The role of international student workshops in the process of educating architects - *Integrated Energy Design*

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ABSTRACT: Students now beginning their study of architecture are going to enter the job market when buildings *with an almost zero energy consumption* are going to be the required standard. Buildings with such high energy efficiency need to be designed in an appropriate manner; namely, with the use of BIM-standard software, in combination with the use of appropriate programs to perform energy simulations. Current curricula at architecture faculties in Poland do not include the teaching of design in accordance with the BIM standard along with elements of the so-called integrated energy design. If one does not change this state of affairs, then students who are currently undergoing education as architects are soon going to enter the job market without being properly prepared to practice their profession. The student exchange between the Faculty of Architecture from Kraków and the Lycée Le Corbusier in Strasbourg, France, has been arranged for the last five years. During the student exchange, a cycle of theoretical classes is taught on the subject of designing buildings that have a high energy efficiency. The theoretical classes are supplemented by the *Integrated Energy Design* design workshop. The article explains the role of international student workshops, the exchange of thought, teaching methods and experiences in the process of educating future architects.

Keywords: Almost zero energy consumption, BIM-standard software, energy simulations, integrated energy design

INTRODUCTION

A student exchange between the Faculty of Architecture of Cracow University of Technology and the Lycée Le Corbusier in Strasbourg, France, has been arranged for the last five years [1]. A cycle of theoretical classes is taught during the exchange on the subject of building construction, materials science, architectural and construction design, as well as the design of buildings with a high energy efficiency. The theoretical classes are supplemented by the *Integrated Energy Design* workshop.

The programme can be divided into two main parts.

The first part, described in the publication by Jagiełło-Kowalczyk, includes theoretical classes to familiarise participants with basic materials and construction technologies, visits to the construction sites of housing estates and design workshops featuring the development of a preliminary conceptual design [1].

The second part, which is described in this article, is focused on designing buildings with a high energy efficiency. It features the following topics:

1. Theoretical classes at the civil engineering faculty of *Genie Civil*, focused on the design of energy efficient buildings.
2. A tour of production plants that specialise in technologies that facilitate energy efficiency.
3. Workshops on BIM-standard compliant architectural and construction design.
4. Workshops on integrated energy design and energy efficiency simulations.

