STSM: "Coupled structural & thermal optimization of a multifunctional building skin"

Reference code: COST-STSM-ECOST-STSM-TU1403-110416-072125

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Involved researchers

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Purpose of the visit

The main objective of this STSM consisted in the analytical and FE numerical analysis of a multifunctional building skin, and specifically in their coupled structural and thermal optimization.
Particular attention was dedicated, thorough the exploratory analyses, to the thermal and structural performance of a case study actually under investigation at UCam. The reference system consists in novel GFRP-glass sandwich solution obtained by joining the glass panels – via adhesive layers – to GFRP frames (Figure 1). Within the framework of the COST Action TU1403, this STSM and the related activities will contribute to the objective of Working Group 2 Task 2.2 *"Evaluate current simulation tools for adaptive facades performance assessment"*, by exploring the capability of FEM tools to perform a coupled structural and thermal analysis, as well as an optimization of such systems. Although the application is not specifically related to adaptive facades, it is a first fundamental step in that direction.

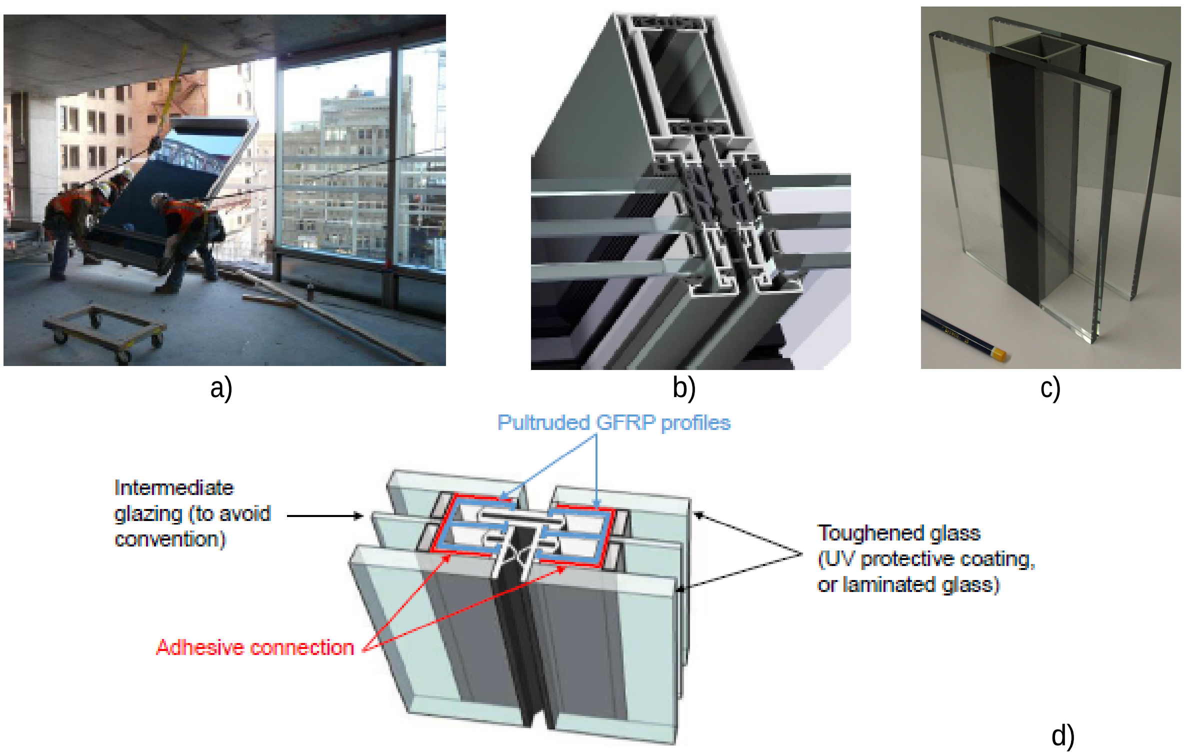


Figure 1. *a) Traditional curtail wall and b) typical metal frame-to-glass connection; c) GFRP-glass prototype investigated at UCam and d) overview of the GFRP-glass system object of optimization (UCam)*

Summary of activities and main results

During the STSM, a parametric numerical study was performed by taking into account several configurations of technical interest, i.e. including several geometrical, mechanical and thermal properties (see Table 1).

