Impact sound pressure values – Field measurements for different configurations of concrete slabs on the ground

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The presentation will summarize and discuss values of field measured normalized impact sound pressure level $L'_{n,w}$ measured sideways with different configurations of concrete slabs on ground within buildings. All results are adjusted to receiving room volume of 100 m^3 and with thickness of concrete slab 80-100 mm. Measurement on continuous concrete slab on expanded polystyrene gives $L'_{n,w}$ between adjoining rooms of 74 dB. Different principles of splitting have been investigated to evaluate the effect on $L'_{n,w}$. The configuration where only the concrete slab is split (and with a plastic film between the concrete base and the upper layer of expanded polystyrene), gives $L'_{n,w}$ of approximately 66 dB which is 8 dB lower than for a continuous bare concrete slab. When both the concrete slab and the upper layer of expanded polystyrene are split, measurements show $L'_{n,w}$ of 58-61 dB for the case of no flooring, which is 13-16 dB lower than for a continuous concrete slab (no split). When both concrete slab and all layers of polystyrene split down to continuous foundation measurement shows $L'_{n,w}$ of 55 dB. The situation with concrete slab and all layers of polystyrene split and with no foundation beneath gives $L'_{n,w}$ of 46 dB. For all configurations we have to consider what kind of flooring that will meet the requirements in Norwegian regulations (NS 8175:2012). Consequences for airborne sound and R'_w will be discussed as well for the above mentioned configurations.

1 Introduction

Impact sound measurements have been done for different configurations of bare concrete slabs on the ground. The following situations have been measured:

- Continuous concrete slab without any splitting
- Only concrete slab is split, but then with a plastic film between the concrete slab and the expanded polystyrene
- Concrete slab and the upper underlying expanded polystyrene (50 mm of 200 mm) are split
- Concrete slab and all layers of polystyrene are split down to foundation or down to the ground

The results from field measurements in different buildings will be summarized and discussed. An assumption for the analysis is that the reduction of floor coating from laboratory ΔL_w measured according to NS-EN ISO 10140-3:2010 and NS-EN ISO 717-2:2013 may be transferred almost onto any desired concrete floor (massive and stiff enough) in practice [1].

Concrete slabs are global reacting regarding impact noise. The impact level in the base is almost constant, and measurements should therefore be compared for the same volume of the receiving room. When the receiving volume is less than 100 m^3, the measured $L'_{n,w}$ is increased because of volume correction, and opposite when the volume of receiving room is bigger than 100 m^3. The results summarized are not corrected for reverberation time in the different receiving rooms.

In the literature there seems to be little written about impact noise and different solutions for concrete slabs on the ground. This is also confirmed by a paper at international congress in 2017, where it was said that lateral impact isolation has had little study compared to vertical impact noise isolation [3].

2 Measurements for different configurations of concrete slab

2.1 Case 1 - Continuous concrete slab

2.1.1 Vågsbygd comprehensive school in Kristiansand

In year 2002 the company Sinus AS (report 810702-0.R01 dated 07.11.02) measured impact sound between adjacent rooms at Vågsbygd comprehensive school. The situation was $L'_{n,w}$ for 80 mm continuous concrete slab with underlying EPS, and it has been confirmed there was no splitting at all of the concrete slab. The construction was as follows:

- Coating
- 80 mm concrete slab (not split)
- Expanded polystyrene (not split)

The measured value of $L'_{n,w}$ sideways was 72 dB with coating of 4-5 dB impact reduction and receiving room volume of 182 m^3. Adjusted for the effect of flooring and normalized to receiving room volume of 100 m^3, the $L'_{n,w}$ for 80 mm continuous concrete slab on the ground is 74 dB. This value may be used for considering what kind of flooring that will be needed to fulfill the the requirements to field measured impact sound ($L'_{n,w}$) in different buildings.

With a continuous concrete slab the sound insulation R'_w is limited to be about 44-46 dB, due to sound transmitted through the slab even though the separating wall on its own has a sound insulation (R'_w) of 55-60 dB.

2.1.2 Bekkestua school in Oslo

Multiconsult has done measurements in Bekkestua school, with the case of continuous concrete slab. The construction build-up was as follows:

- Floor coating
- 100 mm concrete slab (not split)
- 300 mm expanded polystyrene (not split)
- 300 mm concrete plate

The measured value of $L'_{n,w}$ sideways was 68 dB with floor covering of 6 dB impact reduction and receiving room volume of 170 m^3. Adjusted for the effect of floor covering and normalized to receiving room volume of 100 m^3, the $L'_{n,w}$ for 100 mm continuous concrete slab was 72 dB.The difference in $L'_{n,w}$ for Vågsbygd and Bekkestua school is probably due to different thickness of the concrete slab and different thickness of the underlying polystyrene.

