Update of German standard DIN 4109 with respect to lightweight frame constructions

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Introduction

The German building acoustics standard DIN 4109 is currently under fundamental revision. Amongst other things, this standard includes a "catalogue of components", which lists sound insulation figures for common building techniques and components[1]. These figures are allowed to be used for the proof of noise abatement without individual testing. The advantage of such figures is that they provide building contractors with a reliable database for the planning of their constructions, without the need of carrying out costly and time-consuming laboratory tests on their own. Furthermore, clients have the possibility to obtain an estimation of the acoustical performance of a building while it is being planned. Regarding lightweight frame constructions (metal framework lined with plasterboard), the figures in the current standard have to be reviewed due to the technical development of plasterboards, a fact which has been considered only partially in past updates[2]. Also, to a wide extent the origin of the figures listed in the recent standard is unclear. Accordingly, a working group in the standardization committee responsible proposed a research project in order to randomly check the noise reduction measures of Tables 31 and 32 (flanking transmission loss of metal frame walls and heavy walls with linings), and, by doing so, to provide at least a minimum data base for the revision of DIN 4109. Moreover, additional test reports containing related results were supplied by the Rigips company[3]. The usability of these results was also to be checked in the course of the planned investigations. Finally, the obtained results should be used in order to verify if the prediction method according to the current draft of DIN 4109.x delivers a reasonable and safe estimation for the flanking transmission loss of heavy walls with detached and completely interrupted linings. The research project was conducted by PTB, the measurements were performed by IBP Stuttgart. Cooperative funding was provided by DIBt and the industrial associations IGG and HDB. A report on the achieved measurement results and a resulting proposal for the revised standard are presented in this paper.

Measurement programme

As a result of extensive discussions in the working group, a measuring programme as described in Table 1 and Table 2 was established. It includes the measurement of the flanking transmission loss of metal frame walls and heavy walls with linings, in which different designs (continuous, separating cut, completely interrupted) of the junction between the flanking wall and the separating wall were investigated. Figure 1 and Figure 2 show schematic diagrams of the investigated structures. IBP Stuttgart was commissioned with the execution of the measurements. It is accredited for measurements in building acoustics and has a special test facility which allows the configuration of up to four individual rooms with suppressed flanking transmission of ceilings and floors. Such a facility is necessary for the proper measurement of flanking transmission produced by longitudinal walls. Detailed specifications were established for the preparation of the structures under test. Furthermore, the use of standardized off-the-shelf components instead of manufacturer-specific system solutions was proposed. Further details are explained in the final report of the research project.

Table 1: Flanking transmission loss of metal framework walls with different junction designs analogue to Table 32 of DIN 4109

Framework	Panelling/ no. of layers	Junction design
CW 50	1	continuous
	2	continuous
	1	separating cut
	2	separating cut
	1	interrupted
	2	interrupted
CW 100	1	continuous
	2	continuous
	1	separating cut
	2	separating cut
	1	interrupted
	2	interrupted

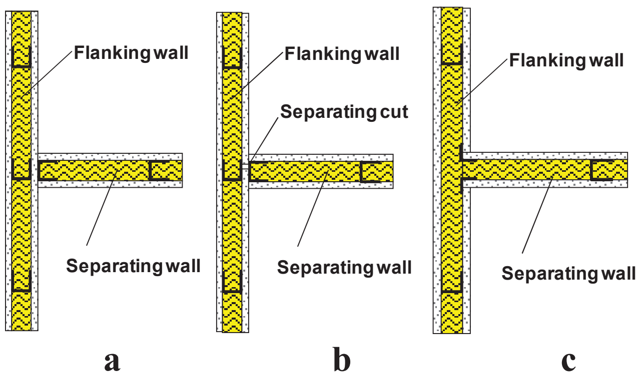


Figure 1: Principal sketch of metal framework wall with different junction designs: a): continuous; b): with separating cut; c): completely interrupted

