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Development of a unified specimen for direct generation of cohesive zone law data of adhesives

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1. Introduction

Nowadays, mechanically characterising an adhesives is essential in order to use advanced numerical models in bonded connection design. Traditionally, determining the necessary properties requires four separate specimens, tests, and data reduction schemes — resulting in a complex, slow, and costly process. A **novel unified concept** [1] addresses these issues by combining four tests into one (see Figure 1). This work presents the design behind the **unified specimen**, **mould** and **apparatus** to address these issues.

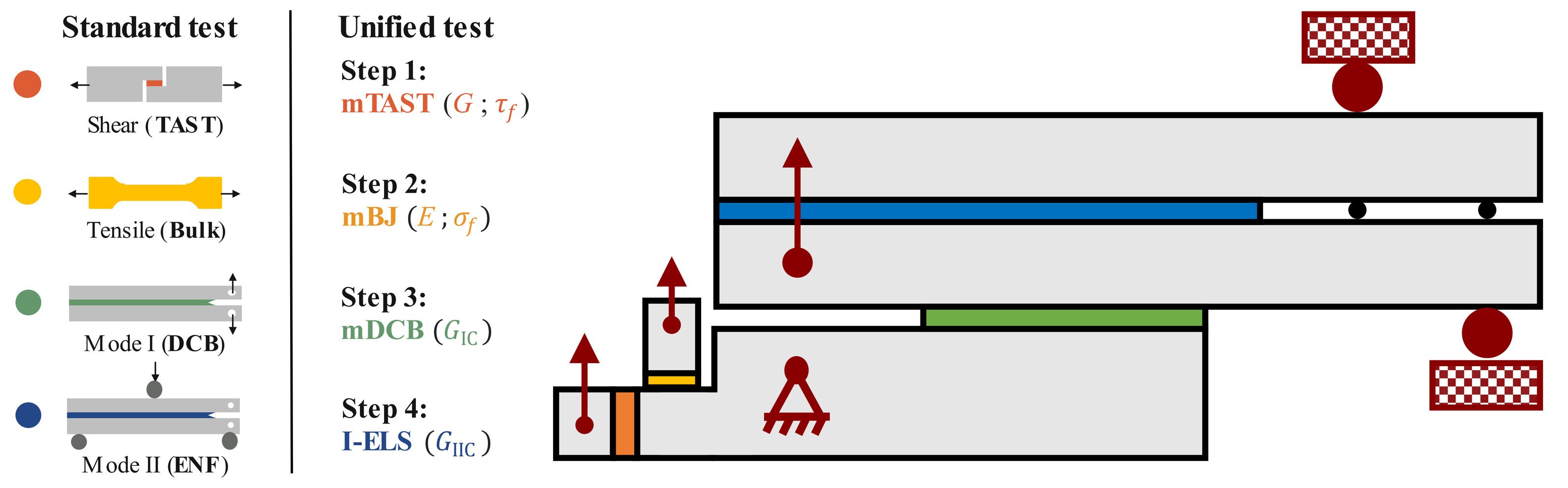

Figure 1. **Unified specimen for adhesive characterisation**: modified Thick Adherend Shear Test (**mTAST**) and modified Butt Joint (**mBJ**), for shear and tensile loading; modified Double Cantilever Beam (**mDCB**) and Inverse End Loaded Split (**I-ELS**) for mode I and II fracture loading. Adapted and updated from Faria *et al.* [1].

2. Unified specimen

The proposed specimen integrates **four modified test geometries into a single configuration**: shear (**mTAST**), tensile (**mBJ**), mode I (**mDCB**), and mode II (**I-ELS**) — from left to right in Figure 2. Nonetheless, its design is **fully modular**, allowing simple **replacement of individual parts** when worn due to testing.