2.2 Case 2 - Only concrete slab is split, but with plastic film between concrete slab and upper layer of polystyrene

2.2.1 Fagerholt school in Kristiansand

Measurements have been carried out in a school in Kristiansand (Fagerholt school). Here the situation was that only the concrete slab was split, but there was a plastic film between the concrete and polystyrene. The construction build-up was as follows:

- Floor coating with impact noise reduction of 17 dB
- 100 mm thick concrete slab (split)
- Plastic film
- 100 mm polystyrene (not split)
- 100 mm polystyrene (not split)

The measured $L'_{n,w}$ was 52 dB with receiving room volume of 200 m^3. Adjusted for the effect of flooring and normalized to receiving room volume of 100 m^3, the $L'_{n,w}$ for 100 mm concrete slab on a plastic film is 66 dB. The reduction of impact sound level compared with continuous slab is 8 dB.

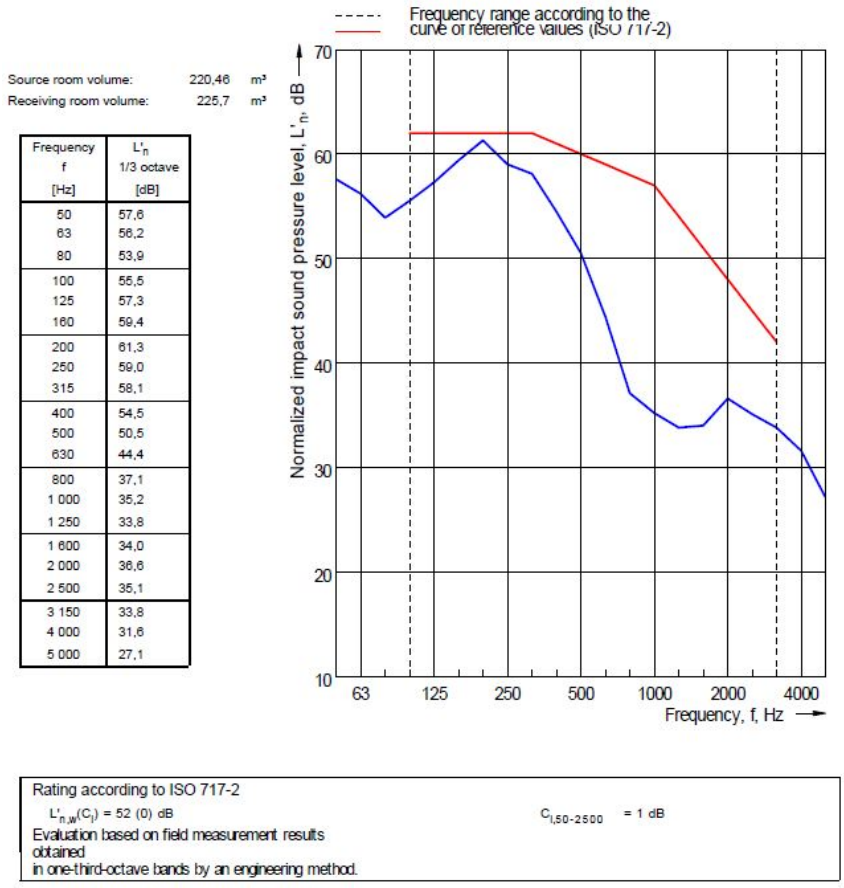


Figure 1: Measured $L'_{n,w}$ with a split concrete slab and a plastic film between the concrete and the polystyrene

In Fagerholt school, the sound insulation requirement for the wall between some classrooms (where only the concrete slab was split) was R'_w of 40 dB because the construction between the classrooms was wall with door. It has therefore not been possible with the current measurements to conclude what value of sound insulation it is possible to achieve when only the concrete slab is split.