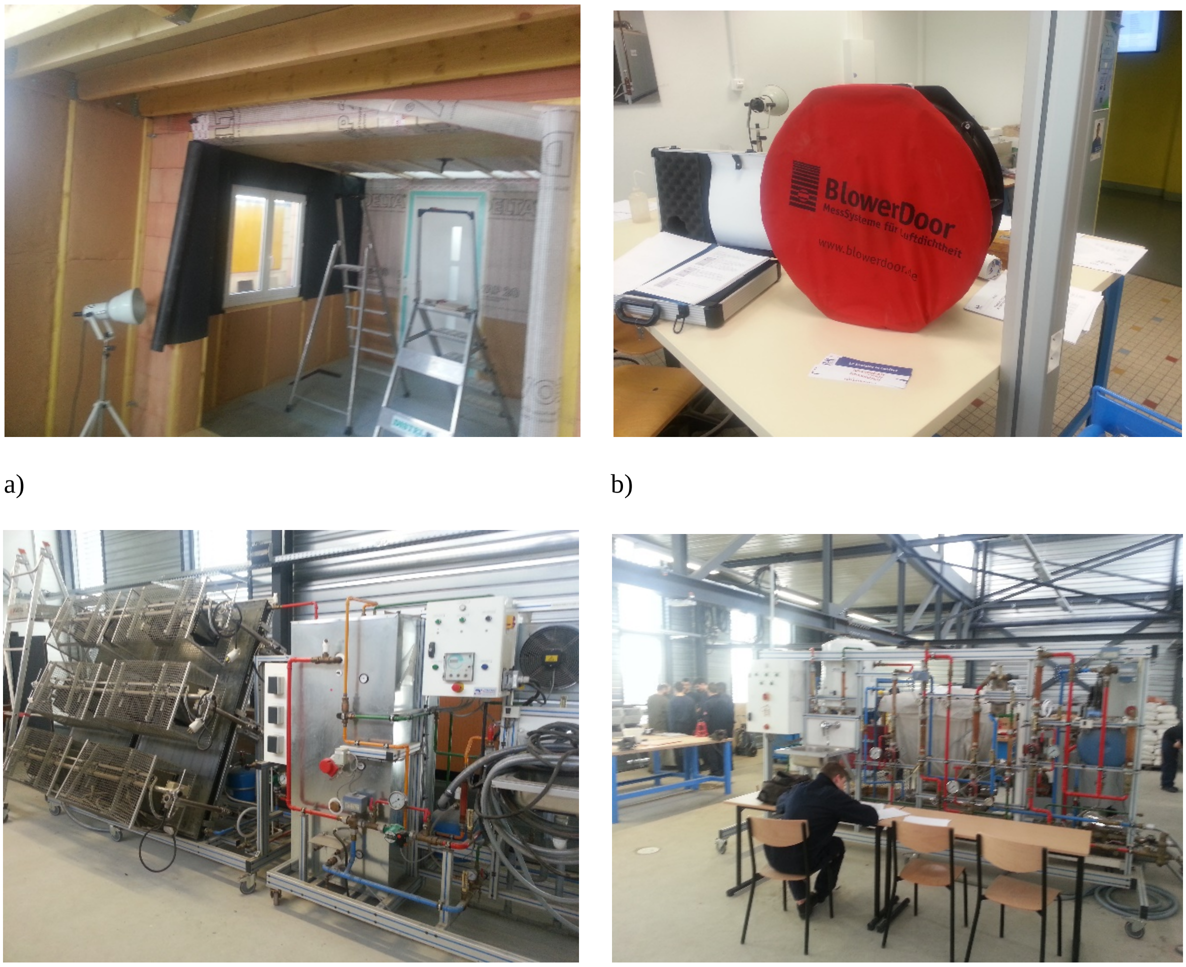
THEORETICAL CLASSES AT THE FACULTY OF CIVIL ENGINEERING OF *GENIE CIVIL*

Education at the Lycée Le Corbusier, where the first part of theoretical classes takes place, does not include carrying out scientific research and, thus, does not include the development of new solutions, but the practical and highly professional use of the current state-of-the-art of technologies, material, systems, etc. As a result, graduates are able to use all the characteristic, modern construction materials, technologies, infrastructural systems and fittings of buildings that are available on the French market.

The second-stage studies feature university level education, which is associated with the sphere of research. The University Faculty of Civil Engineering of the *Genie Civil* differs from schools of the lower tier, like the Lycée Le Corbusier, in that it is not focused solely on the implementation of existing materials and technologies, but rather on the search for new and innovative solutions.

Students from Poland have the opportunity to see the construction materials and energy efficiency technology laboratory at the start of their classes at the Faculty of the *Genie Civil*. Its collection of construction materials includes both existing and newly designed energy efficient construction systems. They are supplemented by such elements like isothermal load-bearing elements, which prevent the formation of linear thermal bridges between the tie-beams of floor slabs and the cantilevered floor slabs of balconies.

Students show a lot of interest in the model of a building adapted to the carrying out of tests of air tightness using the *blower door* machine, as well as to the testing of thermal insulation parameters of external walls with various alternative thermal insulation solutions. Equally high interest has been shown in the research station that tests the energy efficiency of various configurations of thermal pumps, coupled with ground thermal ventilation air exchangers and recuperators [2].



a) b)

c) d)

Figure 1: The *Genie Civil* Faculty laboratory; a) the model of a building for testing air tightness and the thermal insulation of partitions; b) the blower door machine used to perform air tightness tests on a building; c) research station for the verification of the efficiency of a set of solar collectors; and d) research station for analysing various configurations of installation equipment.

