# Integrated Research for Sustainable Building

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Petr Hájek
Czech Technical University in Prague
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Antonin Lupisek
Czech Technical University in Prague
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Jan Tywoniak
Czech Technical University in Prague
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Ctislav Fiala
Czech Technical University in Prague
33 PUBLICATIONS 86 CITATIONS

# INTEGRATED RESEARCH FOR SUSTAINABLE BUILDING

Petr HAJEK
*Czech Technical University in Prague, Faculty of Civil Engineering, Czech Republic, petr.hajek@fsv.cvut.cz*

Antonín LUPÍŠEK
*Czech Technical University in Prague, University Centre for Energy Efficient Buildings, Czech Republic antonin.lupisek@uceeb.cz*

Jan TYWONIAK
*Czech Technical University in Prague, Faculty of Civil Engineering, Czech Republic, jan.tywoniak@fsv.cvut.cz*

Magdaléna NOVOTNÁ
*Czech Technical University in Prague, University Centre for Energy Efficient Buildings, Czech Republic magdalena.novotna@uceeb.cz*

Ctislav FIALA
*Czech Technical University in Prague, University Centre for Energy Efficient Buildings, Czech Republic ctislav.fiala@uceeb.cz*

## Summary

Czech Technical University in Prague (CTU) is building a new research centre UCEEB – University Centre for Energy Efficient Buildings nearby Prague in the town Bustehrad. The main research focus of UCEEB will be integrated approach to sustainable design and construction of buildings. The main mission of UCEEB is to deliver to construction industry a support and knowledge base for massive action to reduce energy demands of buildings, increase utilization of renewable natural resources and improve quality of indoor environment. This research facility will start full operation since January 2014. However research activity within UCEEB in the specified field has already started since the beginning of this year in the frame of Preseed project.

**Keywords:** energy efficient buildings, building physics, indoor environment, renewable materials

## 1 Introduction

Buildings represent an essential element of the built environment created for preserving quality of human live. Construction and operation of buildings belong among the biggest consumers of primary materials and energy resources and environment pollutants as well. Buildings are largest energy consumer in the EU (40 %) and main contributor to green-house gas (GHG) emissions (36 % of the EU's total $CO_2$ emissions) [1]. To decrease energy consumption and GHG emissions, holistic approach, contributing to a proper integration of specific solutions, is necessary.

The EU Joint Research Centre published a Technology Map in 2007 that includes: a) energy savings in buildings represent largest potential in reducing of total energy consumption, b) measures in energy savings in buildings must be implemented immediately since their impact will be relatively fast, c) implementation of renewable energy sources and distributed energy systems can be expected in a medium time frame.

A reaction to this general trend was a conceptual idea of CTU to develop research facility focused to complex holistic research on sustainable buildings and providing high quality research space for researchers and doctoral students from the CTU working in this research area.

A University Centre for Energy Efficient Buildings (UCEEB) is an interdisciplinary research facility of the Czech Technical University in Prague that brings together a critical mass of knowledge from civil engineering, mechanical engineering, material science, electrical engineering and biomedicine. The main focus is on environmental friendly energy efficient buildings providing healthy indoor environment. The main mission of UCEEB is to deliver to construction industry a support and knowledge base for massive action to reduce energy demands of buildings, increase utilization of renewable natural resources and improve quality of indoor environment.

***Fig. 1*** *3D visualization of UCEEB centre*

## 2 Research activities in UCEEB

UCEEB has five basic research groups having different orientation of research programs (RP1 to RP5). These research groups will be focused on specific research topics based on high knowledge base supported by cooperating university faculties. However, for the solution of concrete project tasks, there will be close cooperation between research groups.

### 2.1 RP1: Architecture and interaction of buildings with environment

Research programme Architecture and interaction of buildings with environment is focused on finding optimal solutions in terms of operation energy resulting in zero-energy or energy positive buildings (zero carbon). Simultaneously the security and safety of buildings together with a healthy indoor environment represent key issues in forming high-performance buildings. The testing focus on parameters defining indoor environments (with emphasis on energy savings), interaction of load bearing structures with non-load bearing elements (peripheral wall, roof skin, partitions etc.) and security and safety of buildings (with emphasis on fire safety of combustible elements and materials). Research will focus on long-term behaviour (durability) within the entire life cycle of a building.

