Structural and Environmental Design of a Rainscreen System Using COMSOL Multiphysics®

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SYSTEM DESCRIPTION AND CONTEXT OF THE ANALYSIS

The scope of the study is to perform the environmental and structural design of a bespoke rainscreen system for the Grand Theatre of Rabat in Morocco (**Figure 1**).
The rainscreen system consists of fiberglass individually cast reinforced concrete (GRC) panels supported at four or more points by adjustable steel brackets fixed to the primary structure of the building (**Figure 2 and 3**).

Figure 1. Grand Theatre of Rabat

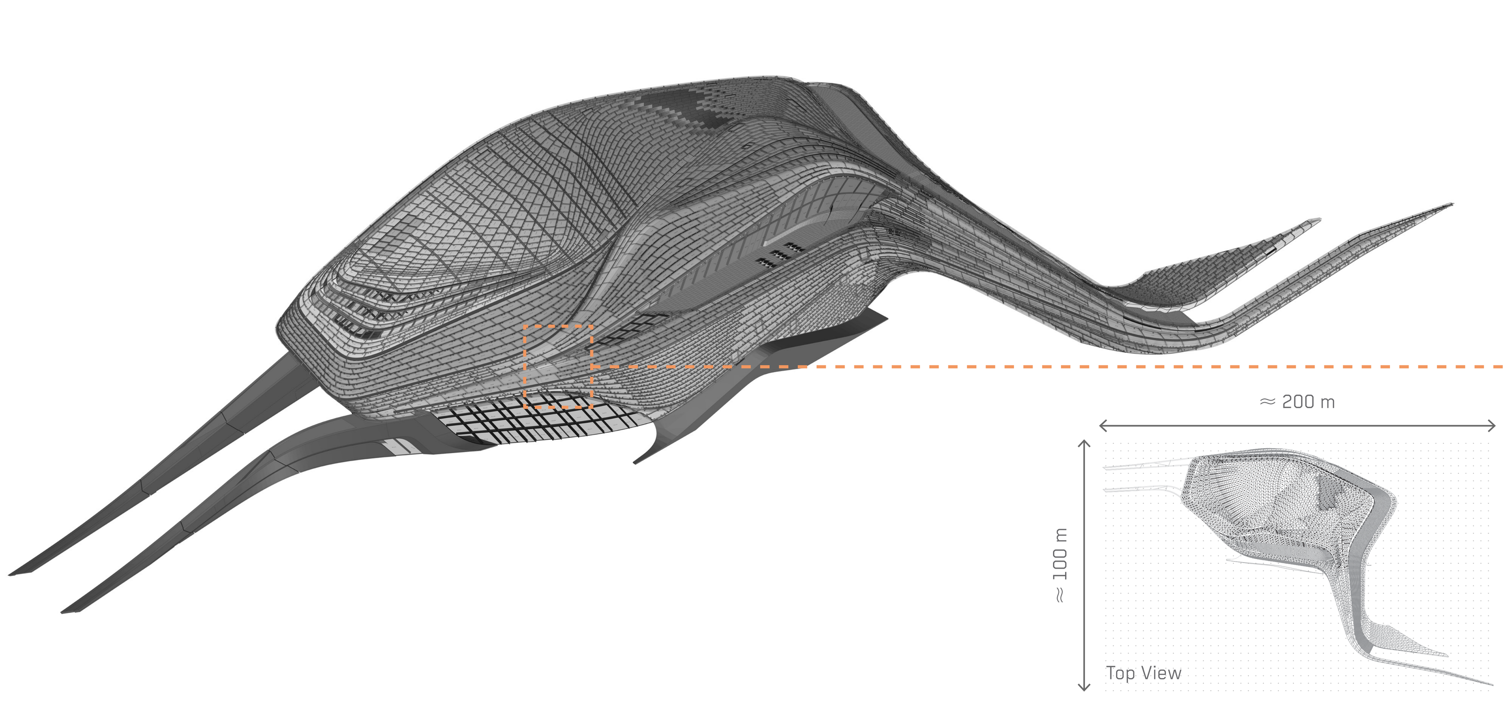


Figure 2. Zoom on Group of Panels

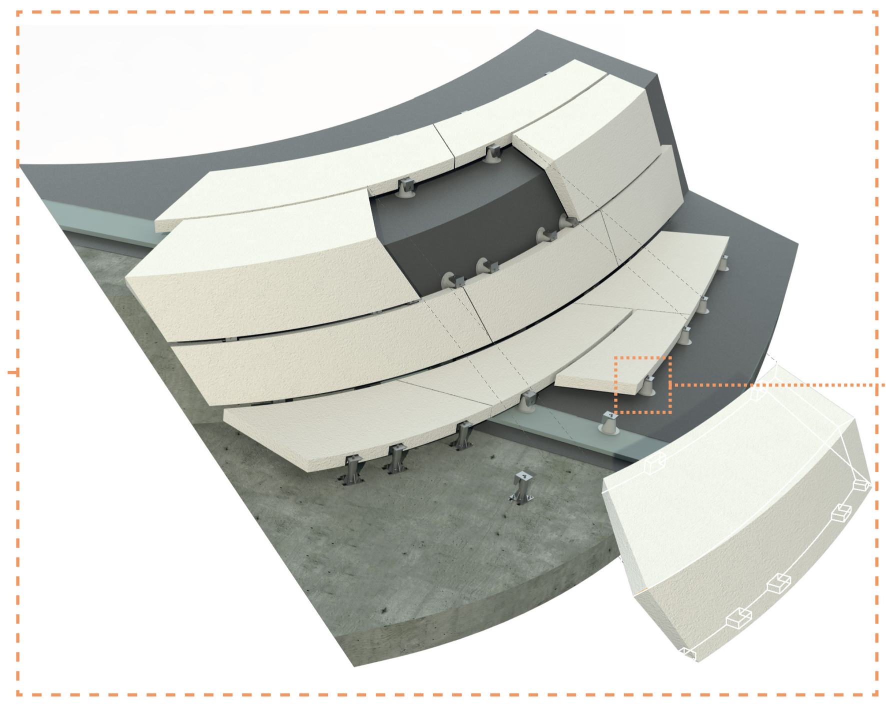
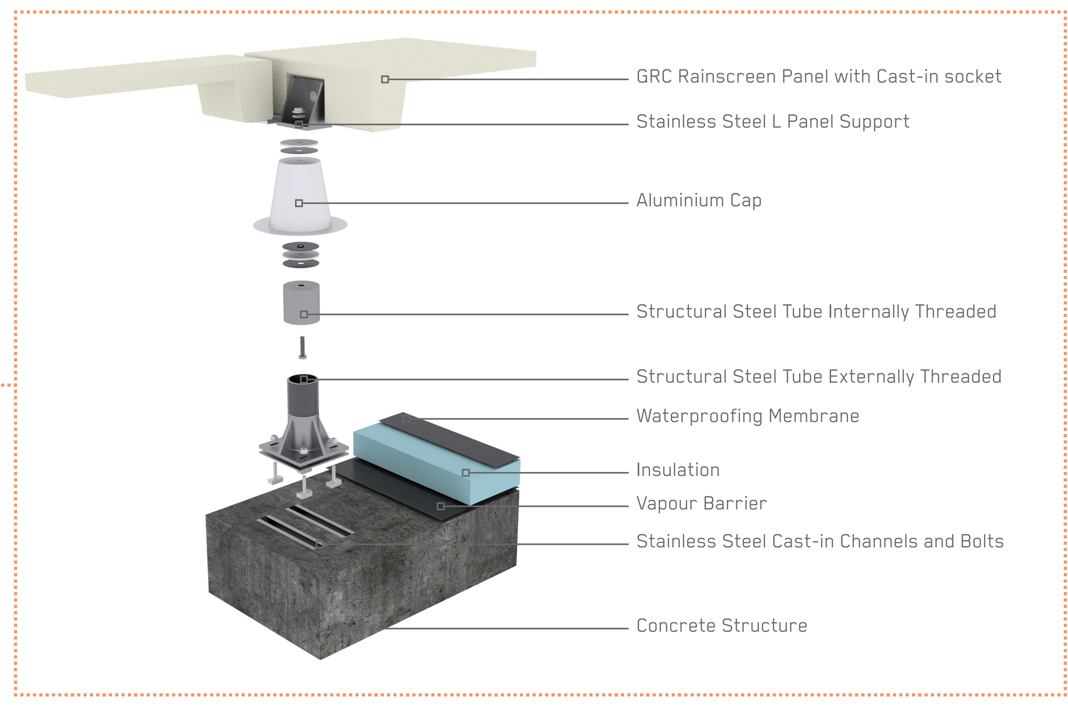


