Data Transfer from BIM to Building Performance Simulation Tools: A Case Study

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Abstract

Recent developments in building planning and delivery processes point to an increased deployment of BIM (Building Information Modelling) and corresponding tools in the AEC (Architecture-Engineering-Construction) domain. BIM is understood as the digital representation of the physical and functional characteristics of a facility that can offer a reliable informational basis for decision-making throughout a building's life cycle in different domains. Given this context, the present contribution addresses data transfer from commonly used BIM-software environments and a specialized simulation tool for thermal bridge analysis in view of heat flow, surface temperatures, condensation, and mould growth risk. Interestingly, much of the input data required for such in-depth assessments is already available in basic design models. However, there is a paucity of related fully functional data transfer solutions. This paper documents and evaluates data transfer issues based on sample building details. The objective is thereby to support software developers toward a better integration of state-of-the-art assessment methods in building design.

1. Introduction

The AEC domain is generally considered to be slow in technological advances. However, in recent years different concepts utilizing the ubiquitous availability of computational power, software tools and the World Wide Web pervaded this branch of economy. The term Building Information Modelling (BIM) was promoted as a key concept for the current and future planning practice. A commonly used description of BIM is: "Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle; defined as existing from earliest conception to demolition. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder" (NIBS, 2012).

Another trend in recent building planning is the increased use of state-of-the-art numeric simulation tools. These tools – if well understood by the user – offer a very fast and rather inexpensive possibility to explore in-depth different performance aspects of yet-to-be-built buildings, such as structural stability, energy use, and thermal performance of building components. Such tools allow new approaches in building construction, which can be extensively tested prior to realization. Moreover, typical uncertainties and issues regarding different aspects of building performance can be clarified to a certain extent or even solved with such tools.

One of the premises of Building Information Modelling is the reduction of redundancies regarding building-related data, and a high degree of compatibility with specialized stakeholder's tools. However, the current practice does not fully follow this premise: Many specialists generate their own building models, although a common building representation created by building planners is available. Borrmann et al. (2015) attribute this practice to the fact that the data exchange is currently not working satisfactorily, due to the high complexity of commonly used BIM-formats such as IFC (industry foundation classes, buildingsmart 2016). Moreover,

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they state that the programmers of specialized software tools often struggle with the high variety of how buildings and building components can be described within IFC files of third parties. To ensure compatibility with all possibilities of data representation would generate an implementation effort that is too large for most producers. A possible relief for this situation is described by Beetz et al. (2015): In the future, the concept of the so called Model View Definitions (MVDs) will offer exact definitions and rules for an easy representation of buildings and building parts.

Only few publications address the data transfer between BIM environments and thermal bridge simulation tools. Narowski et al. (2011) discuss the modelling of conduction transfer functions for typical thermal bridges that were identified out of BIM data. They provide a list of correction factors based on thermal bridge simulations that can be used to modify the 1-dimensional heat transfer coefficients usually derived from whole building simulations (which can be performed based on BIM-models). Ingelaere (2016) gave a talk in the framework of the Qualicheck initiative (Qualicheck, n.d.) about the impact of BIM on energy performance calculations, and stated "detailed calculations (thermal bridges, *…)* require a lot of input data and extra calculation tools." In contrast, recent developments in one of the leading BIM environments, ArchiCad (Graphisoft, 2016), include the integration of a proprietary building performance simulation environment. This encompasses a (simplified) thermal bridge simulation tool for 2D thermal bridges. This feature was highly appreciated by the user community of ArchiCad (graphisoftus, n.d.). A downside of the feature is the limitation to 2D-bridges. Moreover, it is controversially discussed, if the full integration of a thermal bridge simulation module within an existing drafting/modelling tool can be considered as "BIM" following the definition of NIBS. Borrmann et al. (2015) define such an environment as "closed BIM". If used only by a single stakeholder (e.g. the planner), they name it "little closed BIM". On the contrary, the transfer of data between different software tools (of different producers) is defined as "little" or "big open BIM" (Fig. 1).