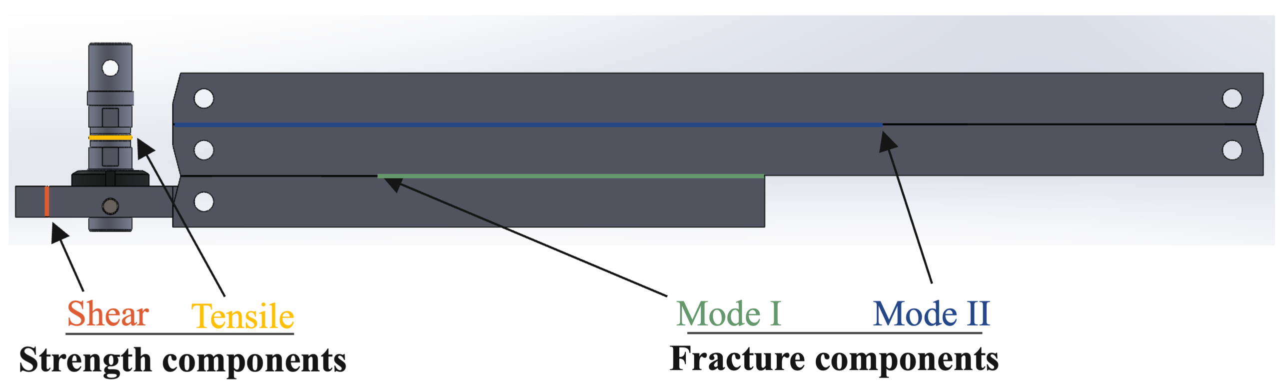

Figure 2. **CAD model** of the **unified specimen**: **mTAST** and **mBJ**, for shear and tensile strength; **mDCB** and **I-ELS** for mode I and II fracture.

3. Unified mould

The specimen is produced using a dedicated mould, designed for **usability** and **scalability**.

During manufacturing it is simple to operate, **reducing sample preparation complexity** when compared to certain traditional test-specific moulds. In a single cure cycle one can produce all four tests simultaneously, ensuring cure consistency across all adhesive layers.

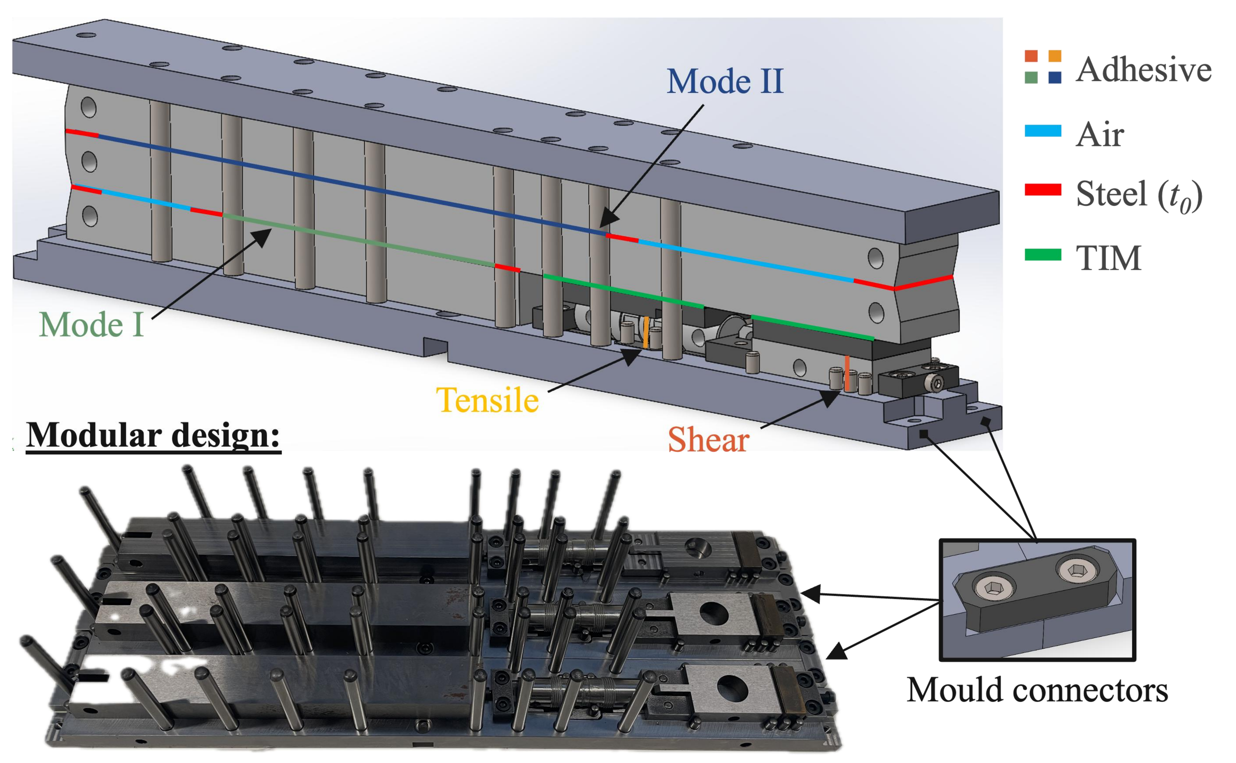

Figure 3. **CAD model** and **experimental setup** of the **unified mould**.

