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ENVELOPE STRUCTURE MATERIALS EXPERIMENTAL RESEARCH IN NON-STATIONARY THERMAL-HUMIDITY CONDITIONS

Content of the article will be the evaluation of fragments and construction details of the building envelope, the heat-air-moisture and energy characteristics, their impact on the state of indoor environment, the material parameters. Research is carried out in real conditions in situ and laboratory research in the preparation of experimental models. The project will build on the results obtained from solved projects. Assessment of the envelope, their fragments and construction details in steady sta/te conditions does not give a true picture of their behaviour and their impact on the indoor environment of buildings. The heat-air-moisture microclimate, the properties of building envelope and indoor environment are characterized by non-stationary processes, in real state. The task of the project will be the analysis of the particular heat-air-moisture and energy processes of building envelope, which is exposed to the experimental laboratory and real in situ conditions.

Key words: buildings, construction detail, laboratory experiment, in situ testing measurement, building envelopes, heat-air-moisture fluxes, non-stationary boundary conditions, material parameters.

Досліджено оцінку фрагментів і деталей конструкції огороджуючих конструкцій будівель, їх теплових, вологостійкостних і енергетичних характеристик, їх вплив на стан внутрішнього середовища і параметрів матеріалів. Дослідження проводяться в реальних умовах in site і лабораторних дослідженнях при створенні експериментальних моделей. Проект буде грунтуватися на результатах, отриманих в попередніх проектах. Оцінка огороджуючих контрукцій, їх фрагментів і деталей конструкцій при сталих умовах не дає реальної картини їх поведінки та впливу на внутрішнє середовище будівель. В реальній ситуації тепло-вологісний мікроклімат, як і властивості огороджуючих конструкцій і внутрішнього середовища характеризуються нестаціонарними процесами. Завданням проекту є проаналізувати тепло-вологісні та енергетичні процеси огороджуючих конструкцій в умовах експериментальних лабораторій і реальних умовах.

Ключові слова: будівництво, будівельні деталі, лабораторний експеримент, тестування на місці вимірювання, облицювання, тепло-вологісні потоки, нестаціонарні граничні умови, матеріальні параметри.

Introduction

Article describes ongoing oriented research, at the Faculty of Civil Engineering at the Technical University of Košice, that´s aim is to monitoring the physical properties of the envelope structures of buildings with emphasis on their thermal and moisture problems, at present. The most important task of research is the assembly of equipment in climate boxes and planted them samples, spread and involvement of the measuring system. This step is essential to continued research. The result is a logical and transparent system for gathering, evaluating and storing the measured data. Contribution shows the embedding system of measurement points in planted samples and system of monitoring their physical properties in the annual run.

The scientific objectives

The project is aimed to fulfil two basic objectives.

1. The first objective:

is the laboratory measurements of selected material parameters of building materials, which determine the behaviour of building structures after built-in.

2. The second objective:

is to monitor selected parameters (physical values) of building envelope:

- exposed to the laboratory conditions (indoor stand)
- exposed to the real conditions (experimental chamber).

Inputs: Experience from long-term measurements of material properties and physical characteristics of fragments and construction details in real conditions of exploitation of construction work – in situ, further knowledge of the applicant's research in the area (previously handled projects).

Methods: Theoretical analysis and synthesis of learned knowledge. Realization of long-term measurements in test models of the established experimental facilities using the monitoring elements in conjunction with a device to monitor changes in outdoor climate:

a/synthesis and evaluation of data (measurement of selected physical quantities) – by in situ and experimental measurement

b / prototype testing samples of facade, the fragments and details,

c / prototype testing transparent parts, the fragments and details,

d / laboratory measurements of material properties.

Outputs:

A / Laboratory measurement material properties of selected building materials.

B / The test measurements of real building structures in transient boundary conditions of real climate become reliable tool to optimize the construction details of building.

C / Material properties used as input parameters for numerical analysis (simulations).

D / Measurements of selected parameters (physical quantities) used as a verification model for numerical analysis (simulations).

Brief of the current state of the problem

In many cases, it is necessary to set the physical characteristics of the fragments and details of building envelope (i.e. some variables) by measurement in real conditions or experimental measurements in the laboratory – for the calculation which is taking into an account the behaviour of them in virtual reality. At present, attention is paid to verifications many of the computer programs (how they can be used to fulfil the set tasks) and specifications of the solved model. This is possibly made only by obtaining the problematic input data, namely by measuring in the real model in scale 1:1.

To verify the selected physical, i.e. heat-air-moisture and energy characteristics there is a possibility to monitor the behaviour of the selected parts of the building envelope, facades as well as the details in transient state while maintaining the dynamics of changes of environmental conditions. This means that the studied sample must be subjected to real environmental conditions on an year round evaluation (or in the selected time period in the laboratory).

