# The Assessment of Construction Details in Terms of 3D Thermal Fields and the Impact on Building Design

To cite this article: M Kalousek and M Novák 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **290** 012097

# The Assessment of Construction Details in Terms of 3D Thermal Fields and the Impact on Building Design

**M Kalousek and M Novák**

Brno University of Technology, Faculty of Civil Engineering, Veveri 95, 602 00 Brno

kalousek.m@fce.vutbr.cz

**Abstract**. Thermal bridge is a very common and undesirable phenomenon in a building. Thermal joint (bridge) is usually based on material or geometry reasons or their combinations. Many types (connection of window – wall, pillar – wall), can be calculated and evaluated sufficiently in 2D section, but in some types it is necessary to take into account 3D heat conduction. For example: a corner with ceiling (roof) and two walls where is strong deformation of isotherms and the internal surface temperature is definitely lower than in 2D section. According to the Czech Technical Standard it is necessary to fulfil law requirement – Temperature Factor at internal surface lowest temperature „at each location“. Recommendation is solving of "differential equation multi-dimensional of thermal field". In this case of "building corner" project engineer has to decide for 3D modelling. In the contribution there is presented a mistake in 2D model, the situation when it is necessary to use 3D model. Additionally, there are recommendations to eliminate the risk of condensation and mould.

## 1. Introduction

About 20 years ago in Czech building practice the thermal field details were not assessed because the software was used only at universities for their research. Thermal requirement about "The lowest internal surface temperature of the structure" was mentioned in the Czech standard Thermal performance of buildings (ČSN730540) already from the sixties of the last century. Now there is very significant shift because every architect knows about necessity of 1D and 2D thermal calculations.

The first notification about mould is usually in the 3D corner, not on 2D corner or a plane and for this reason it is necessary to solve 3D model. In case of "Passive houses" is very common to check thermal joints by calculation of 3D details [1,2]. The scope of the contribution is correct evaluation of the lowest internal surface temperature, according to Czech technical standard, and mainly the big difference between 2D and 3D models.

Coefficient of point thermal transmittance calculations are not performed in building practice and their impact on the heat transfer coefficient (U-value) is calculated as a lump sum surcharge. The aim of this study is to show the real impact on values surface temperature point thermal bond (a joint of three structures) and heat transfer coefficient value with the influence of point thermal transmitance (anchors of suspended facades).

## 2. Methods

Thermal field is modelling by software based on FEM (Finite Elements Method). The basic software AREA from prof. Svoboda CVUT Prague [6] with coupling water vapour calculation is used for 2D modelling. More complex software ANSYS [5] is used for 3D modelling.

Usually 2D and 3D details of a building structure is modelled in orthogonal composition (it means building by rectangles or blocks), but sometimes they are not. A different shape of areas and volumes are possible but sometimes it is better to make simplifications. Classic building materials are isotropic, but wood is anisotropic where parallel heat flows to the fibres and it is three times higher than perpendicular.

In the following models there were calculated heat conduction, water vapour distribution and the lowest internal surface temperature (temperature factor).

The element SOLID70 (see Fig. 1) was used for the analysis. It has a 3-D thermal conduction capability [5]. The element has eight nodes with a single degree of freedom, temperature at each node. The element is applicable to a 3-D, steady-state or transient thermal analysis. The element also can compensate mass transport heat flow from a constant velocity field.

