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# Vibration reduction of thermal break balcony connections

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In energy efficient buildings concrete balconies have to be insulated from the concrete floor by a thermal break element to reduce heat loss and to increase the inside surface temperature. This thermal break element consists of polystyrene in combination with high performance concrete as pressure bearing element and stainless steel bars to bear tension and shear forces. The acoustic performance of such thermal break elements was investigated under laboratory conditions. Therefore the vibration level difference at different junctions between balcony and the thermal isolated concrete floor as well as the normalized impact sound pressure level of the floor when the balcony was excited with the standard tapping machine were measured. The influence of the number of tension and shear force bars and also the type of the insulating material was studied on typical sized balconies connected to small test floors. The vibration isolation at low frequencies was determined using modal testing.

# 1 Introduction

An increase in the number of apartments being constructed has led developers to respond to the need for improving the appeal of apartments by adding balconies. The benefits of concrete balconies, including their durability, have been widely acknowledged among architects who have long maintained an interest in the use of concrete, despite modern balcony design tending to favour steel and glass.

Previously, poorly insulated walls made little difference to heat loss where a concrete slab projected through the wall, to form the balcony. Problems came about as insulation standards were tightened, with the risk of a serious thermal bridge being created where the traditional construction method was used (i.e. without any thermal break between balcony and internal slab).

Designers and builders learned through experience that an insulation layer bridged by a projecting concrete balcony is likely to result in condensation and mould on the underside of the concrete slab. Due to a separation of exterior concrete components from main structures with thermal balcony break heat loss and $CO_2$-emission is reduced, condensation and mould growth is avoided, heating costs are kept to a minimum.

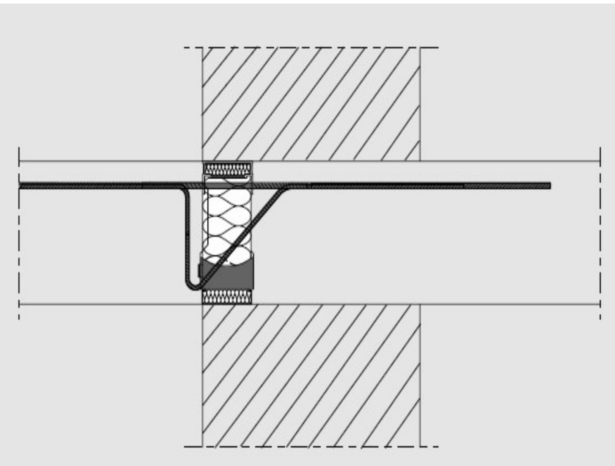

Fig. 1: Sketch of a typical thermal balcony break.

Stainless steel for tension and shear force bars and high performance concrete as pressure bearing elements ensure the load bearing with optimized thermal conductivity. This reinforcement system passes through a continuous insulation layer. By adopting this simple principle, structural connections are made between concrete external balconies and internal floor slabs without interrupting the thermal insulation of the external wall.

The thermal balcony break will also influence the acoustical behaviour of the junction. First of all the impact sound transmission from the balcony into the adjacent rooms will be reduced. Secondly the flanking transmission between lower and upper room along the outer wall from over the junction with the thermal balcony break will change as well. In this study the reduction of impact sound transmission due to the thermal balcony break is investigated.

# 2 Measurement setup

To measure and compare several different balcony thermal breaks a standardized measurement setup was developed. The constructional systems (see Fig. 2) consists of a concrete floor plate of size 1.7 m x 2.0 m of 180 mm thickness. The floor plates lies on two Ca-Si walls disconnected with 15 mm elastic interlayer. The floor and the balconies (each 1.42 m x 2.00 m) consist of partially prefabricated floor plates with cast in place concrete. Along the long sides of this floor plate the two balconies where connected by a thermal break.

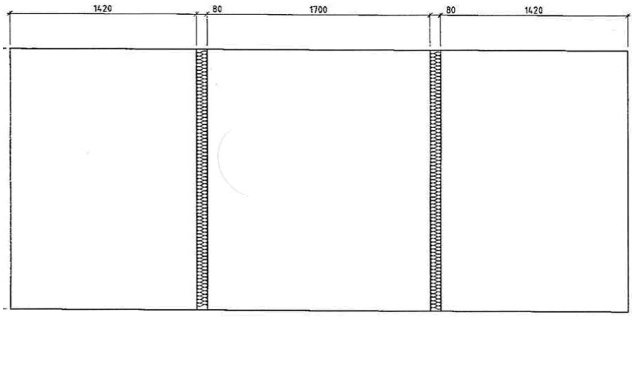


Fig. 2: Ground and side view of the construction system under test.