For the situation where both the concrete slab and upper layer of polystyrene were split, the impact sound $L'_{n,w}$ was approximately 58-61 dB. With a split concrete slab on a plastic film, the impact sound $L'_{n,w}$ sideways increases with 5-8 dB. Based on the fact that the concrete slab will be the dominating flanking construction, it can be assumed that R'_w for the situation with only concrete slab being split will be 5-8 dB lower than measured 61 dB for the situation where both the concrete slab and upper layer of polystyrene are split. This indicates an expected sound insulation (R'_w) of approximately 53-56 dB for the situation with a split concrete slab on a plastic film (continuous layer of polystyrene beneath the plastic film), and should be investigated in more detail through more field measurements.

2.3 Case 3 - Concrete slab and the upper underlying polystyrene are split

2.3.1 Landviktun in Grimstad

Measurements have been done in apartments for the project Landviktun in Grimstad. Here the situation was that both the concrete slab and the upper underlying polystyrene were split. The construction build-up was as follows:

- Floor coating with impact noise reduction of 19 dB
- 100 mm thick concrete slab (split), with vertical mineralwool in the split
- 50 mm polystyrene (split)
- Plastic film (not split)
- 150 mm polystyrene (not split)

The measured $L'_{n,w}$ was 36-39 dB with receiving room volume of 58 m^3. Adjusted for the effect of floor coating and normalized to receiving room volume of 100 m^3, the $L'_{n,w}$ for 100 mm concrete slab and upper underlying polystyrene both split is 58-61 dB. The reduction of impact sound level compared with continuous slab is 13-16 dB.

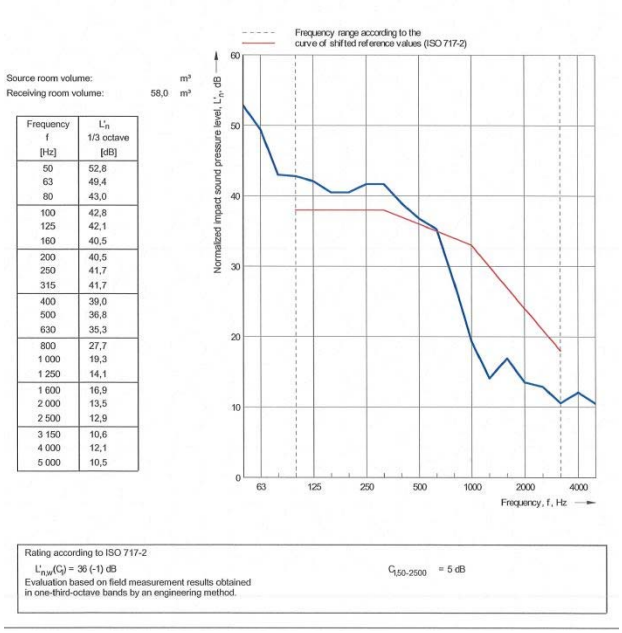
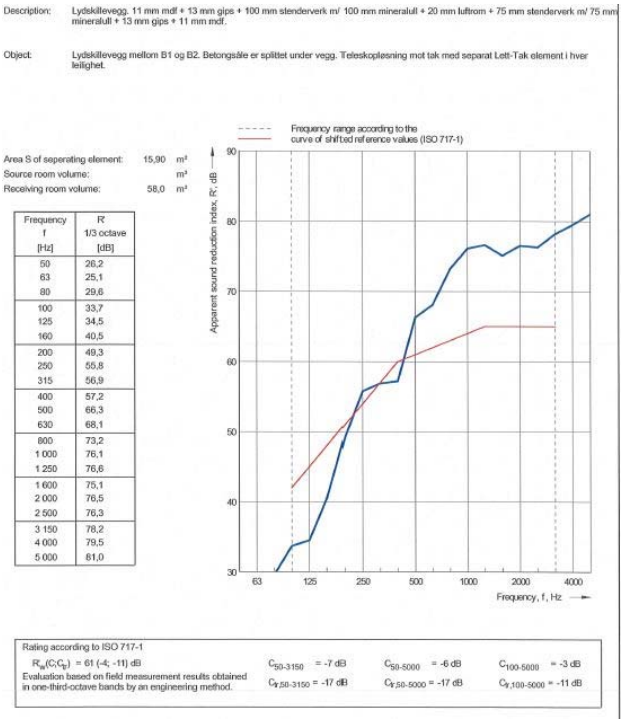


Figure 2: Field measured impact sound $L'_{n,w}$ for a split concrete slab on a split upper layer of polystyrene

The measured value of R'_w is 61 dB. This shows that solution with split of both concrete slab and upper layer of polystyrene is sufficient to fulfill the limit for sound insulation (R'_w 55 dB) between apartments in NS 8175.



