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Structural Testing of Composite Crash Structures

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PhD Final Internal Presentation

ICONIC has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 721256. The content reflects only the author's view and the Agency is not responsible for any use that may be made of the information it contains.

ICONIC

Improving the crashworthiness of composite transportation structures

Beneficiaries

COORDINATOR Queen's University Belfast (QUB - UK)	Ulster University (UK)
German Aerospace Center (DLR - Germany)	RISE SICOMP (Sweden)
University of Patras (Greece)	University of Limerick (Ireland)
Bombardier (UK)	Centro Ricerche Fiat (Italy)
	Politecnico di Torino (Italy)

Goals and Objectives

- Develop an innnovative testing program

- Crash sled tests on demonstrators

- Provide the experimental data for modelling activities

- Help proof of concept of virtual testing of composite structures

Introduction

- Passive safety and crash structures

- To minimize damage and risk of injury

  - ➢Seat belt
  - ➢Air bag
  - ➢The structure of the vehicle

The underlying frame of the Alfa Romeo 4C

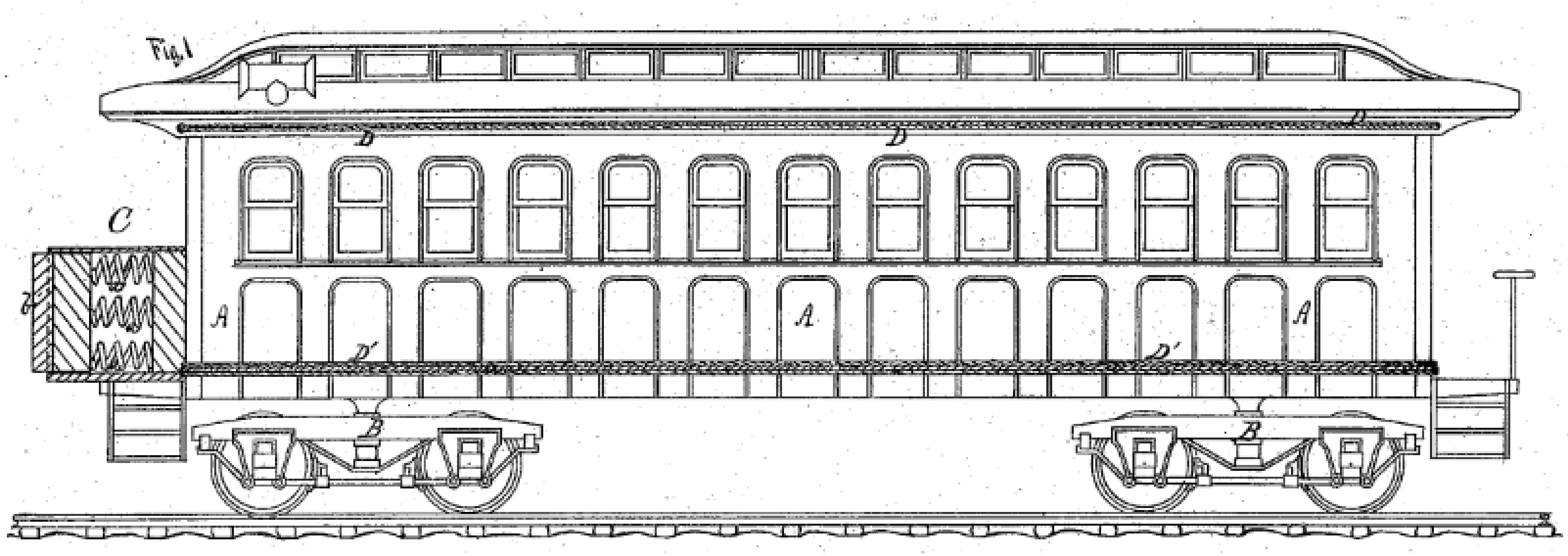
https://driving.ca/alfa-romeo/reviews/road-test/first-drive-2015-alfa-romeo-4c-spider

Introduction

- The idea goes back in time

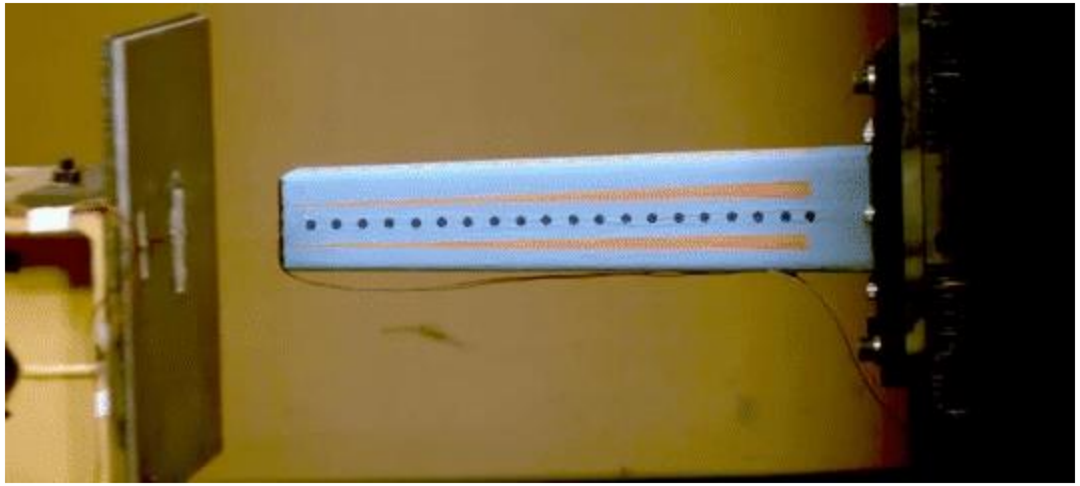
Patent No. 154,564,
December 12, 1873.

