Structural and Environmental Design of a Rainscreen System Using COMSOL Multiphysics

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Abstract

Introduction
The subject of the study is a bespoke rainscreen system designed for the Grand Theatre of Rabat, Morocco (Figure 1). The project presents a complex façade geometry and consists of a 1800-seat theater, an open-air amphitheatre with a capacity of 7000 people, a rehearsal space and a restaurant.

The rainscreen system consists of fiberglass individually cast reinforced concrete (GRC) panels supported at four points or more by adjustable steel brackets fixed to the primary structure of the building.

The connection between GRC and steel fixings is designed from first principles and finally tested at the Engineering Laboratory at the University of Cambridge (UK).

The purpose of the study is to inform the design of the rainscreen system looking at the following aspects:
- Evaluation of the thermal performance of the façade system in terms of U-value
- Study of the local behavior of the connection by means of a detailed 3D stress analysis
- Evaluation of the failure mode shape and identification of load condition under which the GRC reaches the elastic limit with risk for crack formation and propagation.
- Physical test of the connection to validate numerical model

Use of COMSOL Multiphysics®
A thermal analysis is performed on the whole rainscreen system importing the 3D geometry from Rhinoceros® and using the "Heat Transfer in Solids" interface (Figure 2). With COMSOL Multiphysics® software it is possible to estimate the thermal bridging effect caused by the fixing brackets and verify that the target in terms of U-value is achieved respecting the 300 mm façade zone.

Given the innovative nature of the connection between GRC panel and steel bracket, a structural analysis is performed on it. The geometry is modeled in Rhinoceros® and then imported in COMSOL Multiphysics®. The contact surface between GRC panel and steel bracket are modeled together with the nonlinearity of the materials to visualize the resulting local stress

distribution and plastic zones in the steel bracket.

Results
The results of the thermal analysis on the rainscreen system show that the thermal bridging effect caused by the brackets needs to be taken into account in the final evaluation of the U-value of the façade. The use of a 10 mm thermal break plate is needed to meet the expected transmittance target.

The results of the structural analysis performed on the connection detail are used to size the dimension of anchorage and panel ribs and to define the position of the anchorage in the rib.
The analysis shows that the connection is capable to resist to the design loads with an adequate safety margin.

Conclusions
The current study shows how COMSOL Multiphysics® can be used to optimize critical components in complex façade systems and verify that their structural and environmental requirements are met.

With COMSOL it is possible to explore and optimize design solutions respecting the project constrains. In this way the engineer/designer can focus on maximizing the performance of the systems rather than simply relying on conservative assumptions and on obsolete design concepts for safety reasons.

Reference

Andrew Watts, “Modern Construction Handbook” – Third edition, AMBRA, London, England, 2013.

Andrew Watts, “Modern Construction Envelopes” – Second edition, AMBRA, London, England, 2014.

EN ISO 10211:2007 – Thermal bridges in building construction – Heat flows and surface temperatures – Detailed calculations.

EN ISO 6946:2007 – Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.

Recommended practice for glass fiber reinforced concrete panels - PCI, 2001.

Glassfibre reinforced concrete - Practical Design and Structural Analysis, Beton - Verlag, 1995.

Figures used in the abstract

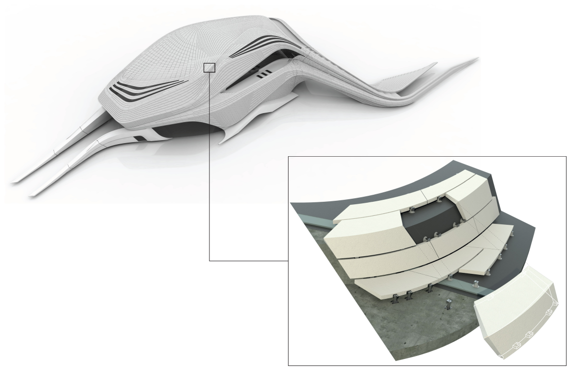

Figure 1: Grand Theatre of Rabat Project and zoom on rainscreen system

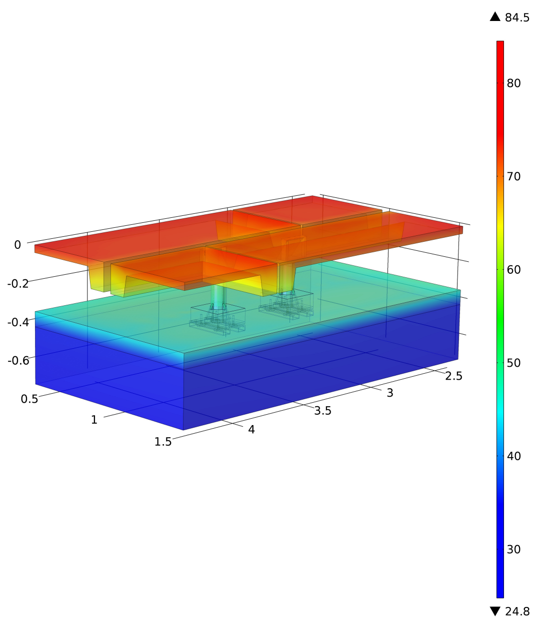

Figure 2: Temperature distribution (summer condition) [degC]

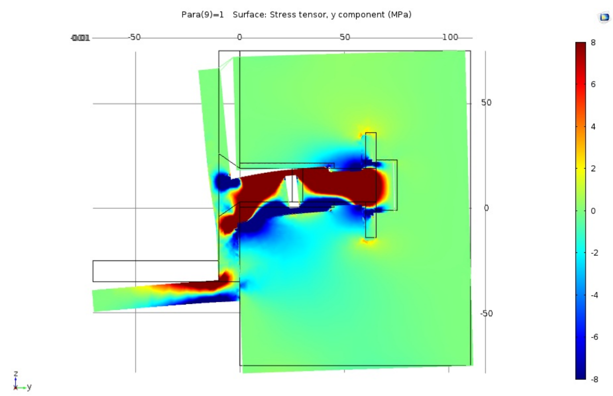

Figure 3: Stress distribution under shear load (2D section) [MPa]

Figure 4