Examples of application of Building physics

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► Element connections and Isothermen

► Noise protection
# Examples of application of Building physics

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6. Apartment separating wall with EN 12354
GENERAL

Icon-switch
Calculation form

Font magenta: Form-field, here is data lodged (DIN-norms / standards)
Font blue: Manual changes

Click with mouse on icon-switch or form-field ⇒ Function appears

Material assistant:

Main groups
Insert layer
Subgroups
Characteristic material data
References – German and European standards

DIN - German Standard
EN - European Norm
ISO - International Standard Organization

Diffusion/Moisture (Thermal insulation)

DIN 4108-1 Thermal insulation in buildings; quantities and units
DIN 4108-2 Thermal protection and energy economy in buildings - Part 2: Minimum requirements to thermal insulation
DIN 4108-3 Thermal protection and energy economy in buildings - Part 3: Protection against moisture subject to climate conditions; Requirements and directions for design and construction
DIN 4108-7 Thermal insulation and energy economy of buildings - Part 7: Airtightness of building, requirements, recommendations and examples for planning and performance
DIN V 4108-10 Thermal insulation and energy economy in buildings - Application-related requirements for thermal insulation materials - Part 10: Factory made products, (Pre-standard)
DIN 4108 Bbl.1 Thermal insulation in buildings; indexes; list of subjects
DIN 4108 Bbl.2 Thermal insulation and energy economy in buildings - Thermal bridges - Examples for planning and performance


DIN EN ISO 10077-1 Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 1: Simplified method; German version EN ISO 10077-1:2000

DIN EN ISO 10211-1 Thermal bridges in building construction - Heat flows and surface temperatures - Part 1: General calculation methods; German version EN ISO 10211-1:1995
DIN EN ISO 10211-2 Thermal bridges in building construction - Calculation of heat flows and surface temperatures - Part 2: Linear thermal bridges; German version EN ISO 10211-2:2001

DIN EN ISO 13788 Hygrothermal performance of building components and building elements - Internal surface temperature to avoid critical surface humidity and interstitial condensation - Calculation methods; German version EN ISO 13788:2001

Sound insulation:

DIN 4109 Sound insulation in buildings; requirements and testing
DIN 4109/A1 Sound insulation in buildings - Requirements and verifications; Amendment A1
DIN 4109-10 Sound insulation in buildings - Part 10: Proposals for improved sound insulation for housing, (Draft standard)
DIN 4109 Bbl.1 Sound insulation in buildings; construction examples and calculation methods
DIN 4109 Bbl.1/A1 Sound insulation in buildings - Construction examples and calculation methods; Amendment A1
DIN 4109 Bbl.2 Sound insulation in buildings; guidelines for planning and execution; proposals for increased sound insulation; recommendations for sound insulation in personal living and working areas
DIN 4109 Bbl.3 Sound insulation in buildings - Calculation of R'w,R for assessing suitability as defined in DIN 4109 on the basis of the sound reduction index Rw determined in laboratory tests

DIN EN 12354-1 Building acoustics - Estimation of acoustic performance of buildings from the performance of products - Part 1: Airborne sound insulation between rooms; German version EN 12354-1:2000
DIN EN 12354-3 Building acoustics - Estimation of acoustic performance of buildings from the performance of elements - Part 3: Airborne sound insulation against outdoor sound; German version EN 12354-3:2000
DIN EN 12354-4 Building acoustics - Estimation of acoustic performance of buildings from the performance of products - Part 4: Transmission of indoor sound to the outside; German version EN 12354-4:2000

Examples of application of Building physics
<table>
<thead>
<tr>
<th>Standard Code</th>
<th>Standard Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIN EN 12354-6</td>
<td>Building acoustics - Estimation of acoustic performance of buildings from the performance of elements - Part 6: Sound absorption in enclosed spaces; German version EN 12354-6:2003</td>
</tr>
<tr>
<td>DIN 18005-1</td>
<td>Noise abatement in town planning - Part 1: Fundamentals and directions for planning</td>
</tr>
<tr>
<td>DIN 18005-2</td>
<td>Noise abatement in town planning; noise maps; graphical representation of noise pollution</td>
</tr>
<tr>
<td>DIN 18005-1 Bbl.1</td>
<td>Noise abatement in town planning; calculation methods; acoustic orientation values in town planning</td>
</tr>
<tr>
<td>*VDI 4100</td>
<td>Noise control in housing - Criteria for planning and assessment</td>
</tr>
</tbody>
</table>

**Material:**

<table>
<thead>
<tr>
<th>Standard Code</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIN 16730</td>
<td>Plasticized polyvinyl chloride (PVC-P) roofing felt incompatible with bitumen; requirements</td>
</tr>
<tr>
<td>DIN 68705</td>
<td>Plywood</td>
</tr>
</tbody>
</table>

*no standard, recommendations of Verein Deutscher Ingenieure (Society of German Engineers)*
Block A: Diffusion/Moisture protection

A.1 Calculation of diffusion for a solid construction – external wall

Cross section

<table>
<thead>
<tr>
<th></th>
<th>a [cm]</th>
<th>ρ [kg/m³]</th>
<th>λK [W/mK]</th>
<th>k [m²K/W]</th>
</tr>
</thead>
<tbody>
<tr>
<td>from inside</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>01 Gypsum plaster</td>
<td>1,500</td>
<td>1200</td>
<td>18,0</td>
<td>0,350</td>
</tr>
<tr>
<td>02 Vert. perf. lgt.wgt. unit (typ B)</td>
<td>24,000</td>
<td>1600</td>
<td>240,0</td>
<td>0,450</td>
</tr>
<tr>
<td>03 PS 20 - 040</td>
<td>10,000</td>
<td>20</td>
<td>2,0</td>
<td>0,040</td>
</tr>
<tr>
<td>04 Lime-cement plaster</td>
<td>1,300</td>
<td>1800</td>
<td>27,0</td>
<td>0,870</td>
</tr>
</tbody>
</table>

ρei

\[ \rho = 37,000 \quad \rho = 207,0 \quad \mu = 3,2 \cdot \]

![Diagram of external wall A1 with layers of different materials and temperatures.](image-url)
Conceptual formulation

Design the shown external wall made of vertically perforated lightweight bricks and a thermal insulation sandwich system made of PS-rigid foam and mineral plaster on the outside. Perform the diffusion proof according to DIN 4108 and display the shown graphics.

Instructions step by step

Create a new project. To do so choose the form „Project“ and click on the icon-switch „New“. Now follow the dialog and avoid characters like dots, double dots and spaces for the short project label.

Short label: Seminar
Confirm working directory
Project title: Block A B C
Alternative:
Form „Project“
Icon-switch „Project table“
A window opens: Project overview, choose in there „create new project“ and follow the dialog.

To create an element cross section, shift to the calculation form „Elements“ and use icon-switch „New“. Select “External wall” as element type and enter the name “External wall A1“. After closing this dialog the material assistant will open. The cross section is built layer by layer starting from the inside. Choose main group: „Plaster-Screed-Coat“ and than subgroup „3 Gypsum / Lime plaster“. You can now transfer the material into the elements cross section (control box on the right side) with a double-click on “Gypsum plaster” (in the white choice window) or by selecting the corresponding material in the same white choice window (characteristic material data will be shown in a blue font to the right) and a click on “Layer ⇒”. You may click on the blue writing to change the properties. In our case it will be done later at a different position. Repeat this process to define the other layers.

Main group: Masonry Subgroup: 4.1 Masonry units DIN 105 D-click: Vert.perf.lgt.wgt. unit B
Main group: Insulation material Subgroup: 5.5 Exp.-Rigid-polystyrene D-click: PS 20-040
Main group: Plaster-Screed-Coat Subgroup: 1.1 Lime-Cement plaster D-click: Lime-cement plaster

The materials are given with common thicknesses which can later be changed in the element form. The short-choice of the material assistant eases the search for desired materials. Choose the main group to search in and enter at least 3 characters of the label/name of the desired material.

Example: Vert.perf.lgt.wgt. unit (type B) 1000
Main group: Masonry
Short selection: Ver

To finish the design process close the material assistant [X].
You may now adjust the layer thicknesses (or other parameter) in the cross section table.

Alternative:
1) You can also open the material assistant via the context menu which will be shown by clicking the right button of the mouse anywhere in the calculation form.
2) A left-click on the magenta colored numeration of the layers in the cross section table and the corresponding menu choice opens the material assistant as well.

If you create a new cross section this way it is necessary to save the element manually because the system had not had the chance to create a filename for the saving purpose.

The diffusion proof is done in calculation form „Diffusion“. To open the graphics-window click with the left mouse button on the graphic. Clicking on icon-switch “Settings” in the upper menu you may add the temperature- and vapour pressure development curves to the cross section sketch. With the pull down menu in the upper part of the graphics window you can switch to the shown graphic (e.g. Glaser diagram).

Accession

In the table with the diffusion resistances (form diffusion) you will find a column with colored arrows to the left of the sd-values. With a mouse click on it you can vary the used sd-value. According to DIN 4108 the worst value has to be taken: inwards of the insulation layer the smaller and outwards the larger diffusion resistance. Although the worst case is not always obvious. If you use the larger sd-value for the vert.perf.lgt.wgt. unit you will get a dew level (border of material layer) instead of a dew field, and so called core condensate (dew leakage inside of a material layer) if you use the larger value for the rigid foam insulation. To correctly calculate the core condensate you need to add “Special calculations” in the “Content menu” on the right side.
A.2 Calculation of diffusion for a sealed flat roof

Cross section

Type of element "wall facing air from outside"
with the heat transmission resistances $R_{m} = 0.10$ and $R_{w} = 0.04 \text{ m²K/W}$

<table>
<thead>
<tr>
<th>from inside</th>
<th>$z$ [cm]</th>
<th>$\beta$ [kg/m²a]</th>
<th>$\lambda$ [W/K]</th>
<th>$R$ [m²K/W]</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 Gypsum plaster</td>
<td>1,500</td>
<td>1,200</td>
<td>18,0</td>
<td>0,256</td>
</tr>
<tr>
<td>02 Normal concrete 2400</td>
<td>16,000</td>
<td>2,400</td>
<td>364,0</td>
<td>0,106</td>
</tr>
<tr>
<td>03 Bauder G 260 S4</td>
<td>0,400</td>
<td>1,310</td>
<td>5,4</td>
<td>0,170</td>
</tr>
<tr>
<td>04 Mineral fibre 920</td>
<td>10,000</td>
<td>20</td>
<td>2,0</td>
<td>0,040</td>
</tr>
<tr>
<td>05 Bauder PFP-PF 200 S5 t</td>
<td>0,500</td>
<td>1,150</td>
<td>5,0</td>
<td>0,170</td>
</tr>
<tr>
<td>06 Bauder PFP PF 200 S5 nr</td>
<td>0,500</td>
<td>1,250</td>
<td>6,3</td>
<td>0,170</td>
</tr>
<tr>
<td>07 Sand, gravel</td>
<td>6,500</td>
<td>1,900</td>
<td>165,0</td>
<td>-</td>
</tr>
</tbody>
</table>

$d = 34,900 \quad e = 529,4 \quad R_{m} = 2,04$

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**Roof**

$U = 0,12 \text{ W/m²K}$

$\text{Wm²m} = 9,11 / 24.4 \text{ g/m²}$

---

**GLASER DIAGRAM**

1. Gypsum plaster
2. Normal concrete 2400
3. Bauder G 260 S4
4. Mineral fibre 920
5. Bauder PFP-PF 200 S5 t
6. Bauder PFP-PF 200 S5 nr
7. Sand, gravel

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Examples of application of Building physics
**Conceptual formulation**

Design the shown roof construction with a mineral insulation layer, vapour barrier and roof sealing. Conduct the diffusion proof according to DIN 4108 and display the shown graphics.

