Testing of Energy-Efficient Building Envelope Materials in Natural Conditions

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Abstract.
The publication presents an ongoing project which aims, by using multi-physical modelling method, to forecast the influence of different building envelope materials on the energy efficiency and the indoor air quality (IAQ). In this project, five identical experimental constructions with different composite building materials of external walls will be created (the indoor area 9 m^2, the height of ceiling 3 m). All external wall constructions (U=0.16 $W/(m^2K)$) will have ventilated façades. Five different insulated materials will be used: aerated concrete, ceramic, lightweight construction, wooden constructions, and an innovative composite building material developed in the course of the project. In all the experimental constructions it is planned to ensure air exchange of 0.6 h^{-1} and indoor air temperature corresponding to category A (CR 1752:2002).
The collected energy efficiency and IAQ parameters will be used to verify corresponding multi-physical models. The monitoring will continue for a whole year, to evaluate and analyze the influence of different outdoor parameters in the natural meteorological conditions for Riga, Latvia, that correspond to a cold maritime climate.

Keywords: energy efficiency, indoor air quality, composite building materials, multi-physical modelling, experimental verification.

INTRODUCTION

As the energy efficiency requirements in the context of building design and engineering performance become more rigorous (Directive 2010/31/EU of the European Parliament), increasing attention must be paid to ensure the required indoor air parameters. The task of a building's design and construction is to ensure that with the minimum energy expenditure yields as consistent quality IAQ at varying outdoor air conditions as possible. The choice of building's design affects the initial investment and exploitation costs as well as the long-term impact on human health, which is determined by the selected design characteristics (e.g., thermal inertia, hygroscopic qualities, etc.) and their impact on the ability to achieve the desired energy efficiency and IAQ performance (Kļaviņš, 2009., 2011).

The aim of the project is to develop a building design based on the building's energy efficiency and IAQ multi-physical model that allows virtually simulating the experimental design of buildings in different climatic conditions. The use of the model can be simplified and it promotes new structures and building design, construction according to an economically feasible choice, building maintenance durability, environmental impact reduction, improved indoor climate in a building and associated improvement in human health and well-being, which, in turn, increases labour productivity, and other benefits.

The article presents the implementation phase results of the energy efficiency and IAQ monitoring project: the developed experimental construction and engineering solutions, innovative structures and construction of the conceptual solution, the planned microclimate parameter measurements.

The choice of building material for the five different walls of experimental constructions was determined by the target to find the best possible application of materials produced from the local resources, and high-quality insulation materials. The project developed an innovative solution of light building construction and created an experimental composition of the building material. Facility construction is to be completed by the beginning of the heating season to ensure the commencement and implementation of monitoring measurements at least within one the calendar year for the duration of the current project. The expected outdoor and indoor air parameters and energy consumption monitoring data will provide an opportunity to analyze the buildings in which five different construction materials have been used. This data will be employed for verification of a multi-physical model and for comparison of physical properties of building materials in natural and laboratory conditions.

METHODS

In the framework of the project is has been planned to build 5 test stands with different exterior materials (type A, B, D, E, F), identical in terms of design, geographic location and engineering solutions.

The building design provides solutions for reduction or elimination of thermal bridges. For all types of exterior wall constructions the U-value equals 0.16 $W/(m^2K)$, calculated according to the standard (EN ISO 6946:2007).

The indoor climate parameters in the typical outdoor climate conditions in the work area must meet the class A office space requirements (CR 1752:2002, EN 15251:2007): the indoor temperature in summer - 24.5°C ± 1.0°C (at the air velocity 0.18 m/s), in winter - 22.0°C ± 1.0°C (at the air velocity 0.15 m/s); the relative humidity 30÷70%; the noise level ≤30 dB(A); continuous constant exchange of air with a layer of 0.6 h^{-1} must be ensured indoors. It means that for a room of 27 m^3 it is necessary to supply and exhaust 16.2 m^3/h of air.

Monitoring should provide the outdoor air and indoor climate parameters' measurements (e.g., temperature, relative humidity, air flow rate, etc.), each stands energy consumption measurements.

The experimental stands' architectural solutions must ensure the layout of interior and engineering systems which could be easily modelled and symmetrical.

RESULTS AND DISCUSSION

1. Experimental constructions

The experimental constructions are localised in the urban environment, under natural conditions in Riga, Latvia, characterized by cold, maritime climate (duration of the average heating period of 203 days, the average outdoor air temperature during the heating period - 0.0°C, the coldest five-day average temperature -20.7°C, the average annual air temperature - 6.2°C, the daily average relative humidity - 79% (LBN 003-01)).

The selected location is the University Botanical garden territory, all five stands are placed on equal relation to the sun and the surrounding shading objects (such as trees) – see Figure 1.