Its **modularity allows stacking of individual mould units** in the same cure cycle, resulting in even higher efficiency by producing multiple sets of unified specimens in parallel. This flexibility is key for both laboratory validation and industrial environments where more specimens are produced in less time, resulting in **faster adhesive characterisation**.

4. Unified apparatus

To properly tests the unified specimen, a specialized loading apparatus (see Figure 4) was developed with two core features:

- **Step Loader** (**StL**): This module is composed of **two screw-based clamps** (Spheres in Figure 4), to fix the **mTAST** (**Step 1**); and **two conic couplings** (Diamonds in Figure 4), to only load the **mBJ** (**Step 2**) and **mDCB**/**I-ELS** (**Step 3/4**) when a certain δ is reached, respectively. Their design ensures that each individual test is **loaded sequentially** without unwanted interactions between different loading modes, since they are always mechanically decoupled from each other during the **single continuous motion of the loading machine**.
- **Mode II rollers** (**mII-R**): **Two rollers** are implemented to properly execute the final mode II fracture test (**Step 4**). These are only actuated for the **I-ELS** test **guaranteeing** conformity to the **boundary conditions** required for both mode I and mode II tests.

Together, these features allow for a **seamless sequential testing procedure** with high fidelity to the mechanical phenomena under study.

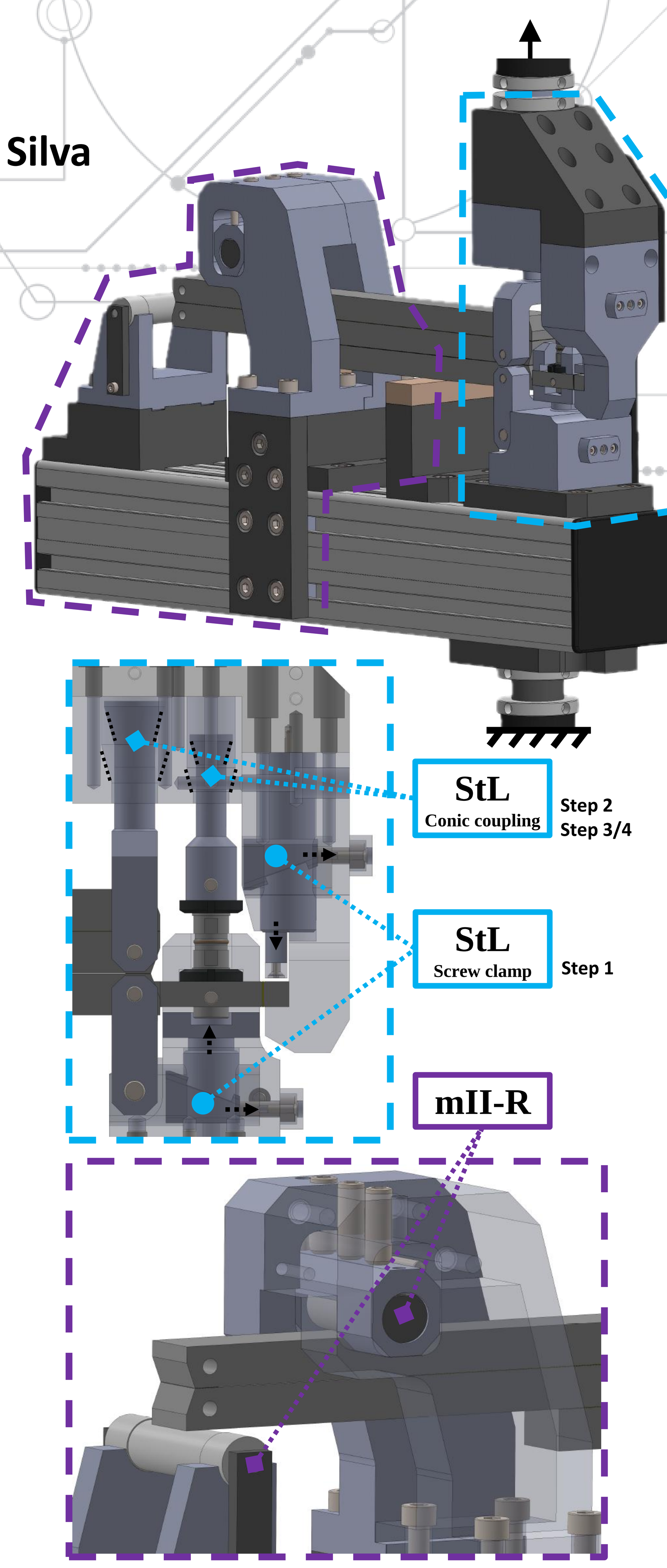

Figure 4. **CAD model** of the **unified apparatus**: Step loader (**StL**) and mode II rollers (**mII-R**).

