Experimental Evaluation of Interface Adhesion of Flax Fiber Composite patch with Epoxy and Polyurethane Adhesives for the Reinforcement of Steel Structures

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Abstract :

An innovative solution has emerged for reinforcing damaged structures (metal or concrete) and, consequently, extend their lifespan, which consists in using fiber-reinforced composite patches. These patches are generally bonded on the structures' surface to protect them from internal stresses and non-neutral physico-chemical external attacks, limiting crack propagation. The adhesive bonding process makes this solution very easy to be applied. Although, the use of eco-friendly composites remains one of the challenges to be overcome. Natural fibers can be an alternative solution to replace glass or carbon fibers commonly used for patches. Towards the same objective, bio-based polymers are also an important sustainable alternative to replacing (or partially replacing) the petroleum-based matrix and adhesive. In this work, an epoxy matrix reinforced with flax fiber is proposed as material for the patches, and bonded to a steel plate using a castor oil derived polyurethane resin. Floating roller peel tests were performed to verify the applicability of these new patches.

Materials and Methods :

To assess the interface adhesion properties between a carbon steel and Flax Fiber Reinforced Polymer (FFRP) bonded joint, floating roller peel test specimens were manufactured – See Fig. 1. Table 1 represents the materials and bonding techniques, used to assemble the carbon steel plate (flexible/parent adherend) with an FFRP plate (rigid substrate).

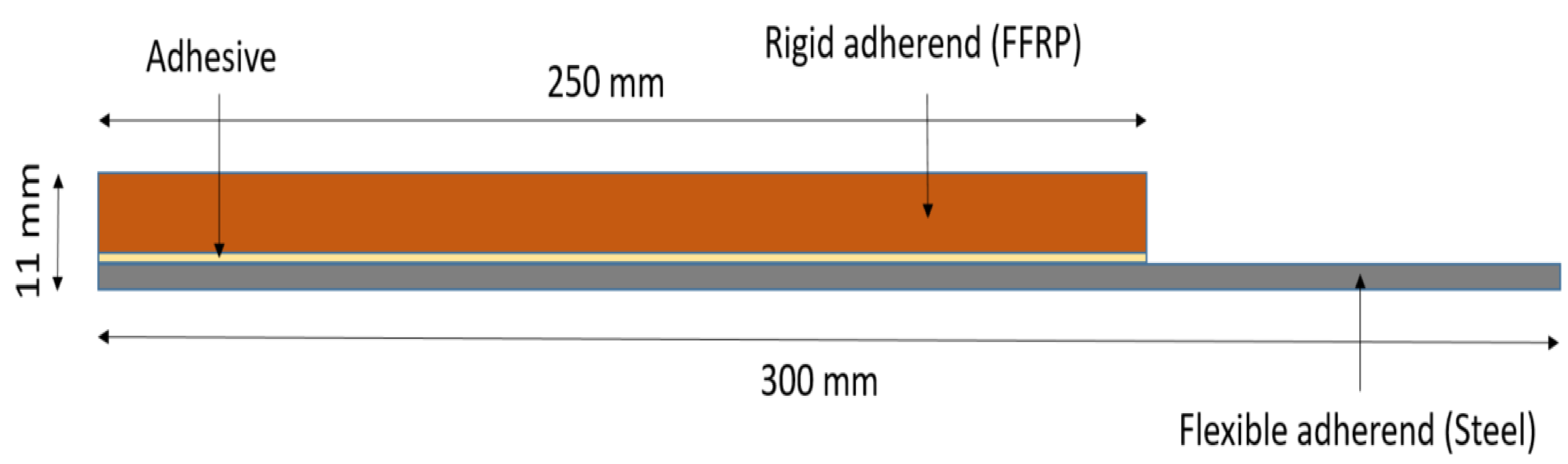


Fig. 1. Scheme of peel sample dimensions (in mm)

Material	Type	Tensile Strength [MPa]	Young's Modulus [GPa]	Bonding technique
Epoxy SikaBiresin® CR83	Bi-component	91	3.2	Co-curing
Epoxy AxsonSika® ADEKIT A155 / H9955	Bi-component	53	1.9	Secondary bonding
Polyurethane Sikaflex®-554	Single-component	3.5	-	Secondary bonding
Castor-oil derived Polyurethane Kehl®	Bi-component	42	1.5	Secondary bonding

Table. 1. Adhesive materials properties and type of bonding technique

During testing, the flexible adherend (Carbon Steel) is peeled off from the rigid adherend (FFRP) – See Fig 3-4. Frames of crack propagation (Fig. 5) and peel loads (Fig. 6) are recorded.