Frequency f [Hz]	R' 1/3 octave [dB]
50	26,2
63	25,1
80	29,6
100	33,7
125	34,5
160	40,5
200	49,3
250	55,8
315	56,9
400	57,2
500	66,3
630	68,1
800	73,2
1 000	76,1
1 250	76,6
1 600	75,1
2 000	76,5
2 500	76,3
3 150	78,2
4 000	79,5
5 000	81,0

Figure 3: Field measured sound insulation R'_w between separate apartments with a solution of splitting both the concrete slab and upper layer of polystyrene

2.3.2 Fyrstikkalléen school in Oslo

Measurements have been carried out by Brekke & Strand for Fyrstikkalléen school in Oslo (project no 46020-00 dated 09.08.2010). Here the situation was that both the concrete slab and the upper underlying polystyrene were split. The construction build-up was as follows:

- Floor coating with impact noise reduction of 17 dB (4.2 mm acoustic linoleum)
- 100 mm thick concrete slab (split), with vertical mineralwool in the split
- 50 mm polystyrene (split)
- Plastic film (not split)
- 100 mm polystyrene (not split)

The measured $L'_{n,w}$ was 45 dB with receiving room volume of 214 m^3. Adjusted for the effect of floor coating and normalized to receiving room volume of 100 m^3, the $L'_{n,w}$ for 100 mm concrete slab and upper underlying polystyrene both split is 59 dB. The result is quite similar with Landviktun for similar solution.

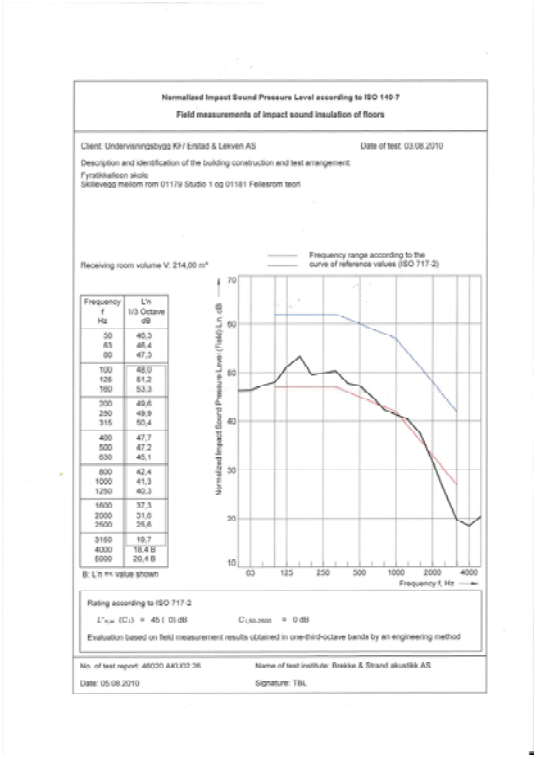


Figure 4: Field measured impact sound $L'_{n,w}$ for a split concrete slab on a split upper layer of polystyrene

From detail drawings, it can be seen that both the concrete base and the upper layer of polystyrene are split.

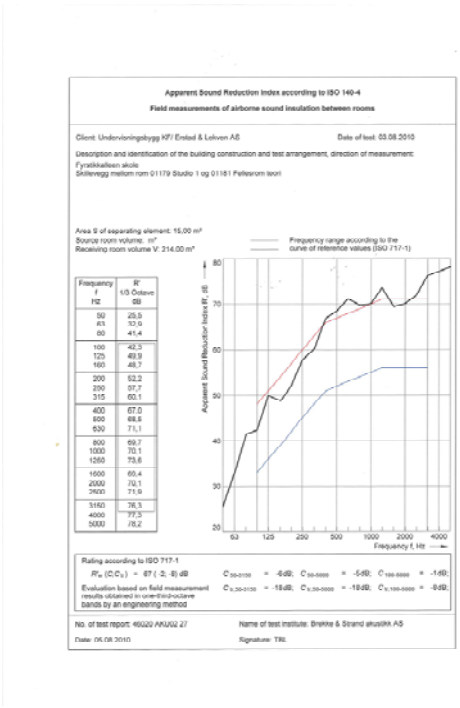


Figure 5: Field measured sound insulation R'_w in school with a solution of splitting both the concrete slab and upper layer of polystyrene

2.4 Concrete slab and all layers of polystyrene are split

2.4.1 Case 4

Between two music rooms at Fagerholt school, the separating concrete wall relaxed on a continuous concrete foundation. Both the concrete slab and the underlaying layers of polystyrene was with a gap (neoprene) to the concrete wall. The situation is shown in case 4 in the table below, and shows $L'_{n,w}$ of 55 dB.

