RAISE – Durability of Adhesively Bonded Composite Systems Used for Structural Rehabilitation in Civil Engineering

Summary

The aging and durability problems experienced by existing infrastructures and the implementation of new requirements associated with the growing concerns with sustainability and the rational use of resources (raw materials and energy) have motivated the need for different types of rehabilitation solutions. In this context, in recent years numerous structural rehabilitation techniques that make use of composite materials, namely fibre reinforced polymers (FRP), have emerged.

Despite the significant progress in the use of bonded FRP systems in structural rehabilitation, and the potential shown by these solutions (Figure 1), several issues related to their durability remain unclear. It is thus very important to understand how the long-term quality of adhesively bonded connections is affected in various combinations of materials (substrates, adhesives, FRPs) and environments.

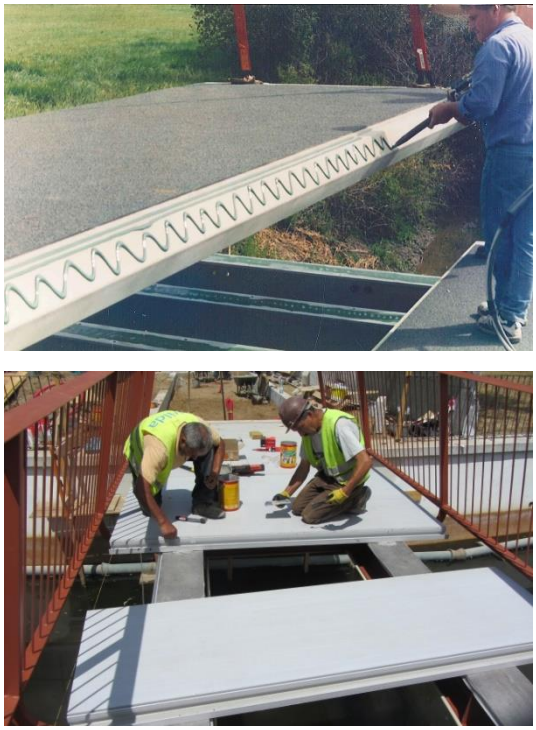

Figure 1. Adhesively bonded connections between FRP components (bridge decks) and steel girders.

In this context, this project addressed the durability of structural rehabilitation systems that are based on bonding FRP composites to different substrates. The aim was to emphasize the importance of long-term performance of the bonded connection established between the FRP and the substrates in this type of rehabilitation solutions.

Indeed, if this connection becomes ineffective over the expected service life of the structure, the rehabilitation solution may be compromised, and its competitive advantages (over alternative solutions) may be lost. In addition, since the rehabilitation with bonded FRP composites often involves the structural strengthening of existing constructions, it is essential to preserve the system integrity, to avoid structural failures, which can be catastrophic.

The main objective of this project was to provide answers to questions that remain unclear regarding the durability of structural rehabilitation systems using adhesively bonded FRPs. The literature review shows that the durability of structural bonding is the cornerstone of the performance of such solutions, and that this durability depends on the appropriate selection of the type of structural adhesive, the conditions of its *in situ* application and curing, and the environmental conditions to which it will be exposed to during the service life of the rehabilitated structure.

An experimental study was conducted focused on the durability of the bonded connections involved with different rehabilitation systems commercially available, in which different combinations of substrates was analysed (FRP, concrete), together with different types of adhesives (epoxy and polyurethane) – Figures 2, 3 and 4.

Figure 2. GFRP laminates and adhesively bonded joints placed in the rooftop of LNEC subjected to natural ageing conditions (left) and single lap shear test (right).

The experimental program essentially aimed at answering the following three questions: (i) How to select the structural adhesive depending on the application conditions and the type of

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Project Reference

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Leading Institution

LNEC – National Laboratory for Civil Engineering (Portugal)

Partners

IST-ID – Associação do Instituto Superior Técnico para a Investigação e Desenvolvimento (Portugal), S&P – Clever Reinforcement iberica - Materiais de Construção Lda (Portugal), Sika Portugal - Produtos Construção e Indústria, S.A. (Portugal), STAP (Portugal)

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CERIS

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Project Website

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rehabilitated structure? (ii) How can the environmental conditions during system installation influence the curing reaction of the glue, its molecular structure and physical-chemical characteristics and therefore their own mechanical properties? (iii) What are the main factors that determine the durability and long-term performance of the structural bonding of different rehabilitation systems?

In addition to the laboratory work, which was designed to help answering these questions, information about rehabilitation works already completed with this type of systems were collected to draw learnings/lessons on their performance and durability.

This project helped increasing the reliability of rehabilitated structures, preventing their premature failure, and provided: (i) a better understanding of the effects of environmental factors during the application and curing process of adhesives and their degradation during service life; (ii) a definition of practical guidelines on bonding systems and their application processes to optimize durability; and (iii) essential knowledge for predicting long-term performance of civil engineering structures rehabilitated with adhesively bonded FRP systems.