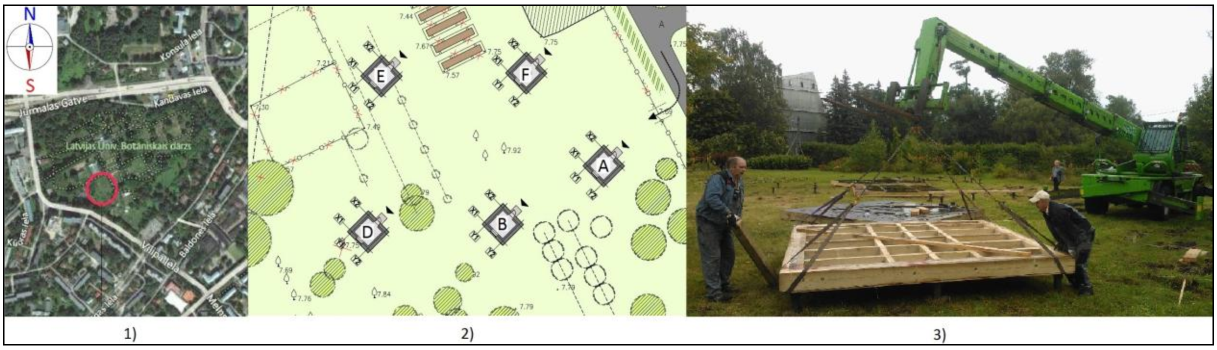

Figure 1. The location of experimental stands: 1) area; 2) orientation; 3) construction

The experimental constructions are designed within the agreed solutions, in order to minimize differences in output data of energy consumption and indoor climate measurement data analysis and interpretation.

Each experimental stand imitates a free-standing building with an interior room (3 m x 3 m = 9 m^2 floor area, ceiling height of 3 m) with a window and a front door - see Figure 2. Each building is placed on pillars and has no contact with the ground. To prevent the thermal bridges, window and door installations have been taken out to the insulation layer.

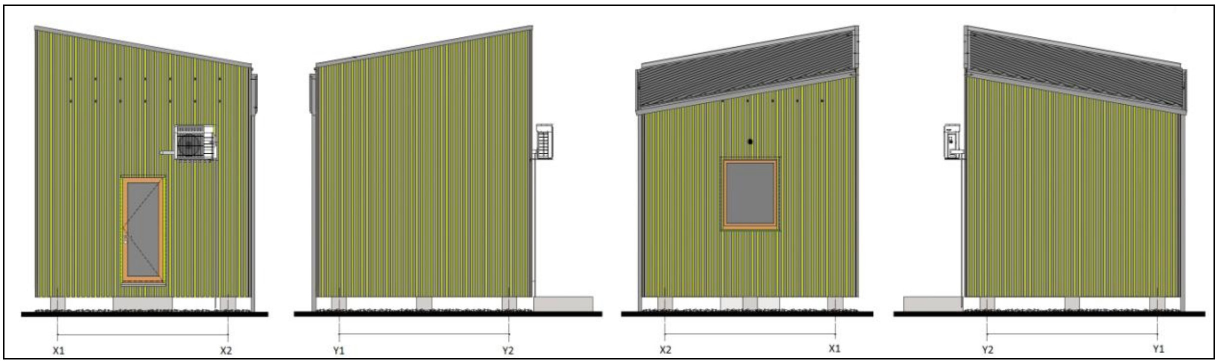

Figure 2. The facades of experimental construction

The basic materials used for the ventilated facade exterior wall construction are shown in Figure 3:

1) type A – ceramic blocks KERATERM 44 (440 mm);
2) type B – aerated concrete blocks AEROC Eco Term Plus (375 mm);
3) type D – experimental insulated birch plywood frame and wood wool slab (296 mm);
4) type E – experimental ceramic blocks KERATERM with filled cavities (500 mm);

5) type F – Ltd. “Dores” glued timber beams (200 mm).

The project has been developed an experimental basis, and yielded two innovative solutions:

- type D - plywood frame construction with a mineral wool cladding (developed by architect Martins Osans in collaboration with plywood manufacturer corporation “Latvijas Finieris”), the building frame assembly solution of experimental construction - see Figure 4;
- type E - experimental ceramic blocks KERATERM with filled cavities, the thickness of 500 mm (developed in cooperation with the ceramic block manufacturer "Lode"), the modelling and analysis of the thermal conductivity of the experimental blocks with a variety of fillings project have been implemented in the framework of the project.

