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Heating and Cooling Simulation using BIM in Norway

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Abstract

Building Information Modeling (BIM) is a platform with great potential to increase the efficiency of building design. A prominent feasibility to increase the efficiency, and potentially the quality, of HVAC design is to use calculation applications implemented in the BIM-based design tools. The purpose of this paper is to investigate if the design tools with BIM facilities, which already commonly are used in design of HVAC systems, can be applied to carry out heating and cooling calculation at room level and to evaluate the quality of such calculations. Heating and cooling calculations were conducted using the following programs: Revit MEP, MagiCAD Comfort and Energy and IDA ICE. Additionally, heating calculations were carried out using NS-EN 12831 as a reference. The calculation model is based on two open plan offices located in Oslo, Norway. The investigation indicates that the calculation applications within the evaluated BIM based design tools are in positive progress, but there are still some limitations with respect to utilizing the tools in the design of HVAC systems. Generally, the study suggest that even though heating and cooling calculations are more easily accessible when using BIM-based design tool, it is even more important that HVAC engineers are the one conducting and controlling the calculations and its results. This is due to the simplifications in the input and output data and the complexity in the calculation methods. If HVAC engineers are not the one doing the calculations, there is a great risk of making design errors when designing HVAC system.

Keywords - BIM, heating, cooling, calculation, comparison

1. Introduction

Building Information Modeling (BIM) is a platform with great potential to increase the efficiency in building design. With respect to HVAC design, a prominent feasibility to increase the efficiency, and potentially the quality, is to use calculation applications implemented in the BIM-based design tools.

Heating and cooling calculations are essential in the design of HVAC systems. Still, according to our experience, consulting engineers in Norway normally carry out these calculations either by hand or by utilizing simulation tools. These approaches might be rather inefficient and time consuming among other things, because the designer needs to manually

gather the necessary information to carry out such calculations, i.e. measuring room areas and volumes and request information regarding key parameters like U-values, surface materials, supply air etc. BIM-based design tools already contain most of the information needed to carry out these calculations. Consequently, utilization of calculation applications in these tools may minimize the risk of errors related to gathering the input parameters and improve the efficiency of the HVAC design.

BIM-based tools, like Revit and MagiCAD, are already widely used in Norwegian building design projects. Applications for heating and cooling simulations have been available within both of these tools for several years. However, earlier investigation carried out internally at Erichsen & Horgen have indicated considerable limitations of such applications both compared to conventional indoor environmental simulation tools and to the calculation method described in the Norwegian Standard NS-EN 12831:2003 [1].

The purpose of this paper is to investigate if the applications, within BIM based tools, at the present time can be used to carry out heating and cooling calculation at room level. Further, the investigation evaluates the quality of such calculations to assess if they are sufficiently accurate to be used as a basis for HVAC design according to Norwegian standards.

2. Software tools

Even though the potential of utilizing BIM-based tools might be great, it is important to notice the drawbacks using these applications. The greatest drawbacks of these applications are that the calculation model is not nearly as sophisticated as the conventional simulation tools and the focus on further developing the applications is not on the same level as developing the conventional simulation tools. This is of course due to the fact that the main focus in the BIM tools is to design HVAC systems, not to perform these calculations.

The following sections introduces briefly the BIM based tools used in the investigation, including the greatest limitations when conducting heating and cooling simulations.

2.1 Revit MEP

Autodesk is the developer of Revit MEP 2015 (build 20140606_1530 update Release 3). The software allows HVAC engineers to design HVAC system in 3D and to apply information to the HVAC system. Revit MEP is compatible with Revit Architecture and allows the users to share models and thereby neglects the need for developing a separate simulation model. Even though it is possible to use a Revit model directly, it is important to verify the quality of the model and to verify that the boundary conditions are correct. The time consumption for developing simulation models are not completely removed, but greatly reduced.