RP1 will utilize several special laboratories and equipment – e.g. acoustic laboratory, room corner test laboratory etc. Acoustic laboratory is designed for measurements of airborne and impact sound insulation of building elements – e.g. walls, floors, windows, as well as of flanking sound transmission via suspended ceilings and double floors. Room corner test will be focused on full-scale fire testing and numerical simulation of fire in enclosure, i.e. in building interior. Particular attention will be head towards to fire characteristics verification of products for surface working of building structures (walls, ceilings etc.), their reaction to fire, contribution to fire growth and flashover effect, rate of heat release, analyses of combustion products etc. Other unique equipment – the large climatic double chamber will enable complex testing of building structures under steady state and dynamic environmental conditions. The chamber will be equipped with temperature and humidity control; solar, wind, rain and pressure difference simulators and hot box apparatus. Furthermore, simultaneous climatic and mechanical loading of structural elements will be possible. Behaviour of specimens (up to 3 by 3 meters) will be monitored by number of precision sensors and high resolution IR camera.

***Fig. 2*** *UCEEB centre under construction*

## 2.2 Energy systems of buildings

The subject of the research program Energy systems of buildings is the new concept of decentralized sources in cooperation of passive renewable energy sources (RES) with active fuel resources and superior networks through intelligent management. Optimized elements of RES are developed for integration into the structure of the building envelope and elements of technical building systems to achieve low demand of primary fuels. In the area of system components there will be explored innovative multifunctional solar collectors, advanced heat pumps, the possibility of accumulation of heat and cold, in the area of whole systems there will be explored technical systems for the indoor environment treatment in energy efficient buildings, energy sources integration into buildings and energy sources integration into superior networks using advanced predictive control methods.

Several laboratories will serve for the purposes of research and development. Energy laboratory is intended for research of thermal cycles, with an emphasis on low-temperature organic Rankine cycle (ORC) technology and micro-generation. Solar laboratory will be equipped with a testing device with a solar simulator for indoor testing of solar collectors and systems. For long-term testing and monitoring of solar facilities there will be available areas outside on the roof and in front of the south facade. For laboratory of heat pumps there was designed testing double-box (two separate test areas) with double wall to maintain extreme weather conditions (-20 °C/+30 °C) for testing heat pumps and cooling systems and their components. It will also serve as multi-purpose climatic chamber for other types of tests and research. The system of UCEEB building energy supply itself is a kind of laboratory (photovoltaic system, gas cogeneration micro-turbine, absorption chillers, heat and cold accumulation).

***Fig. 3*** *UCEEB centre under construction*

### 2.3 Quality of indoor environment

Energy efficient building has to ensure a healthy indoor environment to its users. The research program Quality of indoor environment offers a multidisciplinary view through three main areas: the development and design methods of advanced technical equipments to ensure the quality of indoor environment, research of medical assistance systems as well as monitoring of biological variables and the development of smart composite nanosystems and materials for medical and technical applications (detection of pollutants, monitoring of internal environment, etc.).

Laboratory of indoor environment with parallel test cabin (room in the room) will enable testing of the technical building systems with controlled ambient temperature from -18 °C to 40 °C. Other equipment consists of a Laser-Doppler anemometry, hygro-thermal model of man and apparatus for monitoring and evaluation of the indoor environment (thermal comfort, the concentration of pollutants). Device for hybrid ventilation with a solar chimney on the south facade and test line for small air handling units and components will be used in the research of low-energy ventilation systems. In medical applications, the main research devices are intelligent room with private health system and a separate laboratory for research and development of polymer-based nanofibers with antifungal and/or antibacterial properties. Electrostatic spinners will serve for spinning of polymers for the development of carrier systems, filters and fibrous substrates for biomedical and pharmaceutical purposes.

***Fig. 4*** *UCEEB centre under construction*

## 2.4 High performance building materials and structures

The aim of the program High performance building materials and structures is the research and development of energy-efficient and renewable materials based on timber or ceramic recycled materials for use in building construction, development of multifunctional and innovative materials (e.g. hydrophilic mineral wool) and support for their practical application in construction. The intervention techniques based on nanotechnology (microscopy, micromechanics with application of nanoindentation) will be explored in connection with the materials development.

