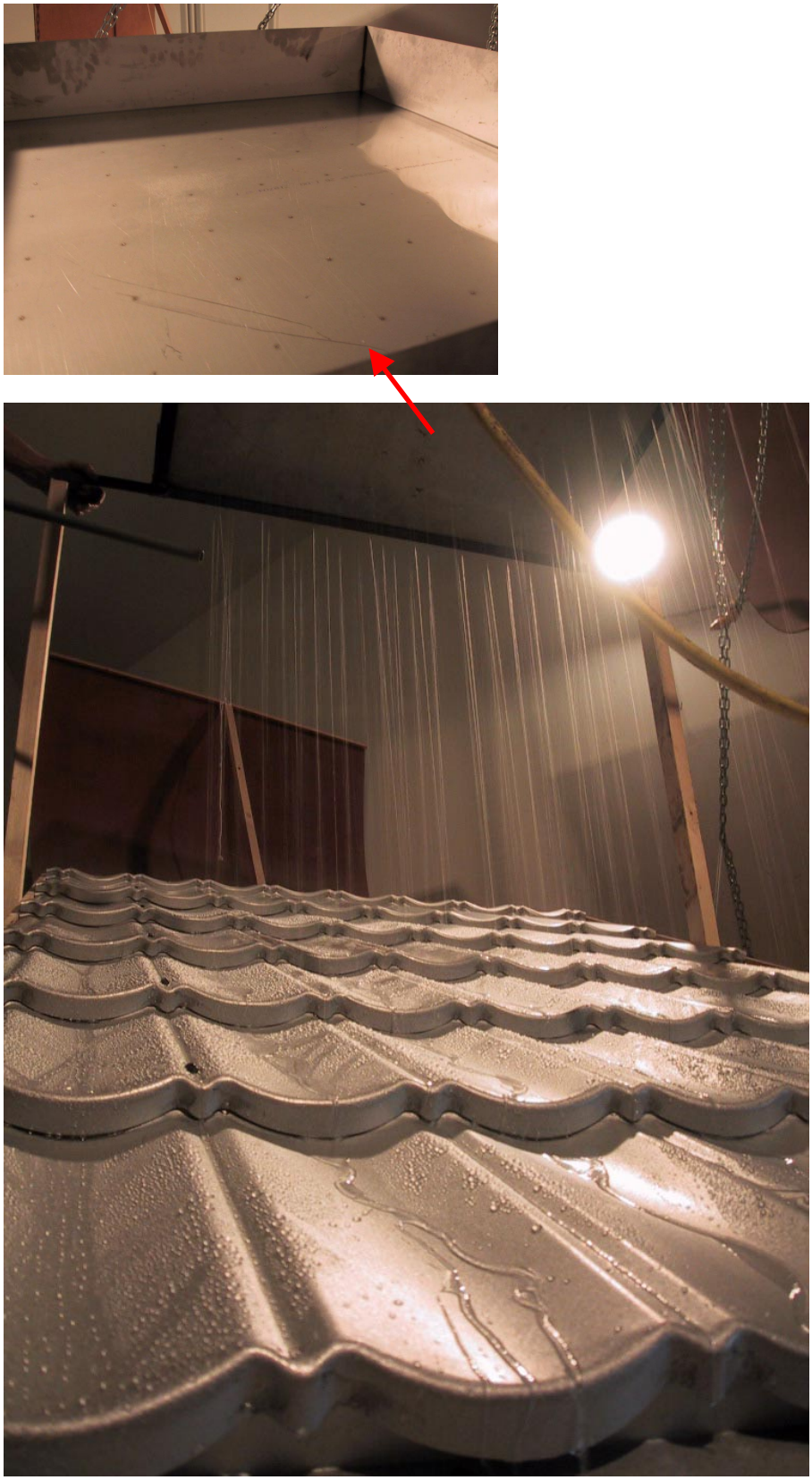


Figure 2.3 – Overview of the artificial rain drop generator with a top view of the rain tank

3 Results

The following table shows the results of the sound pressure level measurements for rainfall and hail noise. The sound pressure levels in 1/3 octave bands can be found in appendix A.