When investigating heating and cooling simulation applications in Revit MEP, the following limitations were discovered:

- Default outdoor temperature wintertime is -17 °C. The correct temperature for Oslo climate is -20 °C [2]
- Heat loss from mechanical ventilation is not possible to include
- Thermal bridges are not included
- Infiltration is limited to four predefined levels. It is not possible for the user to specify arbitrary infiltration levels.
- External wall area outside slabs are not included in the exterior facade area
- Heat loss through internal slabs are not included
- Solar shading is not included
- It is not possible to include night time ventilation
- Min. resolution of internal heat loads are 1 h
- The result shows only the design values
- Great limitations in the range of the output parameters

2.2 MagiCAD Comfort & Energy

MagiCAD Comfort and Energy combines MagiCAD Room and Riuska. Even though it is possible to conduct heating calculations in Room, it is mainly used to build up the simulation model and Riuska is the calculation engine. The simulation model transfers from Room to Riuska using IFC as platform.

Riuska is developed by Granlund OY in Finland in collaboration with the developers of the DOE program, Lawrence Berkeley National Laboratory. In Riuska it is possible to execute dynamic indoor environmental and energy simulation. In this investigation Riuska ver. 4.9.43 and MagiCAD Room ver. 2014.11 are used.

When investigating heating and cooling simulation in MagiCAD Comfort and Energy, the following limitations were discovered:

- External wall area outside slabs are not included in the exterior wall area
- Heat loss calculation in Room does not contain thermal bridges
- Heat loss calculation in Riuska does not contain heat loss from the mechanical ventilation system
- Min. resolution of internal heat loads in Riuska when conducting cooling simulation is 1 h
- Great limitations in the range of the output parameters

2.3 IDA ICE

IDA ICE (Indoor Climate and Energy) ver. 4.6.2 is a multizone simulation tool for investigating indoor environment and energy in buildings. The developer of the program is Equa Simulation AB.

It is possible to use IDA ICE to document the indoor environment and energy use according to e.g. BREEAM and LEED. Our experience is that consulting engineers in Norway mainly uses IDA ICE to perform indoor environment simulations, but can also perform energy and heating calculations.

Compared to the other software tools, all the simulations made by IDA ICE are dynamic including the heating calculation. Beside the missing external wall area outside slabs, IDA ICE does not have the same limitations as Revit MEP and MagiCAD Comfort and Energy. This is due to the fact that IDA ICE is a more sophisticated simulation tools and are to be compared to software tools like IES-VE, BSim, etc.

2.4 Calculation by Hand

The Norwegian standard NS-EN 12831 [1] contains methods both for calculation of design heat load at room level and at building level.

The calculation method described in the standard ensures that HVAC engineers designs heating systems in buildings according to the Building Regulations in Norway. It has not been develop a specific software tool in Norway using the calculation method in 12831, but local spreadsheets containing the method are widely used by HVAC engineers.

The investigation contains no cooling calculations made by hand because it exists no standard for performing cooling simulations in Norway.

3. Methodoly

This study is based on an ongoing building project located in Oslo (59.55° N, 10.45° E) Two rooms in the building are included in the investigation, both open plan offices. The rooms have challenging boundary conditions e.g. large window areas, external solar shading and low temperature in adjoining rooms. Fig. 1 shows a 3D visualization of the BIM model and location of the rooms used in the investigation. Table 1 summarizes key parameters of the building model. Surface materials are (floor/ceiling/wall) wood/gypsum/gypsum.

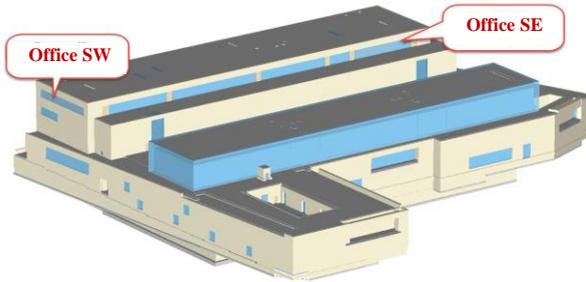


Fig. 1 3D visualization of the BIM model and location of the offices used in the investigation.

