Solar Radiation Effects on the Epoxy Adhesive Temperature Used to Bond CFRP to Concrete Beams

M. Breveglieri [1], B. Weber[1], C. Czaderski[1]

[1]EMPA - Swiss Federal Laboratories for Materials Science and Technology, Dübendorf, Switzerland

Abstract

The service temperature of epoxy-based adhesive used for structural strengthening of civil structures such as road bridges is an important issue and has to be taken into account when, for example, bonded CFRPs(Carbon Fiber Reinforced Polymer) strips are exposed to solar radiation and elevated ambient temperature [1]. The described scenario can lead to an adhesive's temperature very close to its operational limit, typically indicated as glass transition temperature, which is typically 50-60°C [2]. If this limit is exceeded, the epoxy adhesive softens and debonding (loss of adhesion) might occur even at low stresses. The problem of reinforced concrete beams strengthened on the top surface with 2 CFRP strips under the effects of solar radiation and change of air temperature is studied here.
In this work, two modules of the COMSOL Multiphysics® software are used: the Heat Transfer and the Structural Mechanics modules.
The Heat Transfer with Surface-to-Surface Radiation is used to consider the effects of the daily fluctuation of air temperature and the solar radiation on the temperature of the epoxy adhesive, whereas the Structural Mechanics module is used to evaluate the thermal stresses and displacement generated by temperature changes in the cross-section. Since the CFRP strips and adhesive layer are very thin, modeling them by thin layers can make the meshing procedure easier and save computational time. Two modeling approaches are compared here. In the first, the adhesive layer and the CFRP strips are modeled as solid elements (Fig.1); in the second they are modeled using the "Thin Layer" approximation in the heat transfer problem and as a layered shell in the structural mechanics problem. For the concrete, a solid geometry is adopted in both cases. In order to verify the modeling strategies, a simplified geometry of the actual problem and a mesh sensitivity study are presented here.
It is demonstrated that the "Thin Layer" approximation provides very accurate results when compared to the full solid model in the simplified geometry. Nevertheless, for the actual strengthened beam geometry, the full solid modeling approach leads to more detailed and accurate results. The Heat Transfer study shows that the calculated temperature in the epoxy adhesive, for the simulated temperature scenario, remains below the glass transition temperature. The Structural Mechanics study shows that the thermal stresses in the CFRP due to temperature change and radiation are in the order of 25-35 MPa, which is relatively low compared to the stress at debonding.

[1] Gallego, J. M., Michels, J., & Czaderski, C. (2017). Influence of the asphalt pavement on

the short-term static strength and long-term behaviour of RC slabs strengthened with externally bonded CFRP strips. Engineering Structures, 150, 481-496.

[2] Michels, J., Widmann, R., Czaderski, C., Allahvirdizadeh, R., & Motavalli, M. (2015). Glass transition evaluation of commercially available epoxy resins used for civil engineering applications. Composites Part B: Engineering, 77, 484-493.

Figures used in the abstract

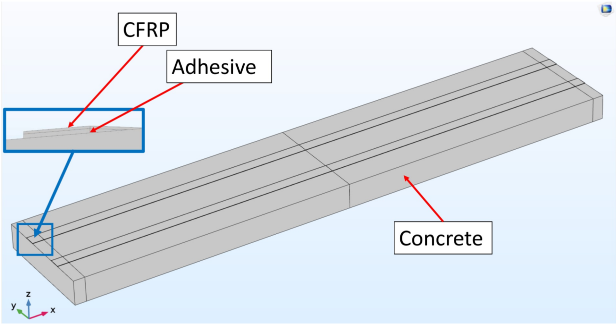

Figure 1: Solid model of the reinforced concrete beam strengthened using carbon fiber polymers (CFRP).