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Fracture Fatigue and Wear

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Evaluation of Normal and Tangential Forces in Single-Lap Adhesive Joints Using Optical Extensometry

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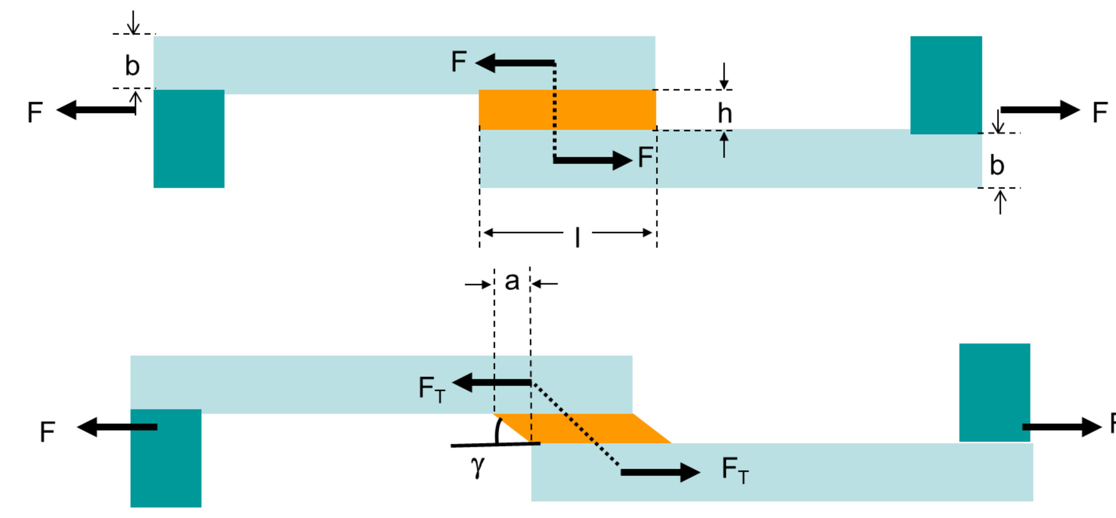
Introduction

The definition of material models represents is one of the key aspects in the numerical analysis of adhesive joints, as the predictive capability of finite element (FE) simulations strongly depends on their ability to accurately reproduce the true mechanical behavior of both the adhesive and the adherents.

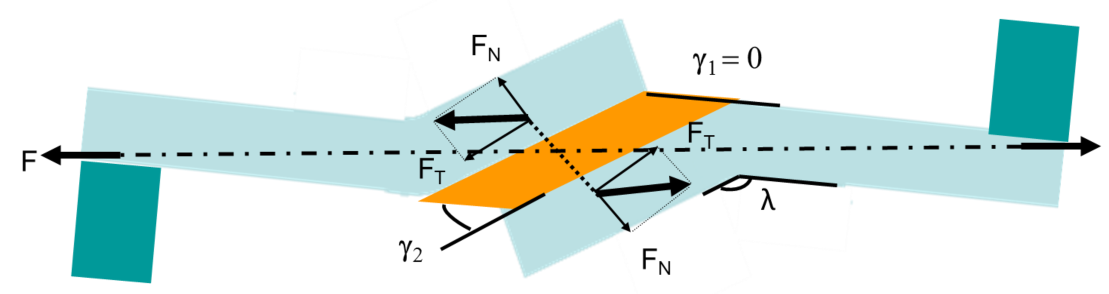
In experimental single-lap joint tests, widely used for the mechanical characterization of adhesive joints, an inherent geometric effect distorts the measured data. Even when specimens are carefully aligned with the loading axis, the tensile load is transmitted through the adherents, introducing an eccentricity in the line of action of the applied force.

As a result, the adherents may bend, and the stresses acting on the adhesive layer become a combination of shear and normal components perpendicular to the bond plane. These additional stress components hinder the direct use of experimental results for the identification and validation of numerical models.

The resulting deformations and stress distribution depend on the mechanical properties of both the adhesive and the adherents. In this context, optical extensometer allows direct observation of the test and enables deformation analysis through image processing, combined with force and displacement data. This approach provides a more accurate determination of the normal and tangential stress components acting on the adhesive joint.



