

Streamlining adhesive characterisation: from manufacturing to testing and data reduction recurring to a unified specimen

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1. Introduction

Nowadays, mechanically characterising an adhesives is essential for the use of advanced numerical models in bonded connection design. Traditionally, determining the necessary properties requires **four different specimens, moulds, apparatus, and data reduction schemes** (see Figure 1) — resulting in a **complex, time-consuming and costly process**.



Figure 1. **Standard adhesive characterisation workflow:** Thick Adherent Shear Test (TAST) and bulk tensile test (Bulk), for **shear** and **tensile** loading; Double Cantilever Beam (mDCB) and End-Notched Flexure (ENF) for **mode I** and **II** fracture loading, respectively.

A **novel unified concept** was developed, combining the **4 into 1**. This work presents the concept behind the **unified specimen, mould, apparatus and data reduction program** to streamline adhesive characterization, making it **simpler, faster and cheaper**.

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) loading — see Figure 2.

Nonetheless, its design is **fully modular**, allowing simple **replacement of individual parts** when worn due to testing, and enabling a **step-by-step testing procedure**.

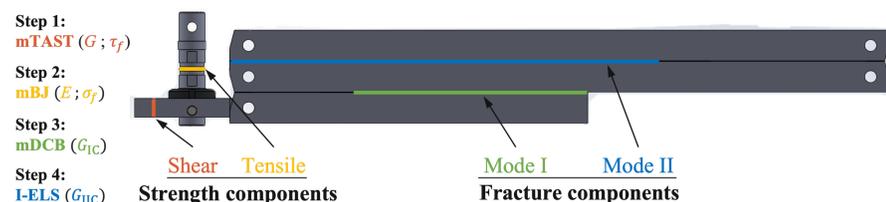


Figure 2. **Unified specimen:** modified TAST (mTAST) and modified Butt Joint (mBJ), **shear** and **tensile** loading; modified DCB (mDCB) and Inverse End Loaded Split (I-ELS), for **mode I** and **II** fracture loading.

3. Unified mould

Specimen production recurs to a dedicated mould, designed for **usability and scalability**. Manufacturing is simple when compared to certain traditional test-specific moulds, **reducing sample preparation complexity**. In a **single cure cycle** it can produce **all four tests simultaneously**, ensuring cure consistency across all adhesive layers.

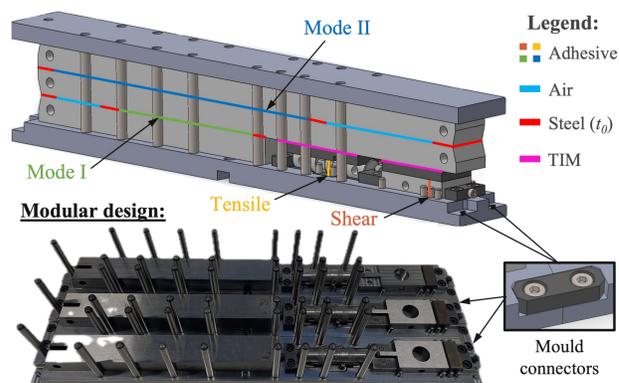


Figure 3. **Unified mould:** manufacturing staking sequence and modular design.

Its **modularity allows stacking of individual mould units** in the same cure cycle. This flexibility is key for higher manufacturing efficiency, by producing multiple sets of unified specimens in less time, resulting in **simpler and faster adhesive characterisation**.

6. Conclusion

The **unified specimen, mould, apparatus and data reduction program** 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 the current standard methods. Overall, this methodology represents a **significant step towards disruptive adhesive testing practices** that are accessible to a broader range of users, from both the **academic and industrial environments**.

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):** Composed of **two screw-based clamps** (● in Figure 4), to fix the **mTAST (Step 1)**; and **two conic couplings** (◆ in Figure 4), to only load the **mBJ (Step 2)** and **mDCB/I-ELS (Step 3/4)** when a certain δ is reached, respectively. Each individual test is **loaded sequentially** without unwanted interactions between loading modes, due to them always being mechanically decoupled during the **single continuous motion of the loading machine**.
- **Mode II rollers (mII-R):** **Two rollers** (◆ in Figure 4), are implemented to properly execute the mode II fracture test (**Step 4**). These are only actuated for the **I-ELS test guaranteeing 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.