Table 1 Key parameters

		Office SE	Office SW
Orientation		SE	SW
Floor area	[m ²]	175	205
Window area	[m ²]	52.9	60
Door area	[m ²]	5.6	6.8
Room height	[m]	3.25	
Ceiling height	[m]	1.25	
Min. op. temp.	[°C]	20	
Max. op. temp.	[°C]	26	
Infiltration n ₅₀	[h ⁻¹]	0.6	
Thermal bridges	[W/m ² K]	0.03	
U _{External wall}	[W/m ² K]	0.18	
U _{wall,air intake}	[W/m ² K]	0.4	
U _{Roof}	[W/m ² K]	0.12	
U _{floor}	[W/m ² K]	0.5	
U _{win}	[W/m ² K]	0.8	
U _{door}	[W/m ² K]	1.5	
Min. airflow	[m ³ /m ² h]	3.6	
Supply air temp.	[°C]	19	
Temp. cold rooms	[°C]	14	
g _{glass}	[-]	0.35	
g _{glass+shading}	[-]	0.05	
τ _{glass}	[-]	0.30	
τ _{glass+shading}	[-]	0.03	
Heat load occupants	[W/m ²]	11.4	
Heat load equipment	[W/m ²]	20	
Heat load lighting	[W/m ²]	8	
Operation hours		8:00-17:00	

Fig. 2 visualizes the schedule for internal gains from equipment and occupants over a day.

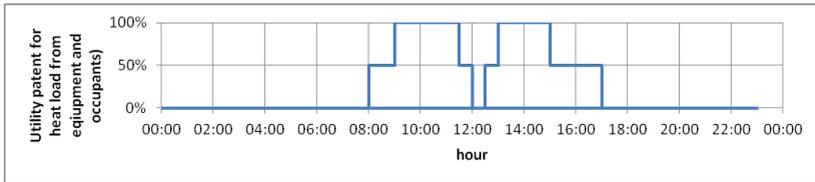


Fig. 2 Schedule related to the heat load from equipment and occupants through out a day.

External vertical solar radiation controls the solar shading and activates when the solar radiation exceeds 180 W/m^2 . The operation of the ventilation system includes the use of night time ventilation i.e. the cooling coil in the ventilation unit is bypassed during night time, when the operative temperature inside the office exceeds $22 \text{ }^\circ\text{C}$.

The building contains some cold rooms with air temperature of $14 \text{ }^\circ\text{C}$. These rooms are located on the floor below the open plan offices and are in the following referred to as “cold rooms”. In addition to this, an air intake is located next to office SE.

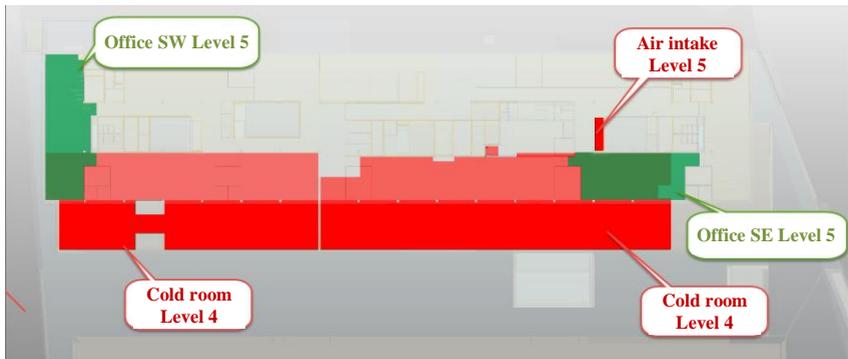


Fig. 3 Location of the cold rooms and the air intake.