“preserving the lives of passengers by lessening the shock”



Introduction

- Difference of composites and metals

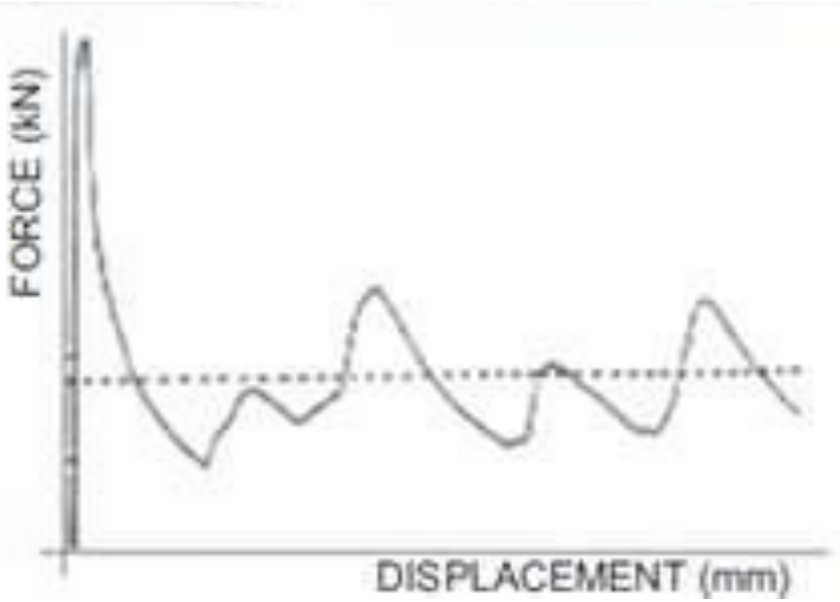


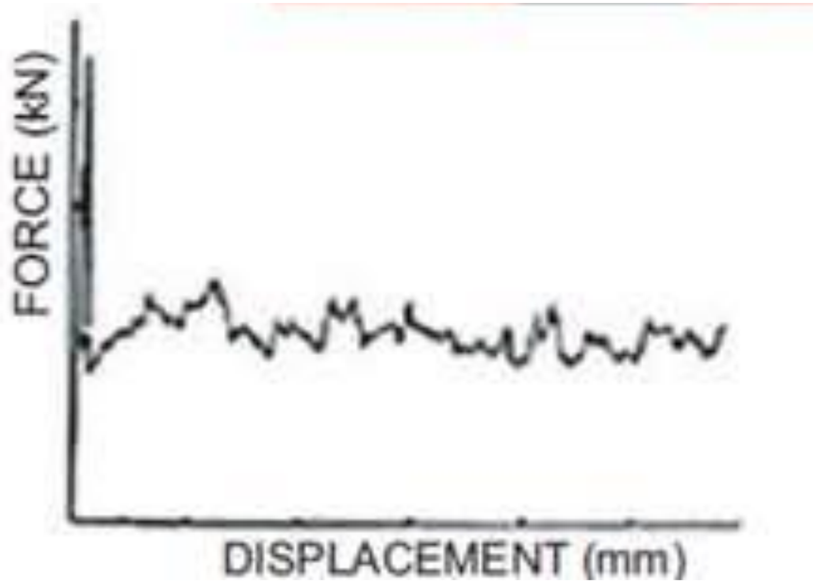
Engenuity Limited

https://www.youtube.com/watch?v=VdP5a4k6aOY&ab_channel=EngenuityLimited

Introduction

- Difference of composites and metals



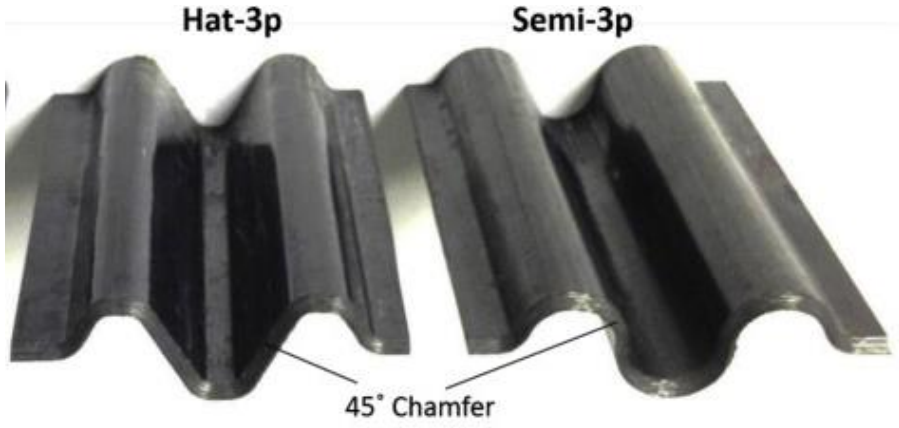


Previous Works

- Self-supporting specimens

Double hat shaped tube specimens

C-channel specimens



Corrugated and semi-circular specimens

Liu et al. *Experimental investigation into dynamic axial impact responses of double hat shaped cfrp tubes*. Composites Part B: Engineering, 79:494 – 504, 2015.

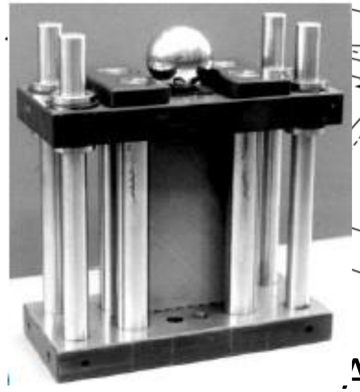
Feraboli et al. *Crush energy absorption of composite channel section specimens*. Composites Part A:Applied Science and Manufacturing, 40(8):1248 – 1256, 2009.

Wei Tan and **Brian G. Falzon**. *Modelling the crush behaviour of thermoplastic composites*. Composites Science and Technology, 134:57 – 71, 2016.

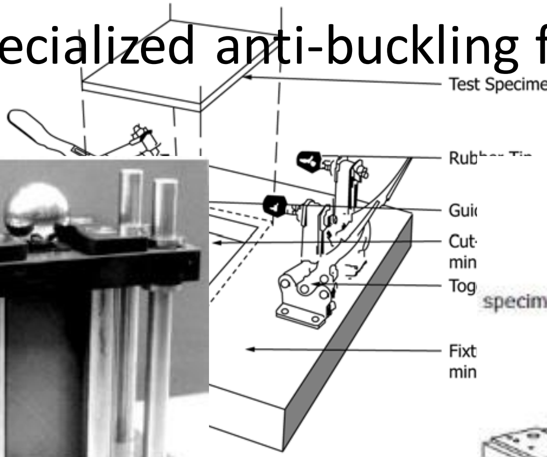
Previous Works

- Flat specimens

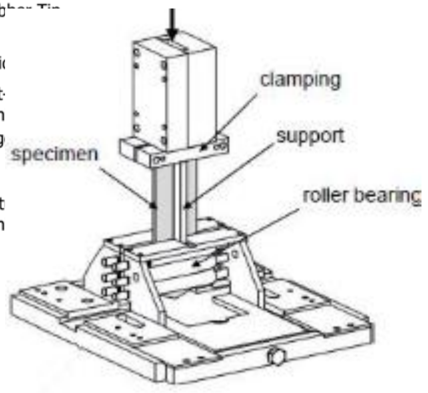
  - Same as standardized characterization ones
  - Easily manufactured
  - A specialized anti-buckling fixture is required