Table 3.1 Measured total sound pressure levels for rainfall noise (inside and outside) and hail noise for various tile designs

		Rainfall noise L_{Aeq} in dB(A) re 20µ Pa		Hail noise L_{Amax} in dB(A) re 20µ Pa
	Roof tile	Inside	Outside	Inside
1	Blank 0.45 mm	69	67	96
2	Blank 0.9 mm	64	62	98
3	Painted 0.45 mm	66	64	95
4	Painted both sides 0.45 mm	66	64	96
5	Felt layer	61	59	93
6	Double tile (2x0.3 mm)	61	59	91
7	Grain 0.45	58	57	87
8	Grain 0.9	56	55	88

4 Discussion

4.1 Acoustic parameters

In table 4.1 the various investigated tile designs are listed again. However, this time some relevant acoustic parameters that are affected for each alternative tile design are shown.

Table 4.1 Overview of the tile design including the affected acoustic parameter and the achieved noise reduction relative to the reference tile (0.45 mm blank)

Roof tile	Finishing	Thickness [mm]	Acoustic parameter affected	Noise reduction for rainfall noise in dB(A)	Noise reduction for hail noise in dB(A)
1	Blank (reference)	0.45	-	-	-
2	Blank	0.90	Mass Stiffness	5	-1
3	Painted	0.45	Damping Texture	3	2
4	Painted both sides	0.45	Damping Texture	3	1
5	Felt layer on backside	0.45	Damping	8	4
6	Double tile	2x0.3	Damping Mass Stiffness	8	6
7	Grained	0.45	Damping Mass Texture	10	9
8	Grained	0.90	Damping Mass Stiffness Texture	12	8

To help to interpret the amount of noise reduction achieved (in dB's) the following guidelines are given:

- 2 dB is hardly audible
- 5 dB is audible
- 10 dB is a doubling of loudness for the human ear and is very well audible.

4.2 Increasing tile thickness

Increasing tile thickness increases the noise production of the tile for hail excitation. However, for rainfall noise, doubling the tile results in a noise reduction of 5 dB(A). This can be expected from acoustic theory. This illustrates that the nature of the excitation mechanism of the tile has a large effect on the noise production and success of design changes.

Doubling of a grained tile results in only 2 dB(A) noise reduction. This is possibly due to a relatively heavy coated grain layer. The additional mass effect of thickness doubling is inferior.

4.3 Increasing damping

Blank tiles are lightly damped plate-like structures, even when point-fixed to the ridges with screws. By introducing additional damping, in the form of a thin felt layer glued on the backside of the tile, a reduction of 8 dB(A) is measured for rainfall noise. This is the same reduction as measured for a 2x0.3 double walled tile. The noise reduction obtained with the glued felt layer is very high, since the felt layer is light and possesses no bending stiffness. This indicates that the blank tiles have light damping. This is illustrated by the fact that a painted tile already gives 3 dB(A) noise reduction relative to an unpainted tile. For a very lightly damped structure it is relatively easy to increase the damping. However, once the total damping is high, it is hard to increase the damping further.

Both for rainfall and hail noise there is no difference between a tile painted on the top side and painted on both top and backside.

For a double walled tile the thin air layer trapped between the two tiles increases the damping of the structure. It is to be expected that the damping can be increased some more if tiles with unequal thickness are used for the double walled tile.

For hail noise the effect of increasing damping is smaller, but still 4-6 dB(A) is achieved.

4.4 Changing outer tile texture

The outer texture of the tile affects the contact area, both for a rain drop and for a hail stone. This could explain the additional noise reduction besides the effect of higher damping.

5 Conclusions and recommendations

Currently, the single painted tiles are put on the market as an alternative for the grained tiles. Complaints were made concerning rainfall noise. No complaints were made for conventional grained tiles. This is consistent with the measurement results, which show that for heavy rain, the difference in noise emission between these two designs is about 7 dB(A). Application of the felt layer, on a plane tile, results in a decrease of about 5 dB(A). 2 dB(A) additional noise reduction, for both rainfall and hail noise, would result in the same amount of noise emission as the grained tiles. So then the noise problem is expected to be solved.