In the indoor environment it is possible to maintain the fixed hygro-thermal microclimate (constant temperature, constant air humidity), or set changes of the parameters. These kinds of devices operate on a number of scientific and research institutes and laboratories in Europe and worldwide.

Verification the effectiveness and reliability of the selected computational simulation programs is possibly made by input the predicted and verified data of real conditions into the chosen numerical computational model. This can be obtained only by experimental research.

Fig. 1. Laboratory instruments for measurements of initial conditions – water profile

Comparison the input data (the time change) with the real state may get us closer to reality in the premise of the proposal, already. The issues of an in-situ measurement and evaluation of the building envelope and its physical properties were solved by previous research projects handled in the workplace of the applicant:

Expected benefits

Experimental devices (the experimental climate chamber in the laboratory, "laboratory Indoor stand") and in situ (experimental chambers) intended for experimental research and testing measurement for unsteady hygro-thermal conditions to allow understanding the physical qualities of building structures, intended for the creation of building envelope, or adjustments and design possibilities of these structures and their construction details.

Device is intended to monitor the behaviour of:

i. opaque envelope parts,
ii. transparent parts,
iii. details of building envelope,
iv. their material characteristics.

Climate Chamber "Indoor stand" and outdoor experimental chambers will allow monitoring changes in the physical characteristics of building structures and internal environment in unsteady hygro-thermal state in real conditions of changing state of the external environment on an annual run.

Research on new building construction for the building envelope with action elements and computing control system, with the possibility of long-term control – monitoring changes in their physical properties at current effect of the changes in the outdoor physical factors and climatic conditions, is based on the integration of the results and knowledge obtained from the theoretical solution and test experimental measurements in situ of the mentioned subtasks and the application and implementation of possible computational models.

Based on previously acquired scientific knowledge will be designed prototypes of new structures of building envelope, intended for experimental research on elements of building structures in conjunction with active monitoring and control equipment and computational control system. In the experimental facilities will be verified the theoretical approaches that will be subsequently used for modeling, research and development of other types of structures intended for passive energy buildings.

Brief of the procedure in research realization:

- The use of test equipment – (in the laboratory climate-chamber "indoor stand") and in situ (experimental chambers).

- Based on the analysis and synthesis of previously acquired scientific knowledge and approaches, as well as the know-how in the development and evaluation of elements of building envelope parts (cladding, facades, their details and transparent parts) –

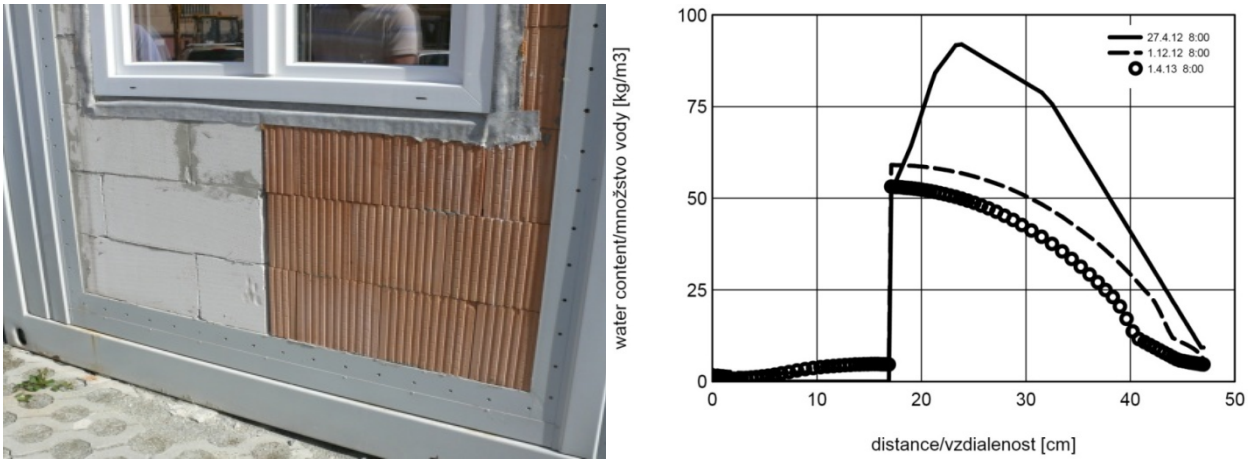


Fig. 2. Material properties and initial conditions used as input data for numerical analysis (simulation) of a coupled heat and moisture transport in the porous media

Design the prototypes of the new construction elements.

- Supply of components and production of models.
- Production, functionality testing and calibration tests.
- Installation of models into experimental facilities in areas of Institute of Architectural Engineering
- Use test equipment to conduct the research on an annual run.

The output of the project will be the implementation of prototypes of design elements for monitoring the physical characteristics of the building envelope, their features and construction details in unsteady hygro-thermal state in terms of outdoor environmental climate conditions changes – in situ.