Flexible adhesive



Elastoplastic adhesive

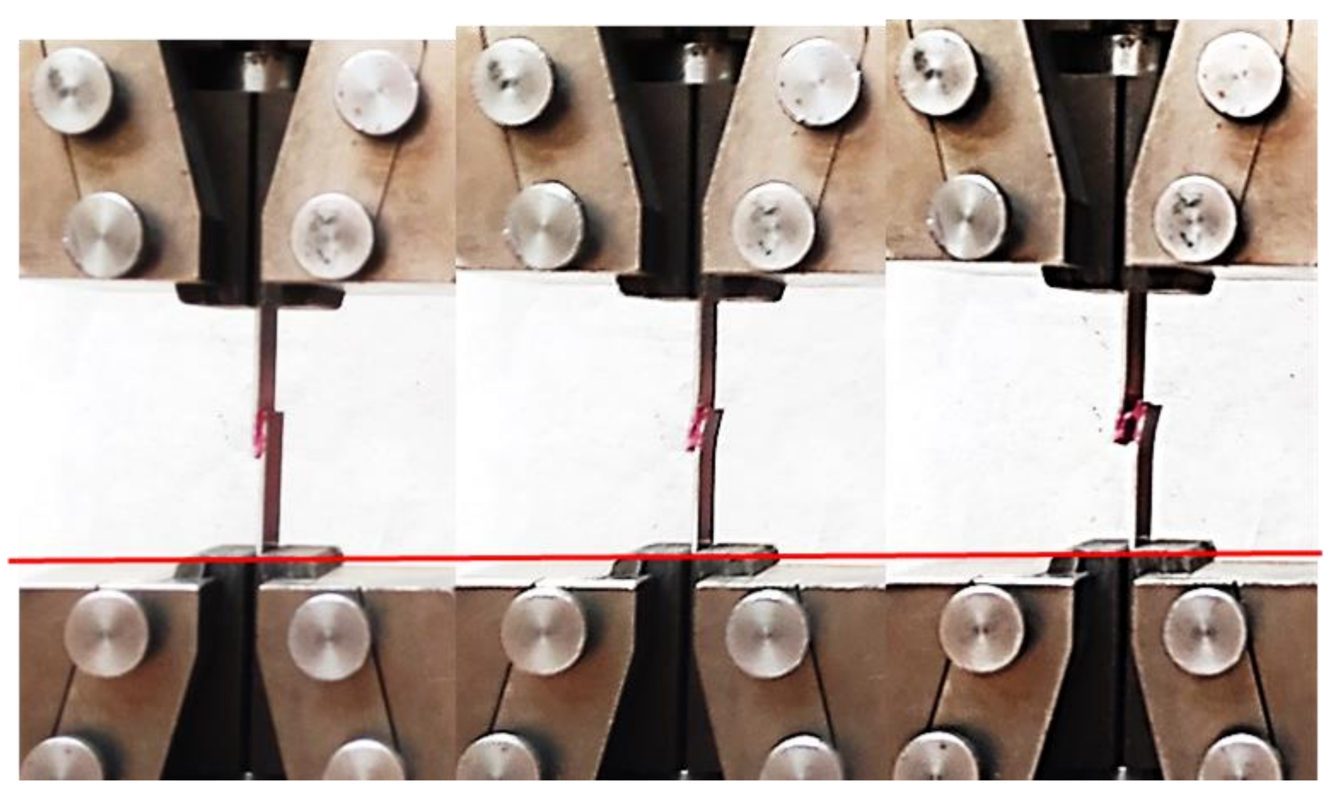
Materials

Adhesive:
SikaPower® 1277

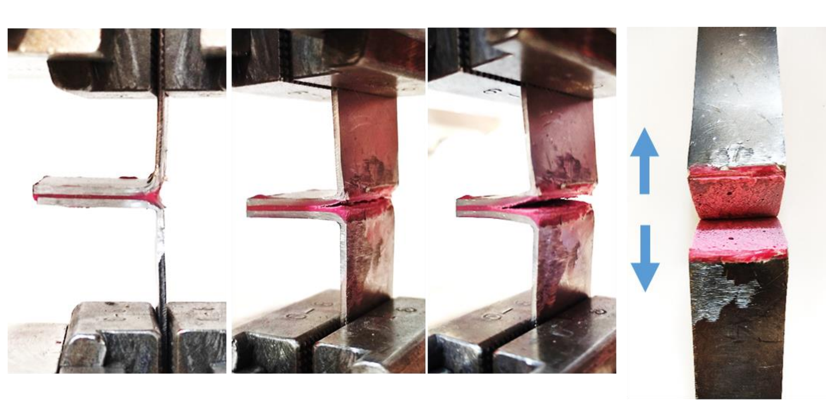
Adherents:
Steel (1 and 1.5 mm)
Hardened steel (1.5 mm)
Aluminium (1.2, 2.0, 2.9 and 6.0 mm)

Methods

The results of tensile shear tests for the different adherents are compared.