The incorporation of a thin felt layer as a free damping layer on the backside of the tile looks promising for Metrotile because of its ease of production. Further research could indicate whether increasing the thickness of the felt layer, application of different glue types or application of other types of free layer damping results in a higher noise reduction. However, it is to be expected that significant effort will have to be required to further increase the damping considerably. As an additional noise control measure searched could be for a soft durable coating on the outer surface of the tile, which both increases damping and decrease impact excitation at the same time.

Increasing of the tile thickness is effective to decrease rainfall noise. However, this does not apply for hail noise.

The effect of studied noise control measures on rainfall noise is higher than for hail noise.

Outer tile texture seems to be of less importance for rainfall noise. Damping is a more important factor.

Considering the way of installation of the metal tiles, structure-borne sound is not important. Since no large wooden plate structure is installed underneath the tiles, in between the ridges, only the direct airborne sound radiation of the tiles is of importance. Therefore vibration isolation of the tiles is not considered as a possible noise control measure.

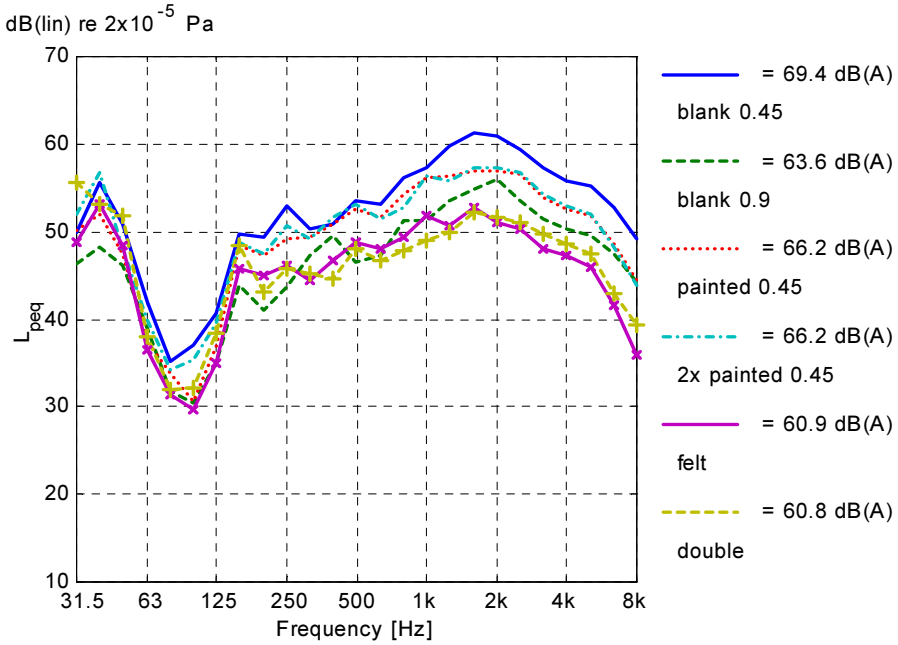
Delft, 16 april 2004 TNO TPD

Ir. H.W. Jansen

6 References

[1] ISO/CD 140-18 ‘Acoustics – Measurements of sound insulation in buildings and of building elements – Part 18: Laboratory measurement of sound generated by rainfall on building elements, 2002.