## 2.1 Impact sound level $L_{n,v}$

To rate the acoustical advantage of different thermal balcony breaks the impact sound level in the adjacent room can be used. When exciting a balcony with a standard tapping machine the average velocity level on the surface of the floor can be measured. The standard impact sound level in an imaginary room under the floor can be calculated from the velocity level $L_v$ using Eq. 1

$$L_{n,v} = L_v + 10\log\sigma + 6\,[dB] \qquad (1)$$

With:

$L_{n,v}$ standard impact sound level determined by velocity level measurements

$L_v$ velocity level ref. 5 x $10^{-8}$ m/s

$\sigma$ radiation factor; assuming 1 for heavy building elements

The standard impact sound level resulting from this structure borne velocity level measurement has been designated the index v. This level can be compared / is equal to the standard impact sound level according to ISO 140-7 “Measurement of sound insulation in buildings and of building elements” part 7 “Field measurements of impact sound insulation of floors” [1]. The determination of the weighted standard impact sound level $L_{n,w}$ is carried out according to EN ISO 717 – 2: 1996 „Acoustics – Rating of sound insulation in buildings and of building elements-Part 2: Impact sound insulation“ [2]. Deviating from the Standard the levels are not rounded up to whole numbers; rather calculated to the exact decimal value.

To designate structure borne sound level measurement the weighted standard impact sound level is labeled with the index v. Furthermore the spectrum adaptation term $C_I$ is calculated.

## 2.2 Impact sound level reduction $\Delta L_{n,v}$

The impact sound level reduction $\Delta L_{n,v}$ of a thermal break element is calculated from the difference between the standard impact sound level $L_{n,v}$ with a thermal break element and the standard impact sound level $L_{n,v,0}$ without a thermal break element.

$$\Delta L_{n,v} = L_{n,v} - L_{n,v,0}\,[dB] \qquad (2)$$

The weighted impact sound level difference $\Delta L_{n,v,w}$ of a thermal insulation element is given by the difference of the weighted standard impact sound level $L_{n,v,w}$ of a thermal insulation element to that of the weighted standard impact sound level $L_{n,v,w,0}$ without such an element.

$$\Delta L_{n,v,w} = L_{n,v,w} - L_{n,v,0,w}\,[dB] \qquad (2)$$

With:

$\Delta L_{n,v,w}$ weighted impact sound level difference of a thermal insulation element

$L_{n,v,w}$ weighted impact velocity level on a concrete slab when a balcony attached by a thermal break element is excited with the standard tapping machine

$L_{n,v,0,w}$ weighted impact velocity level on a concrete slab when a balcony attached without a thermal break element is excited with the standard tapping machine

## 2.3 Velocity level difference $D_v$ and vibration reduction index $K_{ij}$

When the balcony is excited with the standard tapping machine the velocity level difference $D_{v,ij}$ between the balcony (element i) and the floor (element j) is measured. If measurement direction is inverted, i.e. the floor is excited and the velocity level difference $D_{v,ji}$ between floor and balcony the direction averaged velocity level difference and using the structural reverberation time the vibration reduction index $K_{ij}$ can be evaluated following EN 10848-1 “Acoustics – Laboratory measurement of the flanking transmission of airborne and impact sound between adjoining rooms – Part 1: Frame document” although the dimensions of the test junction do not comply with.