Research and development will be supported through a number of devices: e.g. measurements of the water sorption, moisture and thermal conductivity of materials. In the central testing UCEEB laboratory there is built static and dynamic testing equipment for load-bearing tests of samples with a height of up to 6 m and a climatic chamber system for testing of materials and structures under various thermal and moisture conditions. In the analytical laboratory for non-destructive testing there are available 3D digital microscope, NMR spectrometer, X-ray diffraction and especially scanning electron microscope (ESEM) with ultra-high resolution of less than 0.5 nm.

## 2.5 Monitoring, diagnostics and smart control of buildings

The main areas of research within programme Monitoring, diagnostics and smart control of buildings are sensor networks, evaluation of long-term structural changes in building structures and monitoring/diagnostics of building performance in relation to energy resources and technical building systems. Research and development will focus on specific sensors, electronic devices and controls, monitoring and modelling of user's behaviour in buildings, on control systems, ventilation, heating and cooling in relation to the mathematical model of the building and on modelling itself (creation and identification of the model). Attention will be paid to the adaptation of energy consumption according to the state of external network or modelling of communication networks in buildings and further systems of predictive control using intelligent energy storage and its reuse.

Laboratories will poses the equipment for the design, implementation and tuning of electronic and sensor systems, called rapid prototyping, 3D printing centre for the printing of functional prototypes, packaging of electronics and electromechanical components. For non-destructive testing of building structures there will be ground radar (inspection of building sites, search of voids and cracks), devices for flaw detection (detection of structural integrity), etc. Advanced thermal imager will serve to detect thermal performance of buildings, as well as testing of components power loss on designed printed wiring of heavy--current control.

# 3 Commercialization of research results

Research activity within UCEEB has already started since the beginning of this year in the frame of Preseed project. Two projects running under RP1 are described in following text.

## 3.1 Advanced construction elements from high performance concrete composites

Previous research at Faculty of Civil Engineering, CTU showed the ability to produce the building structures from high performance silicate composites reinforced with microfibers. Proof of concept project is aimed at addressing industrial partners and exploring the possibility of inclusion of high performance composites in a products portfolio. Within the project there is proposed the system of reinforced concrete subtle frame structure based on high performance concrete (HPC) and ultra-high performance concrete (UHPC) for low--energy and passive houses. It is a modular system consisting of subtle precast columns in combination with precast or precast-monolithic floor structures with conventional reinforcing bars or tendon. Ceiling panels are designed with box cross-section, longitudinal ribs and transverse ribs enabling cross-linkage of panels. The space between the ribs is filled with lightening elements with suitable acoustic properties.

## 3.2 Façade elements of new generation

Current research is oriented to new generation of light-weight façade elements. One of the first subtasks is to develop non load-bearing curtain wall elements having very low thermal transmittance suitable for passive house level by considering fire safety, noise protection and related issues. These elements should be able to replace old metallic curtain walls (typically from 60ies or 70ies in 20$^{th}$ century) with very poor thermal insulation level, often containing asbestos fibers. These elements can be used in new buildings as well. A system approach was chosen in order to create a variety of options, based on one platform-solution. A substantial part of the solution is an appropriate integration of movable shading elements, active solar areas (PV mainly), different external claddings etc. The embodied energy of the elements should be very low, therefore their structure is wooden based. In the opaque part, a combination of different thermal insulation materials can be used, preferably of non-oil origin. The transparent part is created by triple glazed windows.

## 4 Summary

The built environment is largely responsible for negative environmental impact of human activities due to use of non-renewable, energy demanding materials, inefficient building operation and high energy demand throughout the life-cycle of buildings. In order to effectively address the impact of human activities on the environment, existing buildings must be retrofitted and new buildings designed to respect principles of sustainability.

This can only be achieved by integration of scientific and engineering disciplines that determine the influence of human construction activities on the quality of the environment. The strength of this approach is in integration of key scientific disciplines to achieve optimal solutions to built/natural environment interfaces.

UCEEB represents necessary integration that will lead to new solutions to sustainability of built environment and their transfer to the engineering practice. UCEEB will provide support for transfer of technologies and new knowledge to the industry and society. This will be achieved via classical outlets such as training seminars, publications in trade journals, special publications (briefs), patents and joint projects with the industry.

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## References

[1] EU Energy and transport in figures, statistical pocket book 2007/2008.