The performance of adhesive joints with bent composite adherends

R.C.J. Carbas (INEGI, Portugal), V.D.C. Pires, B.D. Simões, E.A.S. Marques, L.F.M. da Silva

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Introduction

This study focused on the influence of adherend curvature on joint performance. These curvatures are generated during the cure of an asymmetrically stacked laminate or when multi materials with different thermal expansion coefficients are used in a single-lap joint (SLJ). The effect of this curvature was assessed both experimentally and numerically. The numerical analysis was carried out in the ABAQUS commercial software, allowing to better understand mechanical behaviour of adhesively bonded composite joints [1].

Experimental details

Adhesive

Scotch Weld AF 163-2k - film-form modified epoxy adhesive.

Adherend

Texipreg HS 160 T700 - unidirectional prepreg carbon-epoxy.

Joint Geometry

Figure 1 illustrates the geometry of the specimens used.

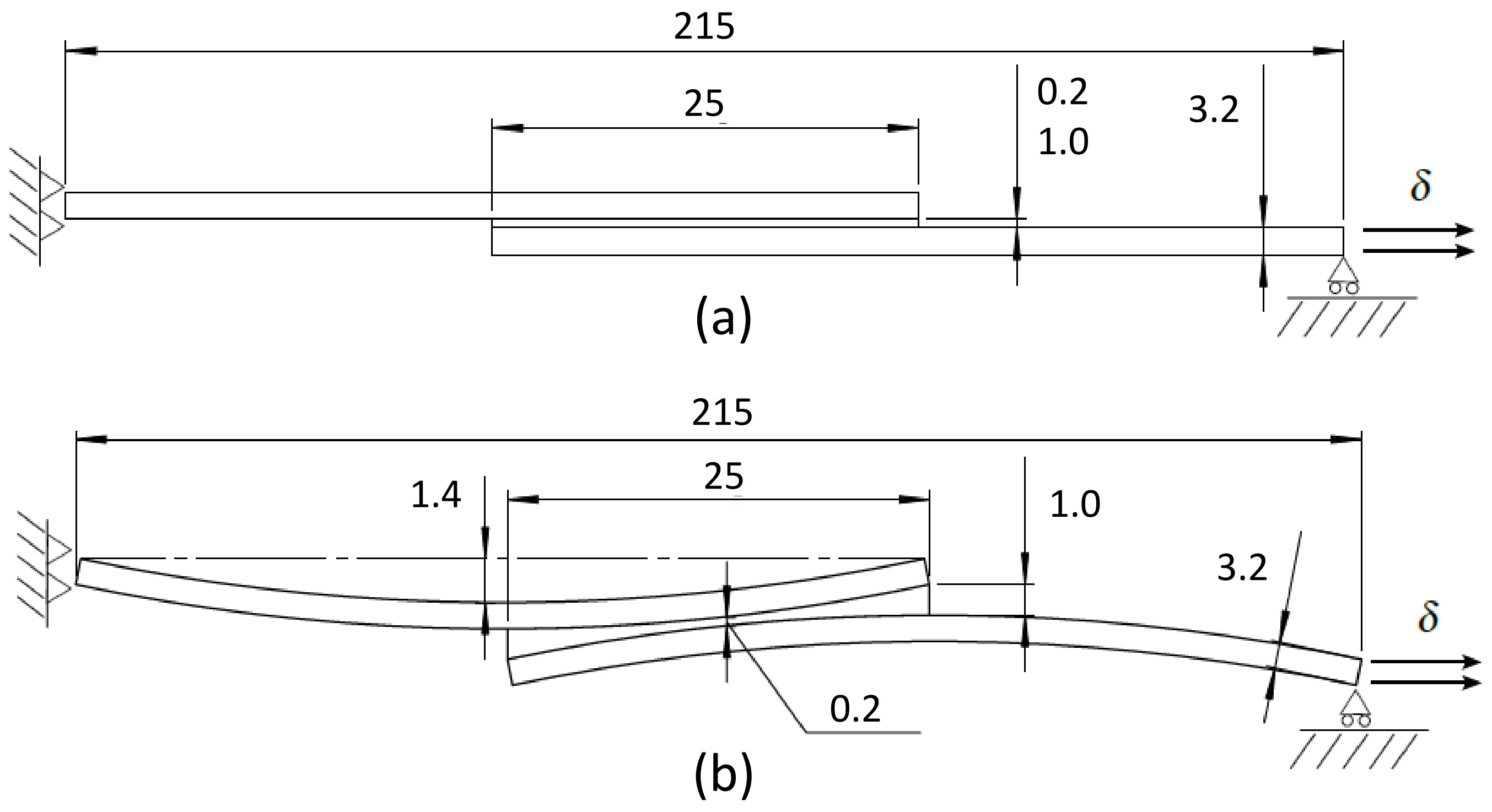

Figure 1 – SLJ specimen geometry. (a) Planar SLJ. (b) Curved SLJ.

The curvature of the adherends is obtained through asymmetric layups of 0° and 90° layers. This leads to the curvature of the adherend after curing as seen in Figure 2. In this case a layup of $[0°_{10}/90°_{11}]$ was used.

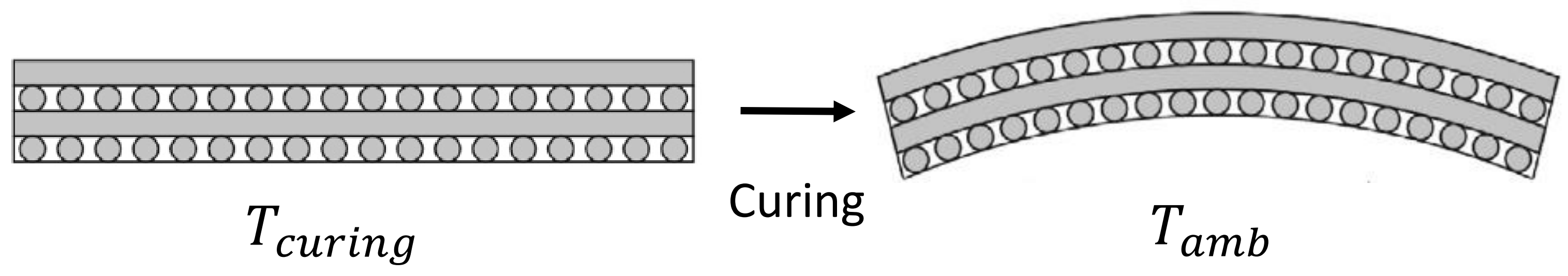

Figure 2 – Warpage deformation caused by orthotropic coefficient of thermal expansion of a composite plate [0º/90º/0º/90º], adapted from [2].

Numerical details

- 2D analysis in ABAQUS® software; Static general;
- Solid elements - for elastic sections (CPE4);
- Cohesive elements – for cohesive sections of CFRP (COH2D4);
- Triangular cohesive law.

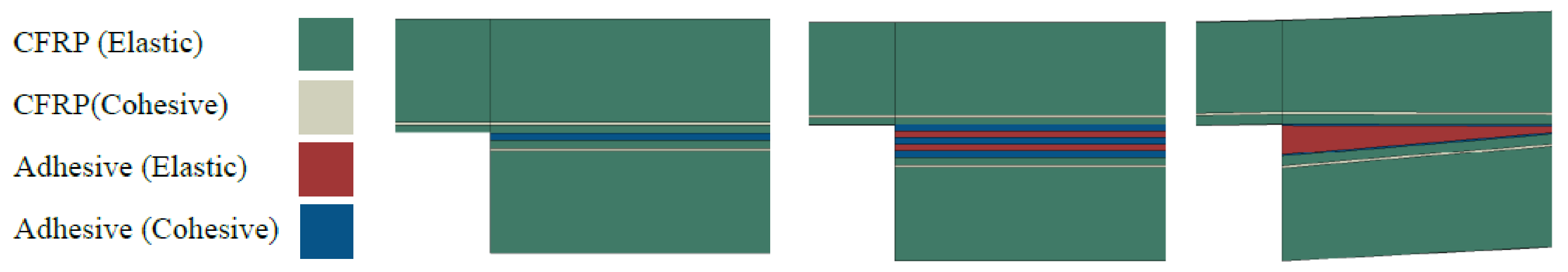

Figure 3 – Section assignment of the numerical models used.

References

[1] V.D.C. Pires, R.J.C. Carbas, E.A.S. Marques, L.F.M. da Silva (2023). An approach to prevent delamination in CFRP SLJ. *Journal of Composite Materials* submitted.