4. Results Heat Loss Calculation

Fig. 4 visualizes a comparison of heating demand results from the different calculations tools. Comparing the heat losses, the results show rather good agreement between NS 12831, IDA ICE, MagiCAD Room and Riuska. However, the heating demand calculated by Room and Riuska are slightly lower than NS 12831 and IDA ICE. This is due to the fact that Room

does not include heat loss by thermal bridges and Riuska does not include heat loss by the mechanical ventilation system. These limitations in Room and Riuska results in a deviation for the total heat loss of approximately 10 % compares to NS 12831.

Comparing the total heat loss calculated using Revit MEP, shows a deviation of approximately 20 % compared to NS 12831. This is due to a great number of limitations in the calculation application, as described in section 2.1.

When comparing the heat loss by transmittance through the roof, windows and walls, all the tools performs well. The deviations occur when calculating more unusual heat losses like internal heat losses, heat loss by thermal bridges and infiltration.

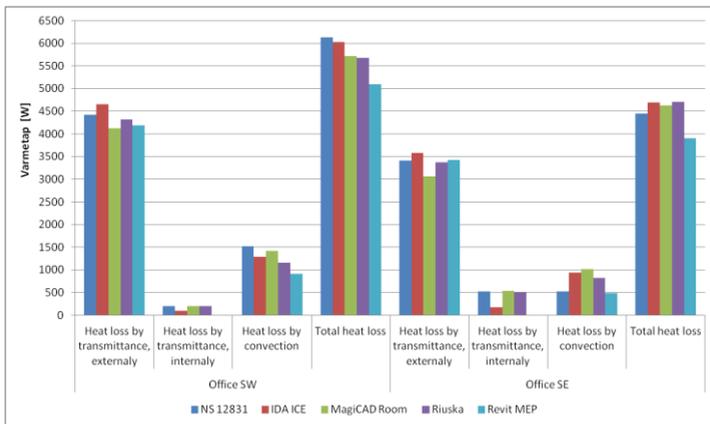


Fig. 4 Comparison of the results for heating load simulations.

Another important feature is the possibility to evaluate the calculation results when using the tools. IDA ICE excels as the most sophisticated tool. In IDA ICE, it is possible to log and show all calculated parameters contrary the other software tools, which only shows predefined parameters.

The greatest challenges when using software tools in order to perform heat loss calculations compared to calculation made by hand according to NS-EN 12831 are summarized in the following bullet points.

- External wall area outside slabs is not included in the exterior wall area
- Great limitations in the input parameters for the different software tools
- Calculation of heat loss by infiltration according to NS-EN 12831 includes different levels of urban location. No software tools, except IDA ICE, consider this
- The ability to evaluate the results

Table 2 summarizes evaluated quality of important parameters in heat loss calculations for BIM based design tools compared to NS-EN 12831. It is assessed that heat loss calculation in IDA ICE are compatible with calculations according to NS-EN 12831. MagiCAD Room and Riuska do have some limitations and designers utilizing these tools have to be aware of these limitations in order to interpret the results correctly. It is assessed that Revit MEP holds too many limitations for performing heat loss calculation according to Norwegian standards.

Table 2 Assessment of key parameters when performing heat load calculation in Norway. Green equals “satisfactory”, yellow equals “some limitations” and red equals ”not satisfactory”

	IDA ICE	MagiCAD Room	Riuska	Revit MEP
Common heat loss by transmittance (wall, window and roof)	Green	Green	Green	Green
Thermal bridges	Green	Red	Green	Red
Heat loss by transmittance, internally	Green	Green	Green	Yellow
Heat loss, mech. ventilation	Green	Green	Red	Red
Infiltration	Green	Green	Green	Yellow
Heat loss through the ground	Not tested			
Assessment for use in Norway	Green	Yellow	Yellow	Red

5. Results Cooling Load

Fig. 5 contains a comparison of the total cooling demand using the different BIM-based tools. The results demonstrate good agreement between IDA ICE and MagiCAD Comfort and Energy. The lack of external solar shading in Revit MEP causes the large deviation shown in the comparison. The open plan offices contain large window areas and the solar radiation on the windows is considerable. Therefore, models that do not account for solar shading do not have the ability to calculate cooling demand satisfactory.