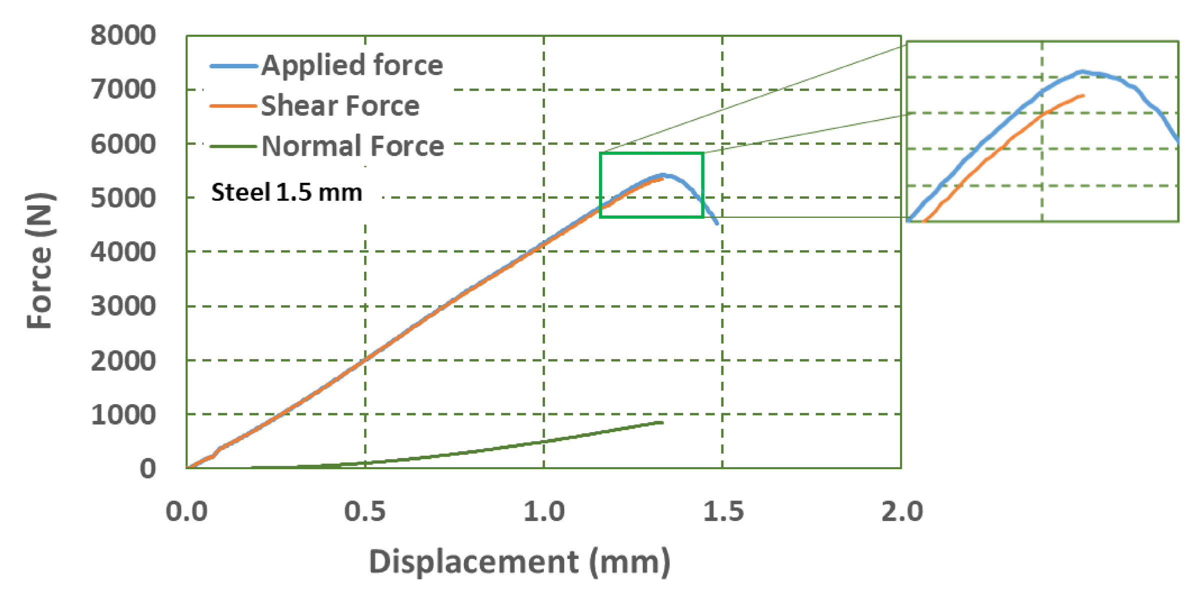
Additional tests:
Tensile tests on bonded joints ⟶ Young Modulus
Adhesive bond tests ⟶ Tear strength