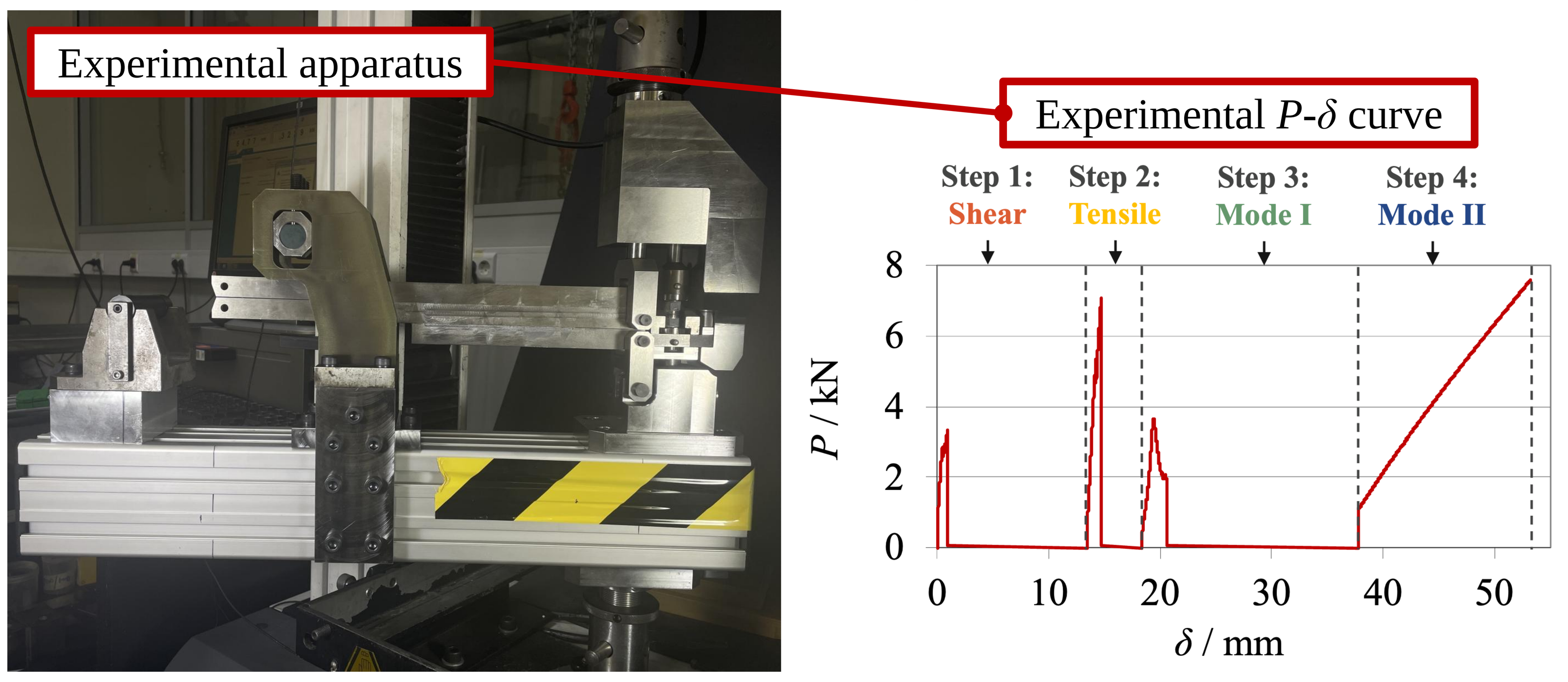

Figure 5. **Experimental setup** of the **unified apparatus** and **experimental curves obtained**.

From the experimental setup one extracts a **load-displacement curve** from which all properties are derived after applying proper **data reduction schemes**. The expected P-δ curve of this unified apparatus is present in Figure 5, where **four separate load evolutions** are observed, **one for each test** performed and separated by predefined $\boldsymbol{\delta}$**'s** due to the conic couplings and mode II rollers.

6. Conclusion

The **unified specimen**, **mould**, and **apparatus** collectively provide a **streamlined solution for adhesive mechanical characterisation**. Testing four key loading modes within a single specimen **greatly reduces** the **time**, **cost**, and **complexity** of this procedure against standard methods.

Overall, this methodology represents a **significant step toward disruptive adhesive testing practices** that are accessible to a broader range of industries.

References

[1] Faria *et al.* (2022). Novel mechanical characterization method applied to non-structural adhesives: Adherend material sensitivity. Univ. Porto — J. Mech. Solids, 1, 25–30.

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