

3D modelling in DELPHIN

1 Introduction

This tutorial demonstrates how to create a three-dimensional detail in DELPHIN. It shows how to model a joist end in an internally insulated masonry. The detail is intentionally kept simple to better explain the general procedure of creating three-dimensional details. Thus, air layers around the joist end and sealing measures between beam head and interior insulation are omitted. The illustration of the ceiling structure is also not shown. Therefore, it is not possible in the example to consider air circulation around the joist end or an air exchange between beam support and room climate (Figure 1).

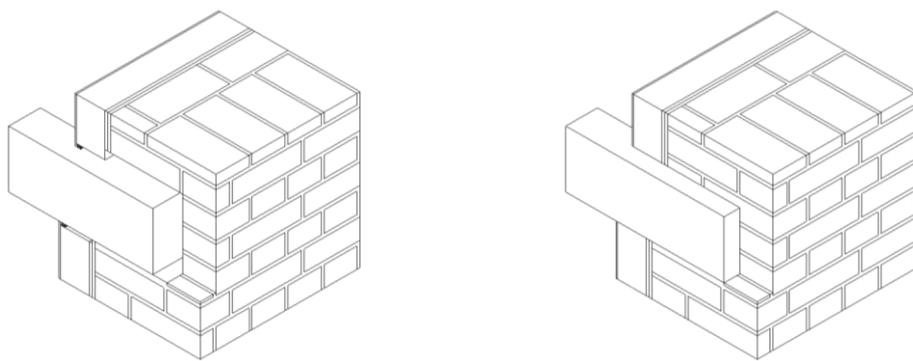


Figure 1 Left detail with air layers around beam head, right without air layers

For the detail shown schematically on the right in Figure 1 wood destruction is to be investigated at three points. Therefore, the detail will be further simplified.

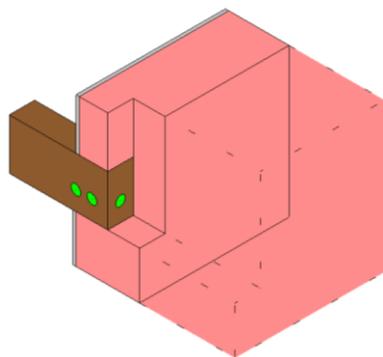


Figure 2 Uninsulated, simplified detail

The structure under investigation consists of an internally insulated masonry with 6 cm extruded polystyrene (XPS). Figure 3 shows the geometry of the construction. Figure 3 The wooden beam is 8 cm wide, 16 cm high and (in the geometric model) 60 cm long. Of this, 10 cm are embedded in the masonry.

The wall is assumed to be 20 cm thick. On each side of the beam, 50 cm of masonry is co-modelled. As the influence of the adhesive mortar is hydrothermally insignificant with XPS insulation, it is not taken into account. The details of each structure are summarised in Table 1 and in Figure 4

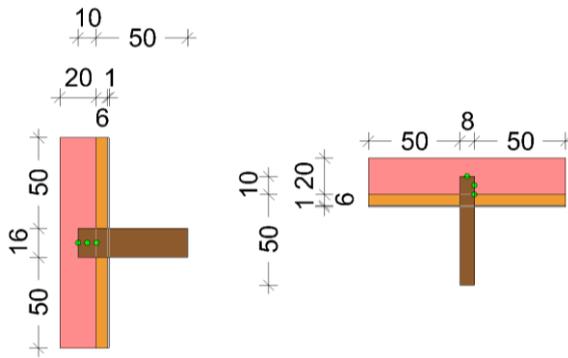


Figure 3 Left vertical section, right floor plan

Tab. 1 Structure

Variant	Description
XPS 6 cm	20 cm brick + 6 cm XPS + 1 cm plaster

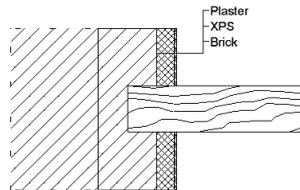


Figure 4 Construction

The output data is reduced to hourly values for temperature, relative humidity and wood moisture (kg/kg) for the points shown in Figure 3 or Figure 5. The wood destruction is calculated according to Viitanen (Viitanen H, Toratti T, Makkonen L, Peuhkuri R, Ojanen T, Ruokolainen L, Räisänen J: „Towards modelling of decay risk of wooden materials” in Eur. J. Wood Prod. (2010) 68: 303–313). The measuring points are located in the middle of the end grain, on the lateral surface of the beam 5 cm from the end grain and on the lateral surface at the contact point between internal insulation, wooden beam and masonry.

