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Connecting BIM and LCA: The Case Study of an Experimental Residential Building

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Connecting BIM and LCA: The Case Study of an Experimental Residential Building

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Abstract. The aim of this paper is to present application of BIM models for the complex quality assessment and environmental analysis based on LCA. An experimental two storey building of TiCo Project representing a full scale part of a real multi-storey residential building has been used for this case study. The presented BIM model contains all relevant environmental characteristics and it will be used for environmental analysis, coordination, and operation (e.g. real-time data analysis from the sensors). Theoretical part covers development of the methodology for data transfer from BIM model to assessment scheme based on SBToolCZ, which is a national tool for building sustainability certification in the Czech Republic. Next step will be focused on describing connection of LCA and the BIM model databases and mapping data between them. Case study is focused on utilisation of BIM model with all relevant environmental characteristics for LCA analysis. All changes during construction phase and their impact on environmental analysis and LCA will be monitored and assessed.

1 Introduction

1.1 Current situation at the BIM market

Building Information Modeling (BIM) has already been widely spread and established during last couple of years at the European markets [1] [2] as well as in the Czech Republic. Markets and legislation start to be mature and ready for the BIM. In the most developed countries there is a plan of implementing BIM on the national level. For example in the Czech Republic the usage of BIM is mandatory from 2022 for the over-limit public tenders financed by the Public sector [3]. Although mentioned data [1] [2] seems positive, it is necessary to dive deeper into data. Study from the Boston Consulting Group (BCG) [4] company points out fact that with revenue of almost \$10 trillion (6%) of global GDP makes AEC industry of Architecture, Engineering and Construction (AEC) one of the most important.

Another study of the McKinsey&Company [5] points out that “the world will need to spend \$57 trillion on infrastructure by 2030 to keep up with global GDP growth” and also presents 5 trends which will shape construction and capital projects. Three of those trends directly contain the BIM technology (Next-generation 5-D BIM, Digital collaboration and mobility and The Internet of Things and advanced analytics respectively). The same document also says that the Construction industry is currently one of the least digitalized industries ever (worse position in the digitalization has only Agriculture and hunting).

Next important topic for further development is Facility Management (FM) perspective which also has high impact to the environment. Review of 3 Case Studies [6] from the Czech market summarizes current market development and shows possibilities of future focus.

All mentioned analyses bring us to the conclusion that AEC industry needs a real evolution and BIM is one of the key factors on the way of digitalization.



2 Theoretical Part

2.1 *BIM and LCA*

Important chapter which is not yet entirely described is implementation of environmental parameters into the BIM model. This topic is widely discussed across the industry, on many various platforms e.g. Annex 72, working group under the International Energy Agency's Energy in Buildings and Communities Programme [6].

The key part always related to the model is its detail. In terms of BIM there is widely used term Level of Development (LOD) [7], standard developed by the BIMFORUM [8], the non-profit organization consists of The Associated General Contractors of America (AGC), The American Institute of Architects (AIA) and American Institute of Steel Construction and its also part of the BuildingSMART¹, the international organization developing international standards related to BIM (e.g. openBIM, Data Dictionary or data exchanging format The Industry Foundation Classes (IFC)).

The LOD in terms of incorporating environmental data can be divided in two parts:

2.2 *Aggregated Data Method*

Simplified method of modeling which can be widely used for comparing different material bases (e.g. load bearing system, façade etc.). The model follows LOD 200-300 and environmental data are aggregated according the whole structure (e.g. environmental values for timber wall with inserted insulation between studs is recalculated according volume of all parts). Elements which are not in the model (e.g. hangers, veneers etc.) are neglected.

2.3 *Element Data Method*

Detailed method of modeling which can be used for precise calculation of building's environmental impact. The model itself has to be developed in LOD 350-400 which means that it contains detailed geometrical data of the building (e.g. concrete rebar, wall studs, veneers etc.). This method is highly accurate but also time consuming. It is also necessary to keep a wide database of environmental data of used materials. Due to high detail of the model there is only minor elements neglected.