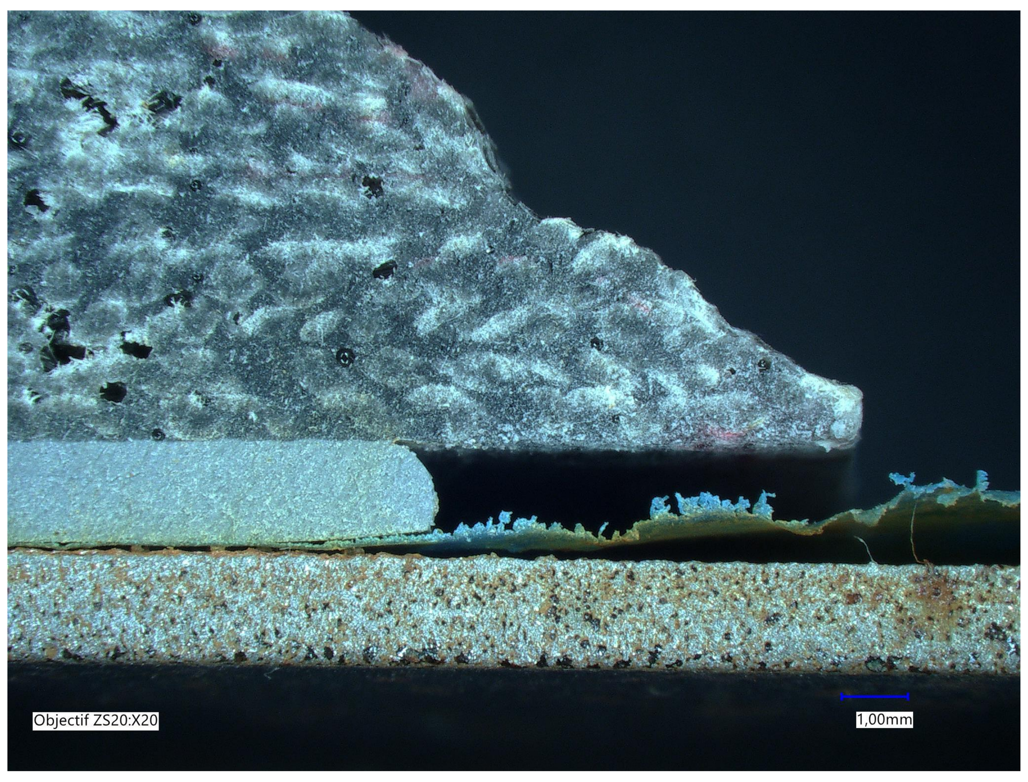


Fig. 2. Image of zone of peel initiation

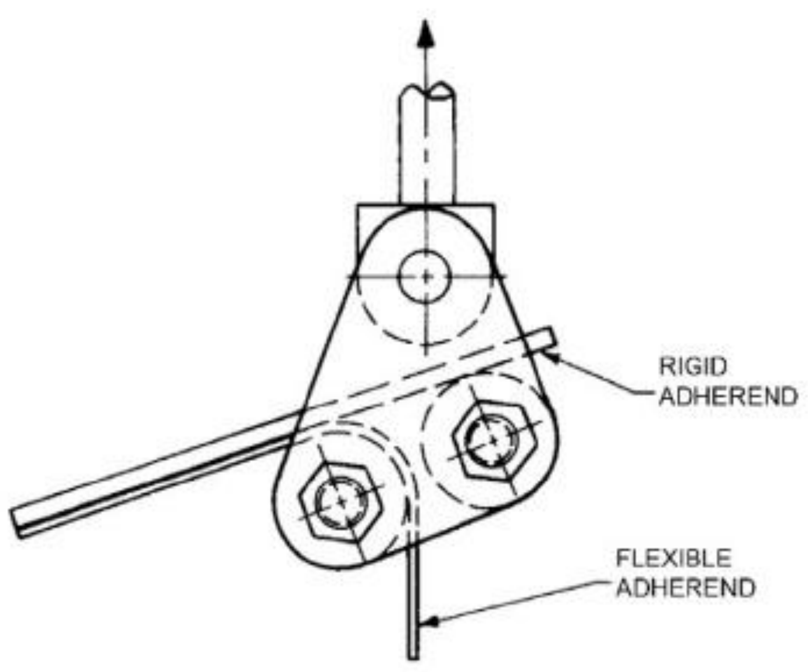


Fig. 3. Scheme of Floating roller peel test [1]