The second part of the classes at the *Genie Civil* Faculty are held in a hall used to perform various types of experiments. One of the more interesting research stations is a model of the structure of a steel storehouse, which can be used to simulate the effect of wind on the structure, and preliminary design assumptions can be properly corrected. This is thanks to a special system of lines and weights. Subsequent, varied research stations make it possible to test the strength of structural solutions in various alternative configurations.

Classes at the Faculty of *Genie Civil* supplement earlier classes at the Lycée Le Corbusier by touching on the aspect of research. They allow the students who participate in them to become aware that modern architectural and construction design is not solely based on standard existing solutions, but also on searching for innovative new ones - that have never been implemented before and that expand the current state-of-the-art in terms of practical knowledge by using prototype solutions.

a) b)

Figure 2: Research station used to perform experiments at the Faculty of *Genie Civil*: a) station for analysing wind load and suction exerted on the structure of a steel hall; and b) station for analysing the strength of concrete beams featuring various rebar layouts.

TOURING PRODUCTION PLANTS SPECIALISING IN TECHNOLOGIES THAT FACILITATE ENERGY EFFICIENCY

Students who participate in the design workshop in Strasbourg have the opportunity to take part in a tour of the Schöck company production plant [3], which has its headquarters on the German side, around 50 km from Strasbourg, in Baden Baden. Schöck specialises in the production of construction components recommended for energy efficient buildings. The flag product of the company is a set of isothermal load-bearing components called Schöck Isokorb, designed for various applications. These isothermal load-bearing components can be used to fasten the external elements of a structure in a manner that does not lead to the breaching of the thermal insulation layer of a building’s envelope.

The most distinct isothermal load-bearing components are meant for use in the assembly of cantilevered floor slabs of balconies. They allow the concrete slab to be moved away from the tie-beam of an interior floor slab by a distance equal to the thickness of the thermal insulation layer. Their structure is based on the use of stainless steel rods in the upper section, which, after being connected to the upper segment of a balcony slab’s rebar, transmit tensile loads, while in the lower part features tiles that absorb compressive loads. The opportunity to see the production and quality assurance control cycle of these isothermal load-bearing elements has turned out to be the best form of getting to understand the principles of operation and the boundary limits of these elements. Tests featuring the tearing of the upper bars show just how immense the forces arising from the torque are of a heavy, cantilever-supported reinforced concrete slab acting on the load-bearing elements.

Figure 3: Isothermal load-bearing element supporting a cantilevered balcony floor slab.

