Multi-physics Numerical Modelling of EBR CFRP-concrete Bonded Joints under Water Immersion Exposure

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Objectives / Description / Main outcomes

The main objective of this STSM was to numerically investigate the durability of externally bonded reinforcement (EBR) CFRP-to-concrete bonded joints of strengthened concrete structural elements continuously immersed in water at 20 °C. The specific objectives were: i) to conduct an extensive literature review on the physical and mechanical modelling of the effects of water ingress into the joint constituent materials and the joint itself, ii) to perform numerical simulation of the bond/joint strength at initial stage before water immersion, iii) to simulate the EBR CFRP-to-concrete bond/joint strength variation under continuous water immersion at 20 °C for up to 4 years, and iv) to develop numerical predictions of the CFRP-to-concrete bonded joint degradation due to long-term moisture exposure (e.g., 100 years of exposure). The concrete block was strengthened with CFRP laminate using an epoxy adhesive as a bonding agent between the concrete and the CFRP laminate. Pull-out tests (Fig. 1) were conducted at the initial stage (before water immersion) and in later stages (after water immersion) to facilitate comparison. The dimensions for the concrete, epoxy adhesive and CFRP laminate were 200x200x400, 50x220x1.5 and 50x520x1.2, respectively (see Fig. 2 – all dimensions in mm). Both concrete and adhesive were modelled as 3D deformable solids using concrete damage plasticity (CDP) for their constitutive models, while the CFRP was modelled as a 3D deformable shell, with linear elastic behavior up to failure. The simulation corroborated well with the experimental results as shown in Fig. 3, and the predicted failure mode (see Fig. 4 – only the joint part and a small region of concrete is shown) agreed well with that observed during experimental program (i.e., concrete cohesive failure). The next stage of this research will be to simulate the effects of water immersion on the CFRP-to-concrete bond strength for long-term periods.

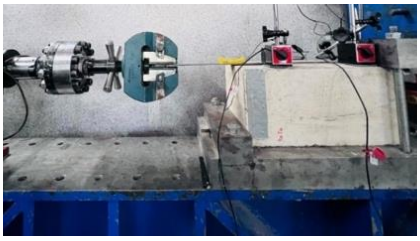

Figure 1: *Pull-out test setup for concrete blocks strengthened via EBR technique*

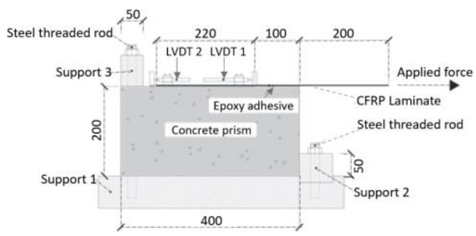

Figure 2: *Dimensioning of the test setup shown in Figure1 (all units in mm)*

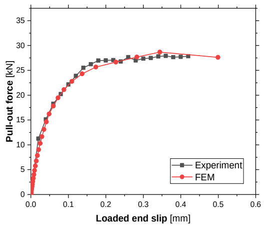

Figure 3: *Pull-out test: Comparison between the experimental and FEM results*

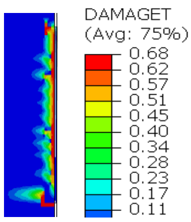

Figure 4: *Prediction of failure mode: Highlights of the tensile damage at failure for the adhesive, concrete, and CFRP laminate*

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