**Instructions step by step**

Design the element in the calculation form „Element“ using the icon-switch „New“. Choose element type „roof“, name it „Flat roof A2“ and enter the element layers with the help of the material assistant. After that switch to the calculation form “Diffusion”. Open the graphics window and add the temperature- and vapour pressure development to the cross section sketch of the element. If necessary complete the Glaser diagram with the pd/ps development for the Summer.

**Accession**

In the evaporation period you can, according to DIN 4108, use a temperature of 20°C on the surface of the roof so that you will get a temperature gradient between the surface of the roof and the soffit. What happens if you instead utilize a temperature of 12°C on the roof surface (inside the room)? How do you explain this special rule?

Make the following changes on the roof construction step by step and control the diffusion calculations:
- delete the vapour barrier,
- replace the mineral fibre insulation with an expanded rigid foam (PS) of the same thickness and
- replace the bituminous roof sealing with a highly polymeric PVC sealing.

**Instructions**

You can change the temperature of the roof surface to 12°C in the calculation form „Diffusion“. The change will directly influence the evaporation rate, which is now not sufficient any more. Sealed roofs can, according to Glaser, only be proven with the assumption of an increased temperature of the roof surface during the evaporation period.

To delete the layers switch back to the „Element“ form and call the material assistant again. Mark the to be deleted material layer in the box on the right side and hit the „del“ key on your keyboard. You can also make use of the material assistant to overwrite / replace layers. To do so mark the to be replaced/overwritten layer, choose a different material and replace the existing marked layer with a double click on the new material.

The earlier compulsory vapour barrier in the design of sealed roofs is now abdicable, if you make use of diffusion repressive insulation layers (rigid foam) and „diffusion open“ roof sealings (plastic).
A.3 Calculation of diffusion for a steep roof

Conceptual formulation

Please copy the shown cross section „Roof old building“ from the element list. Check the diffusion calculation. What diffusion resistance has the PE-Foil on the inside to have to keep the construction through calculation free of dew water? Which factors determine the diffusion resistance of the PE-Foil?

The air-layer between the thermal insulation between the rafters and the sealing is said to be “gently ventilated”. What does that mean and how do one create ventilated, gently ventilated and static air layers? How do you rate the layer of air between the sealing and the roof cladding?

Why was the diffusion resistance of the gently ventilated sealing used in the calculation? Under what circumstances can it be set to zero?

Instructions step by step

To use / copy an element form another project or the element list click in the element form on the icon-switch “Element list”. The element list of your current project will be shown. Switch in the file path on the left into the Dämmwerk installation directory (e.g. DW-E). Now you can choose either folder „Elements“ or “Bauteildatenbank” (with elements in German language). You may do it quicker with the icon-switch “Element data base” in the upper left area of the element list. The folder „Steep roofs“ will be opened by a double click. From the now shown elements you can select (with a mouse click) the “Roof old building”. With the switch copy you will be able to make use of this cross section with a different name „Roof old building A3“. The element is also copied into your current project. You may now change the element according to your likes with the material assistant.

To control the calculation at a glance switch in calculation form “Diffusion” in the „Content Menu“ at right side the Climate caused moisture proofing 4108-3 on (hook). Have a look at the diffusion calculation and the Glaser diagram. The construction is free of dew water. Change in table diffusion resistances the µmin’s-value of the PE-Foil. With sd = 4m the construction will just remain free of dew water. The diffusion resistance of the PE-Foil is determined by the material thickness, the µ-value and the way of laying. Vapour barrier foils have to have sufficient overlapping and the joints should be glued. Damages are to be avoided, connections to chimneys, walls etc. should be done with Compri-band and contact bars.

(To view definitions or building physical knowledge you may read in the help system. To do so use the icon-switch “Help” and click on „Index”. Now you can enter your wanted item into the search field. – Unfortunately the help system is so far only available in German language.)

Gently ventilated air-layers have a connection to the outside air but the exchange is relatively small that means a temperature gradient can develop in the layer of air. The air space between the sealing and the roof cladding is heavily ventilated because of lots of joints between the roof tiles.

The diffusion resistance of material layers outside of a gently ventilated air-layer will be set as normal (secure side). It can be set to zero (= 0) with a full ventilation (not considered).
A.4 Monthly calculation according to EN ISO 13788

Cross section

<table>
<thead>
<tr>
<th>Layer</th>
<th>d [cm]</th>
<th>ρ [kg/m³]</th>
<th>λ [W/mK]</th>
<th>n [m²K/W]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plaster</td>
<td>1,300</td>
<td>1200</td>
<td>0,10</td>
<td>0,350</td>
</tr>
<tr>
<td>Concrete</td>
<td>2,500</td>
<td>650</td>
<td>0,15</td>
<td>0,120</td>
</tr>
<tr>
<td>Lime-cement</td>
<td>1,500</td>
<td>1800</td>
<td>0,27</td>
<td>0,070</td>
</tr>
</tbody>
</table>

Instructions step by step

Go to calculation form „Element“ and create with icon-switch „New“ a new element named „External wall A4“ according to the above shown cross section.

To do the diffusion calculations switch to the calculation form „Diffusion“. In “Content menu” on the right you can add the needed calculation bases (Climate caused moisture proofing 4108-3 and Formation of condensate EN ISO 13788).

If you can not read the names of the months related to the dew water amounts, please switch off „Mark condensation zone(s)“ in the settings menu of the Glaser diagram.

The dew water amount will be calculated to approximately 400 g/m² according to DIN 4108-3 and approximately 200 g/m² according to EN ISO 13788. Looking at the monthly calculated values according to EN ISO 13788 it is to be seen that the largest dew water accumulation is expected in March. The cross section dries in April and is free of dew water from the end of April to November.

The amount of dew water and sometimes also the location of the dew water fall-out depends on the location respectively the regional climate conditions outside.
Accession

Design the following framed external wall and evaluate the results. Kempten was chosen from the graphical overview as location for the building.

External wall ventilated

\[ U = 0.38 \text{ W/m}^2\text{K} \]

from inside
1. OSB-Board
2. Mineral fibre 040
3. OSB-Board
4. Mineral fibre 040
5. OSB-Board
6. Ventilated layer of air
7. Soffitwood

GLASER DIAGRAM

1 OSB-Board
2 Mineral fibre 040
3 OSB-Board
4 Mineral fibre 040
5 OSB-Board
6 Ventilated layer of air
7 Soffitwood

Examples of application of Building physics
The designing process is done as explained in earlier examples. Click in the calculation form „Element“ on the icon-switch „New“ choose element type external wall and enter the name „External wall A4V“. In the material assistant you select now the needed materials for the cross section. The layer of air can not be transferred directly into the cross section with a double click because the thickness needs to be set before this transfer (R-value depends on thickness). Mark the desired layer of air with a mouse click and follow the dialog. The final transfer into the cross section is done with the numbered arrow switch to the left of the list of layers in the cross section. The thicknesses of the other materials will manually be adjusted in the cross section table in calculation form „Element“. It is done with a click on the layer thickness and the confirmation („Enter“) of your corrected value. Because the heat transmission resistances are not correct yet the differentiated choice of the element types are necessary. In choice/menu „1. Element type“ select „EN ISO 6946 → Walls → Ventilated external wall“. The heat transmission resistances (R-values) of the external material layers will be neglected and the diffusion resistance of the external layers will be set to = 0 because it is a ventilated construction.

Switch now to the calculation form „Diffusion“ and choose in the „Content Menu“ the settings for the calculation: Climate caused moisture proofing DIN 4108-3 and the Formation of condensate EN ISO 13788. The location Kempten will be selected in the calculation according to EN ISO 13788. To do so click on outside temperatures, in choice/menu „183. Location → graphically“ and in the map of Germany, with data from the German weather service, on the location Kempten. The blue marked “Room temperature“ will be set with choice/menu „184. Room climate → Living room“.

In the table with the diffusion resistances the larger diffusion resistance needs to be used for the third layer (plywood). The arrow shows than to the left. The default setting will be changed by clicking on the arrow. The other sd-limit value will be now be used for the calculation. You can simultaneously watch the results of those changes in the graphics window.
Block B: Element connections and Isotherms
B.1 Design and calculation of isotherms of a wall corner

Conceptual formulation
Design the shown wall corner from the in example A.4 used framed external wall. First make a copy of the element. Use a construction- and calculation mesh with a width of 5 mm and the dimensions of 80 cm horizontally and 60 cm vertically. Create built-in elements for the structural timber columns and make use of the copy function during this process. Size and position the built-in elements with the mouse and alternatively with the icon-switches “Position, Width and Height.”

Calculate the temperature field for the wall corner and display the development of the isotherms.
**Instructions step by step**

To copy existing elements: Open the calculation form „Element“. Load via icon-switch „Element list“ the already in task A.4 (accession) created element „External wall A4V“ (double click on the corresponding sketch). To copy the loaded cross section, you need to give it a new name. Utilize icon-switch „Save as...“ (black floppy disc) to achieve this. Change with the second saving the filename of the loaded cross section “External wall A4V“ into “Wall corner B1“. In the form „Element“ you give the same name as label for the element using the blue writing “External wall A4V“. Now the name of the file (loaded cross section) and element label are identical. Click on the element sketch (or icon-switch „Open graphics window“). After your click on icon-switch “Thermal bridge” confirm the question „Rotate cross section now“. The main cross section for the design of a connection is generally shown in a horizontal position (the geometries are realized that way).