Table 2: Flanking transmission loss of heavy walls with detached lining analogue to Table 31 of DIN 4109

m´ of longitudinal wall in kg/m²	Panelling/ no. of layers	Junction design
100	1	separating cut
		interrupted
300	1	separating cut
		interrupted

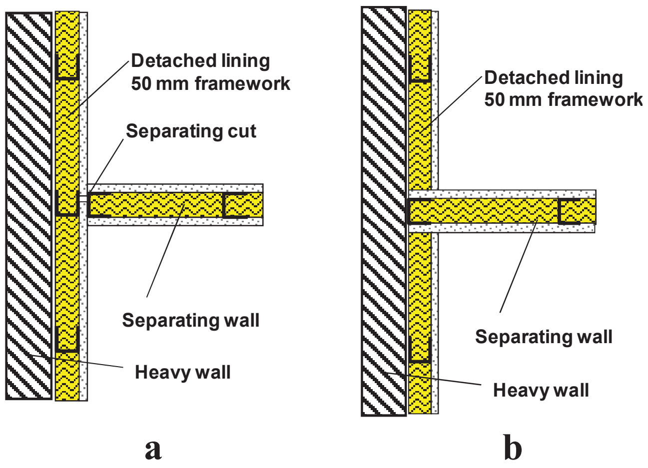


Figure 2: Principal sketch of heavy wall with detached linings. Junction designs: a): with separating cut; b): completely interrupted

Measurement results

Metal framework walls

Figure 3 and Figure 4 show examples for the measured flanking transmission loss of the metal framework walls. As was to expected, increasing the width of the framework and the number of panelling layers leads to an overall improvement of the sound insulation. Also, the introduction of a separating cut adds up to a significant rise of the sound insulation in the higher frequency range. This observation complies well with measurement results from past investigations[3]. In contradiction to this, the introduction of the interrupted junction design did not show the expected results. Both the recent version of DIN 4109 and the measurement results provided by the industry predict a significant improvement when this design is used. This is also shown in Table 3, which gives an overview of all obtained single number values. In contradiction to this, the actual measurement results show no improvement in comparison to the junction design with a separating cut. Furthermore, the sound insulation decreases notably in the frequency range between 160 Hz and 315 Hz. Although some assumptions have been proposed to explain this unexpected behaviour[4], a final explanation for all the observed effects is not yet available and will probably be the subject of future investigations.

Heavy walls with detached linings

As shown in Table 2, two different heavy walls with identical linings were measured. For a surface mass m' of 100 kg/m² an aerated concrete wall with a thickness of 175 mm was built. To obtain a surface mass of 300 kg/m², calcium silicate bricks were used for a compound wall, also with 175 mm thickness. The continuous design of the junction was omitted here because it is not of practical relevance anymore. Table 4 gives an overview of the obtained results. It is remarkable that, in contradiction to the measurements with metal frame walls, this time the interrupted design of the junction shows a considerable improvement when compared to the design with a separating cut.