Fig. 4. Experimental set-up

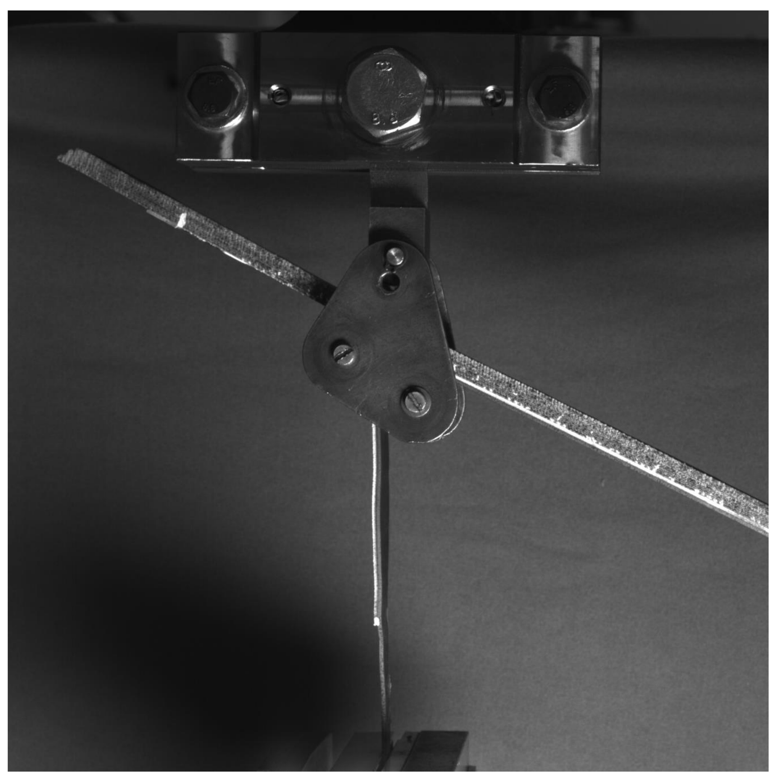


Fig. 5. Frame of test recording

Results and Discussion :

Peel loads : Fig. 6. shows the load-displacement curves for one specimen from each type of adhesive. The average peel laod and failure mechanism are given in Table. 2. The average peel load values are shownas the average ± standard deviation of the three specimens tested for each type of adhesive. Two types of failure mechanism were observed: cohesive failure (CF) within the adhesive and adhesive failure (AF). The percentage area of failure modes is calculated based on the visual observation of specimen failure surface. The average failure peel load was determined along 100mm of displacement, disregarding the first 50mm.