The window „Construct Thermal bridge“ opens. Choose in the pull-down menu „Wall corner“. The same element cross section will hereby rectangularly added to the already existing element.

To change the construction- and calculation mesh click on the blue writing „xx net...“.

To change the construction- and calculation mesh click on the blue writing „xx net...“.

In the dialog window click on switch „5 mm“. Enter the asked values in the following windows (Influence width horizontally = 80, Influence height = 60). Finish the dialog with “OK“. The mesh is now set up. To show the net click in the white field in front of the blue written net dimensions. The construction net will be shown. Switch off the net for the next steps.

You create the structural timber columns with switch „New build-in element“. Select in the choice/menu “2. Materials“ 6. Wood and Woodmaterials → 6.1 Wood → material Softwood. Confirm with “OK“. To position/size the new element use the small switches with the arrows on it or enter the width and height via the blue written dimension/position. The built-in elements can also be moved with the mouse.

Alternatively you may enter the dimensions of the built-in element in a dialog. Click in the construction window on switch „3,0 / 3,0 cm“ and enter the required cross section dimensions width and height (5 cm x 2 cm). You can do the same for the position. First click on the blue writing „Position xx xx“ and than with the arrow of the mouse at the desired position in the element sketch (bottom left corner of the element).

To create another built-in element of the same material click on the already created element of the same kind and hit the „Copy“ icon-switch on the right side of the construction window. Do the same for the other built-in elements.

The dimensions will always be adjusted with clicks on the blue writing „b x h ...“ (built-in element 2 = 2 x 5 cm, built-in element 3 = 10 x 6 cm, built-in element 4 = 6 x 16 cm) and positioned with the mouse or with the arrow switches.

It is important for the calculation of the isotherms to calculate them up to the non disturbed area. You will notice this by having isotherms (on the verge) that follow parallel the elements surface. Decisive is that the element cross section is situated below the calculation net. If necessary adjust the scale of the element cross section so that it sits under the calculation net. You may switch on the net to help to adjust the scale of the element.

Close the construction window and open the isotherm module (rainbow colored icon-switch). To start the calculation use the red „New“ switch. In the next dialog choose „Accelerated calculation“. The number of calculation steps is shown in color next to the switch for the isotherm module. Save the current temperature condition after the end of the calculation. With the icon-switch “Isotherms” you can show the development of the isotherms, the temperature field or the heat flow with the corresponding switches. To change settings of the graphics use the icon-switches „Details...“. The isotherms can be shown as color flow (standard settings) which means the color of isotherm represents its temperature. The last saved calculation procedure can always be reloaded with the icon-switch „Load temperature condition“.
B.2 Design and calculation of isotherms of a wall with concrete column

Conceptual formulation

Design the shown situation „Fair faced concrete column in a monolithic external wall“. First make a copy of the in example A.4 used element. Use a construction- and calculation mesh of 10 mm width and a horizontal extension of 160 cm. The concrete column is 30 x 31 cm and should overhang the external plaster by 4 cm. Position the column in the center of the construction net. Show the net to do so.

The insulation strip (thermal transmittance coefficient 040) on the inside is 30 x 4 cm. Position the column in the center of the construction net. Show the net to do so.

Do the isotherm calculation and display the above shown surface-temperature profile. Evaluate the surface-temperature profile.

The dew point temperature of the room air is 9.3°C (20.0°C 50%) 
80% relative humidity will be reached with a cooling-off of the room air to 12.6°C
Rsi / Rse = 0.13 / 0.04 m²K/W \(\delta_i / \delta_e = 20.0°C/10.0°C\)
**Instructions step by step**

Open in calculation form „Element“ the element list and load element „External wall A4“. Save the element as „External wall B2 with concrete column“. Change the label in the element form.

Set up the construction- and calculation net, by opening the graphics window and clicking on icon-switch „Thermal bridge“. The element cross section needs to be rotated for the calculation. Afterwards click on the blue writing „xx net ...“ and enter the influence width 160 cm and the influence height 60 cm via button „10 mm“. Confirm your entries with „OK“. Now adjust the scale of the element to make sure it sits under the construction- and calculation net.

The concrete column will be designed as built-in element. Use switch „New built-in element“ and choose in material choice/menu „2. Concrete → 2.1 Concrete DIN EN 206 → Normal concrete 2400“. After dimensioning the new concrete element (30 x 31 cm), move it with the mouse to the center of the cross section sketch, base point is upper border of the gypsum plaster. The hangover of the column of 4 cm you can design with the use of the arrow switch „y-Position“ (move 4 steps (10 mm net) upwards).

For the insulation strip use an insulation material with a thermal transmittance coefficient 040 (e.g. mineral fibre) size it to 30 x 4 cm and put it in place as shown in the conceptual formulation (graphic).

Do the isotherm calculation - close window „Construct Thermal bridge“, click on the icon-switch „Isotherms“, and start the calculation with the red switch „New“ (see task B.1).

The graphic of the surface-temperature profile is to be created with the icon-switch „Surface temperature profile“ (it shows a diagram with a curve) in the lower part of the „Calculate Isotherms“ window. But first you need to select a start node for the temperature profile with your mouse. It should be a node on the inner surface of the element to the left of the column (red selection rectangle). Enter the following values into the dialog window:

- **Length (unwound element)** = 100 cm
- **Ordinate** = 20
- **Abscissa** = 10
- **Lowest temperature** = 8
- **Distance of vertical length marks** = 5

You can move the window „Calculate isotherms“ if the cross section sketch is partly covered by it, just grab it with the mouse in the upper dark blue frame and move it to the desired position. The cross section sketch and the surface-temperature diagram can be moved and placed the same way.

**Accession**

To estimate the risk do another calculation without the insulation. Hide the insulation (without deleting it) and use a static air-layer instead.

**Instructions**

Save the element twice and give it the second time the new name „External wall B2V“. To hide the insulation activate switch „Thermal bridge“. Select the second built-in element (mineral fibre) and „hide“ it with the corresponding button (button on the right side of the construction window). Create a new element via “New built-in element“ and select in choice/menu “2. Building materials → Layers of air → Housing/Niche → Cavity“ and put it in the same position as the previously used insulation.

Do another isotherm calculation and create for this calculation the surface-temperature profile as explained above.
B.3 Design and calculation of isotherms of a window connection

Conceptual formulation
Design the shown window connection using the external wall of example A.1. The $U_w$-value of the window is to be 1.34 W/m²K. You should use a 5 mm construction- and calculation net with a horizontal dimension of at least 80 cm.

Make another copy of the element and vary the rabbet of the window as shown above. The reveal on the outside is 17 cm deep.

Calculate for both cases the development of the isotherms.
Instructions step by step

Load element „External wall A1“ from example A.1 via the element list into the calculation form. Save the element as „Window connection 1B3“. Add the calculation for windows according to EN ISO 10077 by selecting the corresponding field in the “Content Menu”. You will notice a further paragraph for windows in the calculation form. You can now choose in choice/menu „3. Glazing“ a coated thermopan glazing acc. to EN ISO 10077-1 with the glazing values of 4-12-4, krypton filling and a U-value of the glazing of $U_g=1,1 \text{ W/m}^2\text{K}$. The window frame is made of soft wood with a width of 90 mm according to EN ISO 10077-1 D.2. Afterwards the table value for the two-pane glazing with 20 % frame share will be determined.

Open the graphics window and select function „Thermal bridge“. The cross section needs to be rotated. In the pull-down menu you can now set a „Window connection“. A constant U-value for the whole window can be used to calculate the heat loss coefficient of the window reveal later on. Thereto a suggestion for a calculation model will be made with the “Thermal bridge window” button. You can confirm the U-value of 1,34 of the window. The panel model will be placed in the approximate right position. With the blue writing „xx net … “ you set the mesh width of 5 mm and the dimensions – horizontal 80 cm and vertical 60 cm. Show the net and configure the size of the element with the scale button to make it fit beneath it.

The reveal plaster will be designed by built-in elements. Open via “New built-in element”, choice/menu 2. Materials and select from the main group 1.Plaster-Screed-Coat the external and internal plaster. The dimensions for the lime-cement plaster are (w=1,5 cm, h=11,5 cm) and for the gypsum plaster (w=1,5 cm, h=18,5 cm). The plaster is being placed in front of the wall because raw dimensions will be used for the Psi-value calculation later on.

By marking the window-panel model with a mouse click you will be able to change the position of the reveal (glazing position) according to the requirements. Design and position all parts as shown.

Save the element with a click on the black floppy disk in the graphics window. Save a second time and give it the name „Window connection 2B3“ (create copy). Open the window “Construct Thermal bridge” and change the construction according to the sketch above.

To bring the reveal to a dimension of 17 cm, change the height of the reveal plaster to 17 cm and place the other elements accordingly.

Open the window „Calculate isotherms“ and do the calculation of the isotherms (with switch “New“). You can see a thermal bridge between the window frame and the thermal insulation system in the second case. At this position a thermal joint is gashing (short distance between outside air and room air without insulation).
### B.4 Design of a floor with balcony connection and a flat roof

<table>
<thead>
<tr>
<th>From Inside</th>
<th>$g$</th>
<th>$\rho$</th>
<th>$\lambda$</th>
<th>$R_e$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psi</td>
<td></td>
<td></td>
<td></td>
<td>0.10</td>
</tr>
<tr>
<td>01 Gypsum plaster</td>
<td>1.000</td>
<td>1.200</td>
<td>0.050</td>
<td>0.039</td>
</tr>
<tr>
<td>02 Normal Concrete 2600</td>
<td>15.000</td>
<td>2.000</td>
<td>0.035</td>
<td>0.071</td>
</tr>
<tr>
<td>03 Floor frost 25-5</td>
<td>2.000</td>
<td>90</td>
<td>0.035</td>
<td>0.071</td>
</tr>
<tr>
<td>04 Cement screed</td>
<td>4.000</td>
<td>2.000</td>
<td>0.035</td>
<td>0.039</td>
</tr>
<tr>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>$R_e = 0.90$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Diagram of floor design](image)

Examples of application of Building physics  Page 20
Conceptual formulation

Design the shown connections. First enter an “Apartment separating ceiling upwards” with the values of the cross section table. For the ceiling choose a connection with three elements. You can use the element from example A.1 for the upper and lower external walls. The cantilever plate is a 60 cm wide built-in element made of reinforced concrete. How wide could the cantilever plate be designed? Where are the borders of the construction net those extensions should be 140 cm horizontally and 60 cm above the upper border of the element (10 mm width of net)?

After that design the attic situation with the use of the flat roof construction of example A.2 and the external wall of A.2 as a two element connection. The ring beam (24 x 25 cm), the bringing up (24 x 48 cm, LS-masonry 1400), the 4 cm thermal insulation PS 040 and the lime cement plaster will be done with built-in elements.