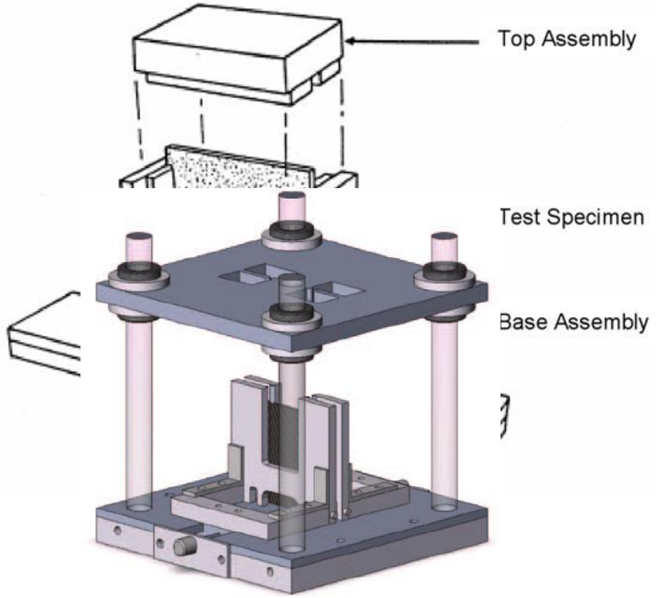
NASA fixture



ASTM D7136



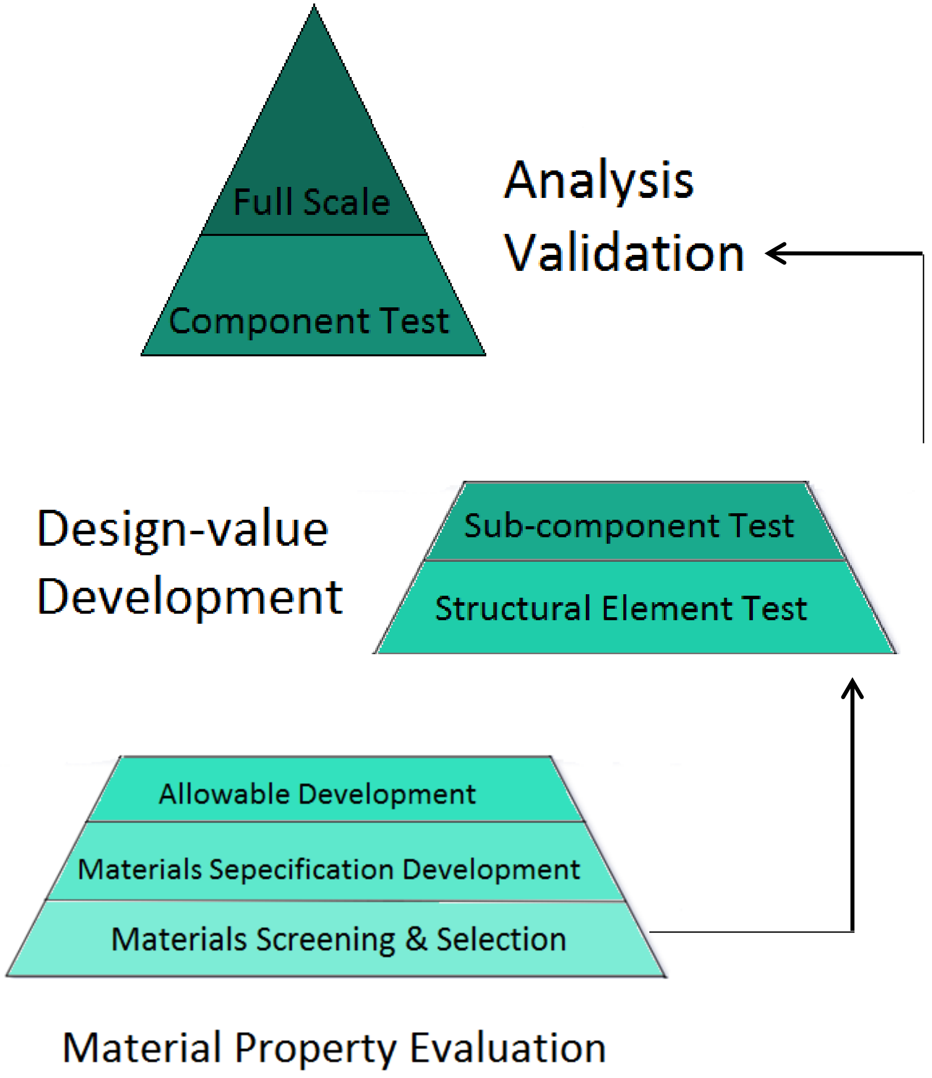
University of Stuttgart



Feraboli fixture

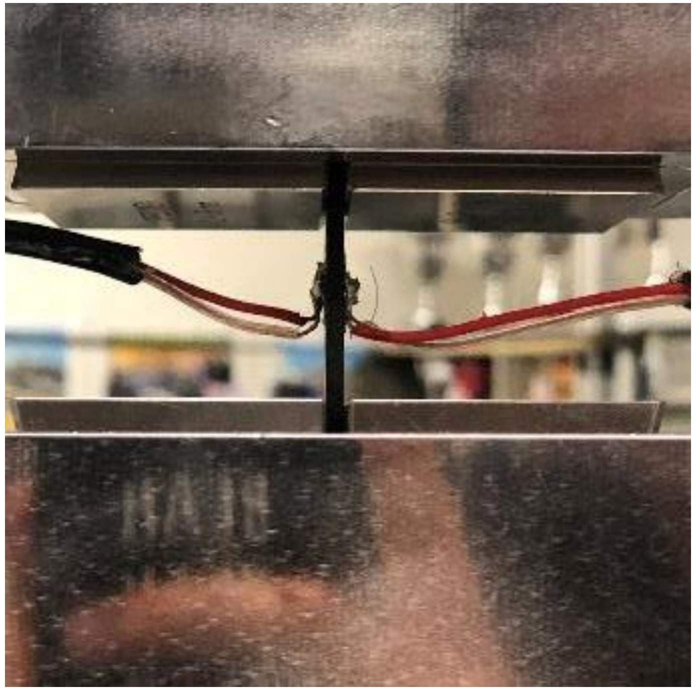
Approach

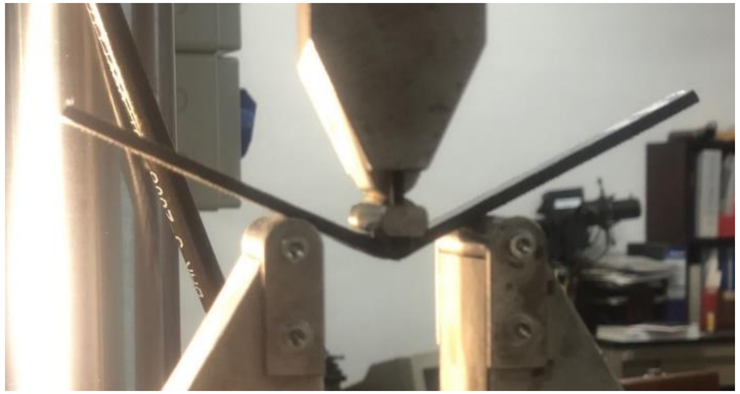
- Building Block Approach
  - ➢Expensive to test all the parameters
  - ➢Numerical analysis are aimed to specific conditions only