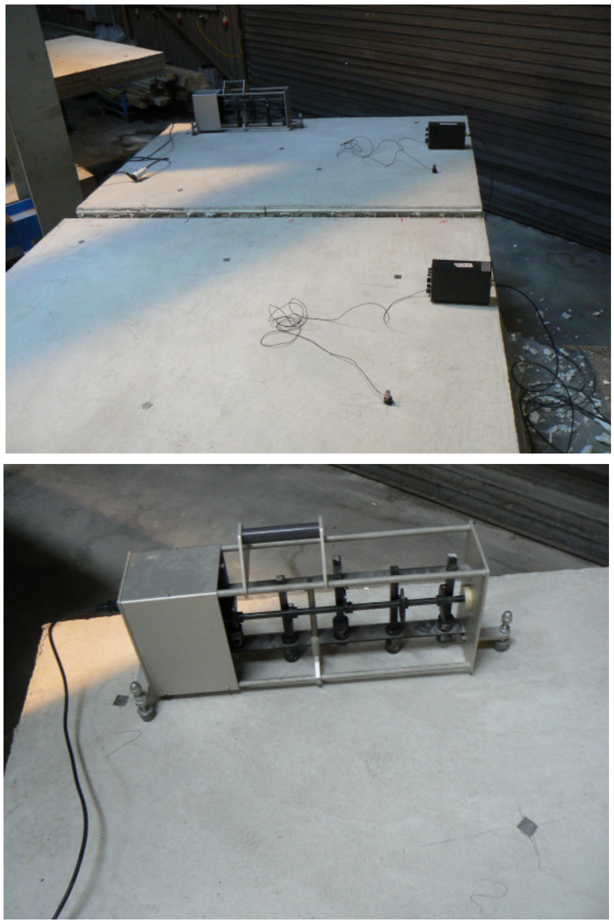

Fig. 3: Standard tapping machine as vibration source and accelerometers with amplifiers for measuring the velocity level on the floor and balcony.

# 3 Measurement results

## 3.1 Modal analysis

To understand the acoustical behaviour at low frequencies of the thermal balcony break modal analysis is used to visualize the vibration pattern of the floor and the balcony detached by the thermal break. To investigate the modal behaviour of the balcony and the adjacent floor plate a modal analysis was carried out on a balcony and a adjacent floor plate.

Three vibration pattern are shown in fig. 3. The vibration pattern on the balcony plate and on the floor plate is strongly coupled at frequencies below 100 Hz. This coupling gets weaker when frequency increases and different vibration patterns on the plates can be observed. At 500 Hz the vibration level difference for this thermal break is about 10 dB and therefore the amplitude on the balcony is about three times higher than on the floor.

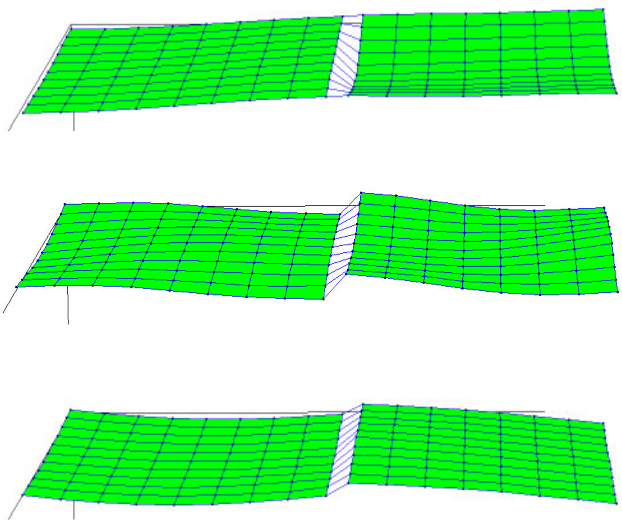

Fig. 4: Vibration pattern at 101 Hz (upper). at 164 Hz (middle) and at 364 Hz (lower) of a floor (left plate) with an attached balcony (right plate) thermally detached by a thermal break (white area in between).

## 3.2 Reduction of impact sound level

When exciting a balcony with a standard tapping machine the average velocity level on the surface of the floor can be measured. The impact sound level reduction $\Delta L_{n,v}$ of a thermal break element is the difference between the standard impact sound level $L_{n,v}$ with a thermal break element and the standard impact sound level $L_{n,v,0}$ without a thermal break element. Fig. 5 shows the measured impact sound reduction of 8 different thermal breaks.