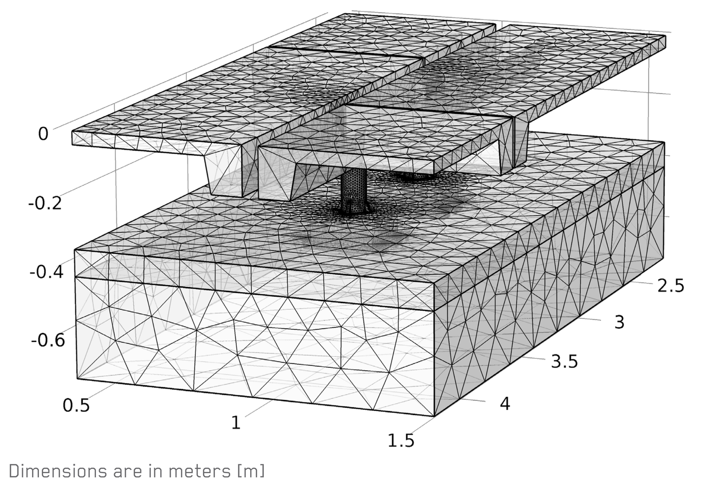
Figure 3. Detail of Bracket and Facade Zone



THERMAL ANALYSIS OF RAINSCREEN SYSTEM

The "Heat Transfer in Solids" Interface is used for the thermal analysis of the rainscreen system.
The model is imported in COMSOL Multiphysics® from Rhinoceros®.
The scope of the analysis is to evaluate the U-value of the system including the 3D thermal bridging effect caused by the steel fixing brackets.
The facade presents about 16000 fixings and the geometry of the scaled model is built to account for their global effect on the U-value.
The results of the analysis (**Figure 5**) show that, in order to achieve the target performance, a 10 mm thermal break plate between the concrete structure and each fixing bracket has to be introduced in the facade zone.
The results also show that further increase in the thickness of the plate brings to minimal improvement in the final U-value (**Figure 6**).

