SHORT TERM SCIENTIFIC MISSION (STSM)
SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: COST Action TU1403

STSM title: Holistic investigation and IEQ assessment of building integrated hybrid façade element

STSM start and end date: 06/09/2017 – 20/09/2017

Grantee name: Aleksandar Andjelkovic

PURPOSE OF THE STSM:

This report represents the research activity carried out by Aleksandar Andjelkovic, assistant professor at University of Novi Sad, during his Short Term Scientific Mission (STSM) at the University of Zagreb, hosted by professor Vlatka Rajcic.

Main idea of this Short Term Scientific Mission was to combine and integrate two ongoing projects. The host, University of Zagreb, is developing a building integrated hybrid façade element thought national project entitled VETROLIGNUM. In order to achieve the main project goal of upgrading the energy efficiency properties of structural glass – timber element, professor Vlatka Rajcic is constructing the full size mock-up building as an onsite laboratory for several year examination of energy efficiency of selected hybrid façade elements. On the other side STSM grantee Aleksandar Andjelkovic is developing the intelligent and affordable IEQ (Indoor Environmental Quality) data logging system (SENSO) within the ASHRAE international project where University of Novi Sad is a leader. Also, during this STSM, Aleksadar will spread his experiences in building performance simulations in order to get preliminary design results of Mock-up building and to educate young researchers at University of Zagreb which will be involved in project VETROLIGNUM.

The main objective is to cooperate in the design of mock-up building and in development of investigation programme where the mutual benefit for both above mentioned research projects will be achieved.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

Research activities were performed in order to accomplish the proposed goals. Because of characteristic of the project, some of the activities were planned before STSM, while some were included later in order to respond to the new developments.

As it was stated in the application form, work carried out in the STSM was divided into five activities:

ACTIVITY 1: Contribute to design of mock-up building and prediction of its energy efficiency behaviour

First activity was development and preliminary design of the Mock-up building which will be set up in the Faculty of Civil Engineering Zagreb, Structural Department. After site analysis and selection of the best position for the Mock-up, we proceeded with modelling and parametric simulations. Modelling and parametric analysis were done in Design Builder (Energy Plus simulation) software (Fig. 1).