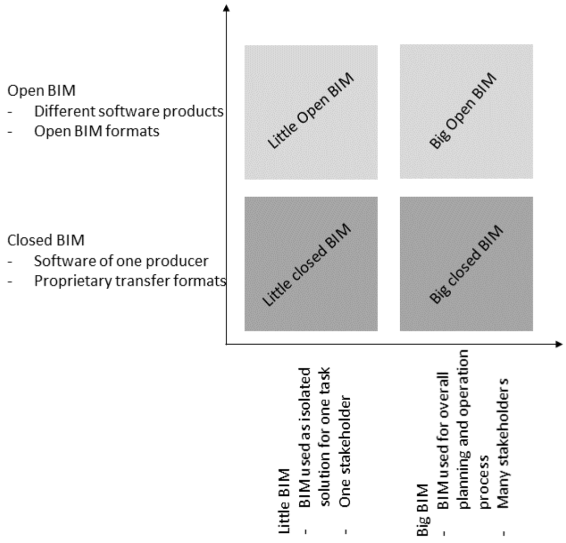


Fig. 1 – BIM classification, based on Borrmann et al. (2015)

2. Objective

In this contribution, we document and analyse the current data transfer possibilities between (architectural) BIM tools and a specialised building performance tool addressing the numeric simulation of thermal bridges. The majority of the required input data for numeric thermal bridge simulation should be included in a BIM representation of a building. Therefore, it can be considered interesting, which part of the data transfer between these environments works properly, and which aspects require improvement. Case studies as the one described might offer valuable insights for future development of the appropriate interfaces between such tools. Another objective of this paper is to suggest potential improvements regarding the data transfer between the mentioned environments, which, from a user's point of view, seem to be feasible in realization.

This research paper is based on a master thesis addressing the topic of interoperability between BIM and building performance tools (Bucevac, 2016).

3. Methodology

3.1 Used Software Environments

3.1.1 BIM environments

Autodesk Revit

Revit has been developed since 1997 and was integrated in Autodesk's product portfolio in 2002. As a third party tool, it was not derived from Autodesk's key product AutoCad, but rather a stand-alone development. One key feature determined the name: Revit is the abbreviation of Revise instantly, and refers to the capability of the tool to instantly update any plan, section, and view after any change. All building components in Revit are processed as 3D representations, and organized in so called families. A family represents a group of elements with a common set of properties. Revit features so-called System families (categories of objects) that include the basic building elements such as walls, floors, ceilings, and other building constituents. Note that in such a family/category all layered components of such a building assembly are stored (as subcategories). For a wall, for instance, these subcategories could refer to the finishing layers on both sides, the thermal insulation, etc.

Moreover, additional so-called component families can be imported to a project from external sources. The basic idea behind this concept was that System families resemble generic building elements, while component families are customized families, originating from producers or system specialists. Within Revit, a wide range of properties of the different building components can be set or taken from a library, including basic properties important for performance assessments. These properties include (amongst others) thermal conductivity, specific heat, density, emissivity, permeability, porosity, reflectivity, and electrical resistivity. Fig. 2 illustrates the "thermal properties" dialogue available for building materials in Revit.

Graphisoft ArchiCad

ArchiCad is considered the first commercial BIM environment, as the use of "building objects" and "virtual building" was already integrated in its first launch in 1987. ArchiCad models are constituted of data-enhanced parametric objects, often referred to as "smart objects". Similar to Revit, the attachment of certain properties is possible, both via manual input, and data from an integrated library. Fig. 3 illustrates the material editor in ArchiCad (for a specific material).

Numeric thermal bridge simulation

The tool used within this study was Antherm 8. Antherm is a software environment focusing on conductive heat and mass transfer within building components and utilizes a finite point method for the assessment of heat flows. It can be used to evaluate two- and three-dimensional thermal bridges, and it features a graphical user interface, drafting possibilities, and different reporting and visualization possibilities for temperature distributions in and on building assembly surfaces as well as for condensation and mold growth risk. The tool is under constant development. Recent developments were described in Kornicki et al. (2012) and Pont et al. (2016).