A Sound pressure level spectra



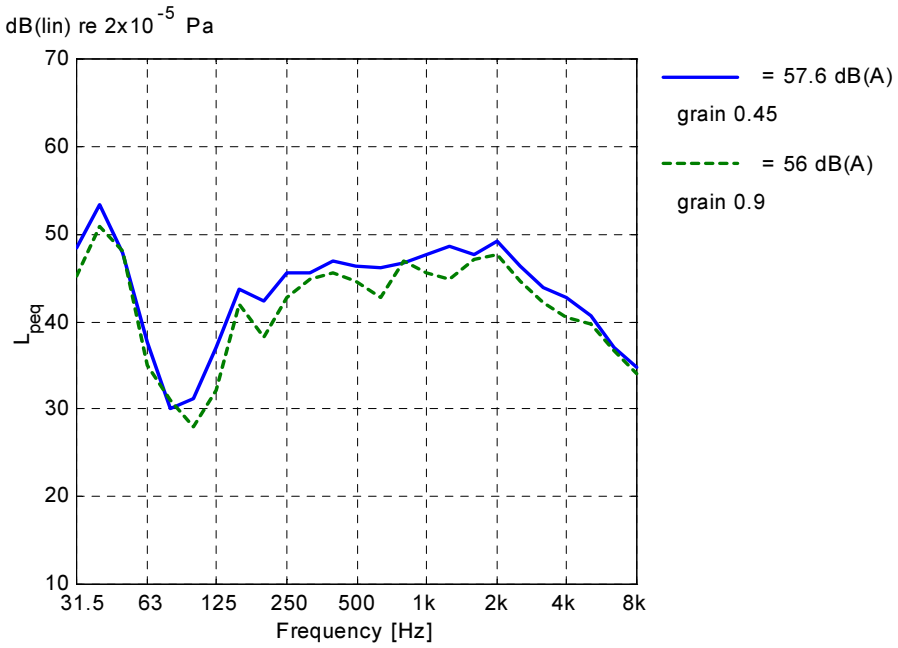
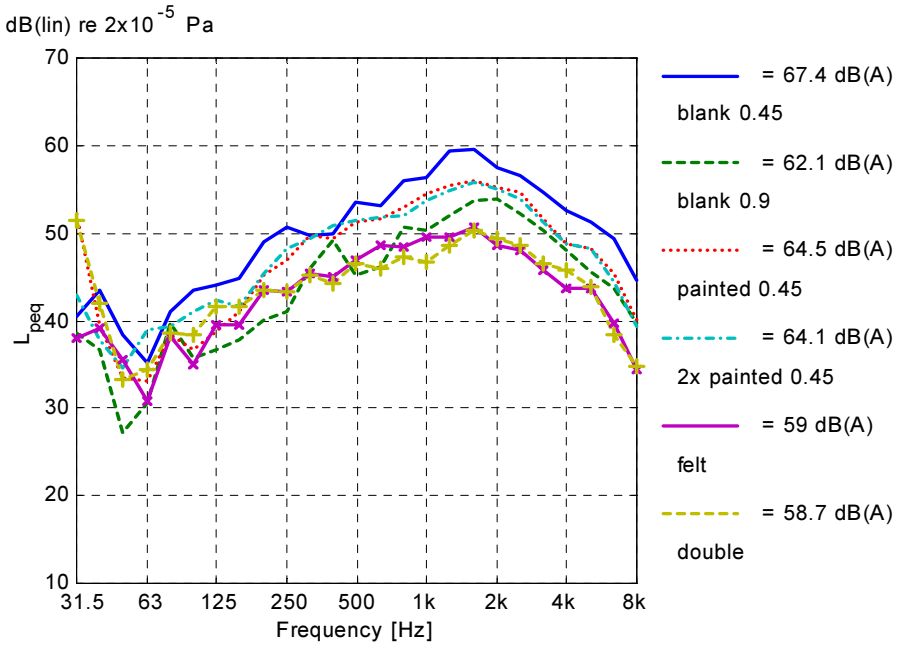


Figure A.1 Sound pressure levels in 1/3 octave bands measured inside the test rig for rainfall excitation.