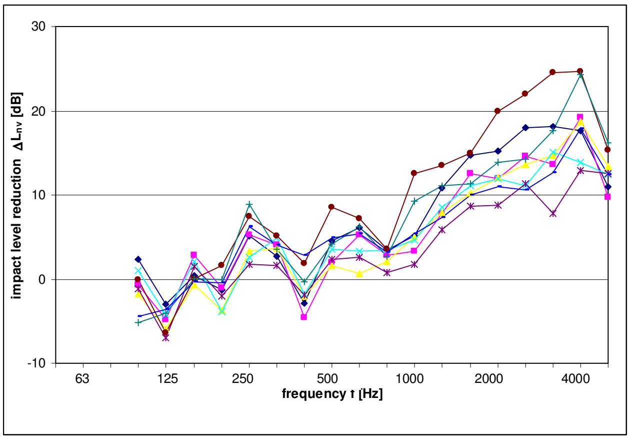


Fig. 5: Impact sound reduction of 8 different thermal breaks

The impact sound reduction depends strongly on the frequency. For the investigated thermal breaks the reduction below approx. 800 Hz is small. Above 800 Hz the improvement due to the thermal break increases with frequency. Hence only in the upper frequency region is an improvement in the sound reduction.

## 3.3 Influence of insulating material

Balcony thermal breaks were offered with different thermal insulation materials such as mineral wool polystyrene or polyurethane foam. To investigate the influence of the thermal insulation on the acoustical behavior of the thermal break the impact sound level of a balcony thermal break was measured with and without polystyrene as heat insulation material.

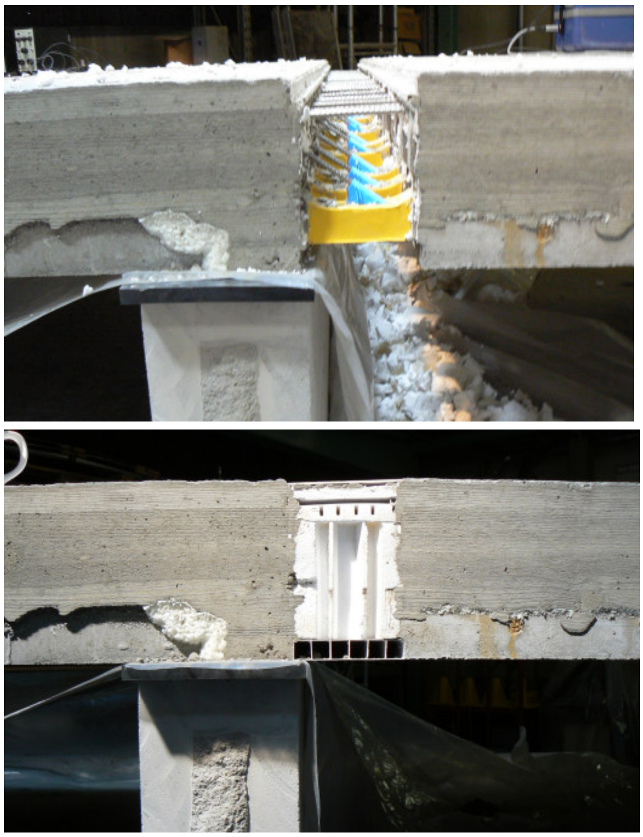

Fig. 6: Thermal break with and without polystyrene.

In fig. 7 the measured impact sound levels with and without polystyrene as shown in fig. 6 are shown. When the balcony is excited with the standard tapping machine, no significant change in the measured velocity level on the floor can be obseved due to the removing of the polystyrene foam in the thermal break.

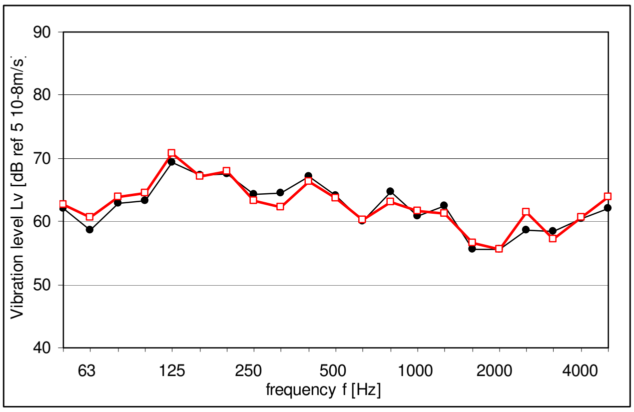


Fig. 7: Measured velocity level on the floor when the balcony is excited with a standard tapping machine with polystyrene (black circles) and without polystyrene (red squares)

The result of this experiment indicates that there is only weak coupling due to the insulating material. The vibration transmission is due to the stainless steel bars and the pressure bearing concrete elements.