Figure 3. Exterior wall base construction materials (type A, B, D, E, F)

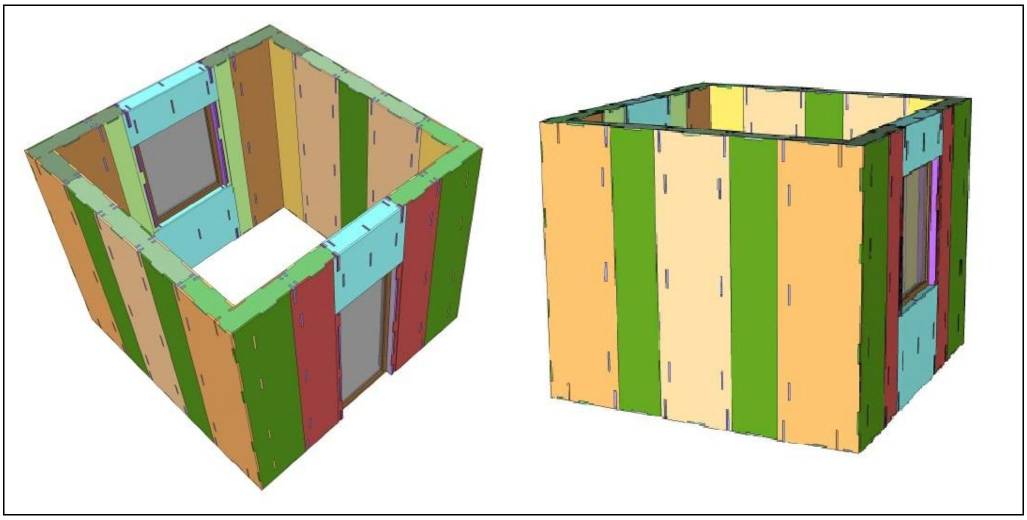

Figure 4. Plywood frame structure installation design (type D)

The layers of different types of building envelopes and the thickness of the layers are summarized in Table 1. The test constructions’ design and engineering solutions in cross section are provided in Figure 5.

Table 1. Exterior wall construction materials and layer thickness (mm)

Type A (701.5)	Type B (561.5)	Type D (387.5)	Type E (606.5)	Type F (516.5)
Outer finishing - timber siding (40)				
Plywood covering plate WG; BB/WG (6.5)				
Air/ vertical timber lathing (30)				
Sheathing board Paroc Cortex (30)		Plywood frame / insulation Paroc eXtra plus (21/(100+100))	Lime-cement plaster SAKRET (15)	“Dores” glued timber beams (200)
Insulation Paroc eXtra / plus / horizontal timber lathing (125)	Insulation Paroc eXtra plus / horizontal timber lathing (50)			
Lime-cement plaster SAKRET (15)	Lime-cement plaster SAKRET (15)		Experimental ceramic blocks KERATERM with filled cavities (500)	Insulation Paroc eXtra plus / horizontal timber lathing (100)
Ceramic blocks KERATERM 44 (440)	Aerated concrete blocks AEROC Eco Term Plus (375)	Wood wool slab F 75 (75)		Insulation Paroc eXtra plus / vertical timber lathing (100)
				Vapour barrier
Internal finishing – lime-cement plaster SAKRET (15)				Internal finishing – vertical timber siding (40)

