SHORT TERM SCIENTIFIC MISSION (STSM)
SCIENTIFIC REPORT

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

Action number: CA17107

STSM title: Numerical analysis of the thermo-mechanical performance of smart textiles and coatings in building skins

STSM start and end date: 07/04/2019 to 17/04/2019

Grantee name: Chiara Bedon

PURPOSE OF THE STSM:

Modern building envelopes are high-tech components that must meet several requirements and constraints with regards to architecture/urban planning/aesthetics, energy efficiency, indoor environmental quality, buildability and value. Most of the systems representative of the next generation of facades in buildings, in addition, typically consists of highly adaptive envelopes, generally involving advanced use of smart materials, kinematic mechanisms, etc. In this regard, the use of smart textiles is continuously increasing, even in absence of standardized procedures to evaluate their thermo-mechanical performance as "composite" systems, based on appropriate / reliable numerical approaches.

The primary aim of the STSM was the thermo-mechanical investigation of glass facades,with smart textiles and novel coatings exposed to experimental time-temperatures histories. Careful consideration – according to the original work plan – was spent for a detailed research on literature case studies and guideline reports (where available). Given a case-study facade system (VETROLIGNUM project, Zagreb University), additional efforts were spent to assess and calibrate the key input parameters of Finite Element numerical models for glass facades with textiles and/or coatings under thermo-mechanical loads (ABAQUS).

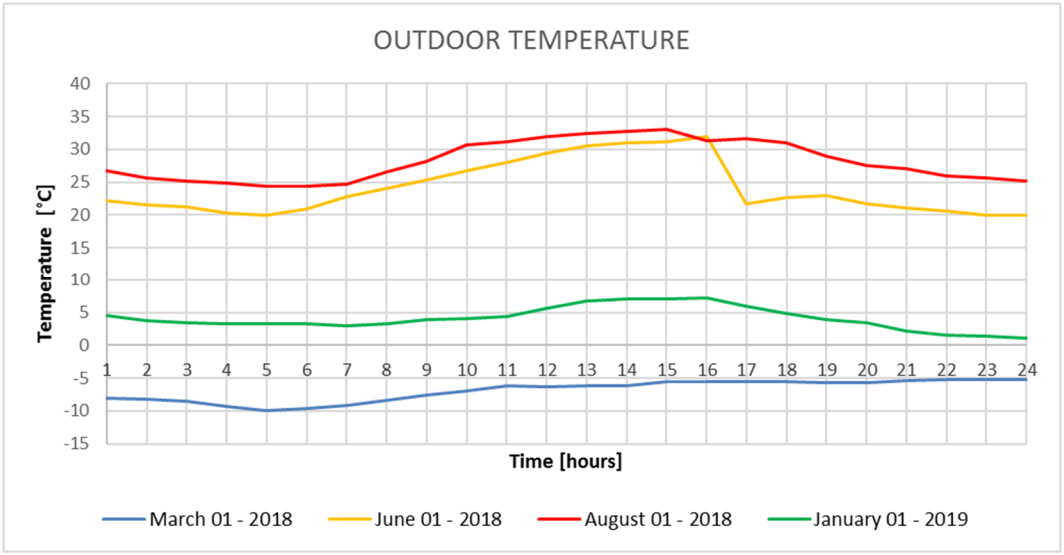
DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

The working activities consisted in two specific tasks, namely (i) a detailed literature research investigation and (ii) a Finite Element numerical study carried out in ABAQUS.

Task (i) included the detection of reference configurations for textiles an coatings that can be used in glass facades and windows. Accordingly, some typical applications of textiles in modern glass facades were selected for the parametric numerical investigations in ABAQUS. The second task (ii) was specifically aimed at investigating the thermo-mechanical performance of glass facades with special textiles and / or coatings. In order to assess the effects on numerical predictions deriving from some key input parameters that have a fundamental role for the thermo-mechanical numerical simulations of glass facades, the case-study VETROLIGNUM timber-glass facade system (Zagreb University) was taken into account. The reference system is characterized by the presence of a double insulated glass unit (IGU) – with 2.4m x 2.9m the global dimensions of the wall – composed by two laminated glass panels (each one with a cross-section consisting of two 10mm thick glass plates bonded by a 1.6mm thick EVA layer). The laminated glass panels can then interact via a 16mm thick cavity, filled with argon. The so assembled IGU system is then supported by a timber frame.