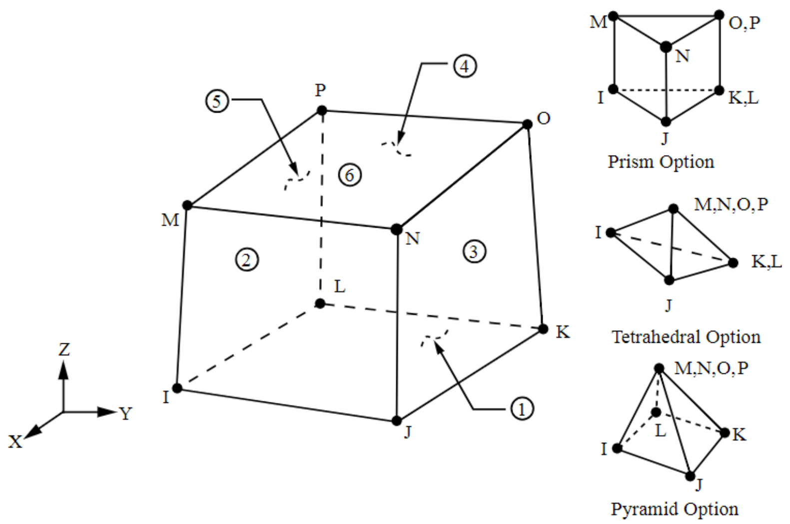


**Figure 1.** Ansys FEM Element SOLID70 for Thermal Analysis [5]

## 3. Calculation

At first, for comparison, there were solved several 2D details of connection between two constructions like wall-wall, wall-floor, wall-roof and another combination of three constructions like wall-wall-roof and wall-wall-floor. Any more critical details like connection wall-window have worse results in 2D and also 3D model [8].

All structures (panels) are wooden and lightweight with thermal insulation inside. Special composition is made from EPS – Expanded PolyStyrene ($\lambda = 0.038 Wm^{-2}K^{-1}$) and envelope by OSB – Oriented Strand Board ($\lambda = 0.2$ $Wm^{-2}K^{-1}$) – wall panel – thickness 170 mm. Frame is completed by structural wooden beams ($\lambda = 0.18$ $Wm^{-2}K^{-1}$) around the perimeter of the panel. Additional thermal insulation, for satisfying requirements of U-value [7] (in this case for passive houses $U = 0.11$ $Wm^{-2}K^{-1}$) up to thickness 200 mm, it is also made from EPS-70F and thin ETICS plaster (External Thermal Insulation Composite System).

The Boundary conditions are strict for the Czech Technical Standard ČSN 730540-2:2011 – air design temperature internal 20°C, external -15°C (for location – town Brno) and internal air humidity 50%. The dew point for internal environment is 9.27°C but the designed critical minimal temperature to eliminate the risk of condensation and mould is 11.04°C (standard requirement). [4,7]

IOP Conf. Series: Earth and Environmental Science **290** (2019) 012097 doi:10.1088/1755-1315/290/1/012097

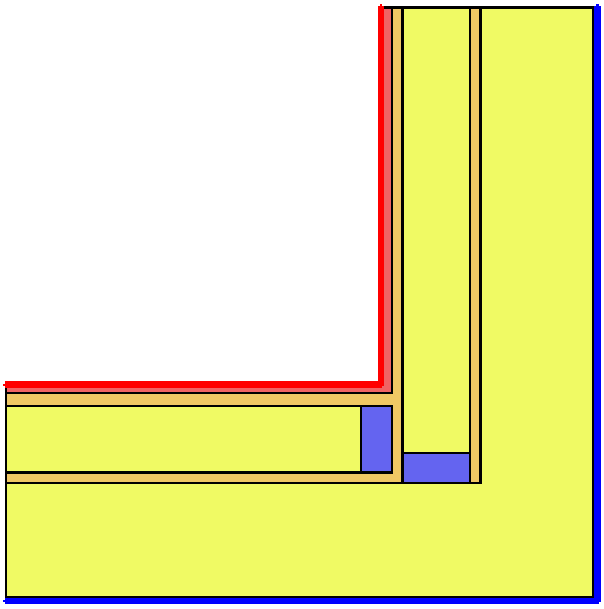

**Figure 2.** The plan (blue – wooden beams, orange – OSB board, yellow – thermal insulation)

The results of 2D modelling are showed on the Fig. 3, where the thermal field with isotherms and the lowest internal temperature in the corner (thermal joint) is 15.8°C. The calculated temperature is very high and it complies with the requirements.