2.4.2 Case 5

At Vågsbygd comprehensive school work was done to improve the sound insulation between rooms. Both the concrete slab and the underlying layers of polystyrene were split down to the ground, on both sides of the separating wall. The result was $L'_{n,w}$ of 46 dB with both concrete slab and the layers of polystyrene split. For the situation of no continuous foundation between rooms on the ground floor, it is possible to achieve $L'_{n,w}$ of 46 dB sideways on a bare concrete slab.

At Kringsjå school in Kristiansand, measurement was done between two rooms on the ground floor. The floor construction is here totally split with concrete on pillars on one side of the separating wall and concrete slab on the ground on the other side of the separating wall. The measured value of $L'_{n,w}$ sideways was 42 dB with floor covering of 6 dB impact reduction and receiving room volume of 271 m^3. Adjusted for the effect of floor covering and normalized to receiving room volume of 100 m^3, the $L'_{n,w}$ for the situation with splitted floor construction was 44 dB. The result is almost the same as for Vågsbygd comprehensive school, and as expected better at Kringsjå because we know the split in the flooring construction at Kringsjå is splitted completely. The difference of 2 dB between Vågsbygd and Kringsjå could also be explained by different thickness of the concrete slab by the two schools, 80 mm at Vågsbygd and 120 mm at Kringsjå. Because the slab and underlying layers of polystyrene at Vågbgyd were split on both sides of the separating wall, it is highly probable that the splitting at Vågsbygd was completely. If $L'_{n,w}$ is corrected for thickness of the slab, the result is quite similar for both schools.

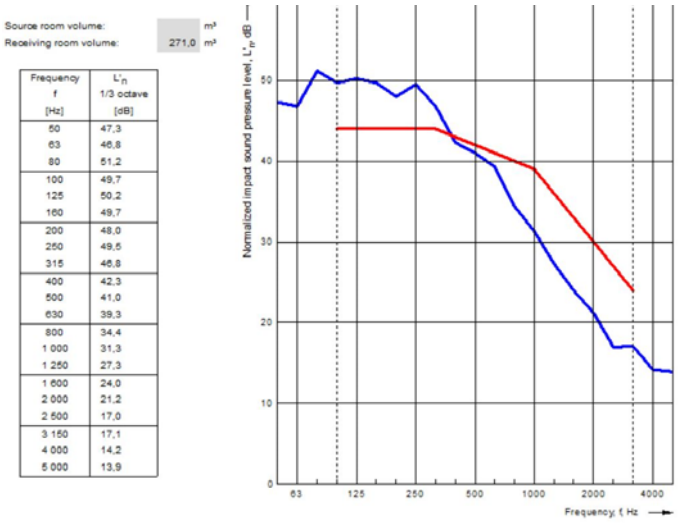


Figure 6: Field measured impact sound $L'_{n,w}$ for a full split with separate flooring constructions. Concrete slab on pillars on one side of separation wall and concrete slab on the ground on the other side of the wall.

For the situation at Fyrstikkalléen school where the concrete slab and upper layer of polystyrene are split, the impact sound $L'_{n,w}$ was approximately 59 dB. With all layers split on a continuous foundation, the impact sound $L'_{n,w}$ sideways reduces with 4 dB, based on the measurements from Fagerholt school. Based on the assumption that the concrete slab will be the dominating flanking construction, it may be assumed that R'_w for the situation with all layers split down to continuous foundation will be 4 dB better than measured 67 dB for the situation where both the concrete slab and upper layer of polystyrene are split. This indicates an expected sound insulation (R'_w) of approximately 70 dB for the situation

with all layers split down to continuous foundation. When there is no continuous foundation beneath the separating wall, it will be possible to achieve higher sound insulation than R'_w 70 dB, but the result will then be limited by other flanking constructions than the concrete slab.