[2] Liu, Z., Zheng, X., Fan, W., Wang, F., Ahmed, S., & Yan, L. (2022). An alternative method to reduce process-induced deformation of CFRP by introducing prestresses. Chinese J. Aeronaut., 35(8), 314-323.

Results

The curvature (Figure 3) was achieved by residual stresses resulting from an asymmetrical composite layup, that allow to enhance joint performance and mitigate delamination risks.

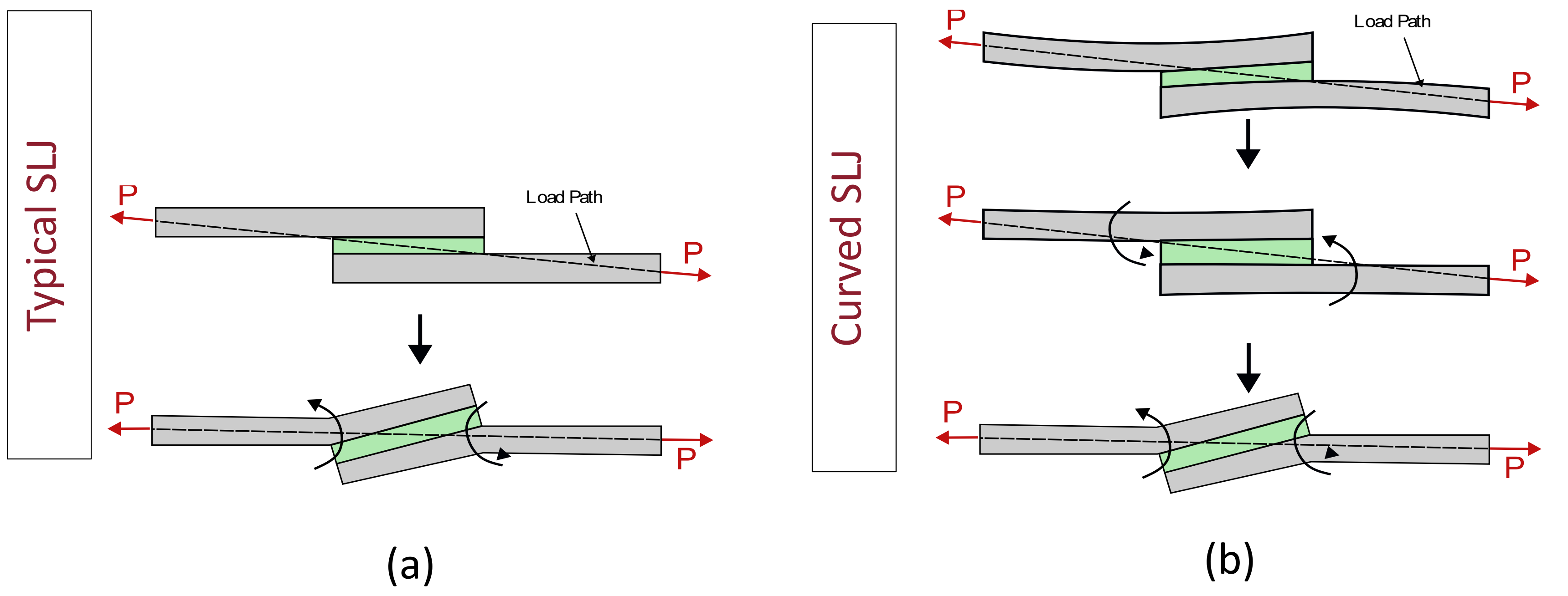

Figure 3 – Behaviour of SLJ under traction. (a) Planar SLJ. (b) Curved SLJ.

The results of the failure modes can be seen in Figure 4, where delamination was obtained for the conventional CFRP SLJ, while cohesive failure was obtained for the other two configurations. It is evident that the curved SLJ exhibits a failure load that is comparable to the reference 0.2 mm configuration.