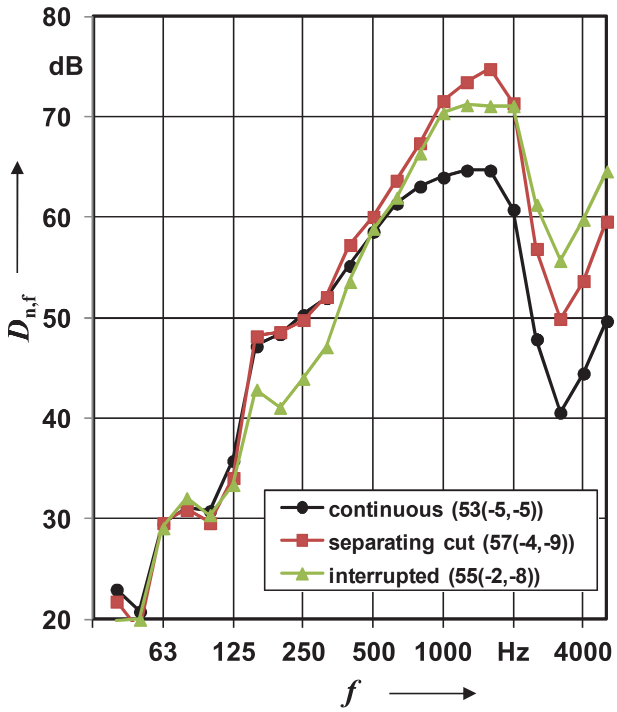


Figure 3: Flanking transmission loss of wall, CW50 framework and single layer panelling; ($D_{n,f,w}$,C,C_{tr}) in dB

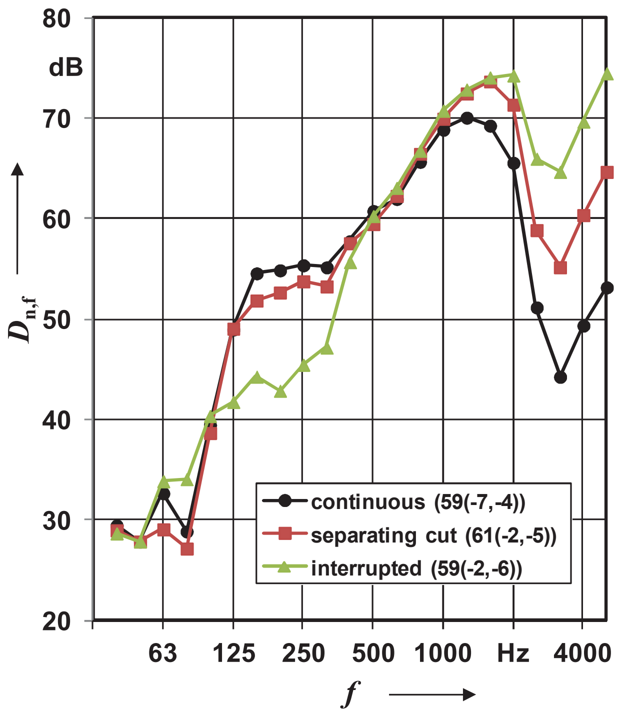


Figure 4: Flanking transmission loss of wall, CW 100 framework and double layer panelling; ($D_{n,f,w}$,C,C_{tr}) in dB

Table 3: Flanking transmission loss of metal frame walls, overview of all measured values $D_{n,f,w}$, compared to results provided by Rigips and DIN 4109 (no safety margin)

Frame-work	Layers	Junction	IBP	Rigips	DIN 4109 Tab. 32
CW 50	1	cont.	53	61	55
CW 50	1	sep. cut	57		
CW 50	1	interr.	55		75
CW 50	2	cont.	56	59[1]	
CW 50	2	sep. cut	60		59
CW 50	2	interr.	61		>77
CW 100	1	cont.	55	58	55
CW 100	1	sep. cut	59	64	
CW 100	1	interr.	57	65	75
CW 100	2	cont.	59	59	
CW 100	2	sep. cut	61	64[1]	59
CW 100	2	interr.	59	68[1]	>77
[1] Outer panelling: One layer only					

Table 4: Flanking transmission loss of heavy walls with detached lining, overview of all measured values $D_{n,f,w}$, compared to results provided by DIN 4109 (no safety margin)

m´ kg/m²	Layers	Junction	IBP	DIN 4109 Tab. 31
100	1	sep. cut	65	
100	1	interr.	73	65
300	1	sep. cut	63	
300	1	interr.	73	74

Comparative prediction calculations

One objective of the research project was to evaluate the prediction models described in the draft E DIN 4109.x and in EN 12354-1 for the case of a lining with a completely interrupted junction. There are some remarkable differences in the prediction formulas of the respective standards. For instance, footnote b) in Table 1 of E DIN 4109-34 specifies an alternative equation for the calculation of the direct sound reduction improvement ΔR_w, which delivers significantly different results. Also, the equations for the prediction of the weighted sound reduction index R_w of monolithic walls given in EN 12354-1 and E DIN 4109-32 yield certain deviations. Both standards permit the use of measured and/or predicted input data. Table 5 gives an overview of the procedure chosen for the prediction.