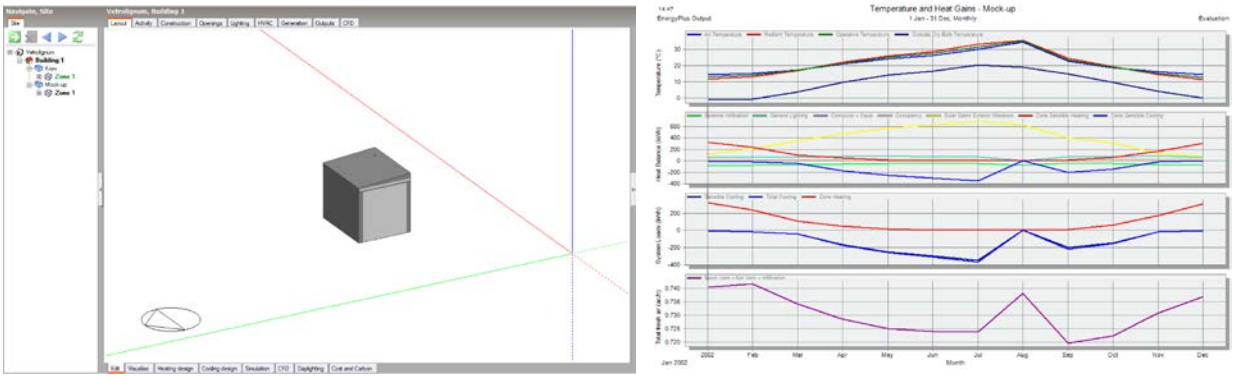

Fig. 1: Design Builder Mock-up model and panel D simulation results

Full-scale specimens were tested in large test campaign dated from 2010 until 2017, by combined constant vertical load and displacement controlled cyclic horizontal load (racking load). Several series of equal specimens were tested varying boundary conditions (shear cantilever, shear wall) and intensity of vertical load. Specimens were repaired after attaining large deformations and damages of frame joints and retested. The purpose of racking test was to obtain data for development of computational model of tested type of structural element that can be used for prediction of inelastic response of buildings with the glass-infilled CLT frames on seismic action. In the paper the results of testing are presented in form of hysteresis loops and backbone curves. Due to CLT frame, the hybrid component can be easily connected with surrounding structural elements made of any structural material by semi-rigid ductile steel fasteners or other types of fasteners that can be fixed to CLT frame. The laminated glass infill is placed inside the timber frame in the way that can carry vertical and lateral load, provides high energy dissipation along the glass-to-timber contact and does not influence structural ductility of surrounding timber frame.
For parametric simulation we used four panel types (from A to D, Fig. 2). Analysis results show that energy efficiency increases from model A to D what was expected. Additional energy efficiency can be expected by using adaptive outside solar protection due to high solar gains in summer. These results indicate us that the Mock-up is feasible in sense of energy efficiency. Attention must be focused on the process of connecting parts of panels, gas tightness and the role of solar radiation protection.

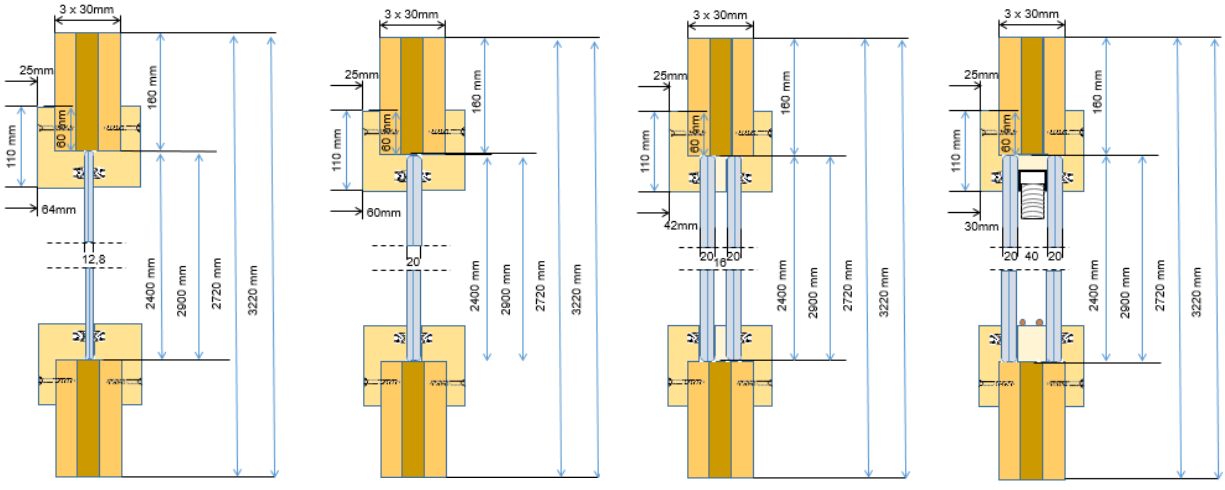

Fig. 2: Panel types (from A to D)

ACTIVITY 2: Advise in process of development of program of long term measurements and interpretation of data

In my previous research I've done a lot field test and lab measurement. Intention of this activity was to collect possible measurement equipment for long term monitoring of the Mock-up. Because of limited budget we decided to order: DAVIS Weather station (Outside air temperature, relative humidity, atmospheric pressure, global solar radiation, wind speed and direction, Wi-Fi connected), two data loggers for indoor air temperature and relative humidity (Testo Wi-Fi logger Saveris 2 H1). For short time measurement plan is: to buy Testo 635-2 according ISO 9869 for U-value measurement of the panels, to rent Blower Door Standard Wi-Fi and to use exiting Flir Infrared Thermograph Camera. Results from this measurement will be used to validate simulations and to test energy characteristics of the panels.

ACTIVITY 3: Cooperate in the design of investigations where SENSO logging system will be used in addition to commercially available data logging system

Idea of this activity was to investigate how additional logging system can be used to improve quality of performed measurement. My team on the University of Novi Sad got ASHRAE fund to develop intelligent Indoor environment quality (IEQ) logging system. The SENSO is low-cost IEQ monitoring platform, consisting of inexpensive measuring units for all of the necessary IEQ parameters and cloud based software that aggregates and visualizes environmental data in user friendly browser environment for all gadget platforms. The physical properties that can be measured are: thermal comfort (air and radiant temperatures, air speed, humidity), air quality (CO_2, CO, Volatile Organic Compounds, Formaldehyde, and Particulate Matter), acoustics, lighting, geo-location, local weather and other related outdoor environmental parameters. Conclusion was that this device can be added value for VERTOLIGNUM project in sense of additional IEQ measurements. Also, on the other side, the VETROLIGNUM project will enable to test the device properties and behaviour in real environment.