To perform basic thermal bridge evaluations, Antherm requires both geometric and semantic information. Geometric information includes dimensions and adjacency situations of different building components (represented as "material boxes" in Antherm), as well as adjacent spaces (represented as "space boxes" in Antherm). Semantic information includes the building material properties (conductivity λ, specific heat capacity c, diffusion resistance μ, and density ϱ), as well as the temperature and relative humidity of the adjacent spaces.

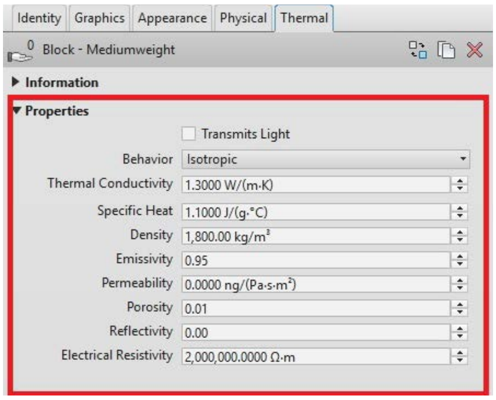


Fig. 2 – Thermal properties dialogue for building materials in Revit

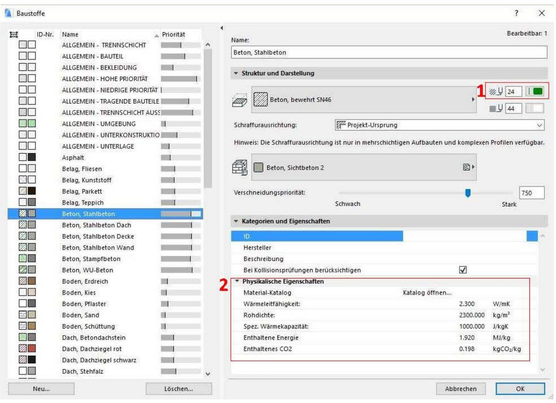


Fig. 3 – Material editor in ArchiCad

Table 1 – Import and export capabilities of Revit, ArchiCad, and Antherm

Tool	Application	Input file formats	Output file formats	Interoperable file Formats
Revit ArchiCad	BIM platform for modelling	dwg dxf gbxml ifc	dwg dxf gbxmlL ifc	dwg dxf gbxml ifc
Antherm	Thermal bridge simulation tool	xml dxf waebru heat2 heat3 kobra86	xml csv png jpg 3D scene	dxf

3.2 Principal Data Transfer Capabilities in the Software Tools

Basically, all described tools feature a range of accepted file formats for import and export. The BIM applications offer "native" BIM formats (gbXML, gbXML 2016; ifc, buildingsmart 2016), but they can also generate commonly used CAD formats (dwg, dxf). Antherm offers import capabilities for different typical file formats of other thermal bridge assessment environments (waebru, heat2, heat3, kobra86), and additionally for dxf files and xml files. Due to the finite-point-based simulation kernel of Antherm, which generates a rectangular grid, dxf files are required to fulfill certain conventions: All imported geometry needs to be constituted from axis-parallel lines. Moreover, only 2D drawings will be accepted for import, and components have to be constituted by closed polylines (other elements will be neglected in import). Table 1 illustrates the different file formats that can be imported and exported from the different tools used in this study.

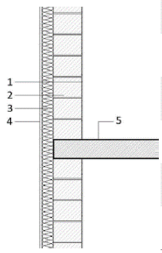
The dxf format is the only file format integrated as file interchange interface in all involved tools. The dxf-format (drawing interchange format) was developed by Autodesk, and due to its simple structure and clear documentation, is considered the industry standard for CAD-drawing interchange (Autodesk n.d.). However, as dxf is a pure drawing interchange format, no additional information (e.g., semantic data) can be attached to the geometric data inside the file.

Both Revit and ArchiCad offer the gbXML format as export possibility. This is an extended markup schema for (green) buildings. Antherm accepts XML as import file format. Therefore, a potential data transfer track, including both geometry and semantic data could be based on XML or gbXML structured information.