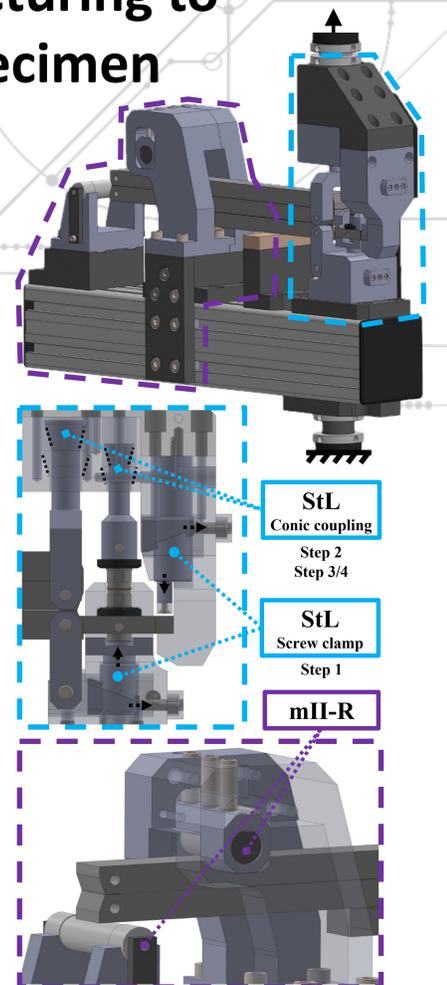


Figure 4. **Unified apparatus:** Step loader (StL) and mode II rollers (mII-R).

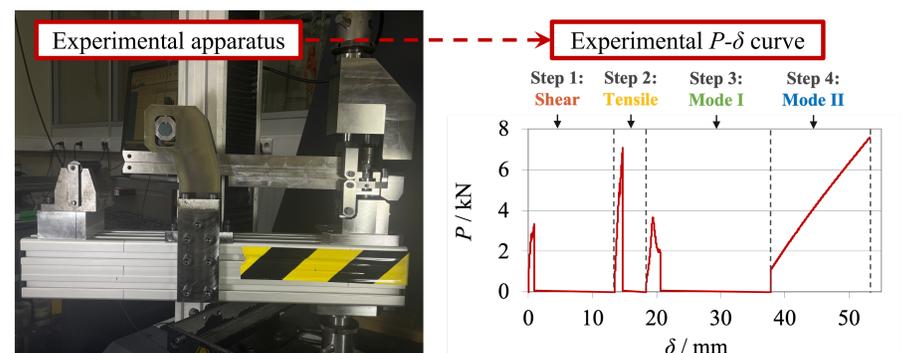


Figure 5. **Experimental setup of the unified apparatus and experimental curves obtained.**

From the experimental setup one extracts a **load-displacement curve** from which all properties are derived after applying proper **data reduction schemes**. The expected $P-\delta$ 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 δ 's due to the conic couplings and mode II rollers.

5. Unified data reduction program

The final step to obtain the adhesive properties is **Data Reduction (DR)** of the experimental curves. The schemes used can be **complex** and require **extensive reading** on the subject. Cleaning the data and applying DR also **requires experience** and can be **highly user dependent**.

As such, the implementation of a program (see Figure 6) that **pre-processes, reduces and post-processes** the data in a **click of a button** simplifies this whole process and eliminates user dependencies, resulting in **simpler, faster and more reliable adhesive characterisation**.

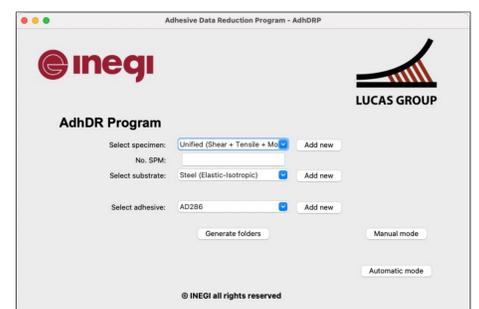


Figure 6. **Unified data reduction program:** Automatic pre-processing, data reduction and post-processing from the experimental data.