Instructions step by step

1. part
In the calculation form „Element“ click on switch „New“. Choose in the following dialog “Ceiling upwards” and as name „Reinforced concrete slab B4“. Enter the materials as shown in the cross section table. Save the element twice and give it the second time the name “Reinforced concrete slab with balcony plate”. Click on the cross section sketch to get to the switch “Thermal bridge” (or use icon-switch „Open graphics window“). Set the pull down menu to connection with 3 elements. On the right side of the sketch you will now notice a vertical red line that is supposed to remind you of missing connection elements. Below the pull down menu there are two more blue writings “Connecting element” with those you refer to the corresponding elements. In this case you will choose “External wall A1” for both connecting elements. Alternatively you can add any other element from any project or database. The construction- and calculation mesh is 140 cm wide, 60 cm above the upper border of the element and has a mesh width of 5 mm. Close the dialog.
Rescale the element according to the size of the mesh.
Adjust the vertical position of the walls so that they line up with the desired final situation. You can do that by moving them with the mouse or/and making use of the little arrow switches.
Use „Normal concrete 2400“ for the cantilever plate built-in element. Reproduce the in the sketches above shown situation. There are a maximum number of 80 nodes for cantilevering elements available, meaning a maximum of 80 cm with a 10 mm mesh. Longer elements would share the outside environment and would lead to wrong isotherms. The outside air has to be able to be around the cantilevering plate (in general for built-in elements).

2. part
Load the flat roof construction „Flat roof A2“ and save it under „Attic B4“. Choose a connection with 2 elements in the pull down menu of the thermal bridge module. The connecting element is “External wall A1“. Before selecting the built-in elements corresponding to the demand check the net dimensions and switch if necessary to a 5 mm net with the same dimensions as in part 1.

Accession
Test the functions „Labellings“ in window „Construct Thermal bridge“.

Instructions
With this function you can label built-in elements and show their dimensions.
The icon-switch „Labelling“ is situated in the window „Construct Thermal bridge“. It is the top icon on the right side. You need to select the element you want to label before clicking on the icon. You do that with a mouse click on the required element (the corners will be marked). In the dialog you will have switches for different labelling options. After using switch built-in elements (in the labelling dialog) material and dimensions will be suggested in a following dialog box. Here you are able to edit the label. With your confirmation of the dialog box you will be asked about the location of label. There are several possible options for your choice to avoid overlapping. You can delete the label by leaving a black line in the edit dialog box (delete text). Via the switches “Main cross section”, “Main dimension line” and „Fitting element“ you can add or delete further legends in a similar style.
B.5. Calculation of the thermal bridge loss coefficient

**Conceptual formulation**

Calculate the thermal bridge loss coefficient for the in example B.2 designed external wall with concrete column. Change the mesh width from 10 mm to 5 mm and recalculate. In the first calculation you should get a psi-value of ~0.17 W/mK and with the 5 mm net a value of ~0.16 W/mK. Decide if the more exact but longer calculation with a 5 mm net is necessary.

Look at the notation of the psi-value in the calculation form Element. What differential value is the psi-value? Does the outside temperature have an influence? Change the outside temperature to -5°C / 80% and redo the calculation.

**Instructions step by step**

Load the in example B.2 created element „External wall with concrete column“. Check the construction- and calculation mesh. Enter a horizontal dimension of 160 cm and a vertical of 30 cm with a 10 mm net width. Finish the dialog. Change from “Construct Thermal bridge” to the isotherm module. Check the settings (Rs, temperature border conditions etc.) and if necessary change them as shown in the conceptual formulation. Start the calculation with the red icon-switch “New” (start/continue iteration). Make use of the accelerated iteration. Once the iteration has finished save the current temperature condition. Click on the icon-switch „ψ psi“ (Thermal bridge loss coefficient). In the following dialog window you have different options to influence the calculation process. Use switch “externally related”. You will now see the calculated length in the element sketch marked with red dots. The result of the calculation will be shown in an information window. The exact calculation can be followed in calculation form “Element” if the option thermal loss coefficient is activated („Content Menu“).

For the calculation with the 5 mm net width create a copy of the element with (save with new name) and change the calculation net in window „Construct Thermal bridge“.

Whether a calculation with a 5 mm width is necessary or not can not be seen in the psi-value. There are no claims to the correctness of the psi-values yet. But EN ISO 10211-1 requires a more precise calculation if the critical surface temperature changes substantially. The EN-criteria talks about a calculated difference of 0.1 °K at the critical position. The critical temperature is situated at the column on the inside of the surface of the element. It can be shown with the label „Tmin / Tmax“. With a 10 mm net width you get 16.71 °C and with a 5 mm net width 16.93°C. this difference is larger than 0.1 K the more exact and longer calculation with the 5 mm is therefore necessary.
Accession

Calculate the psi-values of the constructions in examples B.3 and B.4. You should get approximately the following results:

- Window with rabbet \( \psi = 0.005 \)
- Window with butted connection \( \psi = 0.14 \)
- Floor with balcony connection \( \psi = 0.40 \)
- Attic situation \( \psi = 0.18 \)

Window reveals and lintels are the most important thermal bridges in the building because of their long dimensions and positive psi-values.

The calculation of the psi-value for the wall corner of example B.1 causes problems. You need to delete the ventilated and therefore thermically not relevant external material layers in order to get some reasonable values. Can you explain that?

Instructions

Load the elements „Window connection B3“, „Window connection 2B3“, „Reinforced concrete slab with balcony plate“ and „Flat roof A2“ one after the other and do the isotherm and psi-value calculation for each of them.

The psi-value is the difference between the L2D-value and \( \U_i \times l_i \). The 2D-guiding value in [W/mK] will be counted back from the outside surface temperature of the isotherm calculation. \( U_i \) are the U-values of the engaged elements with their considered lengths. The temperature border conditions do not have any influence on the psi-value. The psi-value of a wall corner at the lower end of a building is as big as a psi-value of the same corner at the upper end of the building if the design is the same. But the heat loss downwards is smaller because of the smaller temperature difference.
B.6 Mold investigation

Conceptual formulation

For a mold investigation at connection situation B4 the border conditions of the isotherm calculation need to be changed. What changes are necessary? Do the changes and recalculate. Determine the critical point for the mold investigation. Show the proof “Avoidance of mold in room corners” and evaluate the result.

Instructions step by step

Load the roof border connection from example B.4 „Attic B4“ and add a surrounding insulation layer (4cm PS 040). The border conditions for a mold investigations are set in DIN 4108-2:2001, 6.2. Accordingly the temperature on the inside is to be 20 °C and the humidity 50%. The internal heat transmission resistance $R_{si}$ is to be set to 0.25 m² * K/W. It considers the reduced air circulation caused by furniture, curtains or other geometrical circumstances. Set the outside temperature to –5°C and the external heat transmission resistance to 0.04 m² * K / W. Change those settings before doing a new calculation (blue writing „with $R_{si}$“ „for mold“ in window „Calculate isotherms“). Do the isotherm calculation. The critical point for the mold investigation is the room corner. This node needs to be marked manual since it can not be determined doubtlessly by the computer. Set a marking for the corner point with your mouse. You can move the selection with the blue arrow-switches (vernier adjustment). The selection appears red for border nodes and gray for external or internal nodes. Now click on the switch $\sqrt{R_{si}}$ and choose $\sqrt{R_{si},2D}$ in the following dialog window. With this the calculated surface temperature of the marked corner node and its border conditions will be saved. In addition (for a later 3D-investigation) select a surface node in an undisturbed slab area and note its values with $\sqrt{R_{si}} - \sqrt{R_{si},1D}$.
You should find undisturbed surface temperatures at the border of the net, where isotherms run parallel to the elements surface and correspond to the steady state temperature development (if the dimensions of the net are selected large enough).

Close the graphic window and open the calculation form „Diffusion“. In the "Content-Menu" on the right side you can now select „Mould formation 2D” and switch off all other calculations concerning moisture control. The 2D-investigation can be followed with the beforehand selected corner temperature.

**Accession**

The critical regions are usually three-dimensional room corners. The surface temperature and the $f_{R}^\text{Rsi}$-factor in those regions can approximately be determined according to EN ISO 10211-2. To do so, load the external wall construction from example A.1, make a copy of it, create a wall corner and calculate the $f_{R}^\text{Rsi}$-factor. Now bring the two-dimensionally calculated wall corner with the attic situation in an arithmetical cut and determine the $f_{R}^\text{Rsi}$-factor for the 3D-corner as shown below.

---

**3D Observation acc. to EN ISO 10211-2, Appendix B**

Intersection of two dimensionally calculated line shaped thermal bridges
2D-section border [15.98°C - $f_{R}^\text{Rsi,2D}$ = 0.539] intersects
with "FlatRoof/2", border [12.61°C - $f_{R}^\text{Rsi,3D}$ = 0.294]
and "FlatRoof/1", border [12.61°C - $f_{R}^\text{Rsi,3D}$ = 0.294]

Mean temperature factor of bordering, homogeneous external elements

<table>
<thead>
<tr>
<th>Factor</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_{R}^\text{Rsi,3D}$</td>
<td>$f_{R}^\text{Rsi,3D} = 0.294$</td>
</tr>
<tr>
<td>$f_{R}^\text{Rsi,2D}$</td>
<td>$f_{R}^\text{Rsi,2D} = 0.539$</td>
</tr>
</tbody>
</table>

Temperature at Intersection

Temperature factor $f_{R}^\text{Rsi,3D} = 1 / (1 / f_{R}^\text{Rsi,3D,1} + 1 / f_{R}^\text{Rsi,3D,2}) = 0.54$

The temperature at the 3D-Intersection is at least 8.5°C

$f_{R}^\text{Rsi,3D} = 0.54 < 0.70$ (not sufficient)

Better values will be achieved with a 3D observation of the temperature field.
The mean value of the one-dimensional temperature factors of the connecting elements has a main influence on the calculation - in our case the external wall on two sides and the flat roof on the top. Select suitable surface nodes $f_{Rsi,1D}$ in the undisturbed element area (graphic). The calculation of the mean value is shown and may need to be adjusted. Thereby the external elements need to be considered in the correct area-shared weighting.

**Instructions**

For the investigation of the 3D-corner the wall corner will be designed (see B.1) and the corner temperature two-dimensionally calculated. To achieve this, load element „External wall A1“ and select in window „Construct Thermal bridge“ „Wall corner“. Also think of the border conditions as mentioned above. Calculate the temperature field. Select and save the temperatures for the critical wall corner ($f_{Rsi,2D}$) and two surface nodes in an undisturbed area ($f_{Rsi,1D}$) as described above.