  - ✓Together the cost is reduced and analysis are guided



- First level of the BBA

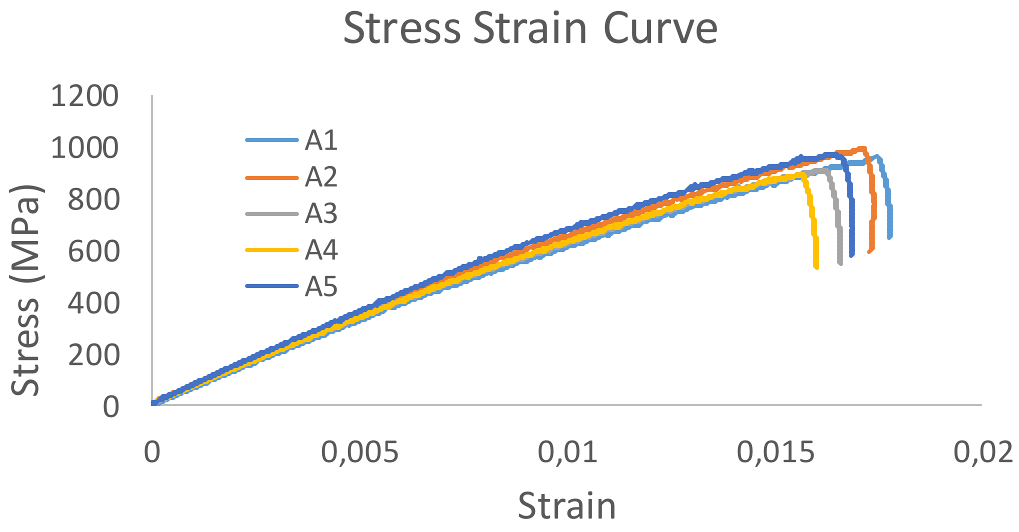
Standard	
ASTM D3039	Traction
ASTM D0790	3 Point Flexural
D695 Modified	Compression
ASTM D3518	Shear





Results

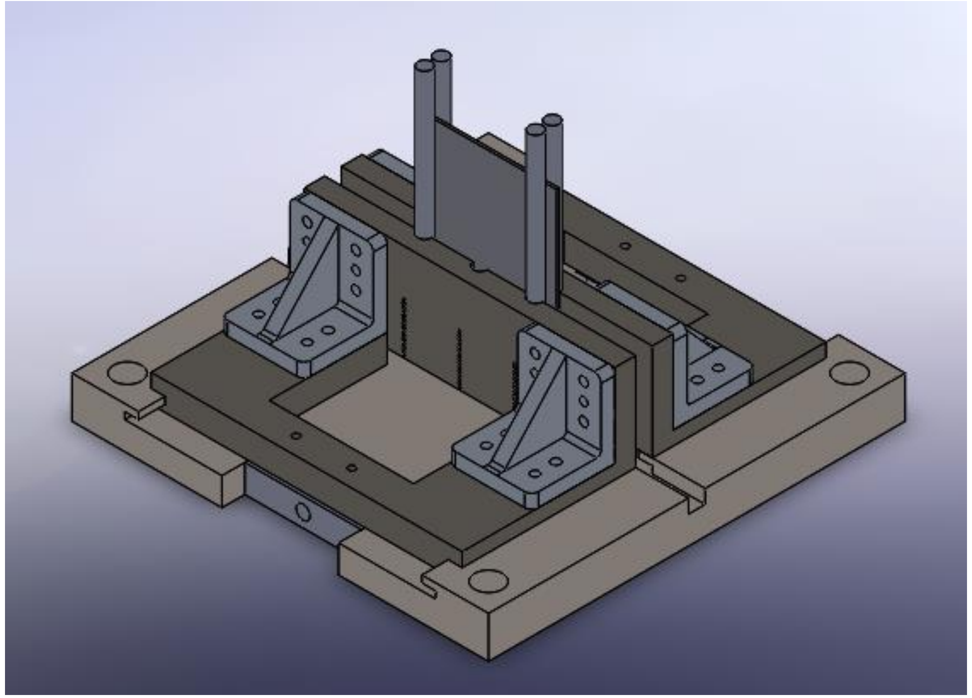
- First level of the BBA
- Standard material characterizations
- Input data for modelling