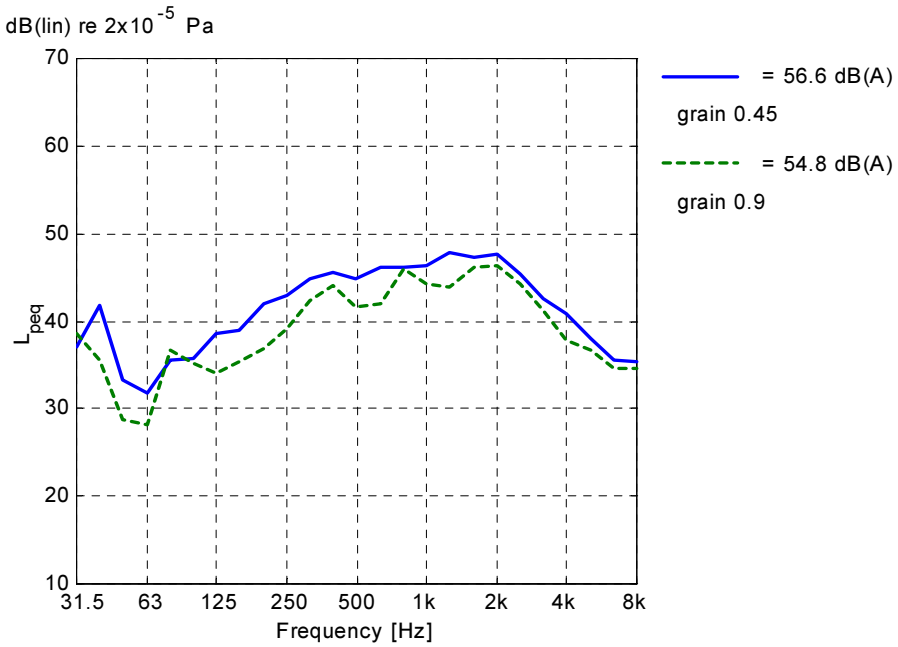
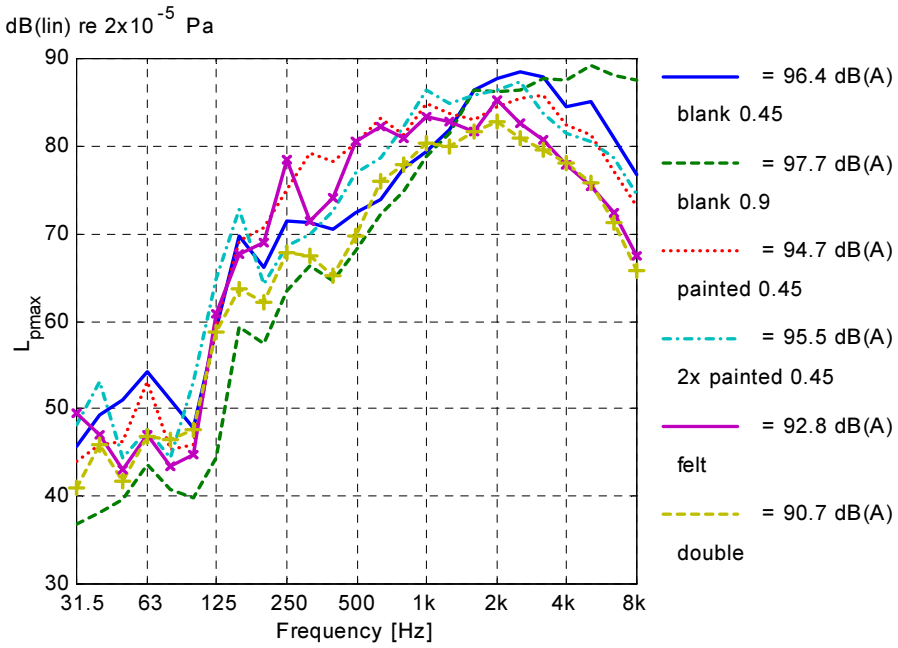


Figure A.2 Sound pressure levels in 1/3 octave bands measured outside the test rig for rainfall excitation.