Experimental research of building structures properties intended for building design in terms of the effects of variable outdoor climatic influences in the prediction of the proposal (in laboratory experiments).

The main benefit will be increasing the quality and effectiveness of research in building structures intended for the design of buildings using integrated simulation methods.

The major milestones in the realization of the research, which will indicate the proper and effective implementation of the activities include:

- Increased quality and quantity of works with a focus on presenting the results of research of advanced building envelope types in magazines, peer-reviewed scientific journals and proceedings.
- Options of participation in exchange programs and joint research projects in Slovak and foreign research organizations.
- Mutual cooperation with TU Vienna (especially in experimental measurements of material characteristics) but also cooperation with foreign partners (see foreign cooperation)

Cooperation with the workplaces:

- Earth Building Association of Australia Inc (EBAA) (Peter Hickson)
- RAMTEC, Pty, Ltd. (Stephen Dobson)

The preparation and testing of packaging structures produced on the basis of unconventional natural ingredients. A growing number of users of research output among PhD students and researchers. Outcomes of the proposed project, i.e. transfer acquired knowledge and scientific results, become an integral part of a comprehensive research aimed on the design and implementation of advanced building envelope structures.

Specific design process

As part of the research will be carried out the following activities:

- Integrated research of building structures designed especially for progressive packaging structures (cladding, transparent panels).
- Monitoring of building elements satisfying the conditions for the application of energy passive buildings.
- Verification of time-dependent variables typical for material properties and behaviour of building structures of packaging building elements necessary for the assessment on the basis of selected integrated computer simulation programs.
- Verification of the methods of evaluation used – analysis of the response and the impact on the optimization of structures and their construction details, the application of advanced systems of Civil Engineering.

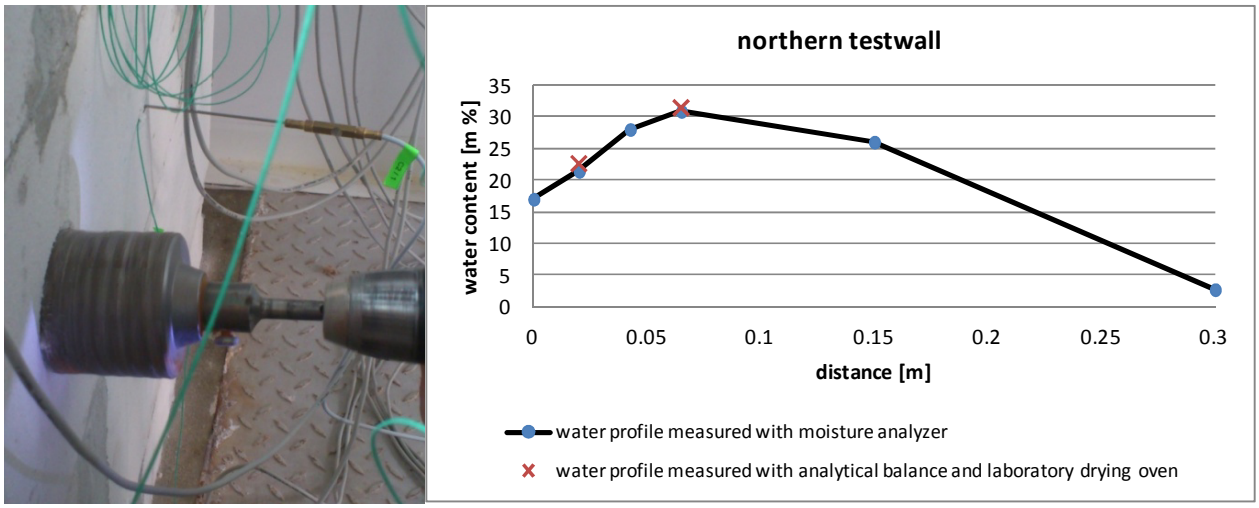


Fig. 3. Measured of the water profile as initial condition with two differential methods

The project will enable direct linkage to other related activities aimed at:

- Integrated design of building structures of passive buildings, based on the synergistic combination and development of the following areas:

(a) the development of modern rational structures and systems of advanced materials (with possibility of implementation the modern elements),

(b) the creation of nonlinear time-dependent transformation of calculation models for the assessment of changes in time-variable properties of structures and elements,

(c) verification of the physical characteristics of building structures in situ in real conditions of exploitation, in order to keep their applications in simulation prediction programs,

(d) application of control methods in the design of structural elements,

(e) promote the application of artificial intelligence methods.

Objectives set for the project

1. Step:

Point 1: production of selected prototypes reference samples (1:1 scale model) fragments:

- peripheral wall (monitoring: temperature, water and heat flows),
- details of building envelope (monitoring: temperature, water and heat flows),
- transparent parts (monitoring: the influence of solar radiation and other parameters).