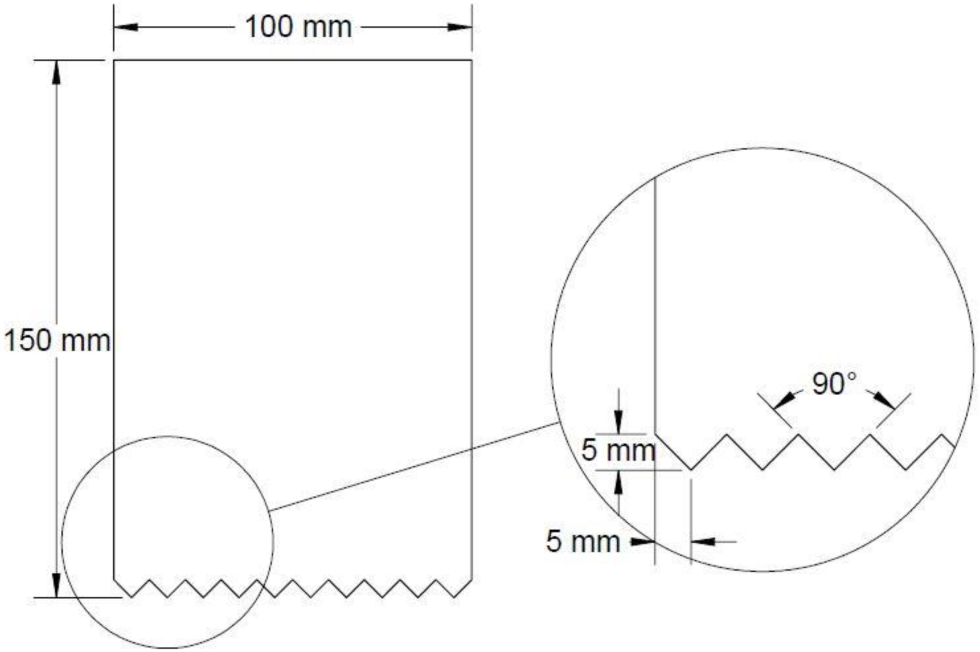


	Tensile Strength	Tensile Modulus	Yield Strain
A1	961	56.308	0.0175
A2	994	60.841	0.0171
A3	911	60.900	0.0162
A4	893	58.348	0.0157
A5	968	62.592	0.0167
Average	**946**	**59.798**	**0.017**