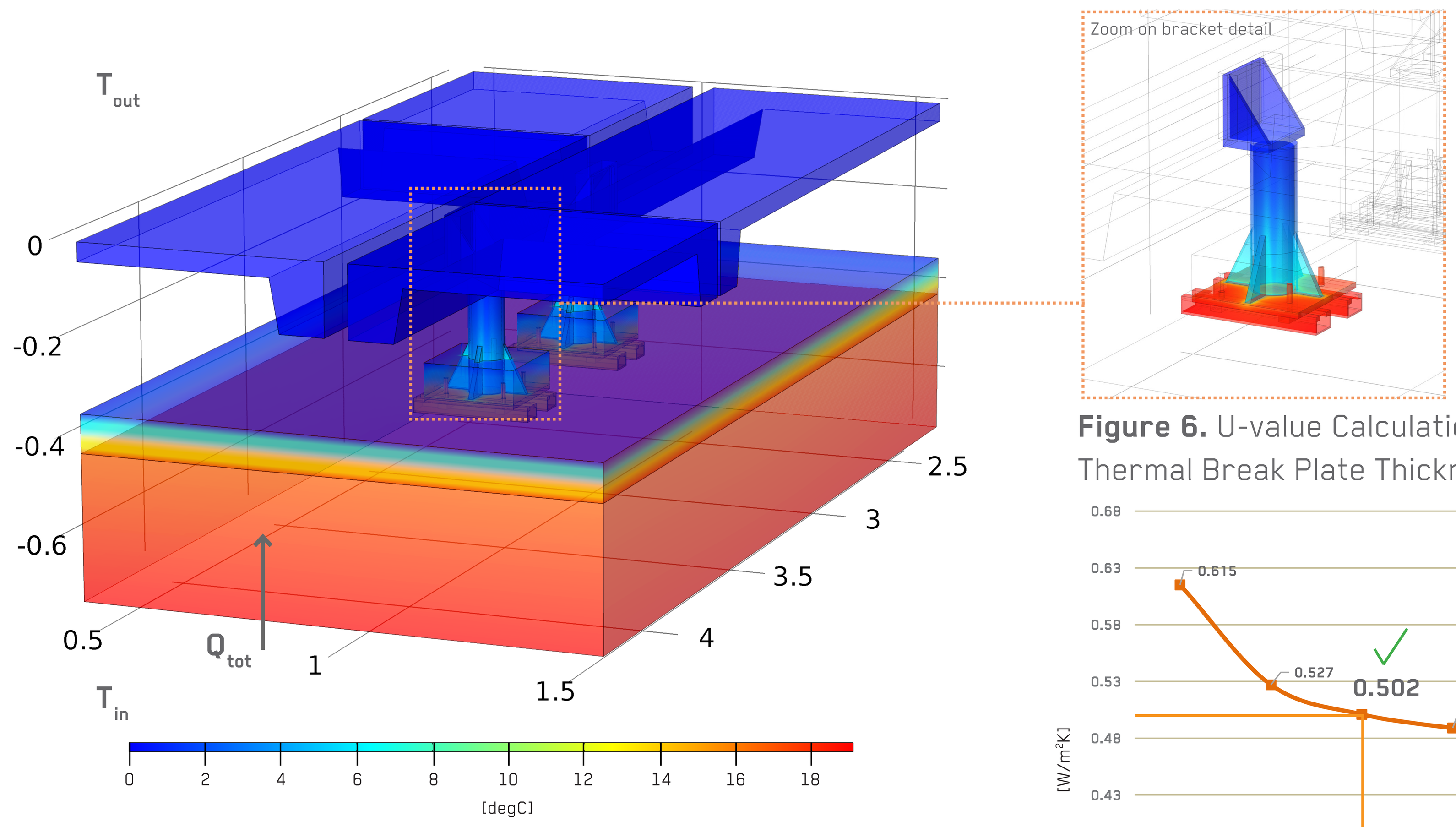
Figure 4. Meshed Model Imported from Rhinoceros



Thermal Conductivity of Materials	
GRC	0.75 W/mk
Structural Steel	44.5 W/mk
Stainless Steel	16.2 W/mk
Insulation	0.041 W/mK
Thermal Break Plate	0.187 W/mK
Concrete	1.8 W/mK

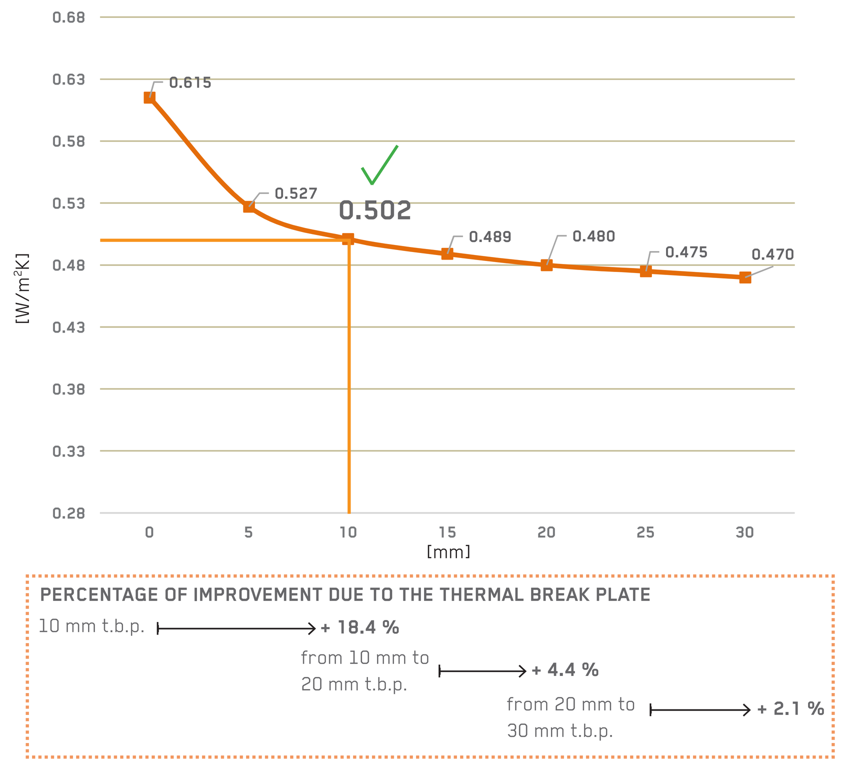
U-Value calculation in accordance with EN ISO 6946:2007 (facade build-up without brackets): **0.439 W/m²K**