3.3 Case Study Building Assembly Joints

A set of typical construction details was chosen to extensively experiment with the data transfer possibilities and to discover strengths and weaknesses of different approaches. All of these details were created based on the specifications given in relevant standards (cut planes based on DIN 2008, thermal properties based on ASI 2013). A full description of all details including simulation results can be found in Bucevac (2016). To document the different transfer processes in this contribution we chose the construction joint of an insulated external wall with a concrete slab. Fig. 4 illustrates this construction detail and its constituent properties.

All details were drafted both in Revit and ArchiCad. Thereby, in both tools the option of setting hierarchies between different constitutive elements was utilized to generate full 3D-representations of correct building constructions. As far as possible, the thermal properties were also set in the environments (both BIM environments do not feature property settings to determine the diffusion resistance of components).



	Name	d	1	μ	ρ	c
		[mm]	[W.m-1.K-1]	[-]	[kg.m-3]	[J.kg-1.K-1]
1	Plaster	10	0.49	20	1300	1
2	Concrete blocks	300	1	130	1200	1.13
3	Mineral wool	120	0.041	2	93	1
4	Plaster	25	1.05	35	1800	1
5	Concrete	200	2.3	130	2300	1

Fig. 4 – Wall/Slab detail and its thermal properties

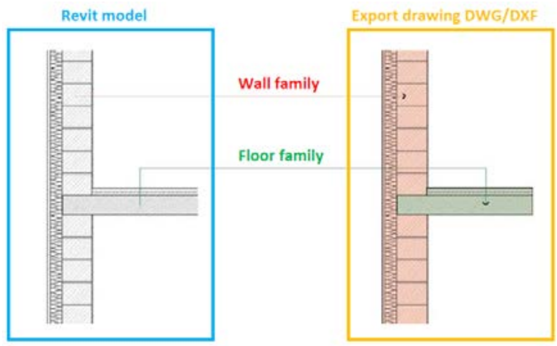


Fig. 5 – Translation process in Revit (categories and subcategories to dsf layers)

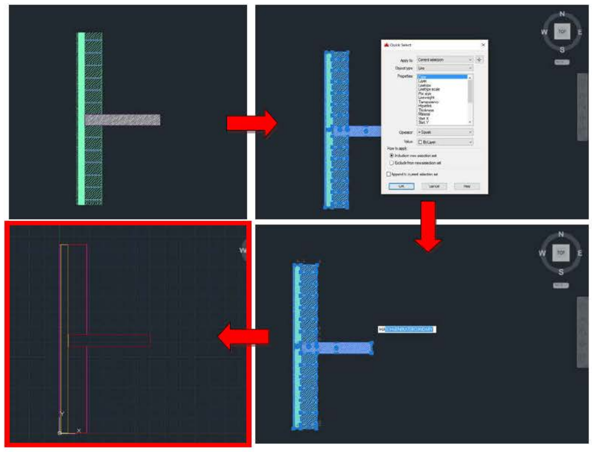


Fig. 6 – Postprocessing of a Revit-generated dxf File in AutoCad

4. Data Transfer Documentation

4.1 Data Transfer via Drawing Interchange Format (dxf)

In both BIM environments, it is required to define the export settings in an appropriate fashion. This is necessary to apply the conversion of elements and parameters into pieces of geometrical information that can be stored in dxf. The export settings, once established, can be stored in a "translator" file and repetitively applied to different models and details. **In Revit**, in a first step, a section (cut) plane needs to be defined. Afterwards the categories and subcategories of elements are mapped to a layer name and color for the dxf. Fig. 5 illustrates this translation principle in Revit. A split of parts of a family or subcategory to different layers seems not to be possible in recent versions of Revit. In terms of further workflow for the export to the thermal bridge simulation, this can be considered a problem. Moreover, a Revit engineered dxf file does not comply with the requirements for dxf import as described in section 3.2 (the exported dxf file does not contain building components in the required closed polylines form). To be able to use the generated dxf file for Antherm, manual postprocessing via a CAD-environment such as AutoCad (Autodesk, n.d.) is required. Fig. 6 illustrates the adjustment process in AutoCad (deleting unnecessary lines and hatches, conversion of boundaries to closed polylines).