2.4 *SBToolCZ*

SBToolCZ is a Czech national sustainability certification scheme similar to BREEAM or LEED with focus to Czech building industry and standards. It is applicable for residential buildings, offices, schools and kindergardens. It is based on complex evaluation of environmental, social, economic and location-related quantitative and qualitative indicators. The received scores from each indicator are normalized and weighted, and the resulting score is translated into bronze, silver or gold certificate, which is awarded by independent certification bodies [9]. Schema of the SBToolCZ and its connecting with BIM models will be used in the future research.

3 Case Study

3.1 *The Case Study Description*

The main project objective is to develop a flexible construction system for a new generation of multifamily residential buildings capitalizing on synergy of non-bearing light timber-based structures and with a light bearing structures from high performance concrete with maximal utilization of advanced prefabrication technologies. The structural system from high performance concrete is characterized by a high bearing capacity, long lifetime, fire resistance, and favorable acoustic and heat accumulation parameters.

Timber-based structures guarantee a low carbon footprint of production, lower weight, and excellent thermal insulation of building envelope. Key issues that project addresses are development and

¹ <https://www.buildingsmart.org/>

optimization of both types of structures, their interfaces and coordination of prefabricated production of the elements and concerted fast assembly on site. Optimization in terms of environmental impacts, energy efficiency and economic feasibility is also part of the project. Load bearing system from high performance concrete and non-bearing timber-based elements will be produced and its function will be tested per parts on special research equipment at UCEEB CTU and as a whole on a small experimental structure. Based on experience from pilot the design of all elements will be improved and verified by production of prototypes. The experimental building will be built in spring 2019 at University Centre for Energy Efficient Building (UCEEB) of Czech Technical University (CTU) in Prague. The resulting building system will become a part of portfolio of RD Rýmařov, which will sell it to developers of residential buildings in Central Europe.

3.2 The BIM Model

The digital model itself has been developed in software Autodesk Revit. This software has been chosen according to the internal research which confirmed it as a leading product of the BIM world with the most advanced tools for many different trades and stakeholders on AEC market.

The case study consists of the following tasks:

- Design model in LOD 300 with applied Aggregated Data Method (described in 2.2),
- Construction Model in LOD 400 with applied Element Data Method (described in 2.3),
- As-built model in LOD 500 with incorporated all parameters needed for Facility Management (FM),
- Dashboard showing real-time data from the incorporated sensors.



Figure 1 – Project visualization and the BIM model

Current situation described in previous section creates a perfect condition for creating the “Real BIM model” which contains all related data important for design, construction and operational phase of the project. Thanks to the TiCo project the real building will be built anyway. With the current market situation and proper knowledge there is a room for this Case Study.

3.3 Current status of the model

Currently the model is developed in LOD 300-350 and it contains all the relevant structures with relevant environmental data: Primary Energy Input [MJ] and Global Warming Potential [kg CO₂,ekv]. The environmental data has been taken out of the Envimat² database, the Czech catalogue of the environmental parameters of building materials.

<http://www.envimat.cz/>

Material: Comments	Material: Volume [m ³]	Material: Area [m ²]	Material: PRIMARY ENERGY INPUT - [MJ/m ³]	PEI Total [MJ]	Material: GLOBAL WARMING POTENTIAL - GWP [PEI CO ₂ ekv,/m ³]	GWP Total [kg CO ₂ ,ekv]
CONCRETE	20.01	53	1211	24227	203.0	4061
CONCRETE - REINFORCED	85.48	468	6866	586933	712.0	60865
HIGH PERFORMANCE CONCRETE	13.26	101	6866	91036	712.0	9440
TIMBER STRUCTURE + MINERAL WOOL	65.98	611	1559	102866	119.0	7852
TIMBER STRUCTURE + GLASS WOOL	15.68	199	1718	26931	110.0	1724
TIMBER STRUCTURE 60/40; 420mm + AIR GAP	4.36	109	116	506	8.0	35
GYPSUM FIBREBOARD	22.12	1265	4465	98758	392.0	8670
HYDROIZOLATION	0.17	116	92964	16184	3377.0	588
BRICK VENEER	0.71	101	19861	14092	1480.0	1050
STEEL	0.08	24	189700	15746	17146.8	1423
GLASS	2.76	100	442	1218	36.0	99
THERMAL INSULATION - WOODENFIBRE	4.06	90	3682	14948	149.0	605
THERMAL INSULATION - EPS - FAÇADE	15.56	104	1903	29605	83.0	1291
THERMAL INSULATION - EPS - FLOOR	11.17	111	2365	26426	104.0	1162
THERMAL INSULATION - EPS - ROOF	37.25	116	2880	107279	126.0	4693
THERMAL INSULATION - XPS	0.86	17	3463	2989	138.0	119
SUM	299.51			1159744		103679