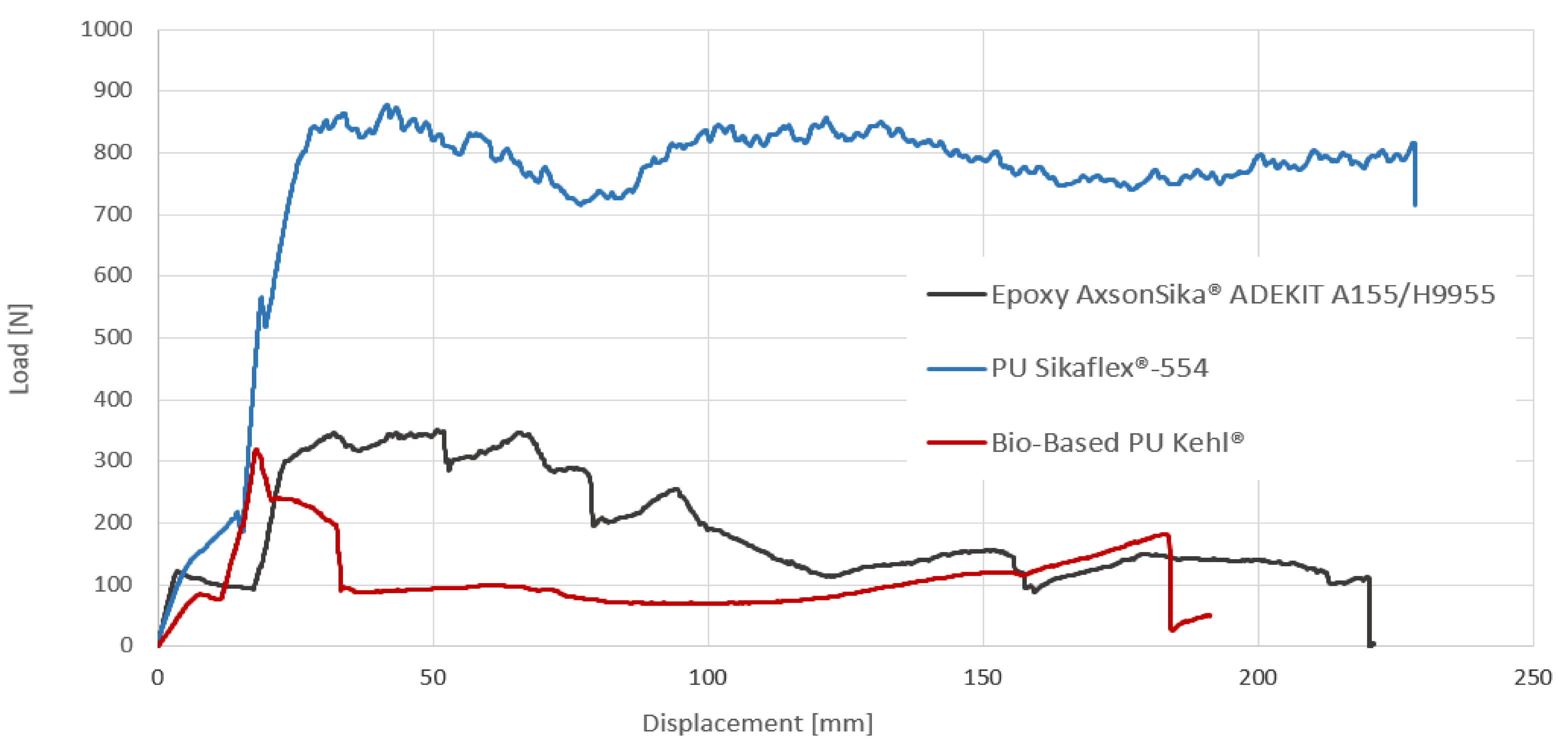


Fig. 6. Load-displacement result curves

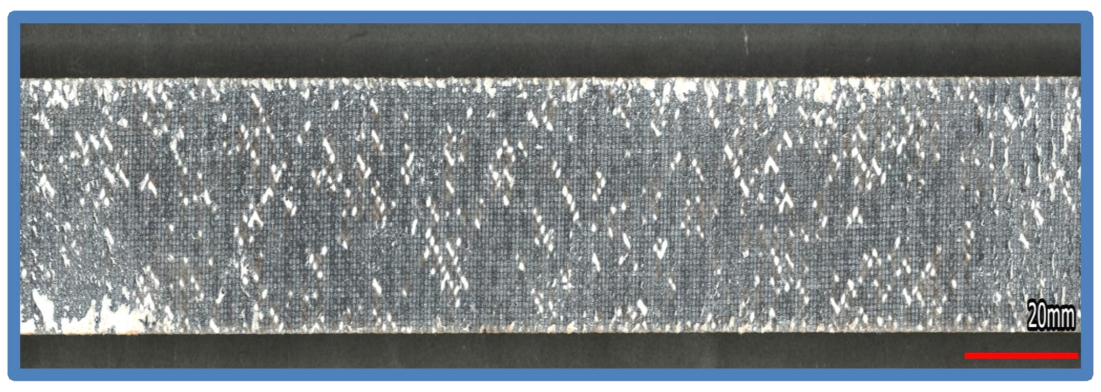
Adhesive	Average peel load [N]	CF (%)	AF (%)
Epoxy SikaBiresin® CR83	-	30	70
Epoxy AxsonSika® ADEKIT A155/H9955	272.6 ± 104.2	0	100
Polyurethane Sikaflex®-554	807.7 ± 66.8	100	0
Castor oil derived Polyurethane Kehl®	74.8 ± 18.5	20	80

Table. 2. Average peel load values (average ± standard deviation) and percentage of failure mode

Fracture surface :

Epoxy AxsonSika® ADEKIT A155/H9955

- Proper surface preparation of the adherends, and storage conditions are crucial for achieving optimal adhesion with the AxsonSika® ADEKIT A155/H9955 epoxy adhesive.



Polyurethane Sikaflex®-554

- The Polyurethane Sikaflex®-554 adhesive demonstrates promising performance and highlights its potential as a suitable choice for achieving reliable and robust bonding in epoxy-to-steel joints.

Castor oil derived Polyurethane Kehl®

- Control of the adhesive layer thickness is important for achieving consistent and reliable bonding results with the castor oil derived polyurethane adhesive. Further optimization of the bonding process, including controlling the adhesive application and curing conditions, may be necessary to enhance the performance and reliability of this bio-based adhesive.

References :

[1] S. Teixeira de Freitas, M. Banea, S. Budhe and S. de Barros, "Interface adhesion assessment of composite-to-metal bonded joints under salt spray conditions using peel tests," *Composite Structures*, vol. 164, pp. 68-75, 2017.

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