In ArchiCad a section (cut) plane has to be defined, similar to the Revit case. The generation of "Detail" views, considering the required dimensions and scale of such sections tailored for thermal bridge simulation assessment, can be performed with ease. Moreover, in its current version Archicad features an elaborated import/export settings wizard, which allows customizing the properties of the exported files. However, similar as in Revit, it is not possible to automatically generate a dxf comprising closed polylines as required for Antherm. While Revit requires the detour via a CAD environment, it is possible to manually modify the detail drawing in ArchiCad, so that an exported dxf is already compliant for import in Antherm.

Regarding the import in the Antherm environment, it is possible to instruct the tool to distinguish between different materials based on Layer name, on Line color, or on Line type, allowing a wide range of different drafting styles being successfully transferred to Antherm. A certain amount of post processing in Antherm – no matter how good or bad a dxf file is prepared – will be required. This is due to the fact that – as already mentioned – the dxf file cannot transport semantic information, such as the thermal building material properties. Therefore, these properties require a manual data entry, even if they were set correctly in the BIM environments. Moreover, the setup of space cells (adjunct boundary conditions for the thermal bridge simulation) needs to be performed, as this is not foreseen in any of the BIM environments.

Given the requirement for manual post processing in Antherm, it seems feasible – out of practical reasons – to generate layers based on the different materials in the imported dxf files. Moreover, if layers are named with appropriate and clear names, the later assignment of thermal properties (manual or from the material database integrated in AnTherm) can be facilitated.

Fig. 7 summarizes the data transfer via the dxf format from Revit and ArchiCad to Antherm.

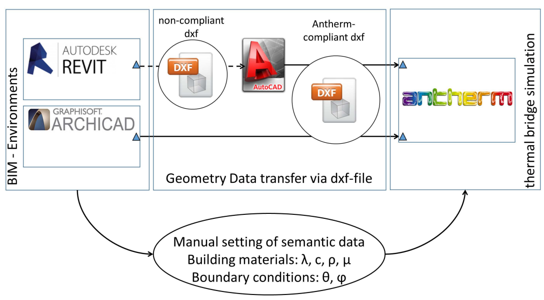


Fig. 7 – Illustration of the principal data transfer process from BIM environments to the thermal bridge simulation via dxf format (triangles indicate required pre-/post-processing steps)

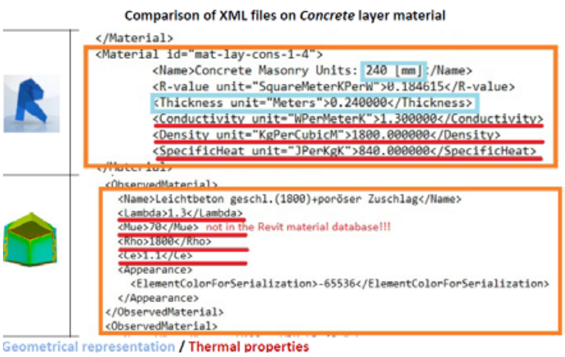


Fig. 8 – Example of xml-files generated by Revit and Antherm (concrete element)

4.2 Data Transfer via (gb)XML

Due to the fact that the common extended markup language schemes are supported both by the BIM environments and the used thermal bridge simulation tool, a data transfer via XML seems to be a viable solution at first sight. Indeed, the XML-file structure that can be read (and written) by Antherm encompasses a major portion of the gbXML file structure that can be read (and written) by the BIM environments (Fig. 8). However, a seamless data transfer from one XML structure to the other without a major effort in later postprocessing of the data is currently not possible. Third party mapping tools, such as Altova MapForce (Altova, 2016), might offer the possibility to map data from one scheme to another. However, some fundamental differences in the way data is stored would persist, such as the geometric definition of elements in one case (Revit gbXML) as extrusion width from a base plane, and in the other case (Antherm) as Cartesian coordinates. While technically a full data transfer from one scheme to another seems to be possible, the effort required is barely feasible. Moreover, this task can hardly be requested by the stakeholders involved in the building delivery process, as this would require the skills and knowledge of a software engineer (especially if data transfer routines are to be used generically).