The two two-dimensionally calculated thermal bridges can now be cut in a virtual 3D-room. With an approximation formula it is possible to determine the temperature in the three-dimensional corner. Switch to calculation form “Diffusion” call choice/menu „173. 3D-Room corner“ and load the previously calculated roof border construction as second, line shaped thermal bridge (2. Calculation of isotherms -> load). According to EN ISO 10211-2 upper building corners will be calculated from three line shaped thermal bridges. Therefore the roof border construction needs to be selected as 3. Calculation of isotherms (3. calculated, line shaped thermal bridge) as well (choice/menu 173), the mean temperature factor of the connecting homogeneous elements will be calculated from the marked $f_{Rsi,1D}$ value. The formula is shown and can if necessary be changed. In general three homogeneous elements, in this case on two sides the external wall and from the top the roof construction, need to be considered. Only the connecting external elements have influence on the 3D-temperature factor. From the reciprocal value of the sum (reciprocal values of one- and two dimensionally calculated temperature factors) the required three-dimensional factor $f_{Rsi,3D}$ is now determined. It also needs to meet the requirement of at least 0.7. The corner temperature can easily counted back.

The approximate calculation according to DIN EN ISO 10211-2 gives a value on the secure side. You will get more favourable values if you do a real three-dimensional calculation. This option is at the moment due to a large memory- and calculation effort and because of the problems caused by the presentation of the results not intended for DÄMMWERK.
Block C: Noise protection
C.1 Solid construction, Apartment separating wall

Conceptual formulation
Design the shown apartment separating wall. Calculate the airborne sound-insulation index R’w and compare it with the requirements.

Is this design suitable for apartment separating walls? Investigate the construction for suitability as separating wall towards stairs and other apartments with increased requirements according to DIN 4108-10.

Instructions step by step
Create in calculation form „Element“ with switch „New“ a new separating wall. Enter the element name “Apartment sep. wall C1“ and confirm it. Go in the material assistant to group “Plaster-Screed-Coat → 3 Gypsum / Lime plaster“. Select in the white material list „Gypsum plaster“, check the material data and transfer the material as first layer into your element cross section. To do that use switch „Layer 1 =>“or double-click the material in the white list. The brick you will find in group „Masonry“. Proceed with it like before. The thickness of the layer will be adjusted later. The third layer is the same as the first. Close the material assistant and change the layer thickness of the masonry in the cross section table.

Switch to calculation form „Noise protection“ by clicking on the corresponding tab. Open choice/menu „23. Fitting in...“ via clicking on the magenta colored writing „Wall element“ and select „in buildings of massive construction type“. In choice/menu „24. for protection against...“ select „Sound transmission from foreign living-/working spaces“.

The calculation method will be set via „Wall element calculated with ...“ in choice/menu 25.. The designed apartment separating wall is a single-shell construction, which will swing as a whole. Its sound insulation index depends largely on the weight (preferably big). It may consist of several rigid layers that are firmly connected with each other. Therefore you select in choice/menu „25. calculated with → Tab. 1 (massive)“. The wall will now be calculated according to DIN 4109, app. 1, Tab.1. Alternatively you can optically determine the needed calculation method in a graphical over view that can be shown with the menu selection „>SEARCH“. Below the table „Compilation of the area related masses“ you will find a magenta colored entry field „xxx“. By clicking on it the choice/menu „26. Mortar technology“ appears. Select setting „laid with standard mortar“. The area related mass depends also on the used mortar technology. Lightweight masonry mortar is good for thermal insulation but less suitable for noise protection.
The weight related calculation value for the airborne sound insulation index $R'_{w,R}$ will now be shown. If this is not the case please add in the "Content-Menu" Noise protection level DIN 4109. With the writing "exist" you are able to add manual corrections. Several special treatments for solid wall- and ceiling elements require/allow corrections in certain cases. Improved values are achieved with walls made of porous concrete or gypsum building boards and true double shell wall constructions.

Flanking elements should first be considered with an average area weight of 300 kg/m². Their influence than is neutral (no correction). Get this setting by selecting in choice/menu ..29. flank transmission → Correction KL,1 → No correction for $m'_L$ Average ca. 300 kg/m² (Tab. 13)" in paragraph „Influence of flanking elements”.

The calculated sound insulation index (53 dB) meets the requirements for apartment separating walls. Choose for the proof in paragraph requirements to airborne sound insulation choice/menu „46. Requirements → DIN 4109:1989 → Multi storey buildings → Apartment sep. walls”. The increased requirements according to DIN 4109, app. 2 (choice/menu „46. Requirements → DIN 4109 Bbl.2 (increased) → Multi storey building → Apartment sep. walls”) instead will not be met. This is after all only a suggestion. The requirements for separating walls towards stairs can also be selected in choice/menu „46. Requirements → DIN4109:1989 → Multi storey buildings → Staircase walls”. The requirement (52dB) is met.

Accession

Investigate the influence of flanking elements more closely. First use an average area weight of 200 kg/m² of the flanking elements and alternatively 400 kg/m². Now calculate the average area weight of the flanking elements with the known element constructions as shown below. Enter the internal 11,5 cm lime-sand brick wall manually (density 1.600). The external wall is the in example A.1 used construction, floor and ceiling are formed by a 16 cm thick reinforced concrete slab with 4 cm swimming cement screed, see B.4.

**Influence of flanking elements**

<table>
<thead>
<tr>
<th>flanking elements</th>
<th>$m'_L,i$ [kg/m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 11,5cm lime-sand masonry, 1,5cm gyp.plaster bothsides</td>
<td>207</td>
</tr>
<tr>
<td>2 External wall</td>
<td>255</td>
</tr>
<tr>
<td>3 Floor with swimming screed</td>
<td>soft bending</td>
</tr>
<tr>
<td>4 Floor slab</td>
<td>378</td>
</tr>
</tbody>
</table>

$m'_L,\text{mean} = \frac{1}{n} \sum m'_L,i = 280 \text{ kg/m²}$

0 dB No correction for $m'_L,$ Average ca. 300 kg/m² (Tab.13)

$\text{vorg} R'_{w,R} = 63$ dB.

**Instructions**

The sound-insulation index decreases by 1 dB with the use of light weight flanking elements (average area weight 200 kg/m²) while heavy flanking elements (400 kg/m² and more) have no influence. For single shell separating elements only the correction value $K_{L,1}$ is defining, for multi shells (e.g. if the relevant apartment separating wall is built with a facing shell) additional the correction value $K_{L,2}$.

The average area weight of the flanking elements eventually needs to be calculated more precisely. To do so open (via „0 dB”) choice/menu „29. Flank transmission” and select „CALCULATE Mass $m'_L,$ Average”. A table for flanking elements will be shown. On the left side you may enter the description. Via the column $m'_L,i$ (on the right side) you will get to the parameter window „Flanking element X”. In there you can set the characteristic material values of the element construction. Click on the blue writings to change the values for the element (thickness of solid shell = 0.115 m) and density (density = 1.600). The additional settings are for the density „Tab. 3 MW / NM” and for the plaster „on both sides”, „P IV” and „15 mm”. In general the simple (brick-) density will be used for flanking elements. Alternatively an area weight with regard to the used mortar can be determined as in the calculation for the area weight of the separating element.

The needed values of the flanking external wall can be derived from the element construction. You only need to set the in A.1 designed „External wall A1” as flanking element. Thereto use switch „Element overview” in the parameter window. The needed wall weight will than automatically calculated. For the floor slab you do a similar thing by selecting the slab „Storey ceiling B4” from task B.4 in the element overview.
For the floor you first need to create an element that is very similar to the „Ceiling upper“. Go back to the calculation form „Element“ and load the element „Storey ceiling B4“. Save the construction with a new name via icon-switch „save as...“. Use as name „Storey ceiling downwards C1“.

You can now vary the element without losing the data of the original element. Change also the element name (click on blue writing and enter the new name) and the element type (click on magenta colored writing, choice/menu „1. Element type → Sound insulation → Apartment separating ceiling downwards“). Now you can reverse the order of the layers by clicking with the left mouse button on the line numbering of the cross section table. In the appearing menu select option „Reverse layer order“. That way you will get the needed „Storey ceiling downwards“ (floor).

Now load “Apartment separating wall C1” via „Element list“ again and go back to the calculation form „Noise protection“. Reopen the parameter window for flanking elements and select the “Storey ceiling downwards C1” as flanking element. Elements with facing shells (suspended ceilings (soffits), swimming screeds, elements in post-and-beam construction) will be perceived and classified as „soft bending“. Alternatively you can set a hook in field „soft bending“. Soft bending facing shells widely reduce the sound transmission.
C.2 Solid construction, Apartment separating ceiling

Conceptual formulation
Calculate the evaluated airborne sound insulation index $R'_{w}$ and the footfall sound level $L'_{n,w,R}$ for the in B.4 designed storey ceiling. The footfall sound level of the raw slab needs to be corrected with a slab cover (swimming screed). But first determine the dynamic stiffness of the used footfall sound insulation.

Compare the calculated values with the requirements according to DIN 4109:1989 and E DIN 4109-10:2000, Characteristic values for sound insulation level II.

Instructions step by step
Load element B.4 „Storey ceiling B4“ and open calculation form „Noise protection“. Use the “Content-Menu” to set the calculation options. Switch off “Influence of flanking elements” (neutral handling) and add a hook at „Footfall sound insulation“. Flanking does not have any influence on the proof of footfall sound insulation. Set the proof method as follows:

- Ceiling element in buildings of massive construction type for protection against sound transmission from foreign living-/working spaces
- Ceiling element calculated with DIN 4109, Bbl.1, Tab.12-2, massive slab, swimming screed/wooden floor

The starting value for the footfall sound level of massive slabs depends on the weight of the slab and possibly existing soffits. The results are given by interpolation according to tab. 16/17/18. The improvement values for swimming screeds depend on the design and the dynamic stiffness of the footfall sound insulation board. Choice/menu „38. Corrections“ (click on magenta colored „exist“) sub menu „swimming screed“ contains values for $sdyn$, if the corresponding materials are used (dynamic stiffness is set in the material database). Insulation boards with dynamic stifferesses $< 20$ MN/m² are quite expensive and have a limited load capacity while insulation boards with $sdyn > 50$ MN/m² are not suitable for sound insulation because of resonance. In this example the footfall sound insulation boards have a dynamic stiffness of 15 MN/m².
The footfall sound level is the sound level that reaches the room below. Smaller values signal better footfall sound insulation. To correct the footfall sound level with a slab cover (swimming screed) you select the dynamic stiffness of 15MN/m³ in choice/menu „38 → swimming screed → cement screed“.