3 Frequency spectrum – Impact noise through concrete slab

Situation	Case 1 Continuous slab	Case 2 Concrete split	Case 3 Concrete and upper layer of polystyrene split	Case 4 All layers split down to foundation	Case 5 All layers split down to the ground
Hz					
50	56	55	56	46	43
63	55	53	52	49	43
80	54	51	46	41	47
100	54	53	46	44	46
125	58	54	45	45	46
160	62	56	44	45	46
200	63	58	44	45	44
250	64	56	45	41	46
315	65	55	45	42	43
400	65	52	42	43	38
500	65	48	40	38	37
630	64	41	38	36	35
800	63	34	31	33	30
1000	63	32	22	31	27
1250	62	31	17	30	23
1600	61	31	20	28	20
2000	59	34	17	24	17
2500	57	32	16	18	13
3150	54	31	14	17	13
4000	48	29	15	16	10
5000	37	24	14	15	10

Table 1: Frequency spectrum of measured impact sound for the different configurations of slab including effect of floor coating – receiving room volume 100 m^3.

In the lowest frequencies, none of the coatings have effect on impact noise. The measurement uncertainty is highest in the lowest frequencies. The results seem to indicate no effect of splitting of upper layers in 50 and 63 Hz, but it is necessary with a totally splitting through all layers down to foundation/ground to get some effect in these frequencies. For 80 and 100 Hz the effect of different splitting is more significant. In other frequencies the table shows total effect of splitting and floor coating.

Situation	Case 1 Continuous slab	Case 2 Concrete split	Case 3 Concrete and upper layer of polystyrene split	Case 4 All layers split down to foundation	Case 5 All layers split down to the ground
Hz					
50	56	55	56	46	43
63	55	53	52	49	43
80	54	51	46	41	47
100	54	57	50	49	46
125	58	60	48	51	46
160	64	58	46	47	47
200	64	61	47	47	45
250	65	60	50	45	46
315	66	58	50	45	44
400	66	57	51	48	39
500	66	55	55	46	38
630	65				
800	64				
1000	65				
1250	65				
1600	65				
2000	64				
2500	64				
3150	64				
4000	64				
5000	62				

Table 2: Frequency spectrum of measured impact sound for the different configurations of slab without effect of coating – receiving room volume 100 m^3.

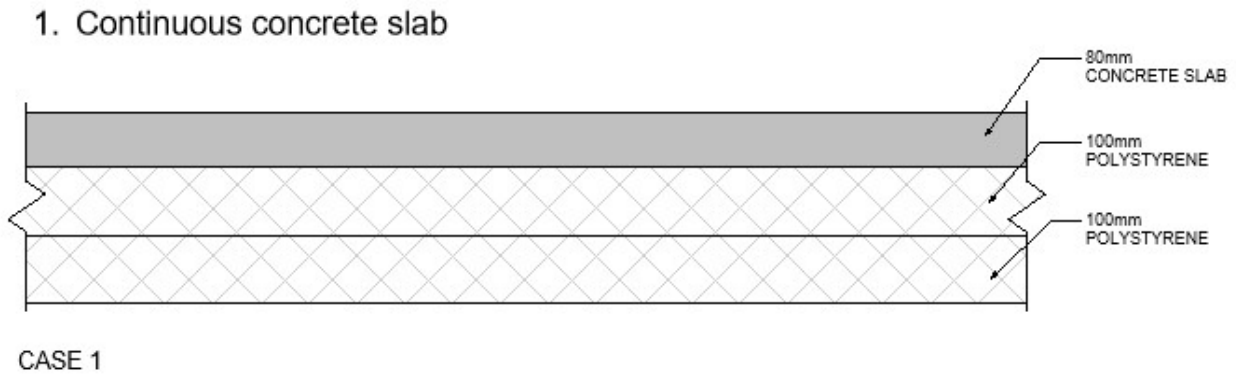
The measurement uncertainty is highest in the lowest frequencies. From the table it seems to be low effect of splitting of upper layers in 50 and 63 Hz, but it is necessary with a totally splitting through all layers down to foundation/ground to get some effect in these frequencies. For 80 and 100 Hz the effect of different splitting seems to be more significant. The results are only reliable up to 500 Hz. Because the measurements were limited by background noise (from other activities/sources and the microphone of the instrument), the good effect of the coating in high frequencies will overestimate the calculated L'_n in high frequencies. Based on the measured R'_w (frequency spectrum) for Landviktun and Fyrstikkalléen school, it seems to be clear that the measured impact level is transferred through the ground and not as airborne sound. For Kringsjå school with splitted constructions and a good separating wall (R'_w 60 dB), it is also to be concluded that the measured impact noise comes from sound transferred through the ground. The measured difference for splitted solutions compared with continuous slab is at least 10 dB lower than would be expected if the sound was transferred as airborne sound. The results are therefore not influenced by airborne sound through the separating wall, but has mainly to be sound transferred through the ground. Case 4 was measured at Fagerholt school, with chrushed