5. A Potential Improvement for the dxf Data Transfer Approach

Both presented data transfer tracks show issues from a user perspective: The XML-approach in its current state does not allow a comprehensive data transfer. Therefore this approach cannot be used – until improved by the software engineers of either side of the transfer. Whereas the dxf-approach does show a set of weaknesses (the generation of dxf files requires cumbersome intermediate processing, no possibility to transfer semantic data), it can at least be utilized to transfer geometry information to Antherm. As the generation of building models is known to require the major portion of time in building performance simulation (Mahdavi and El-Bellahy, 2005), this can still be considered superior to manual (re)drafting of existing geometry in the simulation environment in terms of time and effort. However, the existence and utilization of databases with thermal material properties would allow a simple, but effective, "workaround" solution for the issue that dxf files cannot transport semantic data. This approach would only require little programming effort, and could reduce the post-processing time significantly. If both the BIM-environment (Revit or ArchiCad) and Antherm access the same material catalogues, the unique identifiers of the data lines within these catalogues could be utilized as part of the layer names in the dxf-format used for data transfer. Based on the unique ID of the material, the corresponding library entry could be searched within Antherm, and automatically assign found properties to all components on this layer. For instance, in ArchiCad and Antherm the material catalogue of the Austrian Standard 8110-7 (ASI, 2013) is integrated (amongst a large number of vendor provided catalogues). Therefore, such an improvement would only require a slight adaptation of the already existing "search and assign material" option within Antherm.

Even without the use of unique IDs of a database, e.g., if generic materials are used, the sketched approach could be beneficial. A regular search and find utility could suggest – assuming the corresponding layer in the dxf file is named appropriately – materials matching this name from the catalogue to the user, who then simply selects one of the data entries. In this way the time for the semantic enrichment of the model can be shortened. Fig. 9 illustrates this improvement suggestion.

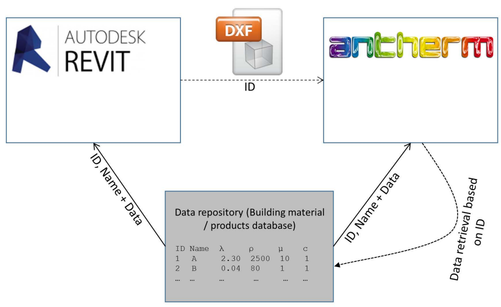


Fig. 9 – Scheme of improved data transfer via dxf format, including data retrieval via Unique ID from a shared database

6. Conclusion

The present contribution has shed some light on the current possibilities of data transfer between commonly used BIM environments and a state-of-the-art numeric bridge simulation tool. It was illustrated that the current data transfer procedures are far from satisfactory. Although the majority of data is already stored in the BIM environments, the data transfer to the simulation tool allows only the transfer of the geometry information in a reasonable form. Even for this transfer - to be successfully completed - a number of cumbersome pre- and post-processing steps are required. We illustrated a straightforward improvement suggestion, which could help to overcome some of the obstacles in data transfer to the thermal bridge simulation environment. Interestingly, the transfer between BIM environments and other building performance assessment tools, such as overall building performance simulation seem to work more conveniently than the transfer to thermal bridge simulation tools.

Future research and development efforts in the improvement of data transfer should encompass a fundamental model view definition (MVD) for the data transfer, which facilitates the implementation of data exchange routines for software engineers on the source (BIM tools) and target side (numeric thermal bridge simulation). Furthermore, the routines presented in this research contribution were checked on a generic base (other BIM-environments, other tools addressing thermal bridge issues). Moreover, as some important pieces of information can currently not be defined in the existing BIM environments (e.g. vapour diffusion resistances), respective integration in the workflow should be put on to the development agenda.

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