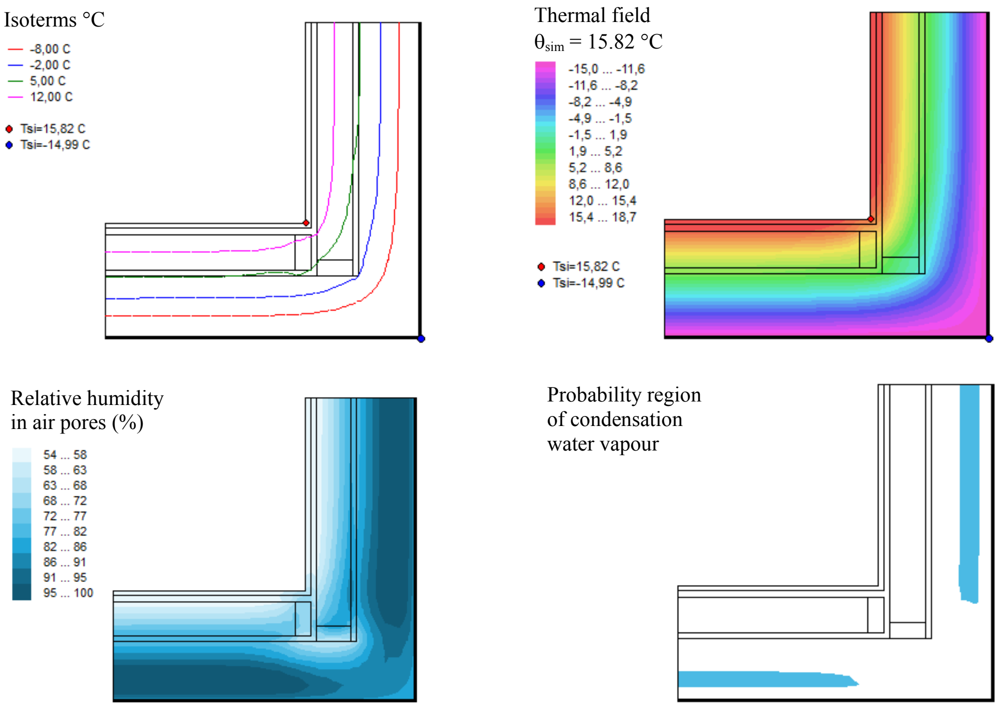


**Figure 3.** The 2D model – isotherms, thermal and water vapour field

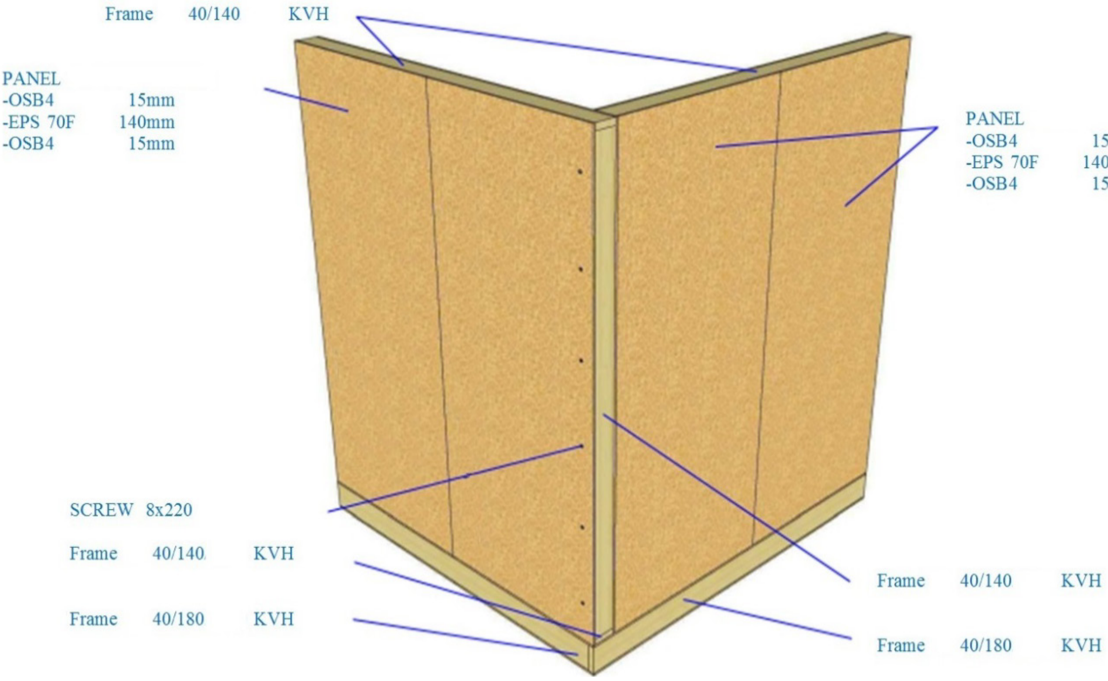


**Figure 4.** The 3D model of the wall-wall-floor with crawling space

The results of 3D modelling are showed on the Fig. 5, where 3D thermal field and the lowest internal temperature in the corner (wall-wall-floor) is only 9.75°C. In the Table 1, there are compared all calculated 2D and 3D details between them and also with the Czech standard. The 3D details are inconvenient.

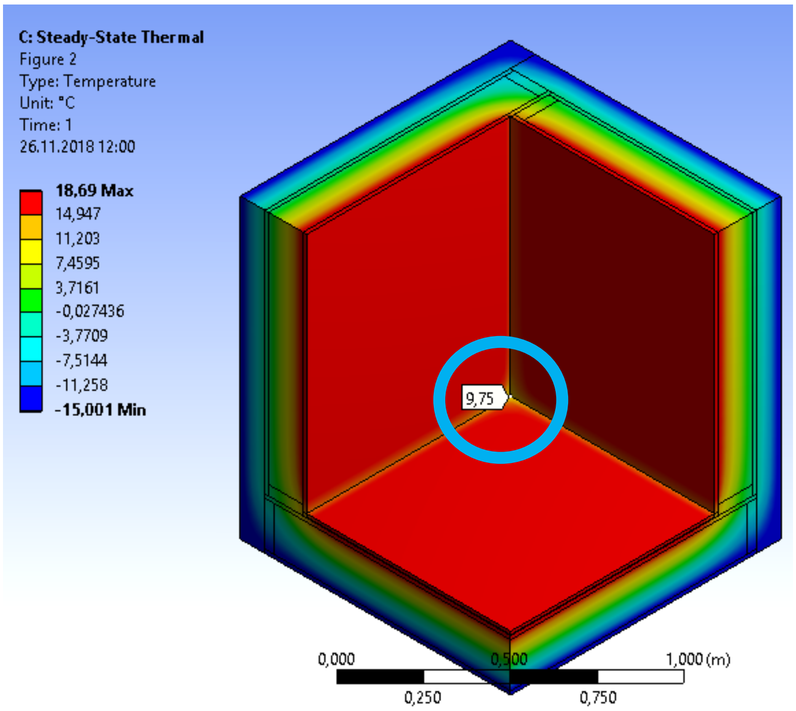


**Figure 5.** The 3D model of the wall-wall-floor with crawling space (lowest temperature 9.75°C)

**Table 1.** Result of temperatures– standard satisfaction

| Thermal Joint | Calculated | Standard satisfied $\theta_{req}$ = 11.04°C |
|---|---|---|
| 2D wall-wall | 15.82 | Yes |
| 2D wall-floor | 18.10 | Yes |
| 2D wall-floor | 18.10 | Yes |
| 3D wall-wall-floor | **9.75** | **Not** |
| 3D wall-wall-roof | **10.61** | **Not** |

## 4. Other application of 3D modelling

Other reason of 3D modelling of sandwich envelope structures (solid wall and thermal insulation) is calculation of value – Point thermal transmittance. The metal anchors are usually ignored part of suspended façades. Basic calculation of the façade with very good conductivity coefficient of a thermal insulation for ex. 0.033 $Wm^{-1}K^{-1}$, leads to a big mistake in U-value of the whole façade. Thermal conductivity of thermal insulation layer with the anchor taking in account is twice and more time higher.