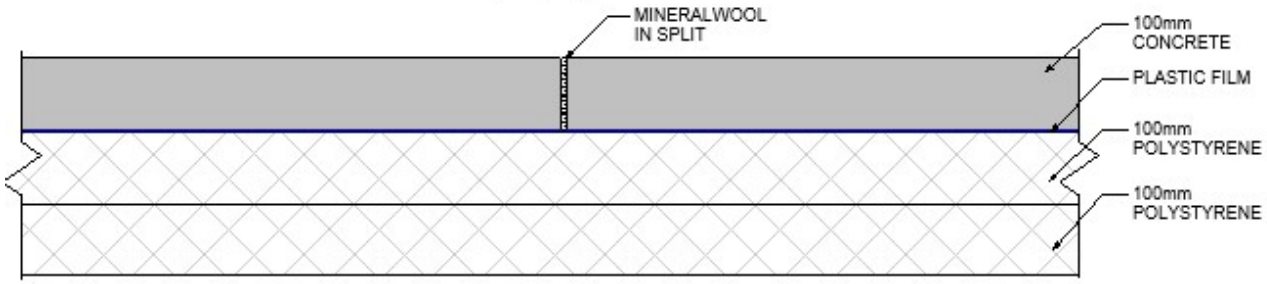
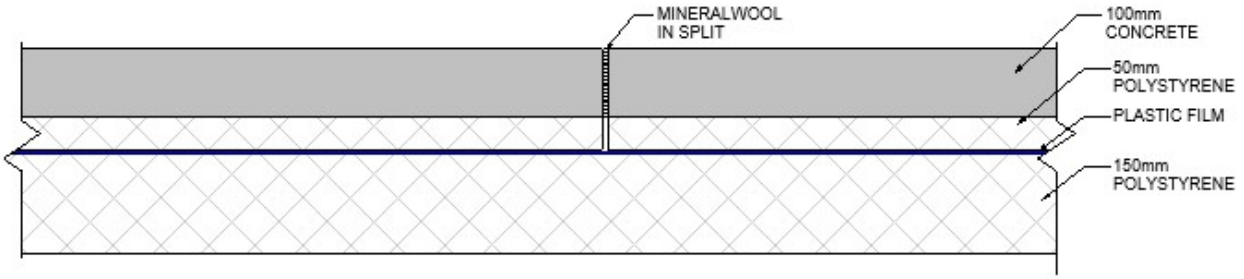
stone/gravel under the polystyrene. For case 5 measured at Kringsjå school the ground also consisted of chrushed stone/gravel. Originally there was peat soil on clay/quick clay both places.

4 Conclusion

Measurements of impact sound pressure for different exposed concrete slab configurations, indicates the following:

- Case 1: A continuous concrete slab gives a sideway impact noise of $L'_{n,w}$ of 74 dB
- Case 2: A split concrete slab on a plastic film (continuous layer of polystyrene beneath the plastic film) gives a sideway impact noise of $L'_{n,w}$ 66 dB
- Case 3: A split concrete slab on a split upper layer of polystyrene gives a sideway impact noise $L'_{n,w}$ of 58-61 dB
- Case 4: Both concrete slab and all layers of polystyrene split down to continuous foundation gives $L'_{n,w}$ of 55 dB
- Case 5: Both concrete slab and all layers of polystyrene split with no foundation beneath gives $L'_{n,w}$ of 46 dB

Construction build-up	$L'_{n,w}$
	74 dB

2. Only concrete slab split, plastic film between concrete slab and polystyrene  CASE 2	66 dB
3. Concrete slab and the upper underlying polystyrene are split  CASE 3	58-61 dB