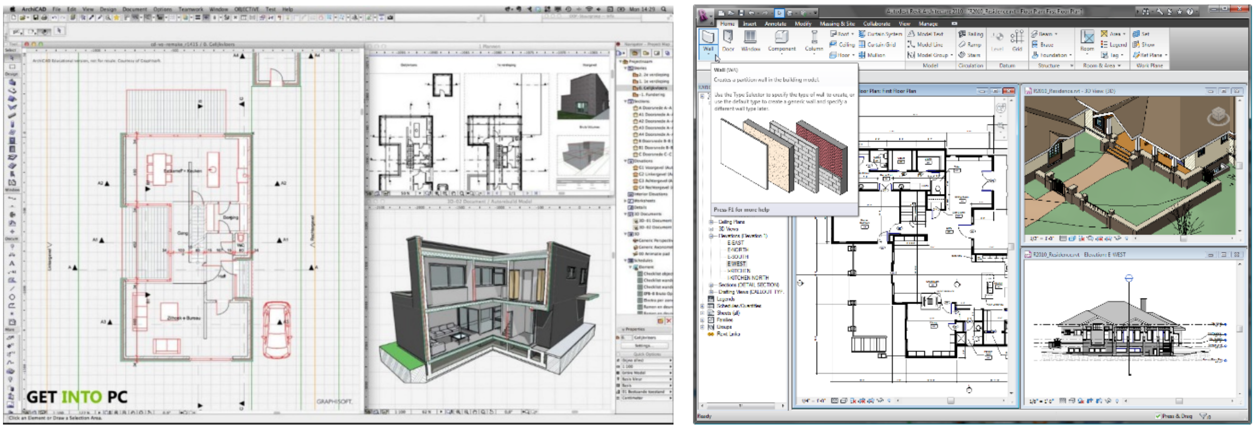
WORKSHOPS ON BIM-STANDARD COMPLIANT ARCHITECTURAL AND CONSTRUCTION DESIGN

The second stage of design work is composed of transferring the virtual model of a building into a BIM (building information modelling) design program [4]. The students can choose from ARCHICAD by GRAPHISOFT [5], and Autodesk Revit by Autodesk, as these are the two main and most popular and competitive standards of these types of programs.

BIM programs allow the construction and precise parameterisation of a model built using SketchUp. It is based on the precise definition of all construction materials that constitute the various layered structures that occur within a building, determining their physical properties. One can say that BIM supplements a design by incorporating into it an immense database [6].

The physical parameters of a building are only a part of the data assigned to a design. The second part is composed of climate data and the functional parameters of the interior of a building. Determining the geographic location of a building is associated with assigning the design to a particular climate zone with distinct climate properties, such as average temperature, humidity, insolation, as well as the strength and direction of the dominant winds. Afterwards, parameters that apply to air inside the building are introduced, such as the functional temperatures for individual rooms. One of the design's objectives is temperature zoning, which is recommended for elaboration in energy efficient buildings.

Windows play an important part in the energy balance of an energy efficient building, which also applies to their combined surface area and the location of individual glazed surfaces in relation to the cardinal directions [7]. In order to verify the surface area of glazing and the appropriateness of the placement of windows in a designed building, it is recommended that an insolation analysis be carried out. It is performed for the spring or summer equinox, when solar rays fall under a right angle in relation to the meridians. The insolation analysis allows one to determine precisely the duration of the time of a room's direct access to sunlight throughout the day. During the workshop, students perform an insolation analysis in ARCHICAD on a previously developed virtual model of a building.



a) b)

Figure 4: Architectural and construction BIM-standard compliant design - in ARCHICAD or Revit: a) ARCHICAD; and b) Autodesk Revit.

INTEGRATED ENERGY DESIGN WORKSHOPS AND ENERGY EFFICIENCY SIMULATIONS

When a virtual model of a building built in accordance with BIM standards has the physical parameters of its structure defined, in addition to the climate parameters relevant to its geographic location, as well as its internal functional temperatures, it can be converted into a building energy model - a model that can be subjected to analyses of energy efficiency throughout the entirety of a yearly cycle [8]. French students use ArchiWIZARD, which is a French program, to perform energy analyses [9]. In turn, Polish students use EcoDesigner STAR [10], which is an integral part of the ARCHICAD digital platform.

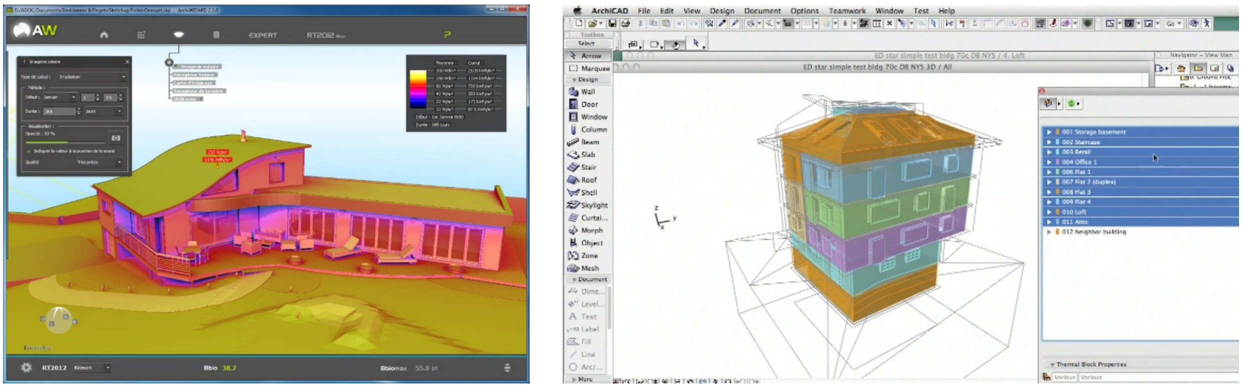
Energy analyses are used to determine three main parameters:

- Internal energy gains - an analysis that determines the total yearly internal gains within a building is usually divided into thermal gains from illumination, machinery, the persons present within a room, solar gains, as well as from heating and cooling. In energy efficient buildings with large glazed surfaces on the southern facade, the largest amount of energy gained is derived from solar gains.
- Energy losses - an analysis of the yearly losses of energy yields a yearly balance of energy loss through individual partitions and the operation of a building's ventilation systems. The results of analyses indicate that in order to obtain high energy efficiency parameters, it is obligatory to use mechanical ventilation combined with recuperation, a system that reclaims heat from the air used by ventilation systems.
- Final energy consumption - in an analysis of the yearly consumption of final energy for the designed buildings, the entire energy demand is divided into the following elements:

  – energy required to run electrical appliances;
  – energy required for lighting;
  – energy required to heat the building;
  – energy required to prepare domestic hot water.

A daylighting analysis is performed in order to check the amount and distribution of natural light in a room. It answers the question of whether a room has an appropriate amount of light for its intended use and how artificial lighting can be conserved.

A separate, but a very important type of analysis is that of comfort and overheating. A comfort analysis can be performed for the period of a year, a month, a day or an hour. A specific day in a year can be selected in order to observe the comfort and temperature on that date. Comfort and overheating analyses are particularly important in energy efficient buildings, in which there exists a potential for rooms to overheat during summer periods - due to large glazed surfaces placed to the south, combined with a high degree of thermal insulation of the walls and their air tightness. This depicts one of the most important recommendations regarding the methodology of integrated energy design, that is, the shifting of the main weight of design decisions to the earliest possible design stage, when it is the easiest to introduce amendments in terms of design solutions and when there are no costs associated with it.



a) b)

Figure 5: An energy design with analyses - made either in ArchiWIZARD or EcoDesigner STAR; a) ArchiWIZARD; and b) EcoDesigner STAR.