The determined value $L'_{n,w,R}$ (45 dB) meets the requirements of apartment separating ceilings. Select in paragraph requirements to footfall sound insulation in choice/menu „46. Requirements“ the following setting “DIN 4109: 1989 → Multi-storey buildings → Apartment separating ceiling“. In the proof according to DIN 4109 an additional value of 2 dB needs to be considered. The minimum requirements (53 dB) are to be reduced/aggravated by 2 dB. The airborne sound insulation index of the construction will be checked parallel. The requirements of apartment separating ceilings will easily be met. To compare the results with the requirements according to the draft of DIN 4109-10:2000, SST II, you choose in choice/menu „46. Requirements→ E DIN 4109-10:2000, SST II → Apartment houses → Ceilings between common rooms“. Evaluated with these requirements the airborne sound insulation index will just be met while the footfall sound level is not sufficient. These requirements according to sound protection levels (SST) are derived from the VDI-Richtlinie (VDI-guideline) 4100. The sound protection levels II and III guarantee a defined quality level of sound protection that goes beyond the minimum requirements (SST I). They probably will not become obligatory in the next couple of years but may be agreed on in building contracts as special building quality.

### Accession

Make a copy of the element and change the design as shown below. The connecting and built-in elements can be deleted (window construct thermal bridges). The footfall sound insulation will be replaced by a PE-sheet (compound screed) and the ceiling plaster by a suspended ceiling construction. Test this design according to the minimum requirements of apartment separating ceilings.

Can the soffit also be single planked? Can you improve the footfall sound protection with a soft flooring (carpet)? What other possibilities do you have to improve the footfall sound level?

---

**Apartment sep. ceiling with balcony**

- 6 Cement screed
- 5 PE-sheet
- 4 Normal concrete 2400
- 3 Mineral fibre 040
- 2 Gypsum plasterboard 12,5 mm
- 1 Gypsum plasterboard 12,5 mm

$U$-value = 0,71 W/m²K

---

Examples of application of Building physics   Page 31
Instructions

To make the desired changes at the element switch to calculation form „Element“. Safe the element under a new name „Storey ceiling C2V“. Click on the sketch and in the now open window on icon-switch „Thermal bridge“. Set „Linear element“ instead of „Connection with 3 elements“. That deletes the connecting elements. To delete the built-in element (balcony plate) select it with a left mouse click and than press icon-switch „Delete construction element“ (on the lower right side). You may now close the graphic window.

Open the material assistant and replace the footfall sound insulation with a PE-sheet. Thereto select the corresponding material layer on the right side and choose the new material in the material database. With a click on switch “Layer 3“ the footfall sound insulation will be overwritten (or just do a double click on the desired material).

The swimming screed has transformed into a compound screed. You do the same with the gypsum plaster which will be replaced by a mineral fibre insulation. To insert further layers you select the most upper layer in the cross section on the right side and hit the “Ins” key. Repeat this for the second needed layer. After that you search for the gypsum building boards 12.5 mm in the material database and enter them as first and second layer into the cross section table. The layer thicknesses will be changed in the cross section table (in the calculation form). For such extensive changes a completely new design could have been easier.

Go back to the calculation form „Noise protection“. In „Ceiling element calculated with“ you now need to select the comparison construction „12-3, Compound screed + sub ceiling“ (32. calculated with → Massive slabs → 12-3 sub ceiling). Choose in „Determination of evaluated footfall sound level“ from choice/menu „38. Correction → swimming screed → do not consider“. Because if there is no swimming screed you are not allowed to enter a correction value. Now set the requirements back to apartment separating ceilings in multi-storey buildings according to DIN4109:1989. The achieved airborne sound insulation index is in comparison to the construction with swimming screed slightly improved but the required footfall sound level is greatly missed. Hint: Swimming screeds are especially suited to improve the footfall sound protection.

Because the comparison construction 12-3 according to DIN 4109 is single planked you could abandon the second layer of gypsum building boards.

You can get better values for the footfall sound protection if you cover the compound screed with a soft flooring. Floorings can later be removed / exchanged and should therefore rather not be considered. On the other hand the raw concrete floor will rarely be used in living rooms without flooring. Try in choice/menu „38. Corrections → Flooring“ different floorings. With Linoleum- or PVC-floorings the required footfall sound level will not be met but with carpets or swimming parquet (swimming screed → Wooden flooring) it will. The possibilities to improve the footfall sound protection with compound screed on a massive concrete slab are limited. Small improvements can be achieved with an increased slab weight.
C.3 Solid construction, External wall

External wall A1
from inside
1 Gypsum plaster
2 Vert. perf. lgt.wgt. unit (typ B) 1000
3 PS 20 - 040
4 Lime-cement plaster

U-value = 0,31 W/m²K

Determination of evaluated sound insulation rate $R'_{w,R,ref}$

\[ \text{vorn } R'_{w, R} = 47 - 3 = 44 \text{ dB (DIN 4109, Bbl.1, Tab 1)} \]

-3 dB Subtraction for Thermoskin with hard insulation layer

resulting sound insulation rate $R'_{w,R,ref}$

<table>
<thead>
<tr>
<th>[m²]</th>
<th>$R_{w,R}$</th>
<th>DIN-reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>External wall A1</td>
<td>10,8</td>
<td>44</td>
</tr>
<tr>
<td>Single window, glass 32 dB, seam seal</td>
<td>3,8</td>
<td>32 Tab. 40-3/3</td>
</tr>
<tr>
<td>Roller shutter box 30 dB</td>
<td>0,9</td>
<td>30 Tab. 41-2</td>
</tr>
</tbody>
</table>

\[ \text{vorn } R'_{w,R,ref} = 10 \log \left( \sum S_{Q_{ref}} S_{Q} R_{w,R} \right) = 35 \text{ dB.} \]

Conceptual formulation

Calculate the resulting airborne sound insulation index for the external wall (see A.1) for the case of „Protection against external noise“. The Thermoskin with hard insulation layer causes resonance frequencies that worsen the $R'$-value of the construction. Consider this circumstance. The façade area of the regarded room has the dimensions of 4,16 x 2,60 and contains two windows with the opening dimensions of 1,26 x 1,51 m. In addition a roller shutter box with 1,49 m width and 30 cm height is to be considered. The single windows with seam seal reach $R_{w,R} = 32$ dB and the roller shutter 30 dB.

Compare the calculated value with the requirements of living rooms in noise level area III.
Instructions step by step

Load via the „Element list“ the „External wall A1“. Set the following calculation options in form „Noise protection“:

- Wall element in massive construction type for protection against External noise
- Wall element calculated with DIN 4109, Bbl.1, Tab.1, single layered, rigid external wall


The evaluated sound insulation index (calculated to 47 dB) should be corrected, because the external plaster on top of the hard insulation layer leads to unfavourable resonance frequencies. You will get an indication, if you click in choice/menu „43. Corrections“ (magenta colored „exist. R’w“) on „Suggestions“. The correction can in general be assumed with 3 dB, an experience value that can only be read conditionally. Therefore the correction needs to be formulated manually (choice/menu „43. → manual correction“). Enter the correction -3 and a description that suits your needs (e.g. see above).

The sound transmission from outside occurs only partly through the wall construction. The windows and roller shutters have also an influence. You need to look with the noise protection proof at each room (most unfavourable room) and calculate a resulting sound insulation index from the participating rooms. A table for this compilation is shown. At first enter for „S_{ex}“ in line „External wall“ the value „4,16*2,60“ (can be written as formula). This is the gross area including openings and subtractions. Select now in choice/menu „44. Windows/doors“ the single window (Single window insulation glazing → Single window, 32dB, seam seal) and the roller shutter box (Roller shutter box → Roller shutter box 30 dB) as shown. Their areas can again be entered as formula (windows = 2*1,26*1,51, roller shutter boxes = 2*1,49*0,3).

To compare these requirements with the limits for living rooms in noise level area III click on the magenta colored writing „xxx“ and choose in choice/menu „52. Requirements → Noise level area III → Residential rooms“.

Accession

The Rw-value of the window was first selected from DIN 4109, Bbl. 1, Table 40. Now use instead a real window, e.g. the first example from the element data base – Windows, „Window-1.43“. Check the assumption of „Noise level area III“ for noise from road traffic caused by a motorway with daily 35,000 vehicles in a distance of 240 m. Do another calculation with the method according to DIN 18005.

The assumptions for this are: long, straight road, road surface made of asphalt concrete, speed limit 120 km/h, during daylight hours 25% trucks, in the night 45%, no protection and a difference in height between noise source and immission location of 4 m.

Instructions

The Rw-value of the window will like the heat transition coefficient be determined by the glazing and the window frame. Because there is no calculative connection and the glazing and frames origin from different producers you can only estimate the sound insulation index of commercial windows without sound protection qualification. (On the other hand, the U-value of a window can be calculated from their frame and glazing shares.)

This estimation is possible with the help of DIN-tables for noise protection and the Rw-values of the used glazing (if available). Call via the single window choice/menu „44. Windows/doors“ select „Choose element / window“ the element list and choose the first window of the Element database → Window. Confirm your selection with „OK“. In the following dialog window the Rw-value of the glazing will be given (if known). You can set the R-value for the window with the „Rw,R“ option and transfer it to the calculation form with your confirmative click on „OK“.

The dimension of sound emissions caused by road traffic can in many cases, if no precise values (noise maps) available, be estimated with the nomogram in DIN 4109. Essentially you need to know the type of traffic route, the amount of traffic and the distance of the building to the route. Open menu „Content“ and activate the calculation options „Outside noise level DIN 4109“ and „Outside noise level DIN 18005“ (hooks). Now set in paragraph „Determination of required outside noise level ...“ the following border conditions (55. Road: Noise caused by highway or slip road, 35000 vehicles/day and 240 m distance to the middle of the road). According to the nomogram in DIN 4109 this results to an average level of 65 dB(A) and a noise level area III. The term in the brackets (A) documents that the noise levels are A-valued. It is an evaluation scheme that considers the character of the noise.

Noise caused by highway or slip road.