Results

- Design of anti-buckling fixture for element level tests

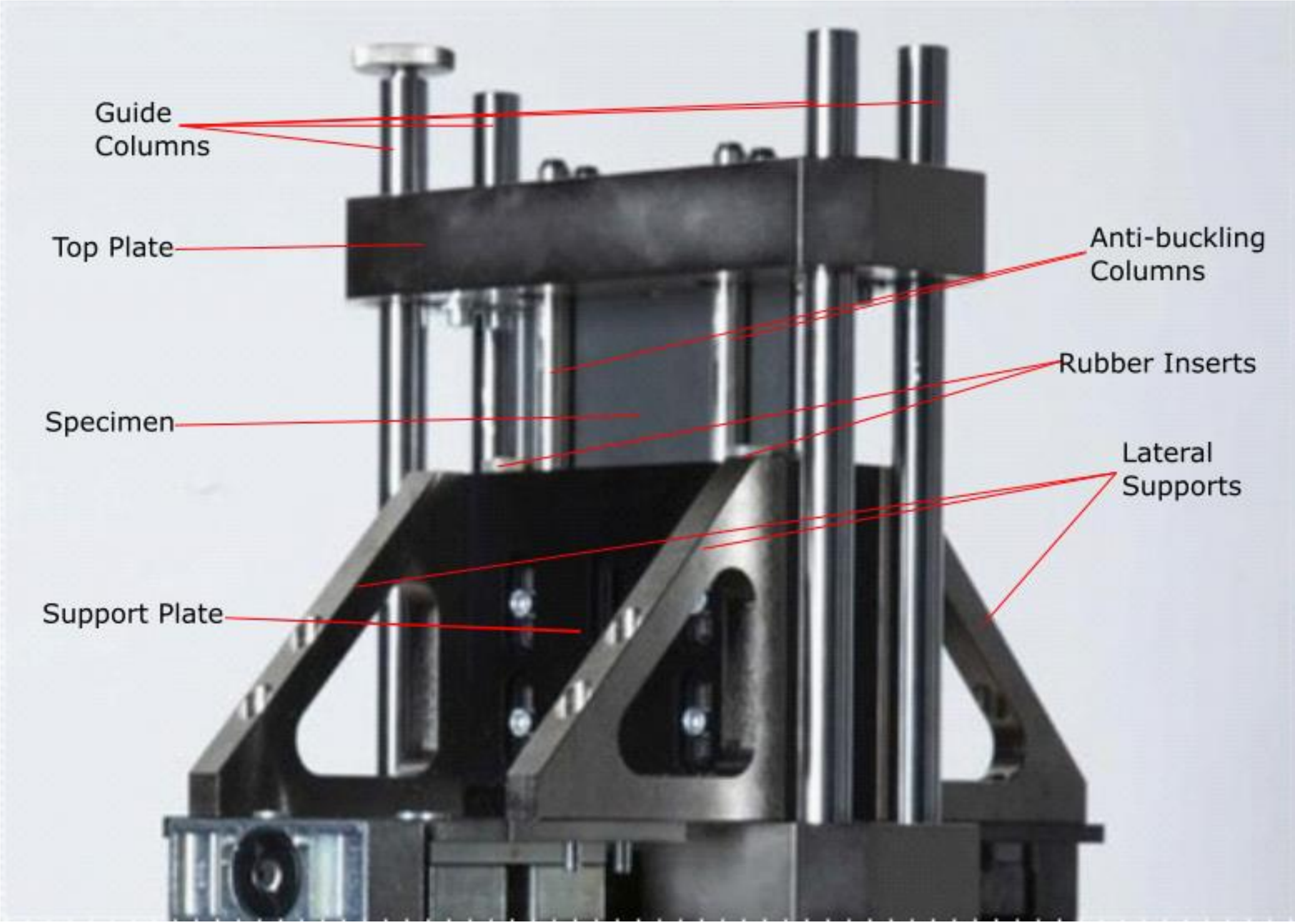




Results

Sub-component Test

Structural Element Test

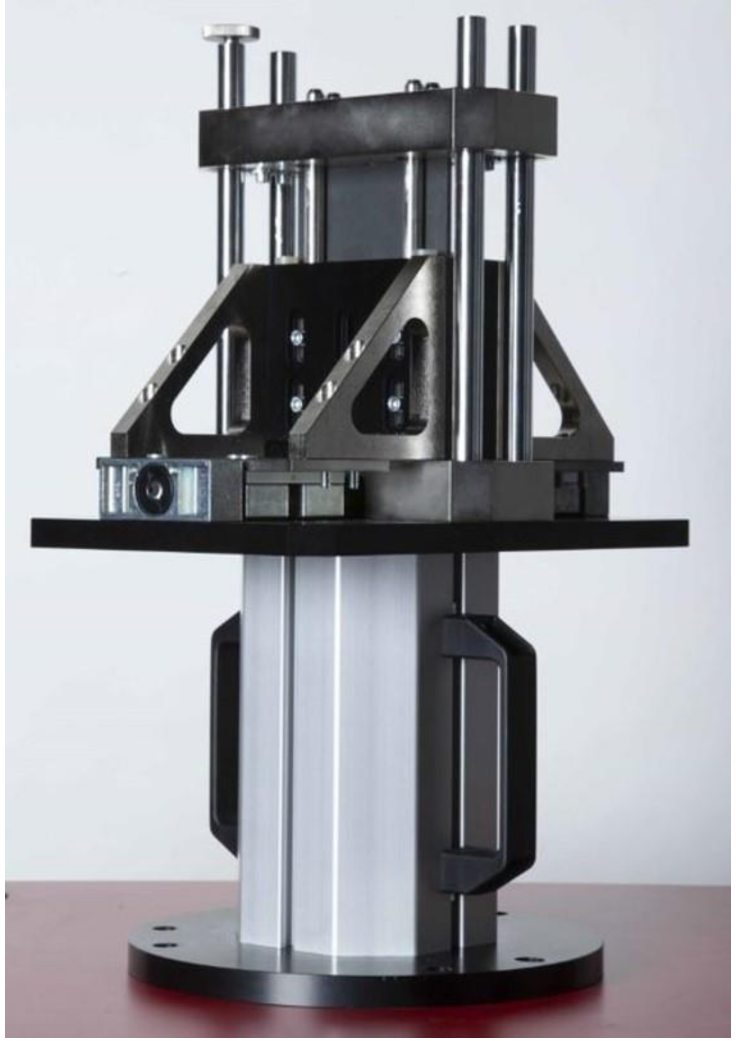


Results

Sub-component Test

Structural Element Test