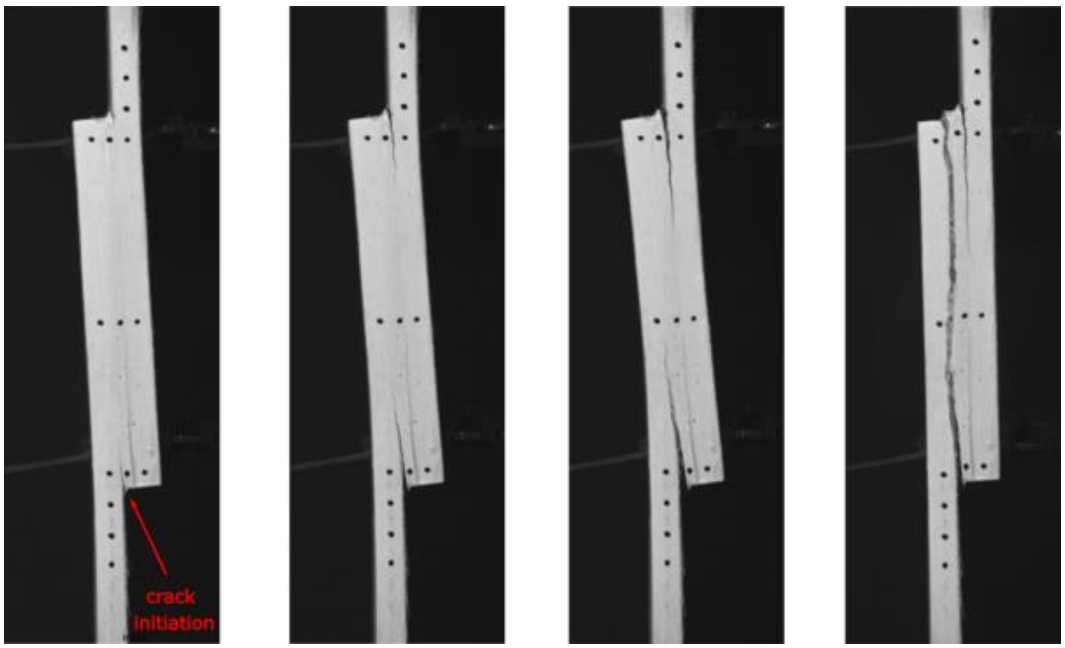

Figure 3. Failure mode of an adhesively bonded joint between pultruded GFRP adherends and a polymeric adhesive.

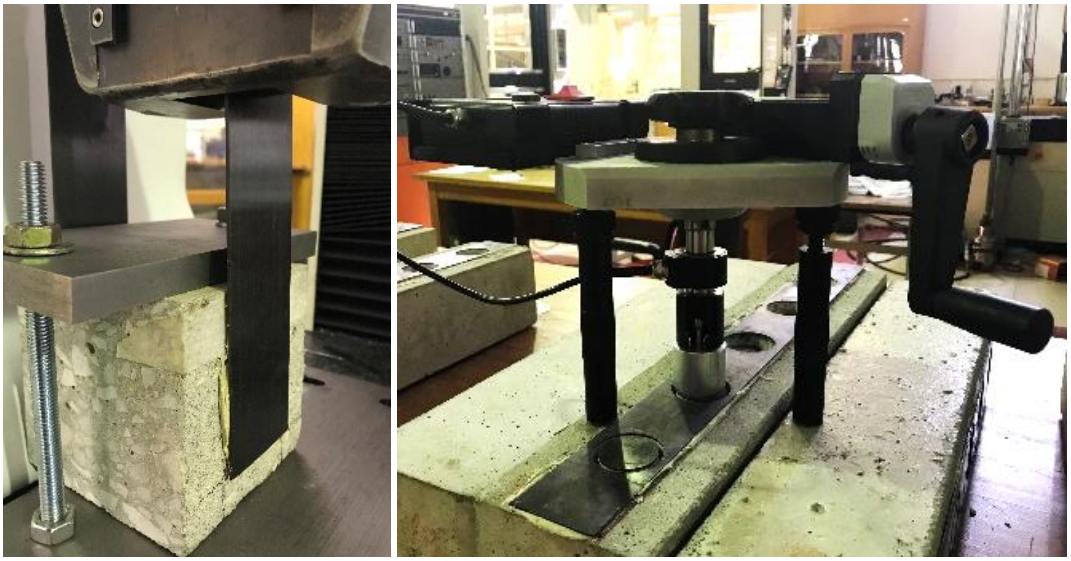

Figure 4. Lap tests and pull-out tests to assess the bond between concrete substrates and CFRP strips used for structural strengthening.