<table>
<thead>
<tr>
<th>Traffic demand</th>
<th>Distance to center of the road</th>
</tr>
</thead>
<tbody>
<tr>
<td>35000 vehicles/day</td>
<td>340 m</td>
</tr>
</tbody>
</table>

Averaging level L_{A,10}= 65 dB(A), Noise level area III.
You can determine the average level $L_M$ even more precise according to DIN 18005. The calculation platform is already switched on. Select in paragraph „Determination of required outside noise level (DIN 18005)” in choice/menu „192. Sound source“ (via „xxx“) “→ long, straight road → Federal motorway”. A dialog system follows. First do the necessary settings for the “Sound emission” (vehicles/per DTV = 35.000, road surface made of asphalt concrete). The truck shares for day and night are standard values that will be kept. Click on “Finish” to get back to the entry dialog. Now enter the important values for the location relation between the emission location (highway) and the immission location (apartment) which are the distance (horizontal distance) 240 m and the height difference of 4 m. Protections or other influences are not considered. You will get the following average levels. $L_{r,i}$ stands for the first calculated partial level (you can summarize several noise sources with this method).

<table>
<thead>
<tr>
<th>$L_{r,i}$ [dB]</th>
<th>$L_M$ [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$6 - 22$</td>
<td>65</td>
</tr>
<tr>
<td>$22 - 66$</td>
<td>60</td>
</tr>
</tbody>
</table>

Examples of application of Building physics
C.4 Framed structure, Office separating wall

Conceptual formulation

Copy the shown gypsum-post wall from the element database – Separating walls, element „Office separating wall“ into your project. The standard construction with metal posts CW 50 is planked on both sides with 2 x 12,5 mm gypsum building boards and has a 40 mm thick insulation layer (Sep. wall boards). Determine the evaluated sound insulation index without and with flank transmission and compare it with the requirements of corridor- and separating walls in hotels.

The calculation from the element database already contains values for flanking elements. Change the flank transmission for a separating wall towards staircase in a hotel as shown below.

Instructions step by step

Load the gypsum post wall via the „Element list“ from the folder „Elements → Separating walls → Office sep. wall“ (on the left side of the window) with a double click into your project (click on copy in the dialog window) and give it a new name „Office separating wall C4“.

Select in the „Content-Menu“ „Noise protection level DIN 4109“. Switch off the „Influence of flanking elements“ in this first calculation. The determination of the mass according to area can also be switched off, since it does not have any influence for light weight soft bending elements.

Choose in the next step in choice/menu “23. Fitting in... buildings of wood- or skeleton structure type” and in choice/menu “24. for protection against... sound transmission from foreign living-/and working spaces”. The sound insulation index of multi shell, soft bending elements can not be calculated directly. It is determined with comparison cross sections. In choice/menu „33. calculated with“ you will choose the comparison cross section from DIN 4109 by clicking on „SEARCH“ and than selecting element “23-6.dwb” in the shown list of elements of DIN 4109. Optionally you can choose “50 CW 50” in choice/menu „33. → Gypsum-system-built walls → 2-layer planking“.

Table:

<table>
<thead>
<tr>
<th>DIN-reference</th>
<th>( R_L_{w,R} )</th>
<th>( \Delta R_L_{w,R} )</th>
<th>( \Delta l_{l/W} )</th>
<th>( R_{l/W} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Contr. slab</td>
<td>60 dB</td>
<td>0 dB</td>
<td>3,2/4,5 m</td>
<td>61 dB</td>
</tr>
<tr>
<td>2 Floor</td>
<td>70 dB</td>
<td>0 dB</td>
<td>3,2/4,5 m</td>
<td>71 dB</td>
</tr>
<tr>
<td>3 xxx</td>
<td>0 dB</td>
<td>0 dB</td>
<td>- / - m</td>
<td>0 dB</td>
</tr>
<tr>
<td>4 xxx</td>
<td>0 dB</td>
<td>0 dB</td>
<td>- / - m</td>
<td>0 dB</td>
</tr>
<tr>
<td>5 xxx</td>
<td>0 dB</td>
<td>0 dB</td>
<td>- / - m</td>
<td>0 dB</td>
</tr>
</tbody>
</table>

1 solid ceiling, \( m = 400 \) kg/m²
2 swimming screened struc separated by sep. wall

\[ R_L_{w,R} = 10 \times \log \left( 10^{-R_{L_w,R} / 10} + \sum 10^{(R_{L_w,R} / 10)} \right) = 50 \text{ dB} \]
The evaluated sound insulation index is set to 50 dB. It meets the requirements of room- and corridor walls in lodging houses (hotels).

The sound transmission via flanking elements is very important in framed structures. Activate in the „Content-Menu“ the „influence of flanking elements“. There are already values in this table from earlier calculations. Change first the value „Element area S_T“ (area of separating element) to 3,20*2,60 = 8,32 m². In the given formula S₀ represents the reference area for which the calculation relation is developed. Flanking elements are elements that exist in the protection needed room (hotel room) as well as in the noisy room (staircase). In this example these are the floor and the ceiling. Light weight separating walls terminate at staircase walls and therefore do not need to be considered. You can delete the table entries via choice/menu „35. Element“. Enter the short labels for the floor and the ceiling manually. After that select in column DIN-reference in choice/menu „35. Element“. Solid ceiling → 400 kg/m²  for the flank transmission of the reinforced concrete slab and „Swimming screed → Struc. separated“. The influence of flanking elements is described by longitudinal sound insulation indices R_L,w,R.

These are typical values for a special design that have to be chosen with regard to the design of the joint. For suspended ceilings the suspension height and the sealing off of the cavities are important and can be considered via the value ΔR_L,w,R if the case may be. Finally the value li = 3,2 m is to be defined which describes the length of the common edge between separating and flanking element. The flank transmission does not negatively influence the sound insulation index in this example.

Accession

Compare the last calculated Rw-values with the increased requirements of corridor walls in lodging houses. How could the noise protection of the staircase wall be improved to 52 dB? Check a wall design with metal posts CW 75 and 60mm insulation.

Amongst others the German Society for Acoustics (DEGA) recorded that metal-post walls do not reach the Rw-values given in DIN 4109. This circumstance especially leads back to the reduced area weights of the planking. What Rw-value will the CW 75-post wall according to DEGA-suggestion achieve?

Instructions

Set in paragraph „Requirements to airborne sound insulation“ via choice/menu „46. Requirements → DIN 4109, Bbl.2 (increased) → Lodging houses → Room walls/corridor walls“. The now required value of 52 dB will not be met. As suggested in the conceptual formulation a separating wall with metal-posts CW75 will alternatively be investigated. To change the element switch to calculation form „Element“ and make a copy of it with a new name e.g. “Office separating wall75 C4V”. Now you can change the element without loosing the first calculation. In the cross section table you can directly change the layer thicknesses for the compartment (insulation 6 cm and static air layer 1,5 cm). You will find the required post CW 75 in the „Material assistant → Structural → Gypsum plaster board installation“. Thereto call the material assistant from table „Compound element – line CW 50“.

Click again on tap „Noise protection“ and change the comparison cross section to „Wall element calculated with → choice/menu 33. Gypsum-system-built walls → 2-layer planking → 52 CW 75, 60mm MF“. The evaluated sound insulation index according to DIN 4109, Bbl.2, Tab.2 is now given with 52dB. But the flank transmission reduces the sound insulation index to 51 dB. The increased requirements are shortly missed. The construction can further be improved. One way could be to suspend the ceiling in the staircase. But the simplest solution would be to replace one of the 12,5 mm planking layer with an 15 mm gypsum board according to the comparison cross section 23-14 (DIN-table 23, line 14). The construction now meets the required 52 dB. To do this switch back to the calculation form „Element“, open the material assistant via the line numbering in the cross section table and exchange the 12,5 mm gypsum boards with 15 mm thick boards. You need to do that in both the compound- and the frame cross section. Following that the new comparison cross section will be selected in the calculation form „Noise protection“ with choice/menu „33. → SEARCH → 23-14.dwb“. The calculation value for the sound insulation index of light weight gypsum board walls is according to DIN 4109 often estimated too favourable. These wrong assumptions are caused by reduced area weights of gypsum building boards which were done in the course of rationalization and for interests of processors during the last years. To realistically estimate the values you can use the suggestions of the German Society for Acoustics (DEGA) instead of the ones from DIN. Select „Wall element calculated with → choice/menu 33. → DEGA-suggestions → 2-layer planking → 47 CW 75, 60mm MF“. With these assumptions you only reach 47dB which is clearly below the DIN-assumption.
C.5 Timber frame structure, Timber beam ceiling

Conceptual formulation
Create the shown cross sections. First copy structure „IdH4-03.dwb” from „DIN4109” folder into your working directory. After that add the swimming screed made of 20 mm thick wood chipboards on top of the mineral fibre-footfall boards 20/15. Calculate the values for the airborne- and footfall sound insulation and compare them with the requirements of apartment separating ceilings in multi-storey buildings in massive type of construction.

Make a copy and change the design as shown. Make use of spring hangers instead of a load bearing lathing and replace the chipboards with (wet) cement screed on top of the footfall insulation MF 25/20 mm.

Instructions step by step
Choose in calculation form „Element” icon-switch „Element list” and copy the timber beam ceiling from folder “DIN 4109” → element „IdH4-03” (on the left side of the dialog window) with a double click into your project (use button “Copy”). In the following dialog you can give the element a new name, e.g. „Timber beam ceiling 1C5”. Open up the material assistant and add the footfall insulation (Material group: Insulation Materials → Mineral Fibre - Footfall sound insulation) and the wood chipboard (Wood and wood materials) in both the frame and the compartment cross section. You can switch off the temperature development in the graphics window → Settings.

Now open calculation form „Noise protection”. The noise protection level and the footfall sound level are to be calculated. The area related mass does not need to be calculated because the influence of flanking elements on the airborne sound insulation will be considered as neutral. Select the necessary options in the „Content-Menu” (Noise protection level DIN 4109, Footfall sound level DIN 4109). Set the calculation method as follows:

Ceiling element

Ceiling element in buildings of massive construction type
for protection against Sound transmission from foreign living-working spaces

Ceiling element calculated with DIN 4109, Bbl 1, Tab. 19-1, timber beam slab, sub ceiling, dry screed

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The selected comparison cross section according to table 19-1 in DIN 4109 is closest to our design. Alternatively there are suggestions from the IdH (Informationsdienst Holz, publisher of „holzbau handbuch“, these are only recommendations). The comparison cross section in there according to table 6-10 does have better values but demands the gypsum ceiling fixed with spring hangers (these are sound absorbing, free swinging hanging constructions). You will get exist $R_{W,R} = 50 \text{ dB}$ with the DIN-comparison cross section. The reached footfall sound level of exist $L'_{n,w,R} = 56 \text{ dB}$ will be parallel determined. Both values are not sufficient to meet the minimum requirements of apartment separating ceilings (setting in section „Requirements“). Timber beam ceilings hardly meet the requirements of apartment separating ceilings (according to choice/menu 46. requirements).