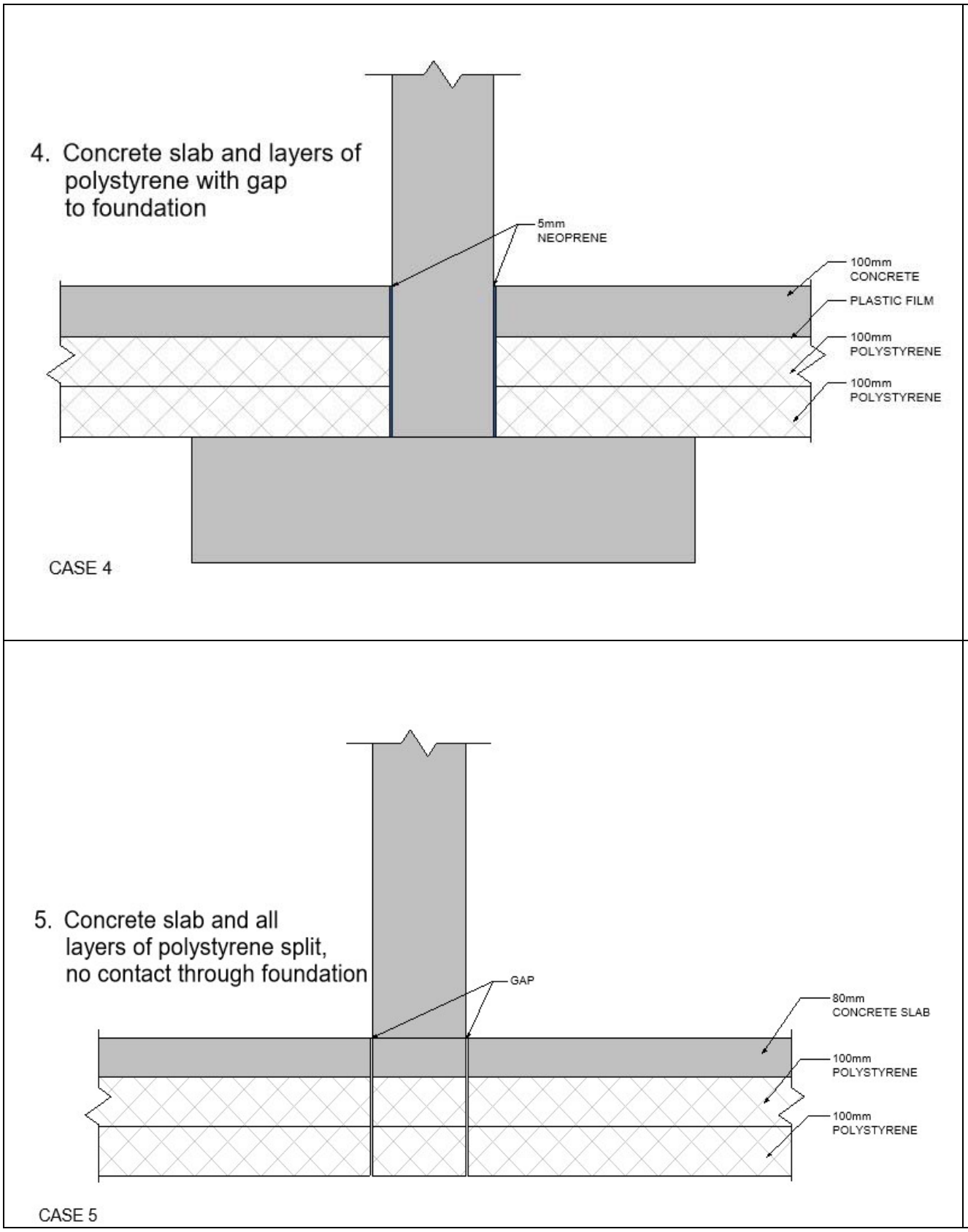


Figure 7 Construction build-up, different solutions for bare concrete slab

The given values are for concrete slabs without flooring, and for receiving room volume of 100 m^3. The effect on R'_w with different solutions for concrete slab should be studied in more detail, and more field measurements would be of great value. For a continuous concrete slab, the sound insulation (R'_w) is expected to be approximately 44-46 dB, even for a wall that on its own has a sound insulation (R'_w) of 55-60 dB. The case of a split concrete slab on a split upper layer of polystyrene will be sufficient to give sound insulation (R'_w) of 55-60 dB, and with a good wall it is possible to achieve around 67 dB with such a solution. Measurements indicate an expected sound insulation (R'_w) of approximately 70 dB for the situation with all layers split down to continuous foundation.

5 References

[1] Sipari, Pekka, Studies On Impact Sound Insulation of Floors

[2] David W. Dong and John LoVerde, Impact Noise of bare concrete slabs, *The Journal of the Acoustical Society of America 143, 1726 (2018)*.

[3] John LoVerde and Wayland Dong, Measurement of Lateral impact noise isolation, *24th International Congress on Sound and Vibration (2017)*.