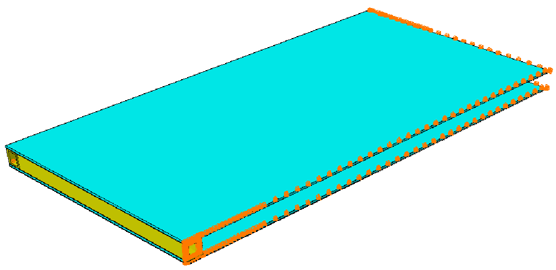
Table 1. *Optimization approach for GFRP-glass multifunctional building skins*

<table>
<tr><th colspan="2">0_CONTROL PARAMETERS</th></tr>
<tr><th>a) STRUCTURAL PERFORMANCE</th><th>b) THERMAL PERFORMANCE</th></tr>
<tr><td>- Maximum deflection
- Maximum stresses in the system components (glass, adhesive, GFRP frame)</td><td>- Linear heat transfer coefficient Ψ
- Surface overall specific heat transfer coefficient U
- Surface condensation risk (i.e. lowest indoor temperature)</td></tr>
<tr><th colspan="2">1_INPUT VARIABLES</th></tr>
<tr><td colspan="2">- GFRP frame geometrical properties
    o cross-sectional shape (hollow profile, etc.)
    o cross-sectional width (min 40mm, max 50mm)
    o cross-sectional height (min 40mm, max 70mm)
    o profile thickness (1/10, 1/15 and 1/20 the cross-sectional maximum dimension)
    o Transom-to-mullion connection (i.e. fully rigid, silicone layer, 1mm gap, etc.)
- Adhesive connection
    o Type of adhesive (silicon, acrylate, epoxy)
    o Adhesive thickness (min 1mm, max 3mm)</td></tr>
<tr><th colspan="2">2_OPTIMIZATION APPROACH</th></tr>
<tr><td colspan="2">Best structural & thermal performances, by minimizing the GFRP cross-sectional dimensions</td></tr>
</table>

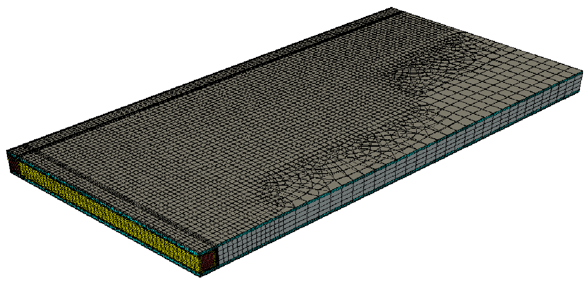
The full investigation was focused on a single curtain-wall modular unit, with B= 1.5m x H= 3m the overall dimensions (Figures 2, 3, 4, 5), composed of two 10mm thick monolithic external glass layers, a middle 5mm thick monolithic glass panel (not structurally active), a GFRP frame, adhesive joints.

In terms of mechanical and thermal boundary conditions, the following configurations were taken into account:

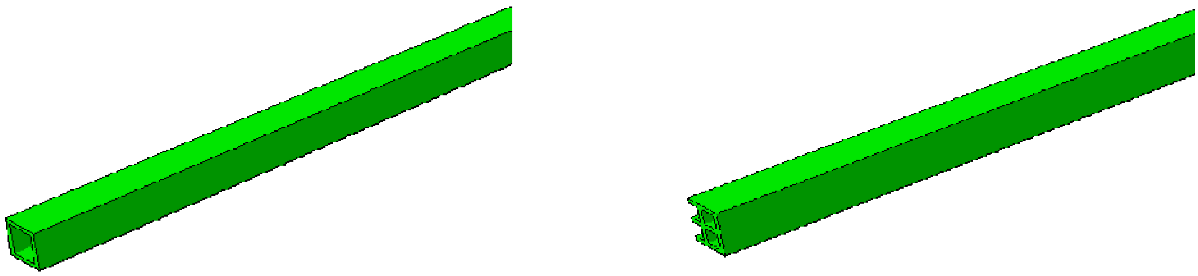
- Structural performance
  - o Short-term wind pressure (1kN/m^2)
  - o External loads distributed between the insulated glass panes via “load sharing” coefficients
  - o Internal loads (i.e. temperature variation) preliminary neglected
  - o Simply supports
- Thermal performance
  - o External condition: T= 0°C, film coefficient= 23 W/m^{2}K
  - o Internal condition: T= 20°C, film coefficient (glass)= 8.02 W/m^{2}K