By passing on the ceiling structure and air layers, the symmetry allows to reduce the detail to a quarter of its real size.

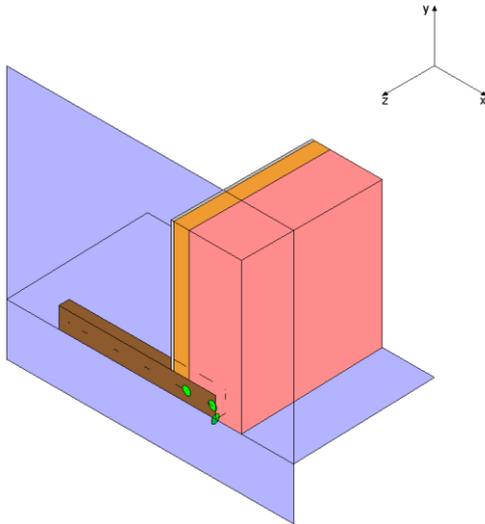


Figure 5 Use of symmetry

The following scheme is used to develop and evaluate the construction:

1. Definition of the geometry
2. Assignments (taking into account the cutting planes) of
 - materials
 - boundary conditions
 - initial conditions, field conditions, ...
 - output data
3. Discretization
4. Simulation
5. Evaluation

1.1 Definition of the geometry

At the moment there is no graphical interface available for the generation of three-dimensional details. Therefore, the building up must be done manually with a text editor. We strongly advise against using the MS Windows editor. Instead, alternative editors should be used, e.g. Notepad++, TextPad or PSPad etc. After installing an external editor, the path should be set to it in the menu Edit >> Preferences: External tools .

First, the detail is broken down into each axis direction, sketches are helpful in this phase. In x-direction, columns are created, in y-direction rows and in z-direction layers. DELPHIN 6 uses a right-handed coordinate system. Please note that the z-axis "protrudes from the screen plane". The numbering of the elements increases in the direction of the axis, starting with zero. The numbering of the beam head detail is shown in Figure 6, the layer thicknesses are described in Figure 7.

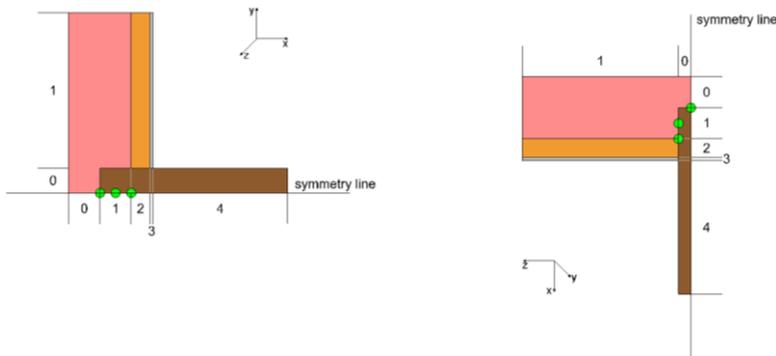


Figure 6 Numbering of the layers: left vertical section, right floor plan

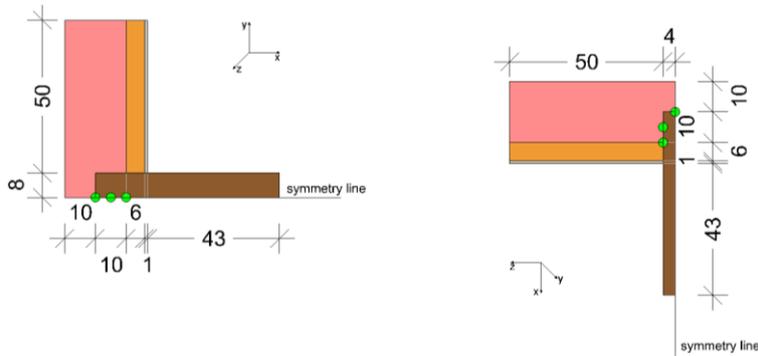


Figure 7 Thickness of the layers: left vertical section, right floor plan

Currently, it is recommended to create the 3D model starting from one 2D model or, for "more complicated" details, two 2D models. Figure 6 and Figure 7 show the xy- and yz-section. In the New Project Assistant, i. e. when a new project is started, a Cartesian 3D grid is also provided. Currently it does not help with creating 3D models.