As it is seen on Figure 6, in the case of aluminium anchor ($\lambda$=200 $Wm^{-2}K^{-1}$), temperature distribution in critical section is specific and deformation of isotherms is very big (left part). And on the right side picture there is very high heat flow in connection detail of anchor and also around the screw ($\lambda$=50 $Wm^{-2}K^{-1}$) in the wall (in metallic parts is heat flow rate more than 100 $Wm^{-2}$.

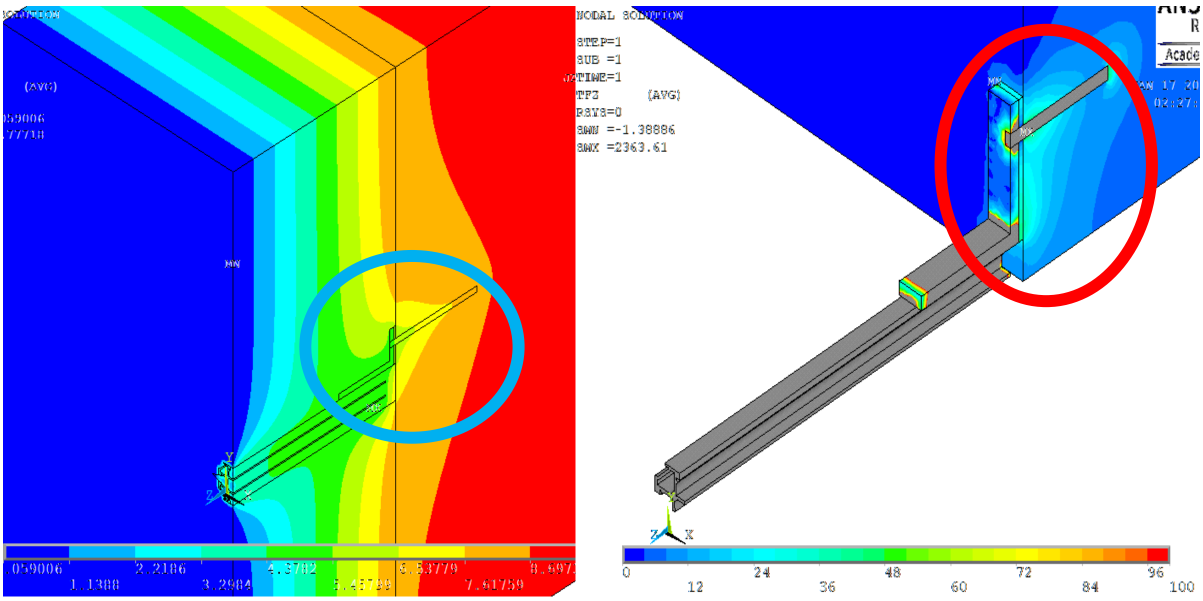


**Figure 6.** Thermal field and heat flow rate 3D – aluminium anchor and the surrounding wall [5]

On the Fig. 7 there are visible white coloured areas that mean higher temperature and point thermal joints. The rest of façade is good insulated but metal bars coming through the mineral wool to exterior – very poor board compactness.