2. Step:

Point 2: installation of fragments into experimental facilities (laboratory climate-chamber, and in situ experimental chamber), in which one side of the fragment will represent the impact of the outdoor

environment and the other side of the fragment indoor environment (constant temperature and air humidity).Process of the measurements will be on an annual run, or in selected time period (summer period, transition periods, and winter period).

3. Step:

Point 3: evaluation the results, determine the dynamics of state of changes in transfer of heat and water:

- through the selected fragments of the building envelope
- through the selected transparent parts
- through the selected details of joints of the envelope

4. Step:

Point 4: evaluation results, determine the dynamics of state of changes in transfers of heat and water:

- the transfer of water (moisture),
- the transfer of heat,
- setting specific values of variables and parameters monitored,
- application of obtained measured data to the potential reference simulation programs.

Description and explanation of the methodology

1) – Theoretical analysis of the current state of scientific knowledge in this field is contained in dissertations of the research team members and in a text part of dissertations exams. Reasoning: The above work provides an overview of the current state of knowledge in the research field, with references to a relevant literature.

2) – Synthesis of acquired knowledge.

Reasoning: Based on the theoretical knowledge of the current state of knowledge in this field the problem areas of interest intended for the observation will be identified (fragments, details).

3) – Selection and production of specific prototypes of models which are intended for monitoring, observation and evaluation.

Reasoning: Based on the specifications of the problem areas of interest to make a selection of suitable representatives that will be the most used composition of building envelope and the corresponding construction materials used in the design of the building envelope (or their performance parts) – Analysis and verification of determining physical properties of selected representatives when mounted during their exploitation in non-stationary temperature state.

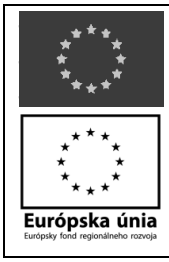
4) – Realisation of test measurements and long-term monitoring of the physical parameters of the selected representatives of building materials, directly applied in the building envelope. Reasoning: The purpose is a mutual confrontation of results obtained by laboratory measurements and in situ measurements.

5) – The creation of a large database of records showing year-round operation of dynamic changes of physical properties of selected models, prototypes of fragments and details of building envelope and outdoor environment processed by statistical methods.

Reasoning: The purpose is to map the cycle of changes of the physical properties and parameters during the exploitation of construction work (or selected representatives). The data collected simultaneously serve as input data for the implementation of integrated computer simulations.

6) – Processing of the obtained results with aim on the conclusions of the construction design and methodology for determining and eliminating heat losses through the structures of building envelope, leading to optimizing the design of the building envelope with the express purpose of reducing

the needs of all types of energy involved and the energy performance of buildings. Reasoning: The combination of knowledge gained with the requirements and needs of practice to be more active in involvement of investment and production companies and implementation issues in science and research in the monitored area.



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1. Katunský, D. et al. Energy efficiency of large-hall objects, the final report on the treatment of grant VEGA 1/5021/98, handled from 1998 until 2000, January 2001 2. Katunský, D. et al. "Energiebedarf der Hallensysteme" project handled for the Austrian Institute for support the Central and South-Eastern Europe, 1999-2000. 3. Katunský, D. et al. „Konstruktiver Entwurf zur Verbesserung der Klimabedingungen in Industriehallen" project handled from 2001 until 2002 for the Austrian Institute for support the Eastern and South-Eastern Europe. 4. Katunský, D. et al. „The interaction of physical factors in creating an appropriate work environment" scientific project VEGA 1/9023/02, 2002-2004. 5. Katunský, D. et al. Evaluation of heat-air-moisture and light conditions of production industrial buildings VEGA 1/2562/05, 2005-2007. 6. Katunský, D. et al. Heat flows in terms of soil-building interaction and outdoor environment for large hall-type buildings VEGA 1/0695/08, 2008-2010. 7. Katunský, D. The 2nd specific objective of the project: Support of Centre for excellent integrated research of progressive building construction, materials and technologies, with the support of the research and development program financed by the European Regional Development Fund, 2009-2011 (ITMS 26220120018). 8. Katunský, D. et al. Architectural, structural, technological and economic aspects of the design of energy efficient buildings OPVaV-2009/2.2/01-SORO. Knowledge and technology obtained by the research and development transfer into the practice. Project is supported by the ASFEU Agency of Department of Education, 2010-2012 (ITMS 26220220050). 9. Katunský, D. The 2nd specific objective of the project: Centre for excellent research of progressive building construction, materials and technologies, with the support of the research and development program financed by the European Regional Development Fund, 2010-2013 (ITMS 26220120037). 10. Katunský, D. et al. Monitoring of changes in physical parameters of the envelope structures during quasi-stationary states in regards to the dynamic changes of the external environment VEGA 1/60/11, 2011-2013.