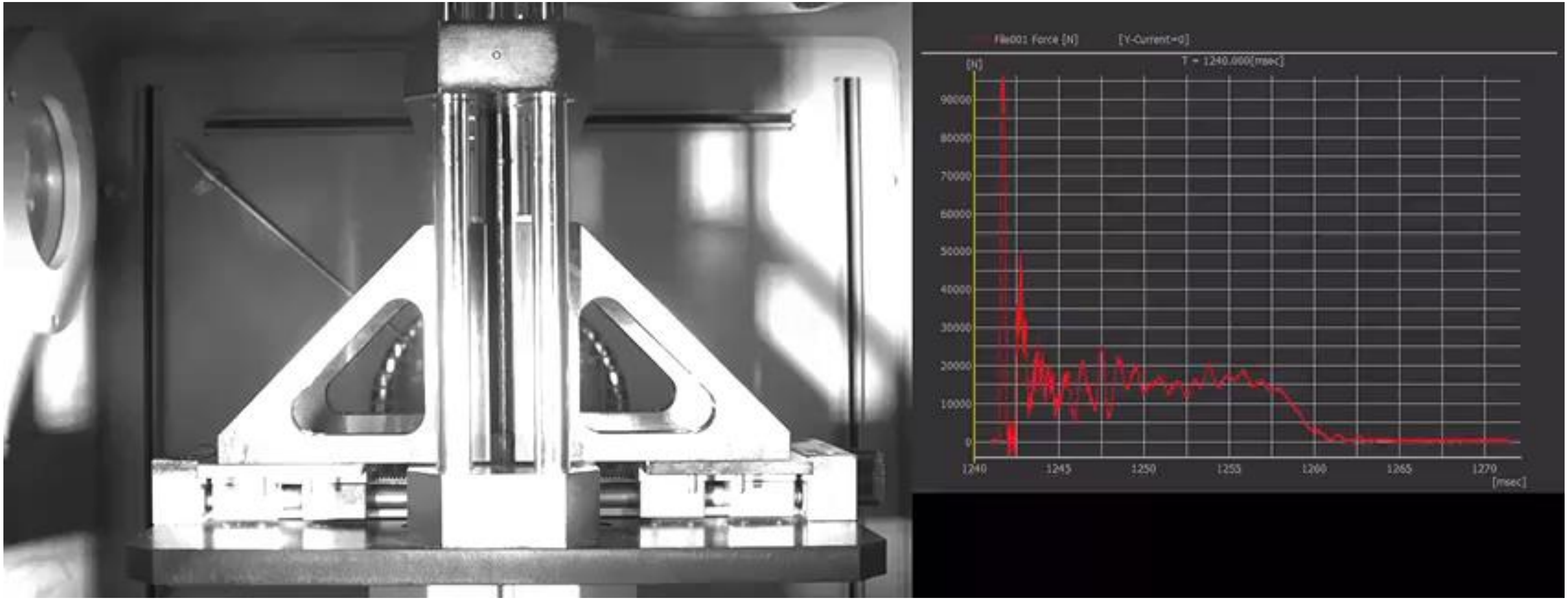
- The anti-buckling fixture



Results

Sub-component Test

Structural Element Test

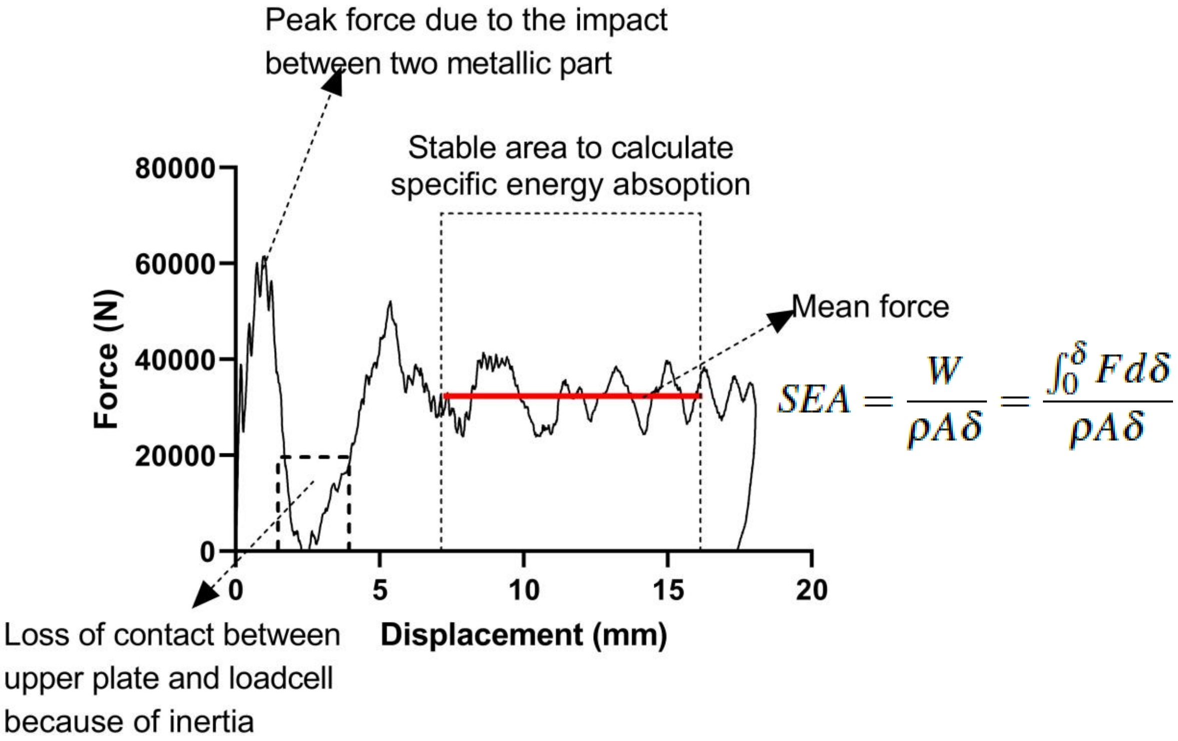


Results

Sub-component Test

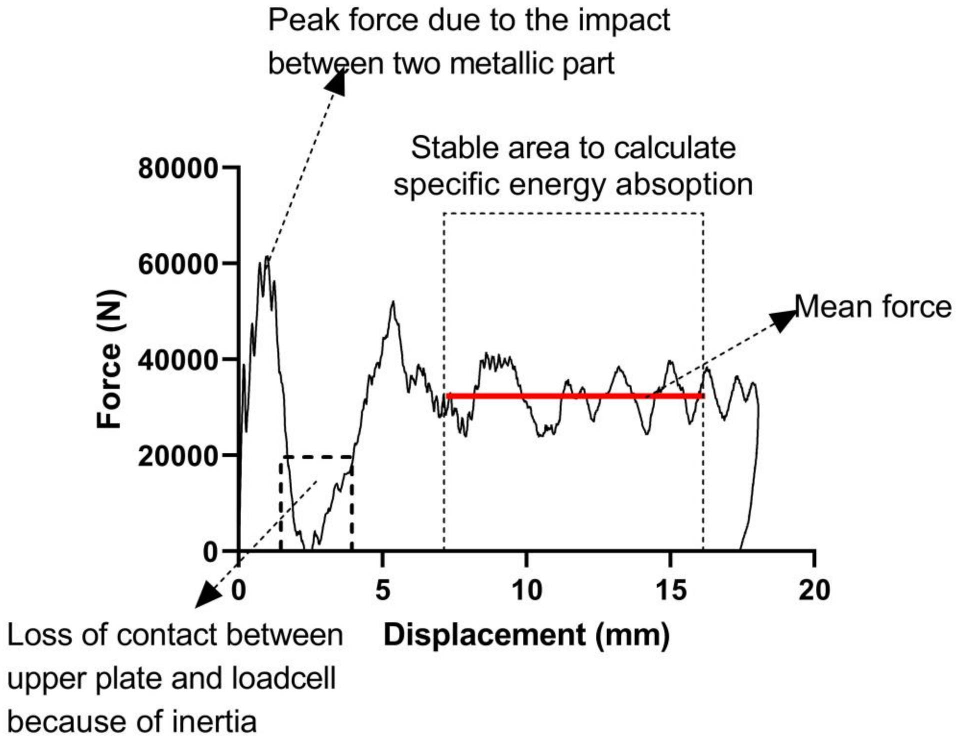
Structural Element Test

- Results obtained from anti-buckling fixture