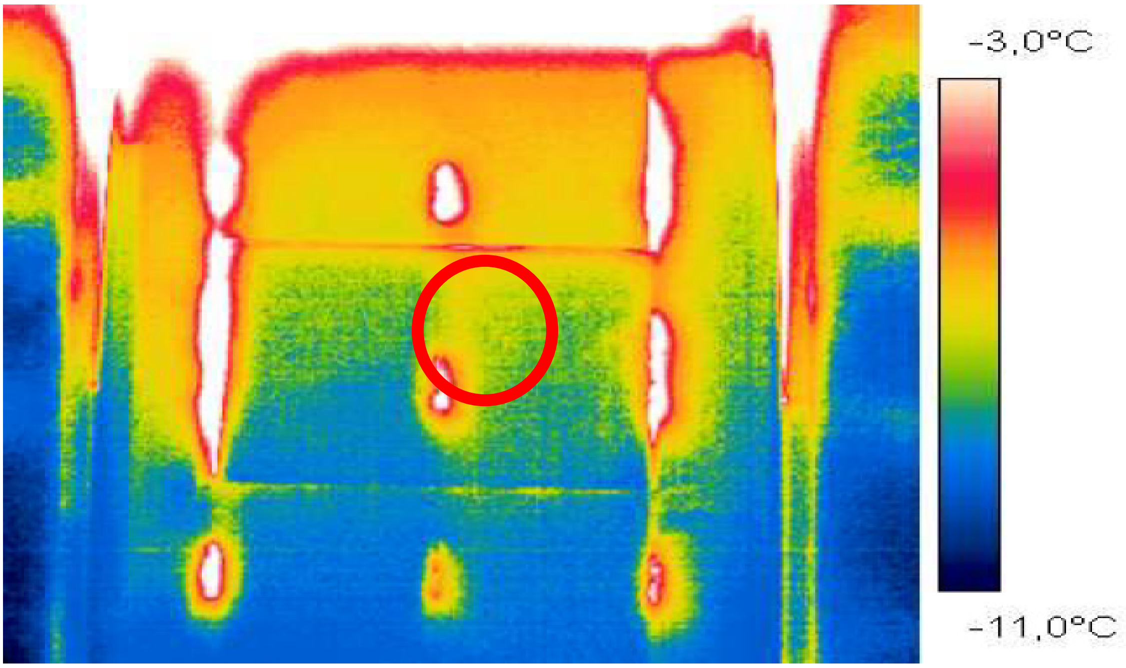


**Figure 7.** Thermovision picture of anchors from the outside (-12°C) [3]

## 5. Conclusions

The above comparison of modelling results in 2D and 3D shows a large difference in surface temperatures. It demonstrates the need to make a model of a detail in more complex way – in 3D – to identify design imperfection and to correct them – for example enlarging of thermal insulation thickness.

The basic requirement for indoor surface temperature and risk of growth mould is not met. U-value is very good in 1D evaluation, but it is not satisfied, because it needs to check 2D models in characteristic sections and 3D for critical points – the corner or the anchor.

The lowest surface temperature in 2D was found at 15.82 °C, but in 3D it was 9.75 °C. This difference 5 K is indisputable and unsustainable, yet it is overlooked in practice in the Czech Republic and Europe and buildings have unsuitable environment.

Likewise in case of suspended façades, it is not checked out very often by calculation in 3D, an influence of metal anchors on U-value of whole façade. The real U-value should be two times higher than a structure without anchors.

## 6. Discussion about results

The Czech Technical Standard is not strict for all constructions to make a model in 3D. The word “multidimensional” means 2D or 3D, but the results are very different, especially when the dew point and the risk of mould growth are between the calculated values (2D and 3D). For me as Forensic Expert in practice is very difficult to assess correctness of the project and realisation of the faulty building. There is poor knowledge of designers and also lack of the education of new regulation, because the change of regulations is always accepted with a big delay in practice.

## Acknowledgement

This paper has been worked out under the support of Institute of building structures, Faculty of Civil Engineering, Brno University of Technology.

**References**

[1] Rybakova A and Kalousek M 2014 Modeling of Details for Single-Layer Wall in a Passive House: The Case of Balcony Slab, enviBUILD2014 *Adv. Mat. Res.* (Curych)

[2] Němeček M and Kalousek M 2016 Influence of Thermal Storage Mass on Summer Thermal Stability in a Passive Wooden House in the Czech Republic *Energy and Build.* (Elsevier)

[3] Šubrt R 2009 *Usage of termovision method and contactless termomethers in building industry – errors and mistakes* (MPO, České Budejovice)

[4] Šála J 2007 *Interpretation of provisions of the Czech standard ČSN 73 0540 Thermal Protection of Buildings for Residential Wooden Houses* (Prague)

[5] Manual Ansys v.14.5 , Ansys, Inc., 2016, www.ansys.com

[6] Manual AREA, Svoboda Software, Prague 2014

[7] ČSN EN ISO 10211:2007 Thermal bridges in building construction – Heat flows and surface temperatures – Detailed calculations, minimum surface temperatures, in order to assess the risk of surface condensation, ISO, 2007

[8] ČSN 730540-2:2011, Z1 2012 – Thermal Protection of Buildings, Requirments, Czech standard institute, 2011, 2012