Figure 2 - Environmental impact of the building elements

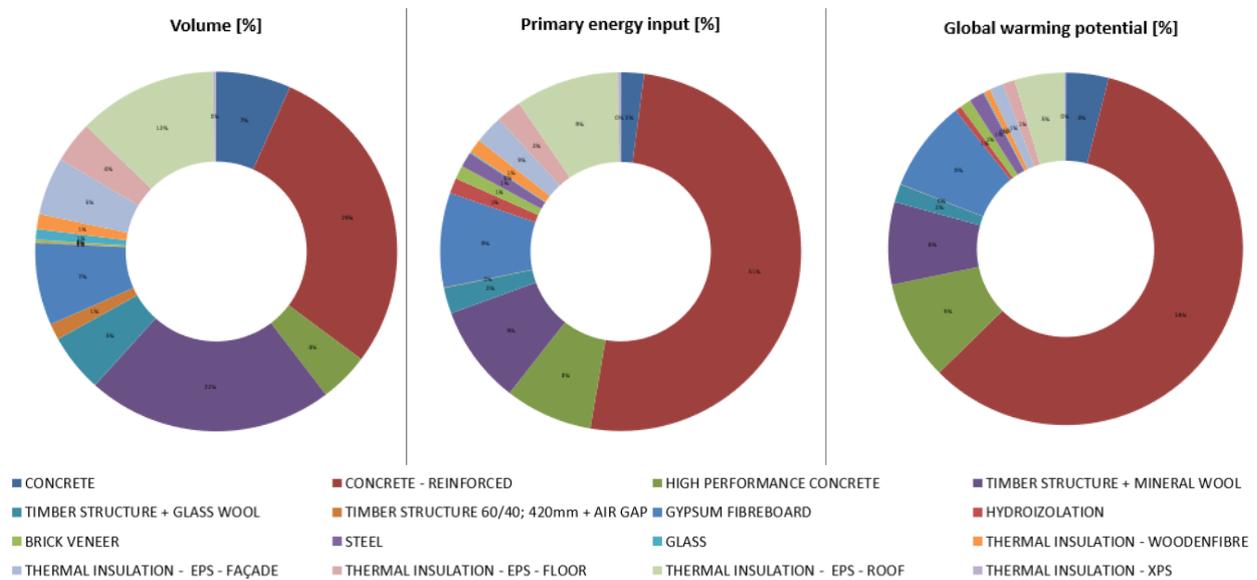


Figure 3 - Environmental data of the model

3.4 Challenges of digital model

During the modeling the team has always dealt with the following obstacles:

- Quality of the model and its LOD,
- Environmental data quality and consistency,
- Software limitations (e.g. volume deviation)..

The idea of this project part is to implement all the related data important for the operational project phase. Due to delay of construction phase this part has not been implemented yet.

4 Conclusion and the future focus

Experimental building TiCo has not been erected by the time of writing this paper yet, so only the Design Model with Aggregated Data Method of implementing the environmental data is applied. This method confirmed a wide benefit of using BIM for similar purposes because it allows simple comparison of different material bases.

Even though there are several lessons learned applicable for each project:

- Incorporating the basic environmental data is a simple process which can be replicable.
- Missing methodology and legislation describes the process of implementing environmental data into the BIM model.

4.1 Future Focus

- Incorporate the sensors data into the BIM model.
- Follow the SBToolCZ scheme and incorporate all environmental data into the BIM model.
- Create the methodology which allows replicability of gained knowledge across the market.

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