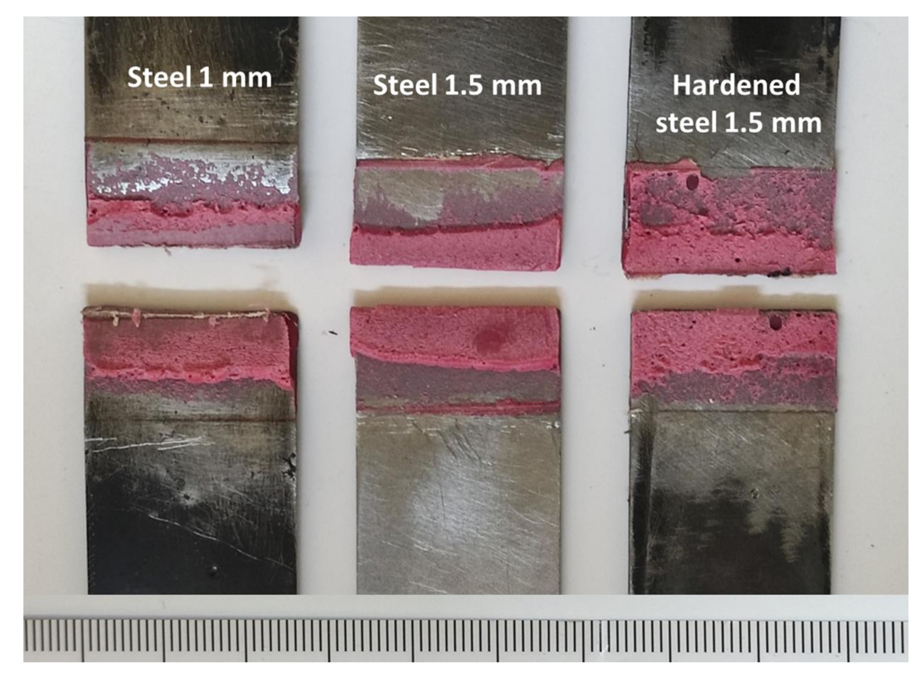


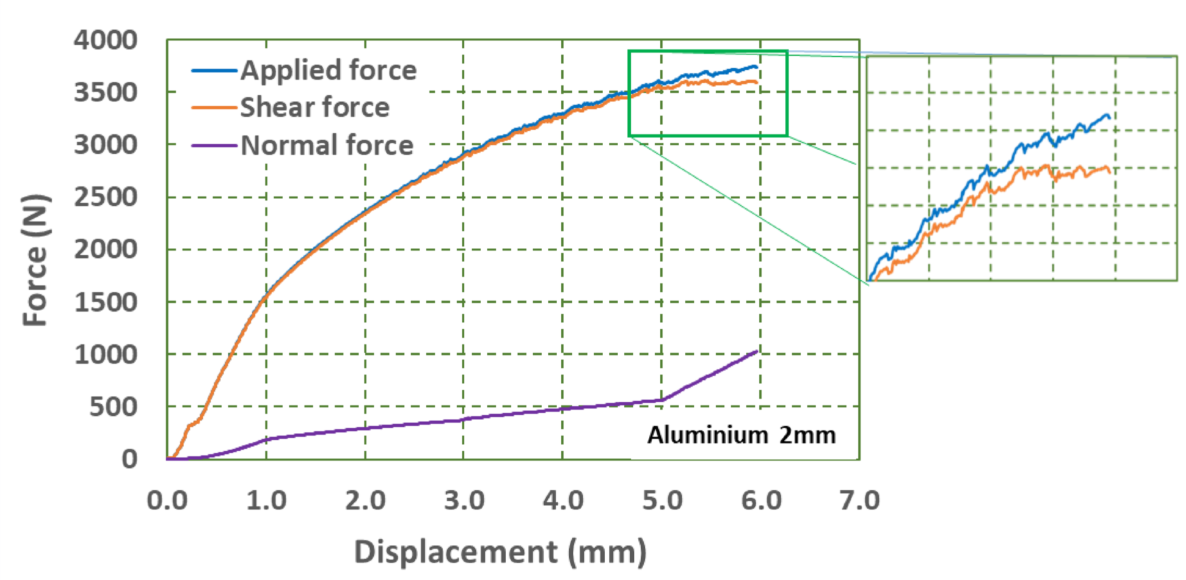
Adherent	Tear Force (N)
Steel	2109
Aluminium	1748

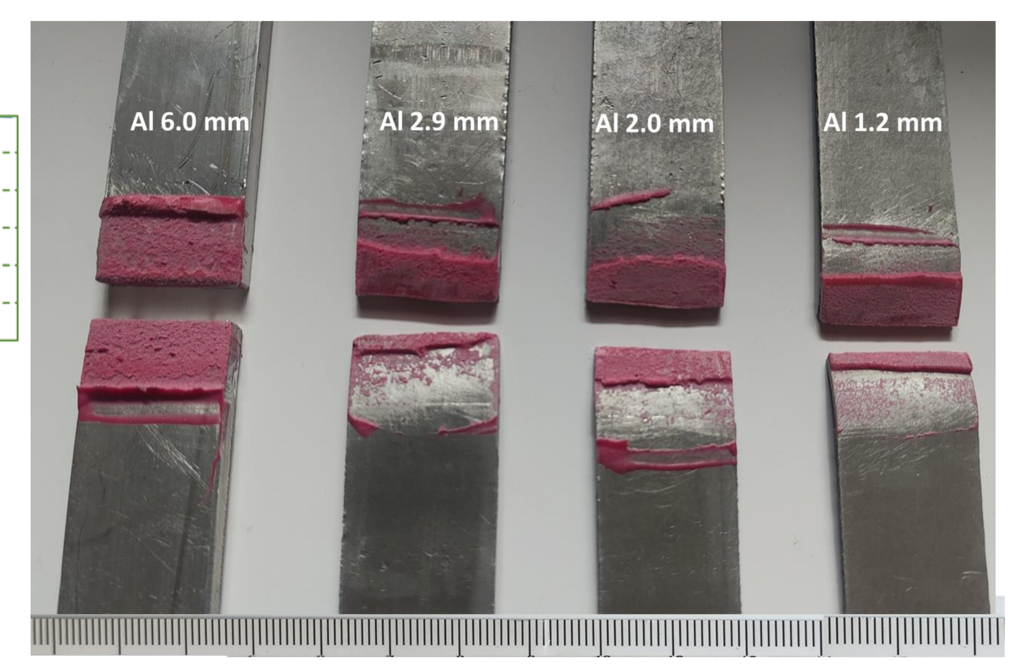
The results of tensile shear tests for the different adhesives are compared.