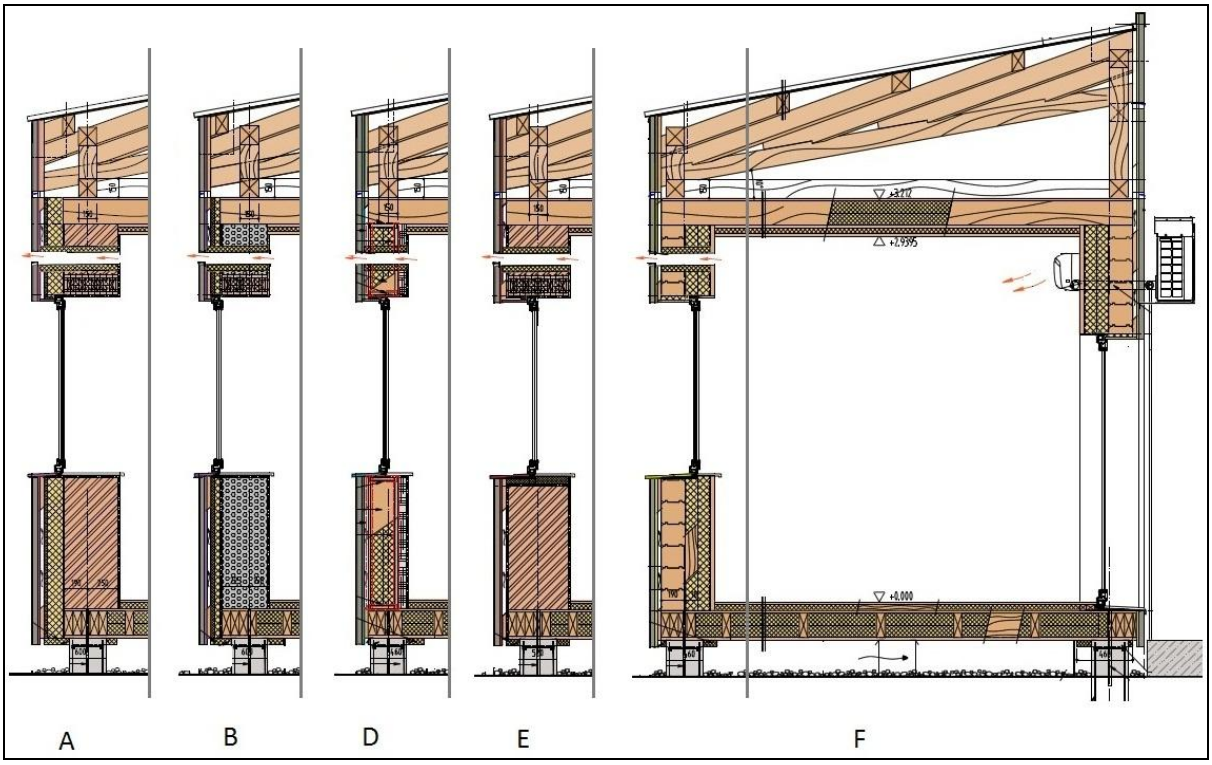

Figure 5. The experimental construction design and engineering solutions in cross section (type A, B, D, E, F)

2. Providing of IAQ

To provide the indoor environment microclimate parameters - temperature, relative humidity and air exchange, every experimental construction has been designed to be fitted with an air conditioning unit. The equipment performance of selected device Ururu-Sarara, "Daikin", Japan (model FTXR28E + RXR28E): cooling capacity 2.8 kW; heating capacity 3.6 kW; the continuous outdoor air supply to the room minimum 24 or maximum of 32 m^3/h; the supply air humidification to 400 ml/h (at room temperature 20°CDB, outdoor air temperature 7°CDB/6°CWB, and relative humidity of 87%); supply air purification; the range of outdoor temperatures cooling -10÷43°CDB, heating -20÷18°CDB; the sound pressure level of the internal unit nominal cooling mode / heating 33/35 dB(A).

Air conditioning equipment is to be installed above the door. Air leakage from the affected area for overpressure relief through natural ventilation ducts fitted with a gravity louver, the channel which is located above a window - see Figure 5.

To ensure the optimal air speed and temperature parameters in the work area of the room, it is intended to use the equipment with a moving lattice, directing the flow of air along the ceiling in the cooling period and directly to the floor in the heating period.

The experimental constructions' heating, ventilation and air-conditioning engineering solutions have been developed in collaboration with Ltd."Indutek LV".

3. Measurements

To examine the performance of the engineering solutions and construction work quality, and to determine the initial parameters of each experimental construction, the tests with infrared method **(**EN 13187:2002) and fan pressurization method (EN 13829:2002) will be made.

In all experimental constructions it has been planned to ensure continuous measurements of the following parameters: temperature and relative humidity (in several places, including the building envelope), pressure and differential pressure, solar radiation, air flow speed and heat flow density throughout the building structures. In addition, periodic measurements of globe temperature, radiant temperature, lighting, CO and CO_2 concentrations, exposure and brightness are planned.

The following continuous outdoor measurements of environmental parameters will be implemented: temperature and relative humidity, wind speed and direction, pressure, solar radiation.

The records of the individual energy consumption (electricity) will be kept for each experimental construction.

4. Numerical modelling

In the framework of the project:

- an experimental construction simplified multi-physical model has been established and the analysis of constructions' thermal inertia impact on the room temperature changes performed (Dzenis, 2012);
- the modelling and analysis of the thermal conductivity of experimental block KERATERM with filled cavities (designed models for a variety of fillings) performed; the results employed to choose the cavities' filling of ceramic blocks KERATERM used for the experimental construction's (type D) exterior wall;
- the methodology explored and the mathematical analysis of heat and moisture transfer affected by temperature difference in the 5 multi-layer structures implemented (Ozolinsh and Jakovich, 2012).

CONCLUSIONS AND OUTLOK

The developed experimental constructions' design and engineering solutions provide the opportunity for further experimental measurements by moving objects to the environment with the environment necessary for research with the minimum requirements for their deployment (supports, electrical outlets and network for measuring devices of data reading from a distance).

Using the developed experimental constructive solutions, it is possible to build new stands from experimental materials and implement testing in operating conditions, to determine their characteristics and their effects on energy efficiency and IAQ impacts.

The five test stands in future can be used to examine the influence of various heating and air conditioning systems on the energy efficiency and IAQ parameters.

Within the current project the VOC concentration measurements have not been scheduled, however, the solution of experimental constructions is suitable for a variety of interior materials' testing facilities in operating conditions.

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