Figure 5. Temperature Distribution in the Rainscreen System [degC]



U-Value calculation from COMSOL Multiphysics® model (facade build-up with brackets and 10 mm thermal break plate): **0.502 W/m²K**

Figure 6. U-value Calculation for Different Thermal Break Plate Thicknesses



The global U-value of the rainscreen system including also the additional thermal bridging effect due to the presence of the gutters is equal to **0.53 W/m²K < 0.55 W/m²K** (Requirement from MEP Engineer)

Definition of U-value: $\text{U-value} = Q_{tot}/(A*(T_{out} - T_{in}))$

STRUCTURAL ANALYSIS OF CONNECTION BETWEEN STEEL BRACKET AND GRC PANEL

The "Solid Mechanics" Interface is used for the structural analysis of the connection between the steel bracket and the GRC panel.
The behaviour and stress distribution of the connection under axial (pull test) and transversal (shear test) force is analysed.
The results of the analysis (**Figure 9**) show the areas where there is stress concentration and allow to identify the direction in which the crack could propagate in the GRC.
The analysis also demonstrates that the connection is capable to resist to the design loads with an adequate safety margin (**Figure 11**).

Figure 7. Technical Drawing

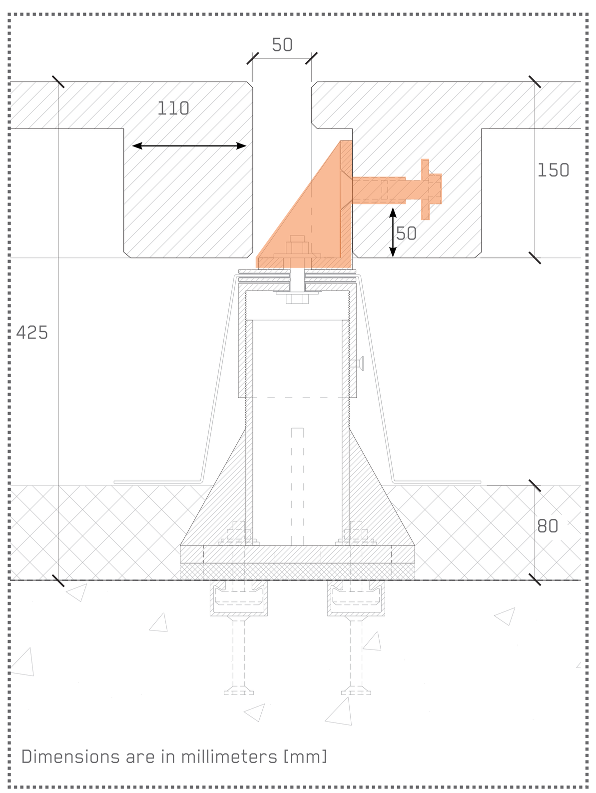
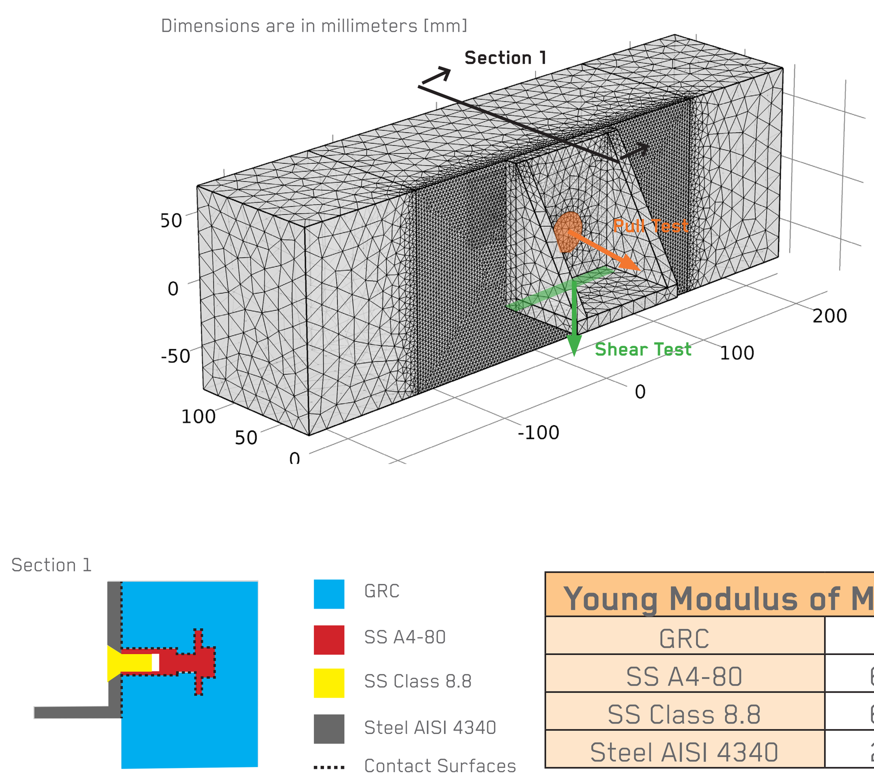
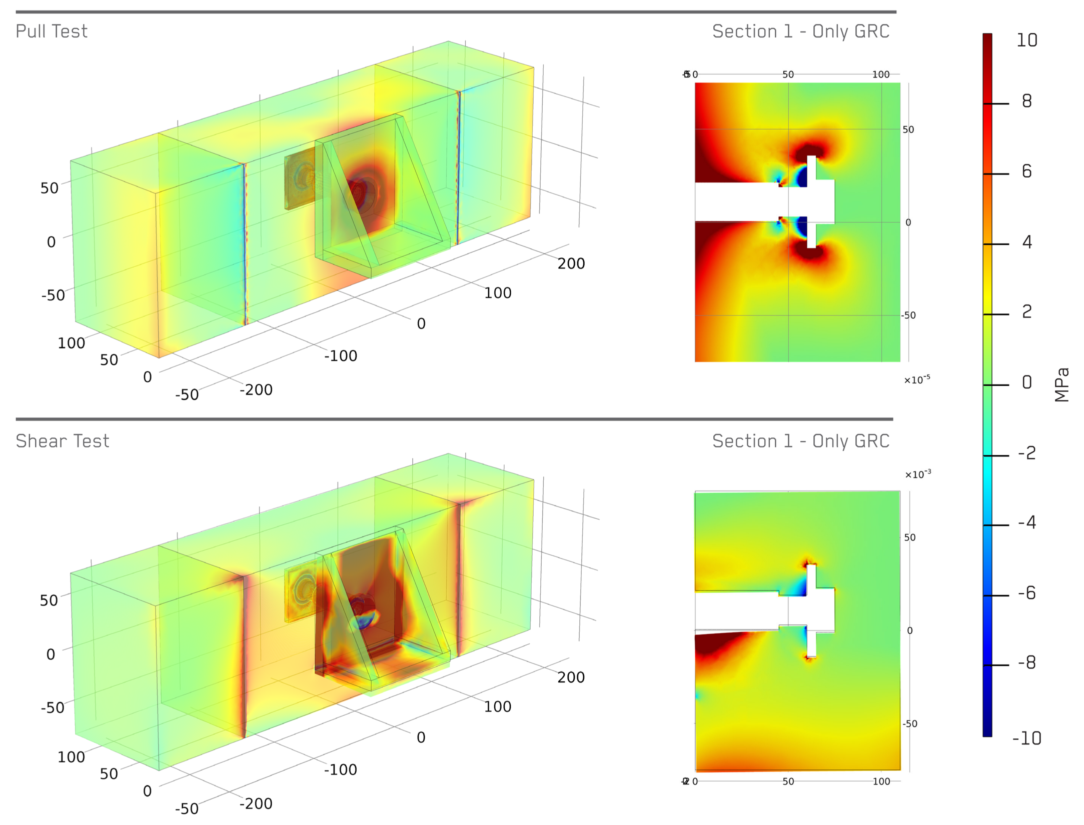