## 3.4 Influence of number of connections

Balcony thermal breaks were offered with a different number of stainless steel bars and pressure bearing elements. To investigate the influence of the number of steel bars a test series was carried out, were the number of steel bars connecting the balcony and the floor was gradually reduced. Fig. 8 shows how the steel bars bearing shear forces were removed.

Fig. 8: Decreasing gradually the number of shear forces bars by intersecting the bars.

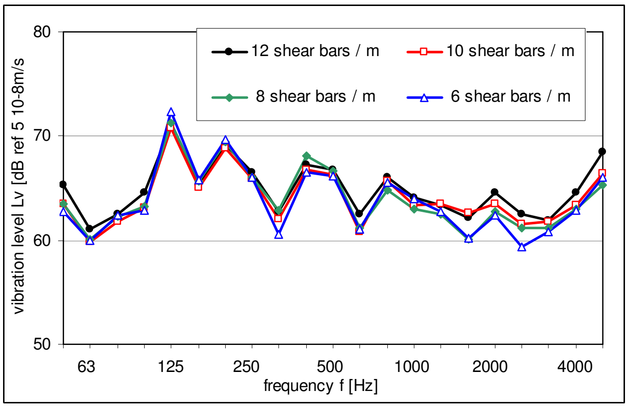


Fig. 9: Measured velocity level on the floor when the balcony is excited with a standard tapping machine with different number of shear bars.

Only above 1000 Hz a significant difference in the measured vibration level is detected on the floor when the balcony is excited. The weighted impact velocity level on the floor due to the excitation with a standard tapping machine on the balcony is decreased of 1 dB when the number of shear force bars is halved.

The main coupling and hence the vibration transmission is mainly due to the concrete pressure bearing elements and the stainless steel bars for tension forces.

## 3.5 Reduction of weighted impact sound level due to the thermal break

The reduction of the transmitted impact sound from a balcony into the adjacent living room diagonal underneath due to the thermal break element can be rated according to equation 2 against a similar construction without a thermal break.

Measurements on 28 similar constructional systems with different thermal breaks show a variation in the weighted impact sound level reduction $\Delta L_{n,v,w}$ from 8.5 dB to 27.9 dB with a mean value of 14.3 dB. Fig. 10 shows the distribution of the weighted reduction. The major values were measured in the range from 10 dB to 18 dB.

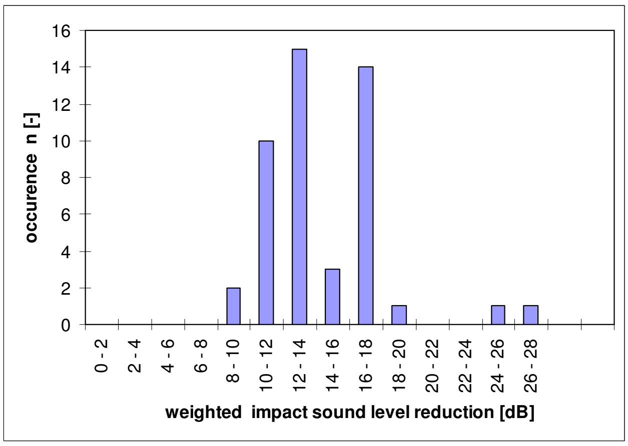


Fig. 10: Distribution of the weighted impact sound level reduction $\Delta L_{n,v,w}$ measured for different thermal breaks

# 4 Conclusion

Thermal breaks reduce the impact sound transmission from concrete balconies into the adjacent rooms considerably. Although the reduction is strongly frequency dependent with small values below 800 Hz the weighted impact sound level from a balcony is reduced substantial.

The vibration of the balcony is transmitted to the floor mainly through the steel bars for tension forces and the concrete pressure elements. The insulation material does not have an significant effect on the vibration transmission.

The influence of thermal breaks on the flanking transmission between rooms is not investigated yet and is a task for future research.

Acknowledgment:

The authors like to thank Schöck Bauteile GmbH, Vimbucher Straße 2, 76534 Baden-Baden/Steinbach Germany.

# References

[1] ISO 140-7: *Measurement of sound insulation in buildings and of building elements; Part 7: Field measurements of impact sound insulation of floors,* 2005

[2] EN ISO 717 – 2: *Acoustics – Rating of sound insulation in buildings and of building elements; Part 2: Impact sound insulation,* 1996