VETROLIGNUM timber-glass facade (https://www.grad.unizg.hr/vetrolignum)

During the STSM, the geometrical and thermo-mechanical features of the timber-glass facade were properly reproduced in ABAQUS. A key input for the STSM study was represented by the availability of monitoring records (1 year apart) for the VETROLIGNUM timber-glass facade, including outdoor temperature and humidity, indoor temperature and humidity, etc.



Example of outdoor temperature records for the VETROLIGNUM timber-glass facade in Zagreb

Given the availability of the "reference" VETROLIGNUM case-study system and the corresponding thermo-mechanical boundary conditions, the FE numerical analyses consisted in uncoupled thermo-mechanical simulations (heat transfer + mechanical), able to account for the thermo-physical properties of each system component, but also for the variation of the mechanical properties of the load-bearing materials, with temperature. Careful consideration was in fact spent, during the post-processing stage, for the analysis of some critical aspects in glass, like the temperature evolution and distribution in the facade components (especially to prevent possible thermal shock phenomena), the facade transmittance, the residual stresses in glass that may derive from ordinary / extreme thermal loads, etc.

Besides the accurate analysis of the "reference" VETROLIGNUM system, the same facade and the literature research outcomes (task (i)) were then used to run additional FE parametric analyses, so as to explore the possible benefits and potentials (but also critical aspects) that may derive from the use of different textiles and / or coatings for the examined timber-glass system.

Also in the latter case, the selected scenarios were numerically assessed in terms of key performance parameters. On one side, the thermal performance requires in fact the analysis and minimization of possible thermal bridges, transmittance, temperature peaks etc. At the same time, pure mechanical considerations are aimed at optimizing the structural capacity of the facade (thus minimizing the total weight and volume of the system, and reducing possible residual stresses in glass that could be responsible of premature failure mechanisms).

DESCRIPTION OF THE MAIN RESULTS OBTAINED

Besides the number of selected textiles/coating configurations of technical interest (due to availability time – but the research collaboration is going on between the involved researchers), the FE investigations allowed to derive some important outcomes for the STSM topic.

At the time of the numerical study, the attention was spent on different solutions of textiles / coatings that could be used in modern glass facades, and in particular the choice was carried out in terms of:

MATERIALS (and their possible combination)

polyurethane,

foam,

cotton,

glass-fibers

SIZE (especially thickness) of the textiles / coatings

POSITION of the textiles / coatings, that is:

external to the surface of glass

internal (embedded in the EVA lamination layer)

internal (within the IGU cavity)

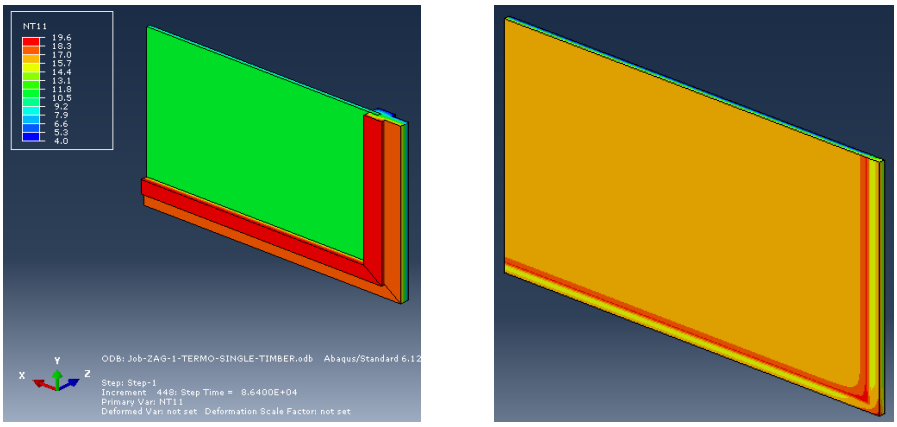
PATTERN of the textile / coating, that is:

uniform thickness

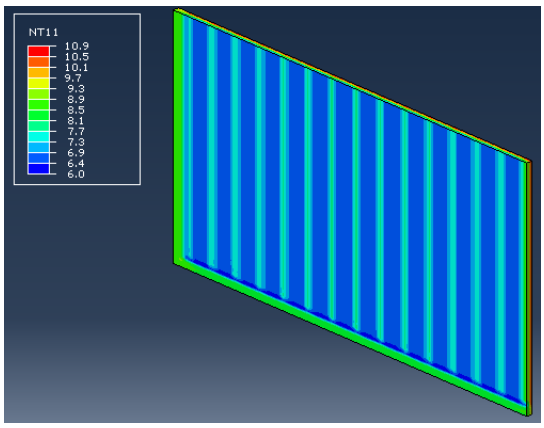
or different shading options

For each one of the selected solutions, the input thermo-mechanical properties were derived from literature efforts. The numerical analysis showed that even minor details in the composition / geometrical features of the textiles / coatings in use for traditional or modern glass facades and windows should be properly taken into account.

In this regard, the FE numerical method can usually offer a robust and efficient tool for investigations. On the other side, no literature documents are available for the specific applications object of study during the STSM (i.e., thermo-mechanical performance of glass facades with textiles / coatings). In some cases, efforts of literature can be found with respect to thermal performance assessment considerations only, while the coupled interaction between thermal and mechanical loads / restraints (being of primary interest for load bearing materials like glass) is often disregarded.



ABAQUS – Typical temperature distribution for the "reference" timber-glass façade under outdoor temperature records (VETROLIGNUM, Zagreb University), with detail of glass panels



ABAQUS – Typical non-uniform distribution of temperatures in glass, due to the presence of a patterned textile on the external face of the facade

Within the full FE investigation, careful consideration was also spent for some key aspects in the numerical modeling of structural glass systems under thermal loading, like for example:

- Mesh sensitivity

- Thermal loading exposure

- Thermo-physical and mechanical properties of the involved materials (glass, interlayers, etc.), including their degradation with high temperatures

- Effect of local details, such as supports and restraints, on the actual thermo-mechanical response of he selected structural systems

Key outcomes of the STSM are used by the involved researchers to draft two common papers (under preparation, the submission is expected before summer):

1) a common paper presenting a state of the art on the use of textiles and coatings in buildings for structural facades. Special care will be focused on the coupled thermo-mechanical performances and effects of these coatings, and how these can be properly accounted for structural design:

Chiara Bedon, Vlatka Rajcic, *"Textiles and structural glass - A review on possible solutions and thermo-mechanical considerations"* – in preparation

2) a second paper presenting a selection of numerical simulations carried out during the STSM (case study VETROLIGNUM system), or in the weeks following the STSM visit in Zagreb. The paper (in preparation) is intended to provide a reference / background document for the reliable numerical modelling of thermo-mechanical effects and performances of adaptive skins and facades with textiles / coatings:

Chiara Bedon, Vlatka Rajcic, *"Numerical analyisis of the thermo-mechanical performance of glass facades with textiles components"* – in preparation

Finally, it is expected that the collected research outcomes could be useful for a further oral/poster presentation in international Conferences (including the Mid-Term Conference of COST Action CA17107).

FUTURE COLLABORATIONS (if applicable)

The STSM visit gave to both the Visitor and the Host the opportunity to establish a robust research networking, that certainly will continue also in the medium/long term period.

The major goals of the STSM visit have been properly achieved, and most of the collected outcomes will be published in common papers their (submission is planned before summer).

In addition, during the STSM, further collaboration was also agreed between the involved researchers.

Such a networking will take several forms. Part of the efforts will be also spent in the application in European calls for research grants, based on common topics of interest for both the institutions where the Visitor and the Host are active.