Figure 8. Model of the Connection (Mesh, Materials and Load Cases)



Young Modulus of Materials	
GRC	20 GPa
SS A4-80	600 GPa
SS Class 8.8	640 GPa
Steel AISI 4340	220 GPa

Figure 9. First Principal Stress [MPa]



EXPERIMENTAL TEST OF THE CONNECTION AND MOCK-UP REALISATION

The strength of the connection between metal bracket and GRC panel is also investigated by means of experimental testing in the Engineering Laboratory at the University of Cambridge (UK).
The cone failure for the two test configurations is shown in **Figure 10**.
The graph in **Figure 11** compares the results between the finite element model and the experimental test showing good agreement in the elastic zone before the crack starts propagating.
The results of the structural and thermal analysis show how COMSOL Multiphysics® can be used to inform the design of facade systems and components. The study demonstrates how an ambitious design can be brought from a digital concept to a physical reality (**Figure 12**)

Figure 10. Testing of the Metal Connection at the University of Cambridge (UK)

Figure 11. Comparison of Results for Pull Test (FEM and Physical Test) for GRC

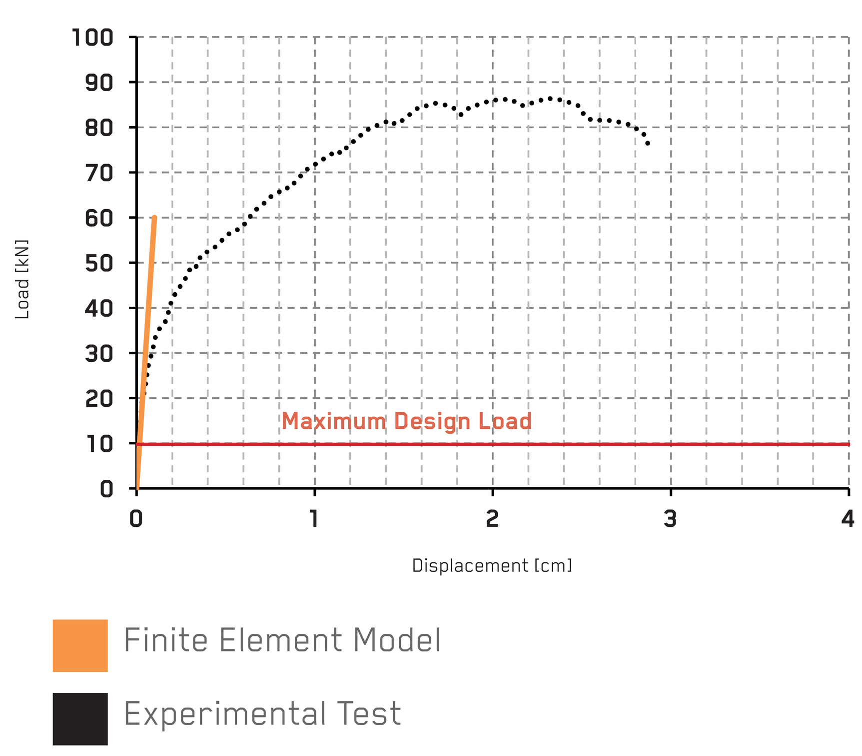


Figure 12. Pictures of the Mock-up

Excerpt from the proceedings of the 2015 COMSOL Conference in Grenoble