Go back to calculation form „Element“ and make a copy of the element (2 x save, give new name with the 2. saving e.g. „Timber beam ceiling 2C5“). Change the footfall insulation and the screed in the material assistant and replace the load bearing lathing with spring hangers (Material group “Structural → Gypsum plaster board installation”). Apply these changes to the frame and the compartment cross section. By comparing the k- or U-value you can check the correctness of your changes.

In calculation form „Noise protection“ you can now set the comparison cross section according to DIN tab. 19-3 (“Ceiling element calculated with ...“). The airborne sound insulation index does not change but the footfall sound level is now valid. The comparison cross section according to tab. 19-3 differs from our design in a double planked suspended ceiling and a 3,5 cm screed with flooring. To estimate the given range of handling select alternatively comparison cross section „IdH6-04“ (choice/menu “32. → SEARCH → IdH6-04“). For this cross section a sufficient airborne sound insulation index for apartment separating ceilings is given with 54 dB (only a recommendation). Also the footfall sound protection could be improved to get into the valid range with a carpet flooring (set in choice/menu “40. Corrections“ via exist $L'_{n,w,R} → \text{increased values IdH' 97 tab. 6}“). This change documents the contrary discussion of the suitability of timber beam ceilings as apartment separating ceilings. The calculated proof is on the tip but the practice shows that timber beam ceilings are common in old and new buildings.

Accession

Alternatively to DIN 4109, Professor Gösele has prepared calculation suggestions for timber beam ceilings. Use the method printed in „holzbau handbuch R3 T3“ (1997) and check the above calculated results. You can choose the design according to tab.4–5 for the raw timber beam ceiling and for the upper structure the design according to tab.5-5 as comparison cross sections from the above named publication.

Instructions

Editions 1997 and 1999 of the „holzbau handbuch“ contain two similar, analytical calculation methods which base on suggestions of Prof. Gösele. Select in the „Content-Menu“ → “Timber beam ceiling (Gösele-procedure)“. You can change between the two methods with switch „holzbau handbuch 1997 resp. 1999“ (blue writing). Select the method from edition 1997. The idea is to determine the footfall sound protection with a combination of a so called raw timber beam ceiling (which is the load bearing ceiling construction with timber beams, framing and suspended ceiling) and different swimming coverings and floorings, similar to massive slabs. First select via writing „not defined“ in choice/menu “12?? Timber beam slabs → >SEARCH → IdH4-05“ a raw timber beam ceiling with a suspended ceiling at spring hangers. Combine your choice with a swimming cover made of cement screed (5 cm thick, construction according to tab.5-5. IdH5-05, choice/menu 128.) and additionally a flooring made of linoleum (choice/menu 129. Floorings DIN 4109).

The calculated value for the footfall sound level would just meet the requirements of apartment separating ceilings (51 dB, 2 dB addition need to be considered). The Gösele-method suggests in further implementations that the footfall sound insulation is the dominating criteria for timber beam ceilings and that the airborne sound insulation index could be derived from the footfall sound values. From a larger amount of measured examples a nomogram was therefore developed. Depending on the flanking element you can directly read off an airborne sound insulation index $L'_{n,w}$. With flanking wood chipboard walls, as widely used in framed structures, you will determine a value of $R_{W} = 57 \text{ dB}$ that suits the requirements (choice/menu “130. flanking elements“). Such a timber beam ceiling would be appropriate as apartment separating ceiling in wood panel constructions but not in massive type of constructions because of its larger flank transmission (DIN 4109 suggests similar results). The result of the Gösele-calculation can serve as comparison values for calculations according to DIN 4109 or as proof itself (switch „the calculated value ...“). But the Gösele-method is no DIN-method and therefore not necessarily „State-of-the-art“.
C.6 Apartment separating wall with EN 12354

Conceptual formulation

The solid apartment separating wall made of 24 cm lime-sand-stone masonry 1600 (example C.1) is alternatively to be calculated according to DIN EN 12354. Compare the determined airborne sound insulation index with the result according to DIN 4109.

Instructions step by step

Load the element „Apartment sep. wall C1“ and switch calculation option „Airborne sound insulation DIN EN 12354“ in the „Content-Menu“ on. The geometry of the room is assumed with the given 4 m floor area and 2.60 m height without any offset. There is an analogy to this room geometry in DIN 4109-methods for flanking elements in framed structures and for elements made of several independent layers (e.g. external elements with windows).

DIN EN 12354 (Europe standard, no international ISO-standard) calculates the sound transmission between the transmitting room (room with sound source) and receiving room (to be protected room) from the direct transmission and the flank transmission via 4 flanks with each 3 transmission paths, which make in total 12 auxiliary sound paths. The room sketch (to be switched on in the graphics window / explanatory appearance) shows the geometry of the room, the transmission paths and the used element constructions.
The most important transmission path is the direct transmission “D-d” (capital letters for transmitting side, small letters for receiving side). In this case the direct transmission via the lime-sand-stone separating wall can be determined from an empirical mass relation. Thereto select „Entry values for separating element“ → choice/menu 141. → “Analyse element → from weight”. The resulting mass related value is with 56.6 dB larger than the value according to DIN 4109 (\(R_w = 53\) dB ⇒ calculation value with common auxiliary sound paths). Firmly connected plaster- or screed layers can be considered in mass \(m\). But the mass relation is only an emergency peg. Alternatively, you could use a known RW-value, e.g. a value calculated according to Din 4109, measured values or in other ways calculated values. Measured values that are available in oktav- or third bands (choice/menu Data in oktav bands ...) can according to regulations of EN ISO 717-1 be transferred to single digit values. Precise values for the sound insulation indices of used constructions remain scarce goods (like in the method of DIN 4109). This is especially true for light weight, multi layer structures where no mass relation can be used. DIN 4109 evaluates the flank transmission of massive type of constructions with clue values according to the average area related mass of the flanking elements (see example C.1). In framed structures special longitudinal sound insulation indices (conceptual formulation C.3) and a logarithmic connection for the summing-up of different flanks are used. DIN EN 12354 uses the following relation:

\[ R_{Ff,w} = (R_{F,w} + R_{f,w})/2 + \Delta R_{Ff,w} + K_{Ff} + 10 \times \log(S_w/(l_%f)) \text{ dB} \]

The flank insulation index \(R_{Ff,w}\) (here transmission path flank - flank Fl) will afterwards be calculated as sum from the average values of the sound insulation indices of the transmitting- and receiving side flanking elements (\(R_{F,w} + R_{f,w})/2\), the improvement value from facing shells \(\Delta R_{Ff,w}\), the joint insulation index \(K_{Ff}\) and a logarithmic term \(10 \times \log(S_w/(l_%f))\) with the common coupling length \(l_f\) between separating and flanking element. There are three such flank insulation indices for each of the four flanks, one for each transmission path.

In the next step the elements of the (in general) 4 flanks need to be specified. In this example we use the external wall from A.1, the lime-sand-stone separating wall itself as internal flanking wall and the storey ceiling from C.1. For the floor the slab constructions needs to be designed ceiling construction downwards (screed on top) (see example C.1).

First select „Storey ceiling C1“ via „Floor F1 → 139. Entry values → Choose element“. Calculate the required RW-value from the mass relation. The swimming screed is not directly connected to the reinforced concrete slab and therefore does not increase the weight but does act as facing shell. Answer the two questions in the dialog accordingly. The following calculation should be seen for the first flank:

**Flanking transmission**

**Entry values for Floor F1**

<table>
<thead>
<tr>
<th>(t)</th>
<th>(\rho)</th>
<th>(\mu)</th>
<th>(l_f)</th>
<th>(l_w)</th>
<th>(R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.16 m</td>
<td>2400 kg/m³</td>
<td>384 kg/m³</td>
<td>400 m</td>
<td>400 m</td>
<td>16,0 m²</td>
</tr>
</tbody>
</table>

\(R_w = 54.9\) dB (EN 12354-1:2000, eq. B.5 empirical value for monolithic elements)

Facing shell: Cement screed (1)

- \(m_f/\mu_g = 304 / 80 \) kg/m²
- \(s' = 15 \) MN/m²
- \(f_0 = 76\) Hz

Improvement value \(\Delta R_w = 7.5\) dB (EN 12354-1:2000, eq. D.1 and tab. D.3)

The resonance frequency \(f_0\) for the cement screed (facing shell) will be calculated with the area related mass of the concrete slab and the screed. With this frequency and appendix D.2 the improvement value \(\Delta R_w\) can be determined. The hint “Receiving room like transmitting room” confirms the same design of the ceiling on both sides of the separating wall. The EN ISO-method gives the option to have two different ceilings (even though it is not suggested). In this case two different RW-values need to be calculated.

Choose for the second flanking element „Storey ceiling B.4“ and continue as above. The swimming screed which is averted from the room does not increase the weight of the ceiling nor does it act as facing shell. Please choose for the flanking walls „External wall A.1“ and the separating lime-sand-stone wall „Apartement separating wall C1“ itself, that occurs also as flank. Calculate the RW-values from the mass relations as described above.

**Entry values for Ceiling F2**

<table>
<thead>
<tr>
<th>(t)</th>
<th>(\rho)</th>
<th>(\mu)</th>
<th>(l_f)</th>
<th>(l_w)</th>
<th>(R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.16 m</td>
<td>2400 kg/m³</td>
<td>384 kg/m³</td>
<td>400 m</td>
<td>400 m</td>
<td>16,0 m²</td>
</tr>
</tbody>
</table>

\(R_w = 54.9\) dB (EN 12354-1:2000, eq. B.5 empirical value for monolithic elements)
The longitudinal sound transmission along a flank or in combination of flanking and separating element happens in element joints which are shown as green dots in the sketch of the room. The sound propagation depends on the stiffness and the design of the joints. Soft connections transfer sound quite bad (large joint insulation values) while rigid cross- or T-joints transfer it better (small joint insulation values). There are 12 joint insulation values for each of the 12 flank transmission paths needed. The default values are „rigid cross-joints“ as common in massive type of constructions. This setting can be kept for ceiling, floor and the flanking internal wall. The joints with the external wall are rigid T-joints. Thereto click on the blue marked values in line „Wall F3“ of the table with the joint insulation values and select choice/menu “140. → Single joint → rigid T-joint”. For transmission path F3-f3 along the external wall sound path „F->f (longitudinal transmission)“ is to be set, for F3-d (external wall in transmitting room towards separating lime-sand-stone wall) path „F-d“ and for D-f3 (separating wall towards external wall in receiving room) path „D-f“. The joint insulation values for the T-joints and their related flank insulation values are a bit smaller meaning the sound transmission is less hindered.

The result of 53.8 dB differs only slightly from the on calculate using DIN 4109 (53 dB).