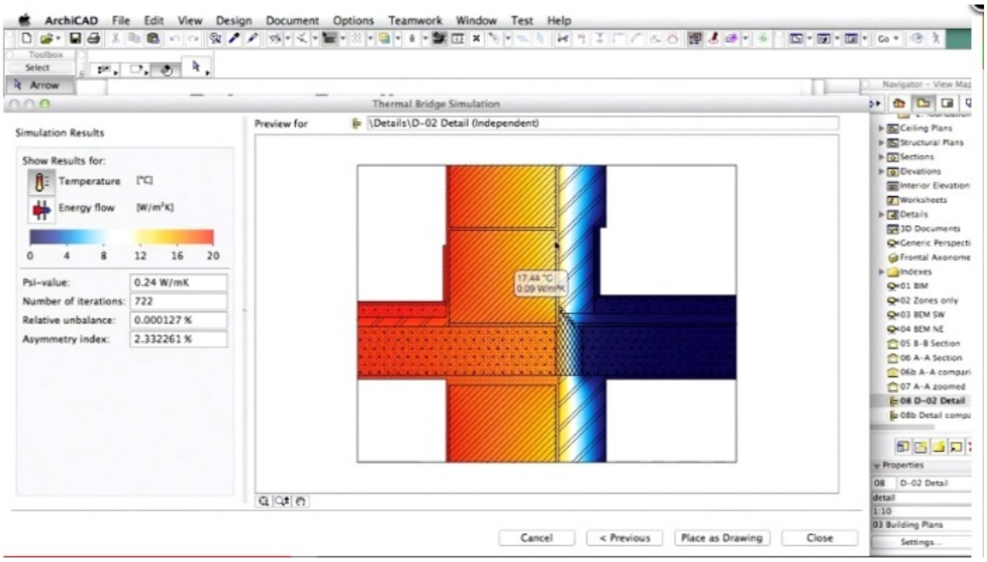


Figure 6: Thermal bridge analysis in EcoDesigner STAR.

CONCLUSIONS

The design of energy efficient buildings chiefly requires the use of appropriate architectural and construction design support tools. These tools include BIM-standard compliant software, as well as programs that allow the designer to perform energy simulations on virtual building models designed and developed in those programs.

When one is given the opportunity and has the skills that allow one to effectively use these tools, one needs to take into account the fact that many factors influence the degree of the energy efficiency of a building, resembling, in a manner, a puzzle.

All over Europe, as an answer to EU directives regarding energy policy, regulations are being implemented that are introducing ever stricter requirements and higher standards that are being set before newly designed buildings in terms of their energy efficiency. All EU member states are required to determine the individual national standard of a building with *nearly zero energy consumption* up to the year 2021. A building with such a high standard of energy efficiency needs to be designed in an appropriate manner; namely, with the use of BIM-standard compliant software in combination with the use of proper programs that allow the performing of energy simulations.

Students who are now beginning their architecture studies will enter the job market at a time when buildings with *near-zero energy consumption* will be the norm. Student workshops on the subject of integrated energy design based on BIM software that make use of the knowledge and experiences of various countries help to prepare architects who are currently undergoing education to work in their profession.

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BIOGRAPHY

Przemysław Markiewicz MSc (Arch), PhD, is a graduate of Cracow University of Technology, Faculty of Architecture, Kraków, Poland (1995). He is an Assistant Professor in the Institute of Construction Design, Faculty of Architecture, Cracow University of Technology. He is also a professionally active architect, author of a number of design studies of one- and multi-family houses, office buildings, public utility buildings, member of Małopolska Chamber of Architects. His PhD dissertation was entitled *Selection of Advanced Construction Technologies for Housing Purposes* (1999). His scientific activity is connected with the Section of General Construction of the Committee of Urban Planning and Architecture of the Polish Academy of Sciences, Branch in Kraków. Within the scheme of his didactic activities, he conducts classes with students at the Faculty of Architecture, Cracow University of Technology in the subject of General Construction. He has authored a series of books devoted to general construction, and architectural and construction design, including Interior Design with the Application of Drywall Partitioning Systems of Plaster - Cardboard Panels (2001); Glazed Shell Walls (2007); Shaping Architecture by Changing Construction Solutions (2006); General Construction for Architects (4th edition 2011); Design Details for Architects (2010); Architectural and Construction Project - Graphic Standards for Design Studies (2014) and Building Construction (2014). He is also the author of a number of technical catalogues and information/educational publications for architects, developed for the leading construction companies, including - without limitations - RIGIPS - Rigips Systems; Assembly of Rigips Systems; ISOVER - Catalogue of Architectural and Construction Solutions for Designers and Investors; Catalogue of Architectural and Construction Solutions - Essence of Insulation; PFLEIDERER - URSA Insulation Materials; BRAAS - Technical Solutions - Pitched Roofs; WIENERBERGER - Structural and Construction Design of Walls in the POROTHERM System and XELLA - Principles of Designing in the YTONG System. He is an organiser of courses devoted to designing and modelling virtual buildings in ARCHICAD, and co-organiser of the exchange of students with France and workshops entitled *Integrated Energy Design*.