In the context of this tutorial, the xy-section will be modeled, with five layers in x-direction and two layers in y-direction. The generation of one- and two-dimensional details is explained in tutorials 1 and 2.

1.2 Assignments

After the generation of the geometry you can start assigning the individual design properties. The assignments necessary for editing the detail are explained in more detail below.

1.2.1 Materials

The materials from [table 2](#) are taken from the DELPHIN 6 material database. For different woods, material data sets are available that take into account the anisotropic properties. These data records can

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be requested by the DELPHIN customer support. In this tutorial, the data set of a spruce with longitudinal properties will be used for simplification.

Tab. 2 Materials

Layer	Material	DELPHIN ID No.
Bricks	Old building brick Dresden ZL	500
Plaster	Gypsum plaster	799
XPS	Polystyrene sheet – extruded	189
Wood	Spruce longitudinal (or spruce anisotropic)	711 (or support)

1.2.2 Climate conditions

In DELPHIN 6, individual climate conditions are combined to interfaces ("Surfaces/Boundaries"). In the xy-cut, assign an indoor and outdoor climate you have chosen to the surfaces (see tutorial 1 and 2).

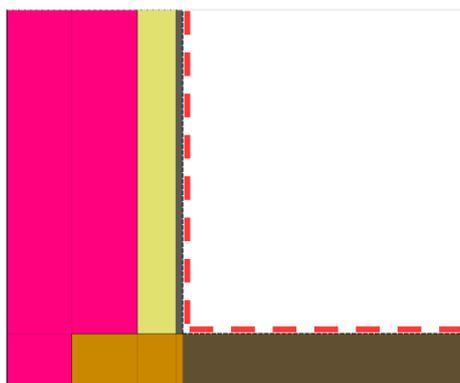


Figure 8 Arrangement of the indoor climate in xy-cut

Special initial conditions or conditions will not be used in this tutorial.

1.2.3 Output data

Since the wood is a particularly moisture-sensitive material, it will be examined in more detail. For this purpose, three outputs are defined (see Tutorial 1, Tutorial 2 or DELPHIN5-Tutorial 4).

Output type	Unit	Output type	Output type
Temperature	°C	Average value	Coordinate output
Relative air humidity	%	Average value	Coordinate output
Mass related water content	kg/kg	Average value	Coordinate output

Outputs can be assigned to individual points or areas of (discretized) elements. Here, the three outputs are to be assigned to three sensor positions each, e.g. shown in Figure 6. For the x-direction a value of

0.101 m (Figure 9), 0.15 m and 0.2 m can be specified. For the y-direction 0.0 m is used which means that all output points are located along the middle of the real wooden beam (double use of symmetry).



Figure 9 Arrangement of the outputs directly on the end grain of the joist end

1.3 Consideration of the third dimension

The third dimension can be taken into account by editing *one* existing project file in a text editor. The other possibility is that *two* project files with two different sections are put together, also with the help of a text editor. This tutorial describes how to extend *one* project file.

After saving the undiscretized model, the project file can be edited within an editor by pressing the 'F2' key. The syntax of the project files is based on the XML standard. The width and height of all elements are stored in the area <Discretization>.

```
<Discretization>
  <XSteps unit="m">0.1 0.1 0.06 0.01 0.43</XSteps>   → Layers in x-direction
  <YSteps unit="m">0.08 0.5</YSteps>                → Layers in y-direction
</Discretization>
```

```
<Discretization>
  <XSteps unit="m"> 0.1 0.1 0.06 0.01 0.43</XSteps>
  <YSteps unit="m">0.08 0.5</YSteps>
  <ZSteps unit="m">0.04 0.5</ZSteps>                → New layers in z-direction
</Discretization>
```

Figure 10 Geometry grid: above originally from xy-cut, below "added by hand" in the editor

In the upper part of Figure 10, the layers created so far are shown. Using the sketches in Figure 6 and Figure 7, they can now be completed by the layers in z-direction ("out of the screen plane") as shown. For projects with many layers, it may be easier to copy the missing information from a second Delphin project with a different section direction, whereby care must be taken to enter the axis letter <ZSteps ... /ZSteps> correctly.