Table 5: Procedure chosen for the prediction calculations

E DIN 4109.x			EN12354-1	
R_w, ΔR_w measured	R_w, ΔR_w predicted		R_w, ΔR_w measured	R_w, ΔR_w predicted
	ΔR_{w1} : Tab. 1	ΔR_{w2} : Tab. 1, footnote b)		ΔR_{w1} : Tab. D.3

The measurements of R_w and ΔR_w were not in the scope of the project. These results were obtained with additional measurements commissioned by IGG and kindly provided for this research. The results of the prediction calculation in comparison to the measurement results are shown in the following table.

Table 6: Measured and predicted flanking transmission loss $D_{n,f,w}$, in dB, for single layer lining with interrupted junction on a heavy wall with the surface mass *m´* in kg/m².

m´	Meas. IBP	E DIN 4109.x			EN12354-1	
		R_w, ΔR_w meas.	R_w, ΔR_w pred.		R_w, ΔR_w meas.	R_w, ΔR_w pred.
			ΔR_{w1}	ΔR_{w2}		ΔR_{w1} only
100	73	69.7	64.3	69.0	69.7	63.9
300	73	72.7	67.2	72.3	72.7	66.4

Taking into account that only singular measurement values are available, it can be stated that all prediction procedures deliver results that are always on the conservative side. If the sound reduction improvement ΔR_w is calculated according to footnote b) of Table 1 in E DIN 4109-34, the result of the prediction complies much better with the measurements.

Criteria for the assessment of the results

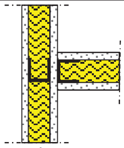
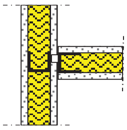
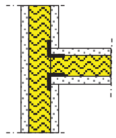
The task is to check by single measurements whether the sound reduction indices given in DIN 4109, Tables 31 and 32 are still applicable today. The origin of the values given in DIN 4109 is not clear and their uncertainty is unknown. They are therefore treated as single results. This means that two single measurements are compared to each other from a statistical point of view. A deviation between single results is regarded to be significant when it is larger than the critical difference for a confidence level of 95%. The critical difference is calculated by multiplying the standard deviation of reproducibility by 2.8. The standard deviation of reproducibility can be estimated by [5] to be 1.2 dB for a weighted sound reduction index. The critical difference is thus 3 dB. The values of DIN 4109 are therefore verified when the modulus of the difference between the new measurement results and the DIN 4109 values is smaller than 3 dB. If it is larger than 3 dB, a significant change has to be stated.

Usability of the measurement results

Metal framework walls

Table 7 gives a condensed summary of the measurement results compared to the values given in DIN 4109. The figures $R_{L,w}$ in DIN 4109 have the same physical meaning as $D_{n,f,w}$, but contain a “safety margin” of 2 dB. In order to make the results comparable, 2 dB have been added to the values from DIN 4109. The measurement results that fit the criteria mentioned earlier are marked as green numbers, this also holds for the results where no direct comparison is possible. Red numbers, however, indicate a violation of the given criteria.