Assembly and constraints, with symmetry conditions (1/4 the full geometry)



Mesh pattern



Examples of GFRP profiles

Figure 2. *FE model overview (ABAQUS/Standard)*

From a numerical point of view, different modelling approaches were considered and compared, so that both the structural & thermal performances of the examined system could be properly explored. All the FE models were implemented with the ABAQUS/Standard software package. In doing so, particular attention was dedicated to:

- Geometrical description of the GFRP-glass modular unit (e.g. connections, boundary conditions, etc.)
- Mechanical characterization of materials (i.e. glass, adhesives, GFRP profiles, etc.)
- Thermal characterization of materials (glass, adhesive, GFRP profiles, cavity infill, sealants, spacers, etc.)
- Mesh size and pattern, with specific care for
    - Type of elements (full 3D models)
    - Size of elements, with careful consideration for the effects on the predictions of both structural and thermal simulations
    - Shape of elements and mesh pattern (free meshing techniques)

The selected geometrical configurations were then also compared with the structural and thermal performance of a traditional curtain-wall panel supported by steel tubular mullions and transoms ("TWIST", see Figure 3).

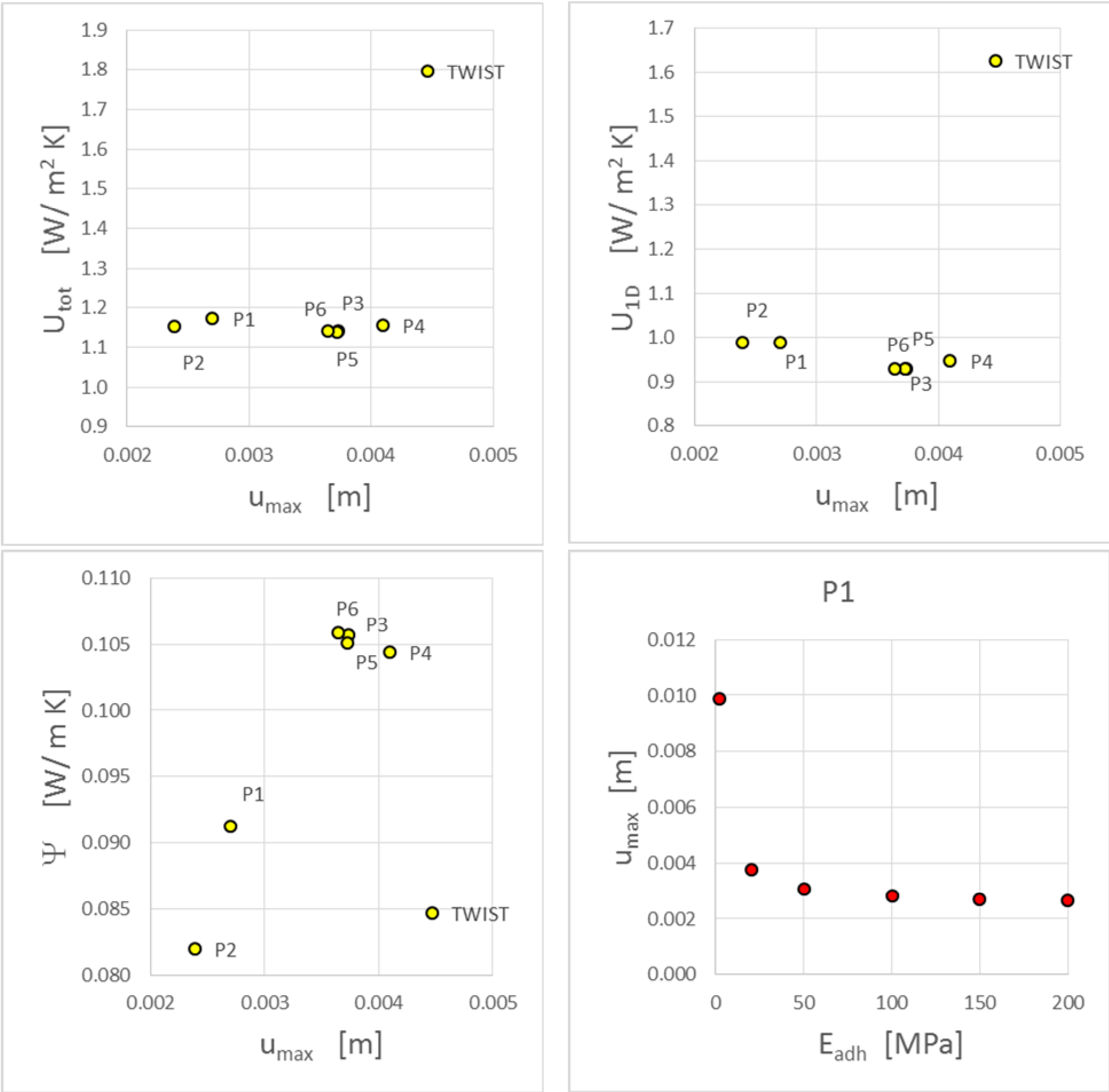


Figure 3. *Example of thermal and structural parametric results, for some selected configurations (ABAQUS/Standard)*

Networking

During the STSM, the visitor had the possibility to join the activities of the Glass & Façade Technology (gFT) Research Group of Cambridge University, including a gFT plenary meeting (13/04/2016).

In this respect, the STSM allowed to establish a stable networking and collaborative link between the involved researchers. For this reason, the financial support of the COST Action TU 1403 in facilitating the STSM and the related activities is gratefully acknowledged.

Output

The activities planned during the STSM will be continued and finalized in the weeks and months following the STSM.

At a first stage, the actual parametric study will be further extended, so that the optimization of the system object of study could be fully exploited.

In terms of medium/long term activities, further collaboration was also discussed and agreed during the STSM. Both thermal and structural experimental activities are in fact already planned at the University of Cambridge. These experimental activities will be further supported by FE simulations to be carried out at University of Trieste.

The final aim of the ongoing collaboration is to collect the main outcomes in a common conference paper (i.e. the Mid-Term COST Action TU1403 Conference) and in an extended journal paper (to be defined).