Then the other components material allocation, climate conditions, initial conditions etc. and outputs must be edited. All these assignments are located further down in the .d6p file, in the section <Assignments>.

1.3.1 Material Assignment

In DELPHIN any assignments are stored as follows:

```

<Assignment type="Material" location="Element">
  <Reference>Material</Reference>
  <Range> x1 y1 z1 x2 y2 z2
</Assignment>

```

Figure 11 Assignment of materials to elements

In the first line of an assignment area is specified what is allocated to the indicated elements, in Figure 11 it is a material, directly afterwards location specifies the allocation. In this example, the assignment is carried out using the information of the elements specified in `<Range ... /Range>`. Initially the first elements `x1, y1` and `z1` in the direction of the axis are specified, followed by the last elements `x2, y2` and `z2` in each direction.

In relation to the wooden beam this means the assignment type `Material1`, the assignment kind `Element`, and the Reference names the assigned material, here `Spruce` (Figure 12). The range of coordinates is shown in Figure 13, taking into account the grid. In x-direction (red) the assignment extends from element 1 to 4. In y- (green) and z-direction (yellow) only the first layer contains the material, which is why only zeros are assigned. As we start from the xy-cut in this example, only the two zeros for `z1` and `z2` have to be inserted.

```

<Assignment type="Material" location="Element">
  <Reference>Spruce</Reference>
  <Range> 1 0 0 4 0 0</Range>
</Assignment>

```

Figure 12 Assignment of the material wood to the corresponding elements

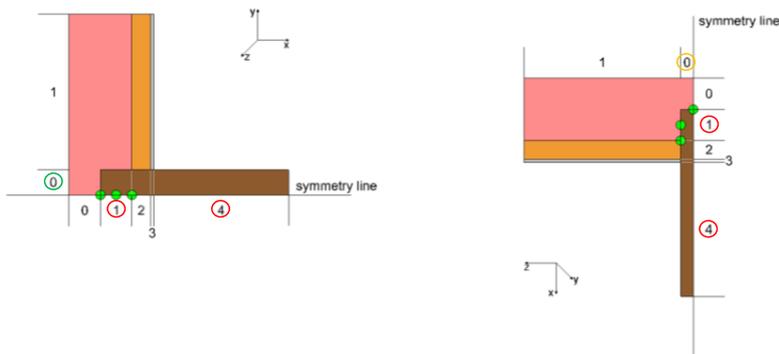


Figure 13 Geometry grid

With this detail, it would be cumbersome to arrange all assignments as exactly as in Figure 14. In DELPHIN, the rule applies that the most recently arranged assignments overwrite older assignments. You can make use of that here by first assigning all other materials as if the wooden beam was not there. Then the wooden beam is assigned last, which then overwrites the previous assignments in the corresponding elements (Figure 14).

```

<Assignment type="Material" location="Element">
  <Reference>Altbauziegel Dresden ZL [500]</Reference>
  <Range>0 0 0 1 1 1</Range>
</Assignment>

<Assignment type="Material" location="Element">
  <Reference>Gipsputz [799]</Reference>
  <Range>3 0 0 3 1 1</Range>
</Assignment>

<Assignment type="Material" location="Element">
  <Reference>Polystyrolplatte - extrudiert [189]</Reference>
  <Range>2 0 0 2 1 1</Range>
</Assignment>

<Assignment type="Material" location="Element">
  <Reference>Spruce</Reference>
  <Range>1 0 0 4 0 0</Range>
</Assignment>

```

Figure 14 All material assignments

1.3.2 Climate boundary conditions

Individual climatic boundary conditions are grouped together in "surfaces/edges", which are designated in the .d6p file with interfaces. These interfaces are assigned to constructions in the same way as for materials, using ranges. However, climatic boundary conditions have an effect on surfaces, which is why it is necessary to specify more precisely which surfaces of the elements are involved. Therefore, several options are available for specifying the location, in x-direction Left and Right, in y-direction Top and Bottom and in z-direction Front and Back (Figure 15).

```

<Assignment type="Interface" location="Left/Right/Top/Bottom/Front/Back">
  <Reference> Name</Reference>
  <Range> x1 y1 z1 x2 y2 z2
</Assignment>

```

Figure 15 Assignment of climate boundary conditions or surfaces/boundaries

Figure 16 shows the areas affected by the indoor climate (red colour) and the outdoor climate (blue colour). Model edges without climate boundary conditions (green areas) are treated as adiabatic.