Results Shears Tests





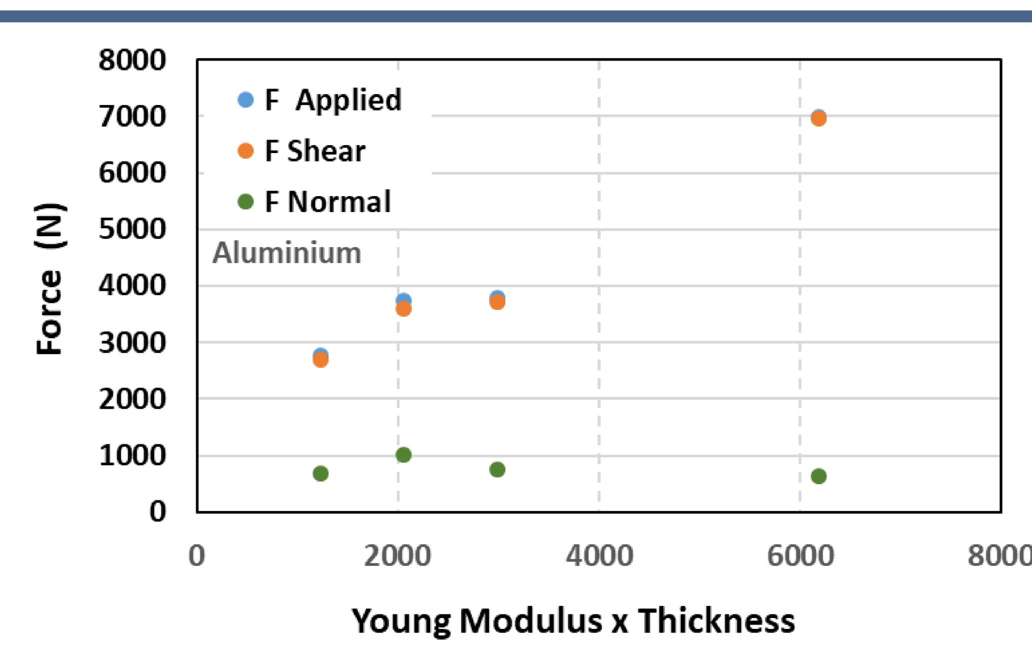


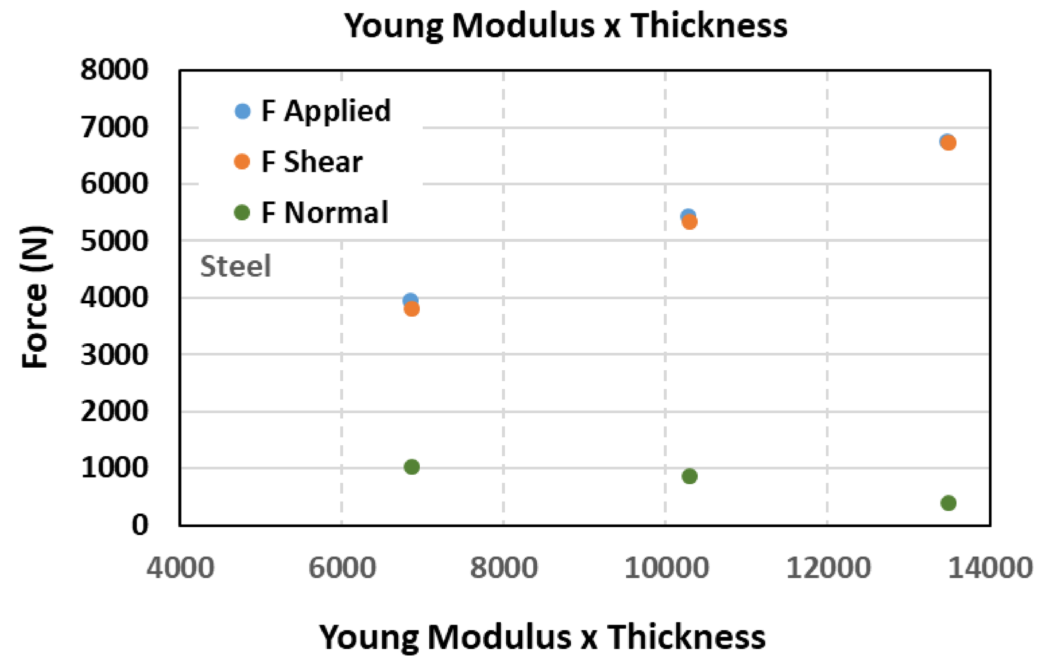


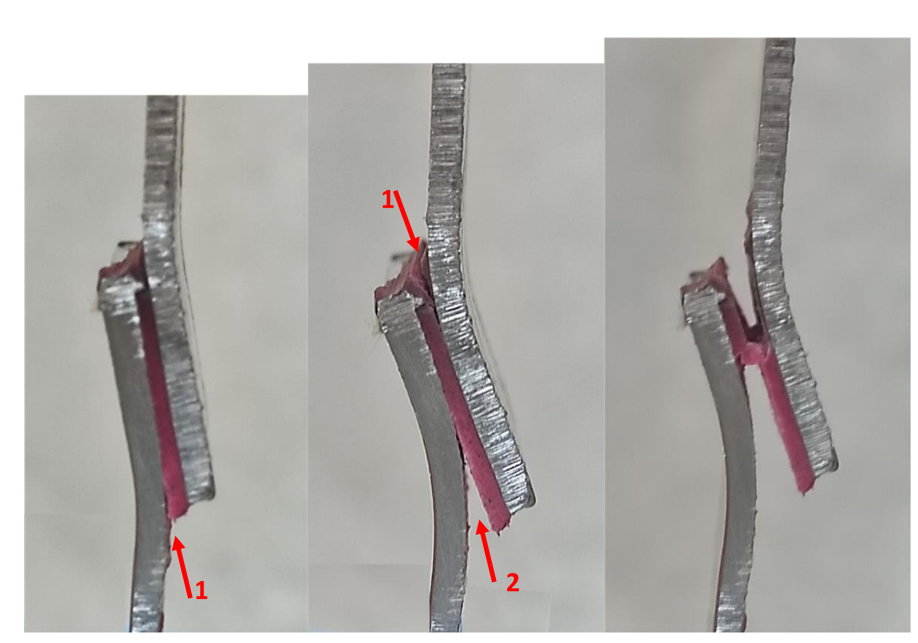
Specimen	Thickness adherent (mm)	Young Modulus adherent (MPa)	F shear applied (N)	Angle (rad)	F shear true (N)	%	F normal true (N)	%
Steel	1.0	6862	3944	0.264	3808	97	1028	26
Steel	1.5	6862	5418	0.158	5350	99	856	16
Hardened Steel	1.5	8992	6732	0.580	6721	~100	390	6
Aluminium	1.2	1030	2770	0.247	2687	97	676	24
Aluminium	2.0	1030	3742	0.273	3603	96	1010	27
Aluminium	2.9	1030	3785	0.197	3712	98	747	20
Aluminium	6.0	1030	6981	0.087	6953	~100	625	9

Discussion and Conclusions

- ✓ The results of shear tests on adhesive joints show that an increase in the Young Modulus x Thickness of the adherents leads to higher strength values.
- ✓ The variation in strength is related to the bending effect of the adherents due to load eccentricity. The smaller this effect, the better the correlation between the applied shear force and the actual shear force (red circles in the results table).
- ✓ Although the tests were performed according to the standard, the results of simple-lap tests cannot be used without considering the type of materials, their geometry, and their mechanical properties.







- ✓ Failure analysis shows that, for materials with low specific modulus, failure initiates at the ends of the joint, (adhesive/adherent interface (1)) and propagates progressively by tearing until rupture (2). This effect reduces overall the strength of the joint.