Table 7: Flanking transmission loss of metal frame walls, overview of measured single number values $D_{n,f,w}$, compared to $R_{L,w}$ from DIN 4109, without safety margin

Junction	Panelling/ no. of layers	$D_{n,f,w}$ or $R_{L,w}$, resp., in dB			
		CW 50		CW 100	
		IBP	Tab. 32	IBP	Tab. 32
 continuous	1	53	55	55	55
	2	56	-	59	-
 sep. cut	1	57	-	59	-
	2	60	59	61	59
 interrupted	1	55	75	57	75
	2	61	>77	59	>77

For the continuous junction design, and also for the junction design with a separating cut, the hitherto existing values are certainly confirmed. Only the interrupted junction design shows significant deviations, for which a completely satisfying explanation still has to be found. Considering these facts, the working group responsible proposed a draft, which now includes the junction design with a separating cut as an independent construction, and utilizes the measurement data from IBP. Because of the shown discrepancies, the interrupted design is not included anymore. There is, however, an indication that allows the use of the data for the junction design with a separating cut instead, as these values can be regarded as a reliable minimum estimation in this case.

Heavy walls with detached linings

Table 8 shows the measurement results in comparison to the hitherto existing data from DIN 4109 and the predicted values, where the prediction was performed considering footnote b) of Table 1 in E DIN 4109-34. In the case of an interrupted design, the agreement between these values is acceptable. Only the recent data from DIN 4109 for the aerated concrete wall gives significantly lower values. This value has been repeatedly contested in the past. Consequently, the use of the prediction following E DIN 4109 is recommended in the draft for the new standard. For all other constructions, the following suggestions are made:

- The data for detached linings are maintained. As a safety measure, a separating cut is always required.
- A separating cut is also mandatory for detached linings. As a dependence of the results on the surface mass of the heavy wall is not clearly visible, the lowest obtained measurement result (63 dB) is used as table data for a minimum surface mass of 100 kg/m².

Table 8: Flanking transmission loss of heavy walls with detached lining, overview of measured single number values $D_{n,f,w}$, compared to $R_{L,w}$ from DIN 4109, without safety margin, and predicted values following E DIN 4109.x

Heavy wall	Junction design	$D_{n,f,w}$ or $R_{L,w}$, resp., in dB		
		IBP	Tab. 31	Predicted
100 kg/m²	sep. cut	65	-	-
	interrupted	73	65	72.3
300 kg/m²	sep. cut	63	-	-
	interrupted	73	74	69.0

Summary

In the course of a research project, the measurement and prediction of the flanking sound transmission of metal frame walls and heavy walls with detached linings was investigated. In most cases, the measurement and prediction showed good compliance to the table data used previously. Corresponding drafts for the revision of DIN 4109 have been generated and forwarded to the standardization committee responsible. Details of the research may be reviewed in the appropriate report which is publically available[6].

Acknowledgements

Funding for the research was provided by the Deutsches Institut für Bautechnik, the Industriegruppe Gips and the Hauptverband der deutschen Bauindustrie. The authors from PTB also express their gratitude to Ramona Jaron (Rigips) for additional data and constructive discussions.

[1] Beiblatt 1 zu DIN 4109: *Schallschutz im Hochbau; Ausführungsbeispiele und Rechenverfahren;*1989-11

[2] Beiblatt 1/A1 zu DIN 4109: *Schallschutz im Hochbau; Ausführungsbeispiele und Rechenverfahren; Änderung A1;* 2003-09

[3] Bohnsack, S.: *Schall-Längsleitung von Montagewänden;* Technik aktuell (Rigips), 2001-11

[4] Weber, L., Brandstetter, D.:, *Neue Werte längs der Wand*, TrockenBau Akustik 2-3.2013, S. 34-38

[5] Draft of DIN EN ISO 12999-1: *Bestimmung und Anwendung der Messunsicherheiten in der Bauakustik - Teil 1: Schalldämmung (ISO/DIS 12999-1:2012); Deutsche Fassung prEN ISO 12999-1*; 2012-06

[6] Bietz, H.; Wittstock, V.; Scholl, W.: *Aktualisierung des bauaufsichtlich eingeführten Bauteilkatalogs der DIN 4109, Teil "Skelettbau"*, Fraunhofer IRB Verlag 2013-02