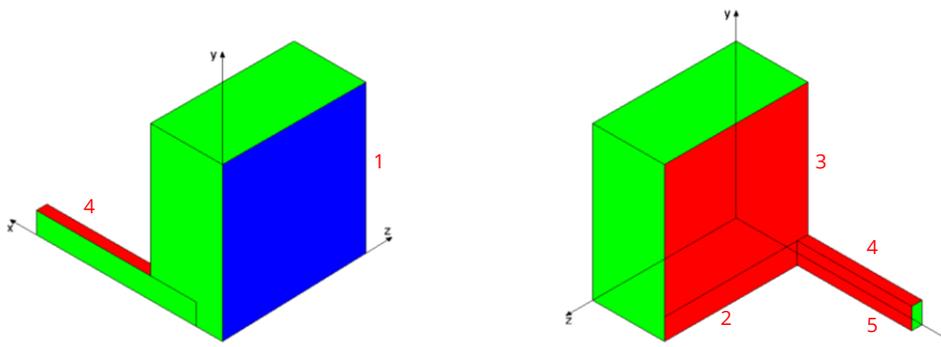


Figure 16 Assignment of outdoor climate (blue) and indoor climate (red)

All assignments are shown in Figure 17. The indoor climate was designated Inside, the outdoor climate with Outside. The individual assignments are numbered from 1 to 5.

```

<Assignment type="Interface" location="Left">
  <Reference>Outside</Reference>          1
  <Range> 0 0 0 0 1 1</Range>
</Assignment>

<Assignment type="Interface" location="Right">
  <Reference>Inside</Reference>          2
  <Range> 3 0 1 3 0 1</Range>
</Assignment>

<Assignment type="Interface" location="Right">
  <Reference>Inside</Reference>          3
  <Range> 3 1 0 3 1 1</Range>
</Assignment>

<Assignment type="Interface" location="Top">
  <Reference>Inside</Reference>          4
  <Range> 4 0 0 4 0 0</Range>
</Assignment>

<Assignment type="Interface" location="Front">
  <Reference>Outside</Reference>        5
  <Range> 4 0 0 4 0 0</Range>
</Assignment>

```

Figure 17 Assignment of the interfaces in the .d6p file

1.3.3 Outputs

In section 1.2.3 new outputs have already been defined and assigned, but only to the xy-cut, so that the specification in z-direction is still missing here as well. The sensor positions are e.g. shown in Figure 6 and Figure 7. In the assignment area of the d6p-file, outputs get the name or the "type" Output. Since these are outputs with coordinates in this case, location does not have the designation Element but

Coordinate. Accordingly, these outputs are not assigned to elements but to coordinates, which are entered in meters [m]. An output assignment with coordinates is basically as follows:

```
<Assignment type="Output" location="Coordinate">
  <Reference>Name</Reference>
  <IBK:Point3D>x y z</IBK:Point3D>
</Assignment>
```

Figure 18 Expenditure allocation with coordinates

The following Figure 19 shows the temperature assignments for the three outputs. The first sensor point should be in the middle of the front wood, therefore the z-component is 0. The other two points should be located one millimeter below the wood surface. Since only a quarter of the beam has to be modelled for reasons of symmetry, the z-component here is 0.039 each.

```
<Assignment type="Output" location="Coordinate">
  <Reference>Temp_EndSurface</Reference>
  <IBK:Point3D>0.101 0 0</IBK:Point3D>
</Assignment>

<Assignment type="Output" location="Coordinate">
  <Reference>Temp_5cm</Reference>
  <IBK:Point3D>0.15 0 0.039</IBK:Point3D>
</Assignment>

<Assignment type="Output" location="Coordinate">
  <Reference>Temp_ContactInsulation</Reference>
  <IBK:Point3D>0.2 0 0.039</IBK:Point3D>
</Assignment>
```

Figure 19 Assignment of the temperature outputs

Assignments of further initial conditions or field conditions etc. can be made in the same way as described above.