ACTIVITY 4: Transfer his experiences and knowledge to young researchers at University of Zagreb which will be involved in project VETROLIGNUM

I have done series of lectures and practical excesses on building performance simulation for young researchers who are involved in project VETROLIGNUM. All excesses were done in Design Builder software and researchers got the basic knowledge of building modelling and simulation.

ACTIVITY 5: Prepare the contribution to educational pack of TU1403 together with the hosting partners

During the STSM we mutually collected the material for COST action TU1403 education pack. The prepared presentation consists of three major parts:

1. Highly energy dissipative and ductile strengthening timber-glass hybrid element,
2. VETROLIGNUM - Mock-up + simulation and
3. SENSO – Intelligent platform for IEQ Assessment.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

The STSM activities were marked as positive in terms of the progress made in research content. Besides, advancement in terms of exchange, considering networking and discussion were also very productive. Table 1 represents the level of accomplishment of each planned activity, considering main objective of submitted STSM.

ACTIVITY	ACHIEVED BY STSM	COMMENTS
Contribute to design of mock-up building and prediction of its energy efficiency behaviour	Fully achieved	Full-scale specimens were tested in large test campaign dated from 2010 until 2017, by combined constant vertical load and displacement controlled cyclic horizontal load (racking load). Preliminary design of the Mock-up test building was done by the Design Builder software. Parametric simulation were performed for all selected hybrid façade panels. Conclusion is that the Mock-up is feasible in sense of energy efficiency.

Advise in process of development of program of long term measurements and interpretation of data	Fully achieved	Necessary measurement equipment was selected and pre-ordered. The equipment will be used for long and short term measurements. The measurement results will be used in order to validate simulations and to test energy characteristics of the hybrid façade panels.
Cooperate in the design of investigations where SENSO logging system will be used in addition to commercially available data logging system	Fully achieved	Conclusion was that this device can be added value for VERTOLIGNUM project in sense of additional IEQ measurements. Also, on the other side, the VETROLIGNUM project will enable to test the device properties and behaviour in real environment.
Transfer the experiences and knowledge to young researchers at University of Zagreb which will be involved in project VETROLIGNUM	Fully achieved	Trough series of lectures and practical exercises young researchers from VETROLUGNUM project got the basic knowledge on building performance simulation (Design Builder software).
Prepare the contribution to educational pack of TU1403 together with the hosting partners	Fully achieved	The material was collected during STSM. The presentation for educational pack was prepared and sent after STSM.

Note: Additional future activity

Plan for finalizing the Mock-up test facility in Zagreb and SENSO logging system is the beginning of the 2018. After that, plan is to collect the first measurements, to validate simulations and to test energy characteristics of the hybrid façade panels. The results obtained from the evaluation will be shared in the form of a scientific journal or conference paper.

FUTURE COLLABORATIONS (if applicable)

Next step is finalizing work on the Mock-up in Zagreb and on the SENSO IEQ logging system. Results from this SSTM shows good potential and feasibility of the Mock-up test facility with various types of structural glass – timber element. Developed SENSO IEQ logging system will provide data for validation of performed simulations results in design faze (obtain during this SSTM). Also, additional sensors and measuring equipment set for calibration of the SENSO will be used to increase quality and accuracy of the data. Besides that, SENSO IEQ logging system will be able to analyse IEQ in the Mock-up and influence of the integrated hybrid façade element on indoor clima and well-being. Plan is to analyse various types of wood material in order to obtain a proper quality of indoor clima.

The cooperation of Universities of Zagreb, Novi Sad and Ljubljana will not be concluded within the framework of the finished STSM, but will continue with potential of development future research proposals. Also, after obtaining experimental results from Mock-up, plan is to publish journal and conference papers.

Additionally, future plan is to introduce and develop a mutual lecture course and to contribute to long term plan to establish the test laboratory facility. This work will also help to extend intellectual work and collaboration of involved Universities and pass this knowledge onto students, professionals and industry.