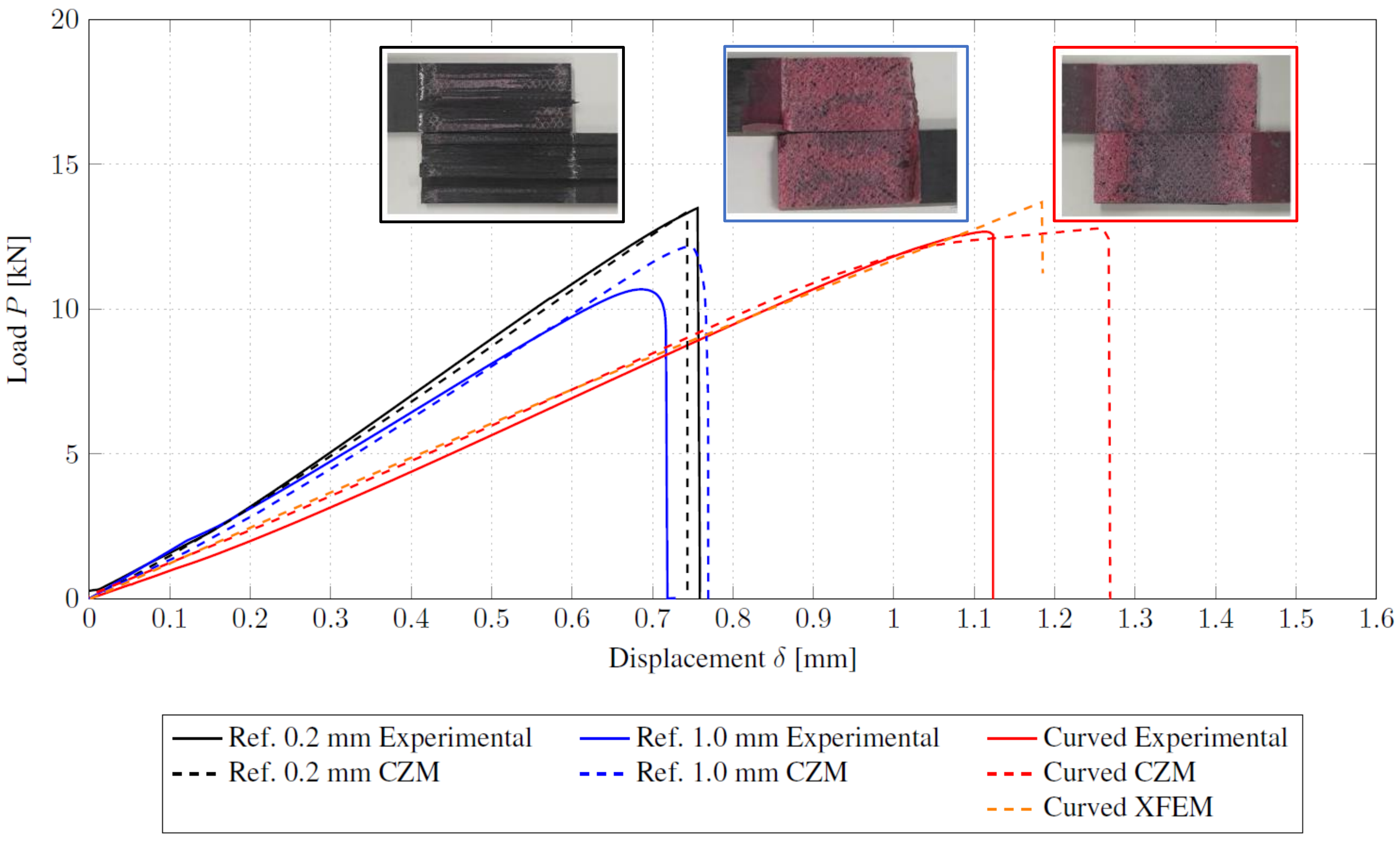

Figure 4 – Load - displacement curves obtained experimentally and numerical for all configurations.

Conclusions

- The curved joint exhibited a cohesive failure mode. This can be attributed to the combined effect of compressive residual thermal stresses resulting from the curing process and the curved geometry of the joint. Furthermore, the failure load of the curved joint remained comparable to that of the conventional CFRP SLJ.
- Increasing the adhesive thickness in planar SLJs resulted in a transition to a cohesive failure mode. However, there was a significant decrease in the failure load. On average, a decrease of 22.1% in the failure load was observed for these thicker adhesive configurations.
- The numerical models exhibited a strong correlation with the experimental results, successfully predicting both the failure load and the failure mode.

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