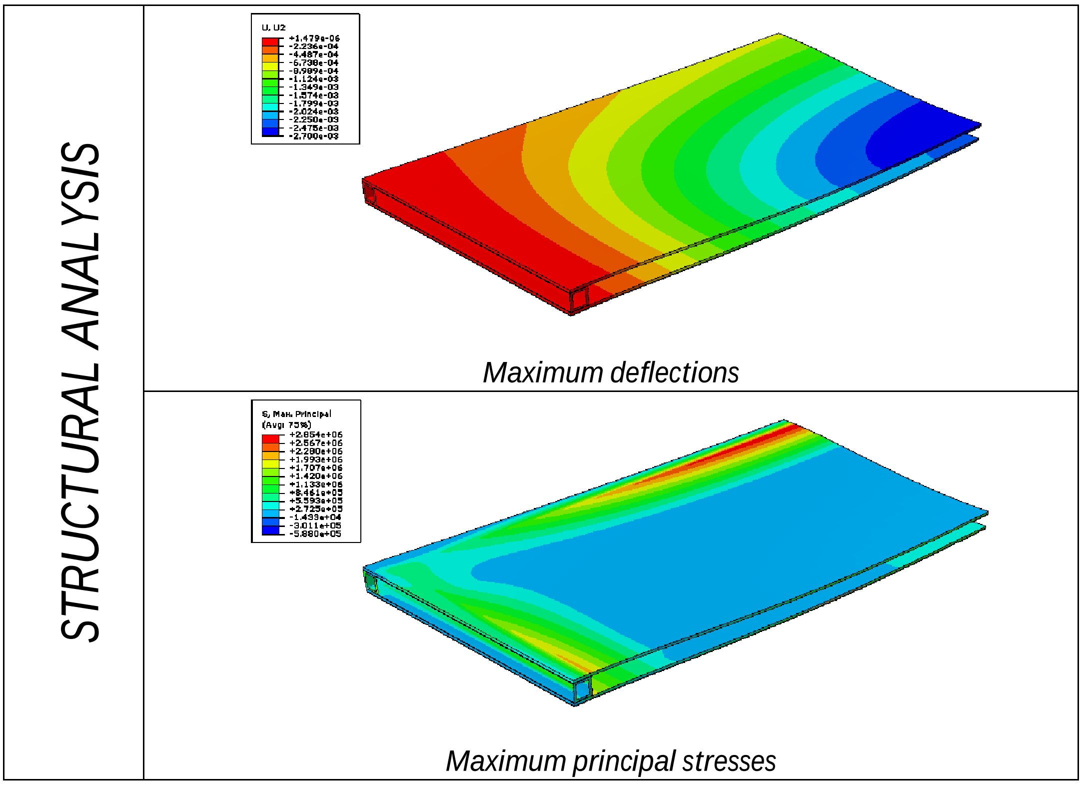


Figure 4. *Example of FE structural analysis (ABAQUS/Standard)*

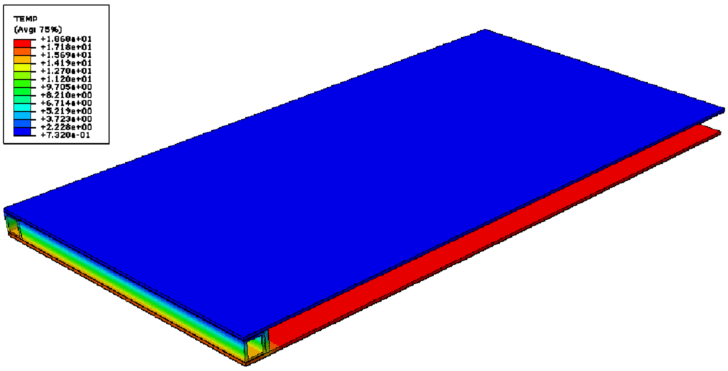
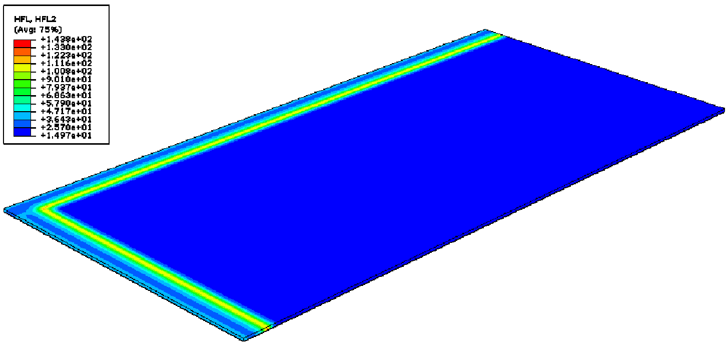
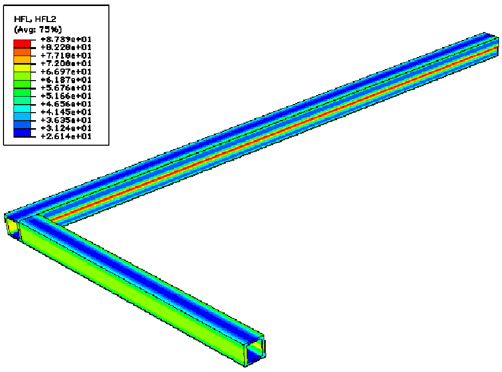
THERMAL ANALYSIS	
	 *Temperatures in the GFRP-glass modular unit*
	 *Heat flux in the glass panel*
	 *Heat flux in the GFRP profiles*

Figure 5. *Example of FE thermal analysis (ABAQUS/Standard)*

Trieste, 22/04/2016

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