Adhesion of Bio-based Composite Repairs

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Objectives / Description

The main objective of the STSM was to assess the interface adhesion properties of a carbon steel and a Flax Fiber Reinforced Polymer (FFRP) bonded joint, through floating roller peel tests (see Figure. 1). The manufactured specimens consisted of bonding the carbon steel (flexible/parent adherend) with an FFRP plate (rigid substrate) using four different adhesives/resins, including a bio-based Polyurethane resin. The study focused on evaluating the viability of the use of this bio-based resin as an alternative material to synthetic adhesives. Table. 1 summarizes the adhesive materials properties and corresponding bonding techniques.
After manufacturing, testing of the specimens were carried out using the TU Delft's electro mechanic Zwick machine, with maximum capacity of 20kN. A digital Camera was used at a frequency of 0.5 frame per second to capture the crack propagation during the tests. During testing, load-displacement curves were recorded (See Figure. 2).

Main Outcomes

The results of peel tests, including the average peel load values and failure mechanisms observed for each type of adhesive, are presented in Table. 2. The average peel load values are shown as the average ± standard deviation of the three specimens tested for each adhesive material. Two distinct failure mechanism were observed: cohesive failure (CF) occurring within the adhesive layer, and adhesive failure (AF) at the interface between adhesive and adherends.
The percentage area of each failure modes was calculated based on the visual observations of the specimen failure surfaces. The average failure peel load was determined over a displacement of 100mm, excluding the first 50mm. This procedure for calculating average failure peel load values aligns with ASTM Standard D3167 for peel tests.

From the analysis of the obtained results, the following conclusions and directions of research for furure works can be drawn:

- Polyurethane is a promising material for steel-to-composite bonded joints. The industrial Polyurethane from Sika® showed high peel loads and full cohesive failure, hence good adhesion. This justify our interest towards developing the Kehl® bio-based polyurethane application and industrial implementation.
- The Kehl® castor oil derived polyurethane showed 30% cohesive failure on the peeled area. The manufacturing of the joint with this material is very sensitive to moisture exposure and temperature control. In this study, it was done at room temperature. Further optimization of the bonding process, including controlling the adhesive application and curing conditions, are necessary to reach higher cohesive failure mode ratio, and thus higher peel loads.

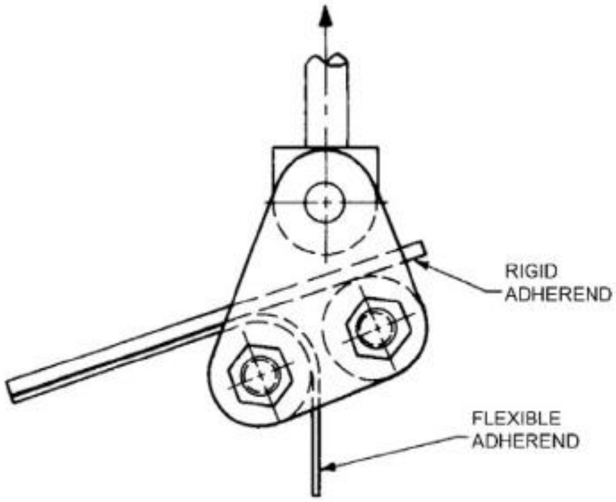

Figure. 1: *Scheme of floating roller peel test*

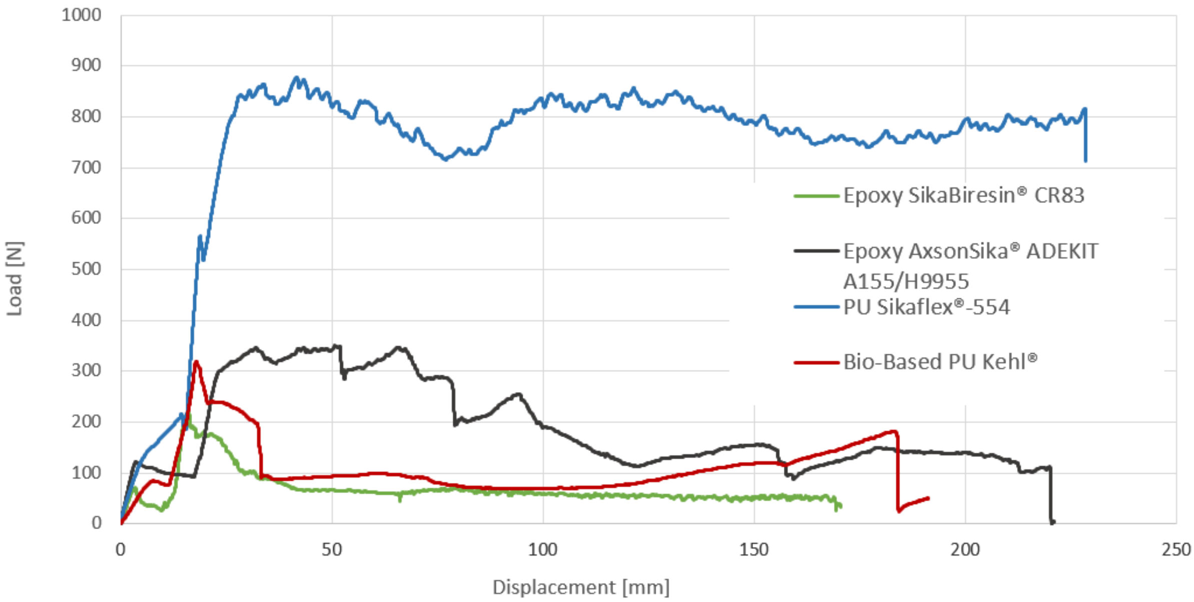

Figure. 2: *Load-displacement result curves*

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 corresponding bonding technique*

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*

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