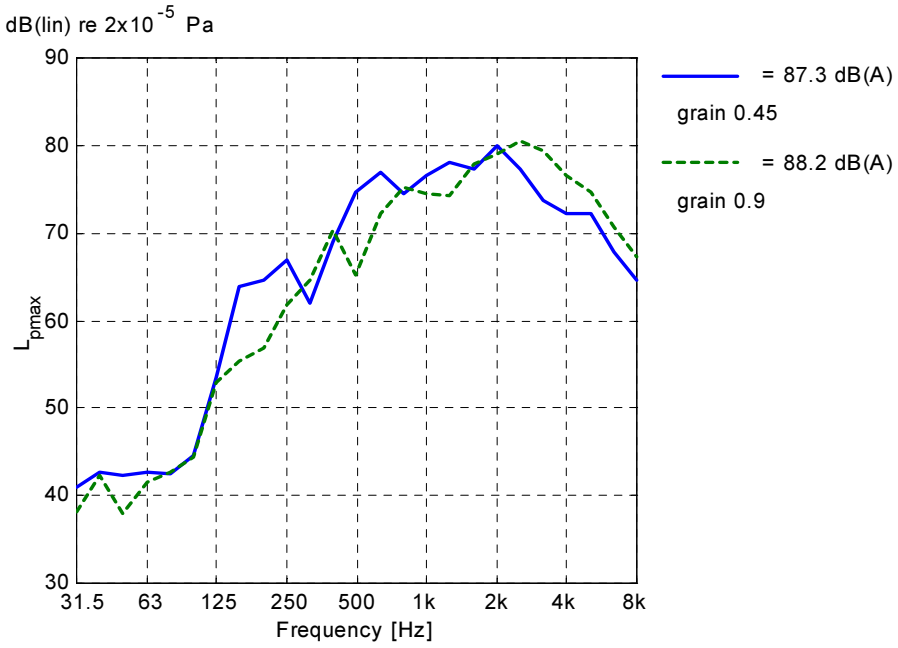


Figure A.3 Maximum sound pressure levels in 1/3 octave bands measured inside the test rig for impact excitation.

B The acoustic quality of the test rig

To check the airborne noise isolation of the wooden test rig, a calibrated B&K sound source was placed inside the rig. With the rotating microphone the time and space averaged sound pressure level was measured, see figure B.1. Also an measurement with the sound source outside the rig in the reverberation room was conducted. From figure B.1 it can be seen that for frequency higher than 200 Hz the isolation of the housing is at least 10 dB. This implies that from this frequency noise radiation of the tile into the housing and into the reverberation room can be clearly distinguished.

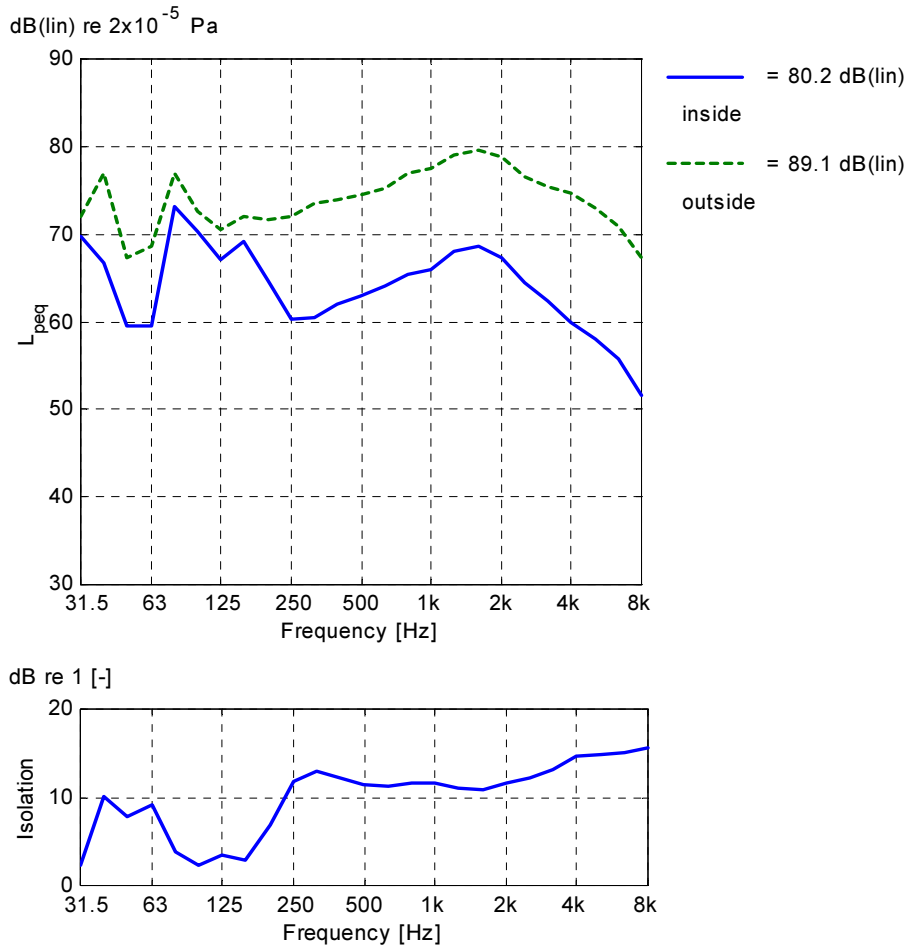


Figure B.1 The isolation of the test rig in 1/3 octave bands measured with a B&K calibrated sound source located both inside and outside the test rig.

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