The evaluation of the entire 3D calculation field is not possible with the DELPHIN postprocessors. Cuts can be output nevertheless. You must make sure that this is actually a section, i.e. that in one of the three planes only one (discretized) element plane is cut.

1.4 Checking the assignments

As the DELPHIN program interface cannot yet display 3D models, the assignments made in the editor cannot be checked visually. On request at the DELPHIN support the beta version of a file converter (DelphinConvertX3D) can be provided. This converter converts the geometry and the assignments of a .d6p file into a .x3d file, which can be opened by different (free) visualization programs (e.g. Octaga). There you can then check all assignments.

After the installation the file DelphinConvertX3D is located in the folder C:\Program Files\IBK\DelphinConvertX3D and must be started with the Windows command prompt like the 3D discretisation (see below). Open the Windows command line by calling the execution window via [Win + R], enter the program code "cmd" and press the enter key. Or click on the *Start button in the* lower left corner, type "cmd" and press enter.

The following simple command generates visualizable 3D data from random Delphin project files:

```
D6pToX3d.exe Path_to_Delphin_file\filename.d6p Desired_path_to_output_file\filename.x3d
```

The path and file name eventually have to be put in quotation marks in case of spaces in the path or file name. The generated file can be opened in an editor. At the beginning of the file, a short paragraph explains how the colour or transparency of each material or climatic boundary condition can be changed.

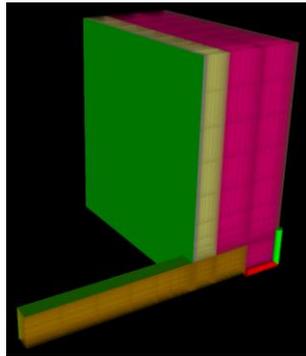


Figure 20 Screenshot from the software Octaga: the whole detail with discretisation; bottom right in detail the coordinate axes from the software Octaga

2 Discretization

The discretization of a 3D file is currently only possible "by hand" with the help of the file "CmdDiscretise.exe", which is located in the installation folder of DELPHIN (usually in C:\Program Files\IBK\Delphin 6.1, please check!). The file CmdDiscretise must be started with the Windows command prompt (see above). If you enter the line

```
"C:\Program Files\IBK\Delphin 6.1\CmdDiscretise.exe" --help
```

in the command line, all commands for controlling the program as well as syntax information will appear. When copying the above line, it is possible that the command prompt does not recognize the copied quotation marks and displays an error message. In this case, delete the two quotation marks and write them again. If necessary, create a backup copy of the file before discretization. You can use the line

```
"C:\Program Files\IBK\Delphin 6.1\CmdDiscretise.exe" -l=1.7 Path_to_Project\Project name.d6p
```

to carry out a discretization of your project with reasonable parameters. The option "-l=1.7" defines a scaling factor of 1.7 for the discretization. With further options, you can influence the discretization, e.g. -y=0.005 causes that the smallest discretized element in y-direction will be 5 mm. In case of spaces in the project path or project name the command might not be executed. In this case, set quotation marks or delete the spaces.

3 Simulation

After you have created a discretized file in the described way, you can open it with DELPHIN as usual and start the simulation. Only the xy-plane will be visible. For the calculation of simulations, DELPHIN contains many solvers. For 3D simulations, the user should define the corresponding solvers. Therefore, click on the simulation view in DELPHIN in the middle of the left edge and select the tab "Performance Options".

Set BiCGStab (or GMRES) under "Solver for linear system of equations". Then select ILU at "Preconditioner".

3D projects can quickly exceed a hundred thousand or a million elements. For such cases, it is advisable to use many processors. In previous test series, it has proven to be helpful to use up to 24 processors for 3D simulations. In the future, users will be able to use a special computing server at the TU Dresden for more complex simulations.

4 Evaluation

One-dimensional diagrams and two-dimensional fields can be created and edited as usual by the DELPHIN-Post-Processor 2. An online help can be called from the post-processor. The illustration of three-dimensional result fields is possible with programs like Tecplot. The file DSixOutputConverter.exe in the DELPHIN program folder creates files from DELPHIN outputs that can be processed by Tecplot. Here, too, use "`DSixOutputConverter.exe -help`" to call up a concise help on the command line level.