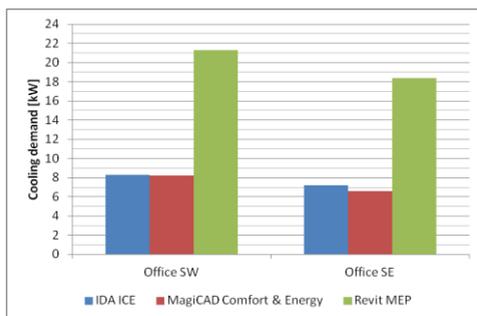


Fig. 5 Comparison of the results for the cooling demand simulations.

Similar to what was seen for the heat loss calculations, a great lack of output parameters were also discovered for the cooling demand calculations, especially when using Revit MEP. This means that it may be difficult to control and verify the calculation results. The greatest challenges when using applications in BIM compatible tools are summarized in the following.

- Limitations in the schedule for equipment and occupants
- Possibility to include night time ventilation
- No solar shadings are available in Revit MEP
- Only predefined solar shading control strategies can be used in MagiCAD Comfort and Energy
- Quality assessment of the calculation results can be challenging I Revit MEP and MagiCAD Comfort and Energy, due to lack of variability in the output parameters.

Assessment of key parameteres are summarized in table 3. It is considered that even though MagiCAD Comfort and Energy do have some limitations related to the intern heat loads, the software tool perform satisfactory compared to IDA ICE for relatively simple cooling calculations. Revit MEP, on the other hand, is assessed to be unapplicable for cooling load calculations due to a great number of limitations.

Table 3 Assessment of key parameters when performing cooling demand calculations in Norway. Green equals “satisfactory”, yellow equals “some limitations” and red equals “not satisfactory”.

	IDA ICE	MagiCAD Comfort & Energy	Revit MEP
Climate			
Solar shading			
Internal heat loads			
Night time ventilation			
Cooling by ventilation			
Assessment for use in Norway			

6. Conclusions

The purpose of this paper was to investigate if the design tools with BIM facilities, which already are commonly used in design of HVAC systems, can be applied to carry out heating and cooling calculation at room level. Further, it was an aim to evaluate the quality of such calculations according to Norwegian standards. The investigation included the following software tools: Revit MEP, MagiCAD Comfort & Energy and IDA ICE. The investigation of heat loss calculation used the Norwegian standard NS-EN 12831 as a reference for the calculations. Since no national standard for

calculation cooling load exists the investigation of the cooling load calculation used results from the sophisticated tool IDA ICE as a reference.

The study indicates that the calculation applications within the evaluated BIM based design tools are in positive progress compared to results from an earlier internal investigation at Erichsen & Horgen, but there are still some limitations with respect to utilizing the tools in the design of HVAC systems. Concerning the heating calculation, the greatest limitations are found in relation to the external wall area, thermal bridges, heat loss to the mechanical ventilation system and internal heat losses. Concerning the cooling calculation, the limitations are regarded the use of solar shading, internal heat load, mechanical ventilation system and the limitations in options for analyzing the results.

Generally, the study suggest that even though heating and cooling calculations are more easily accessible when using BIM-based design tool, it is still important that HVAC engineers are the one conducting and controlling the calculations and its results. This is due to the importance of understanding the simplifications of input and output data and the underlying complexity in the calculation methods used in the BIM-based tools. If the physical understanding for these calculations and their associated simplifications are missing, there is a great risk of making mistakes in the calculation and thus design errors when designing HVAC system.

Acknowledgment

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