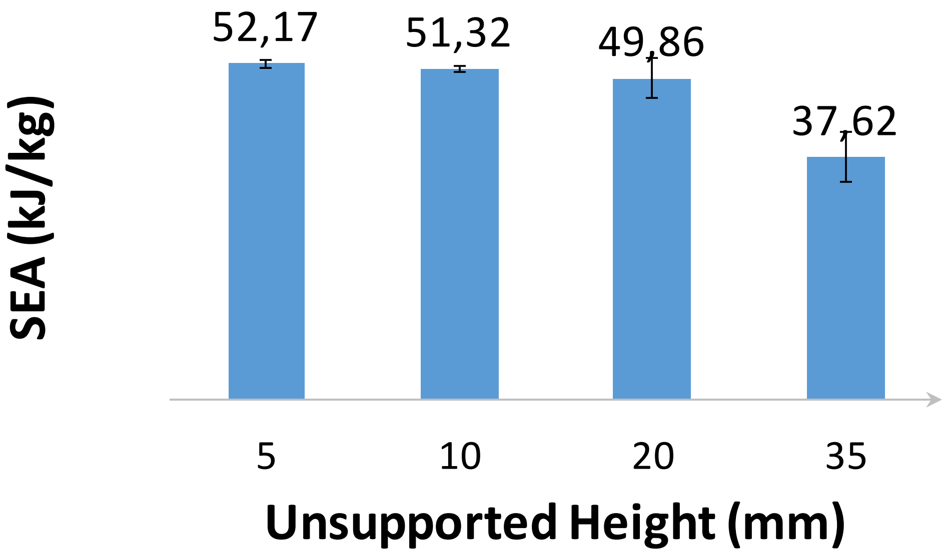
Results

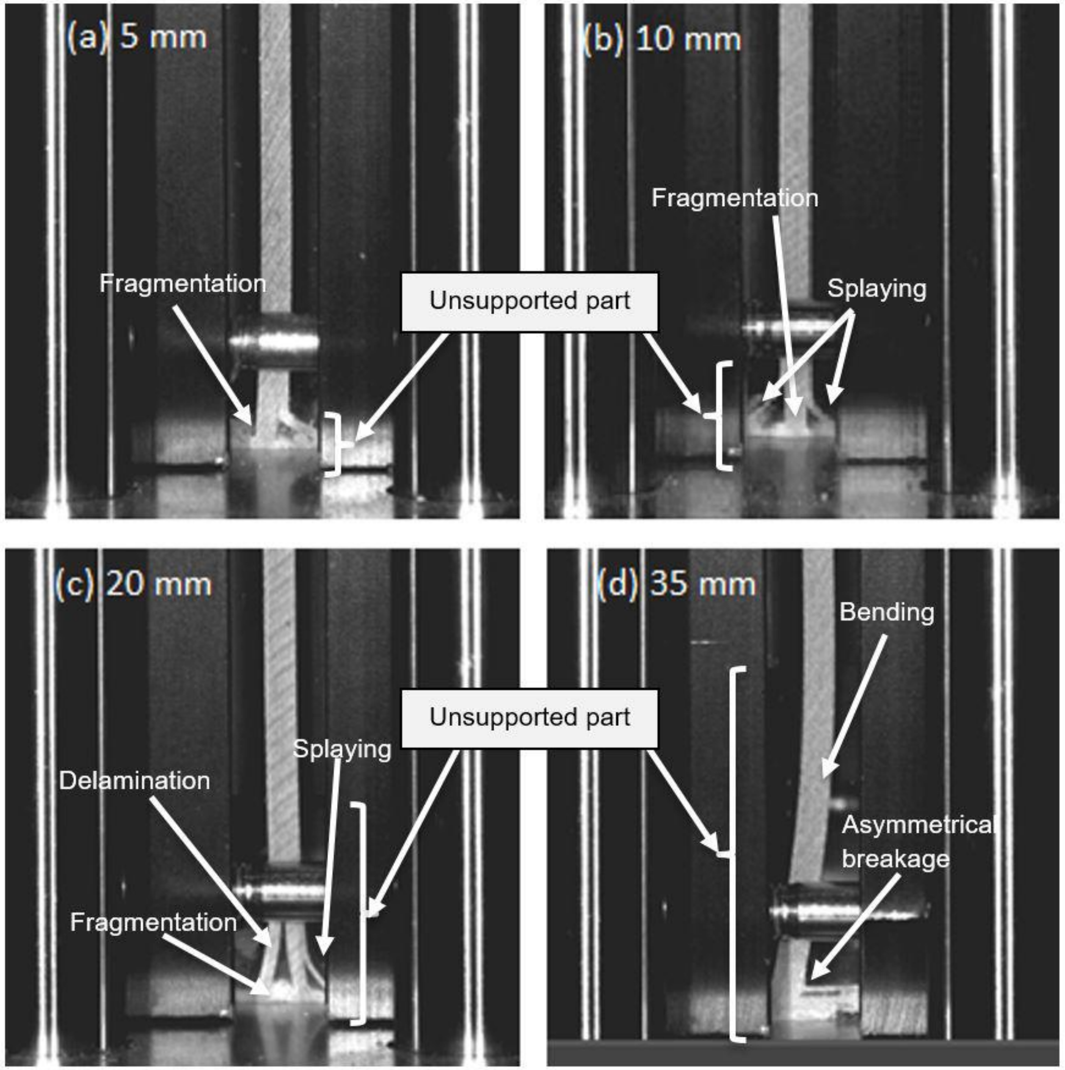
- Studied parameters:
  - Unsupported height
  - Impact mass
  - Impact velocity



Results

- Effects of unsupported height

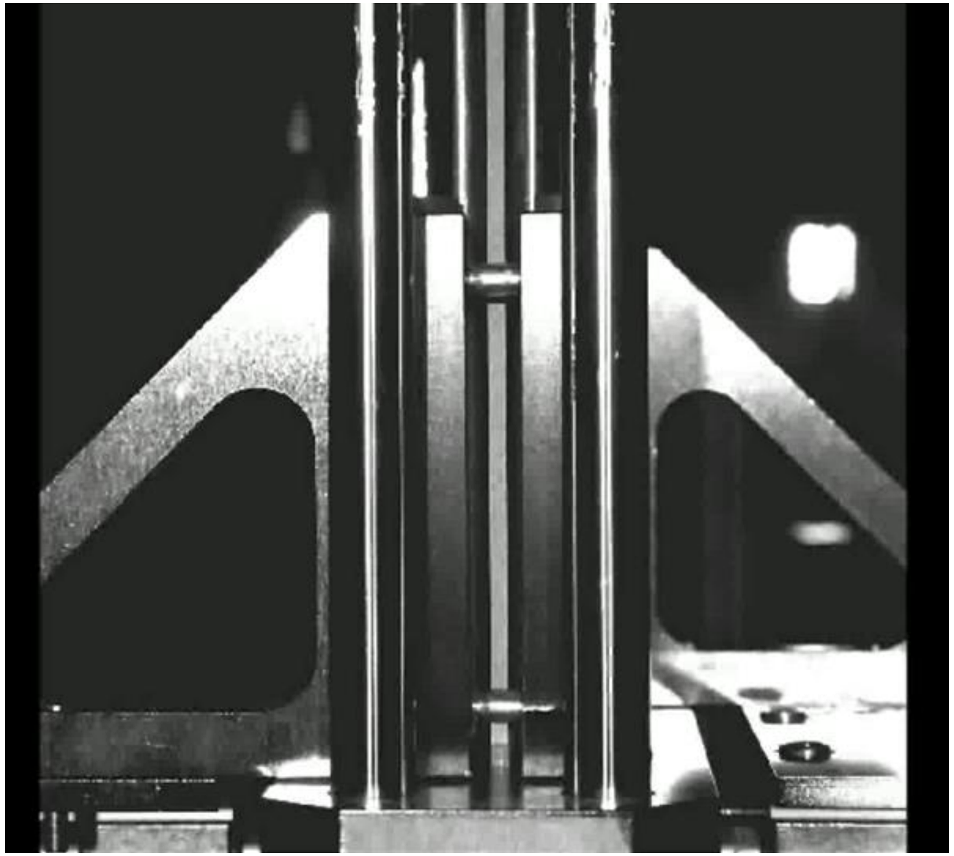




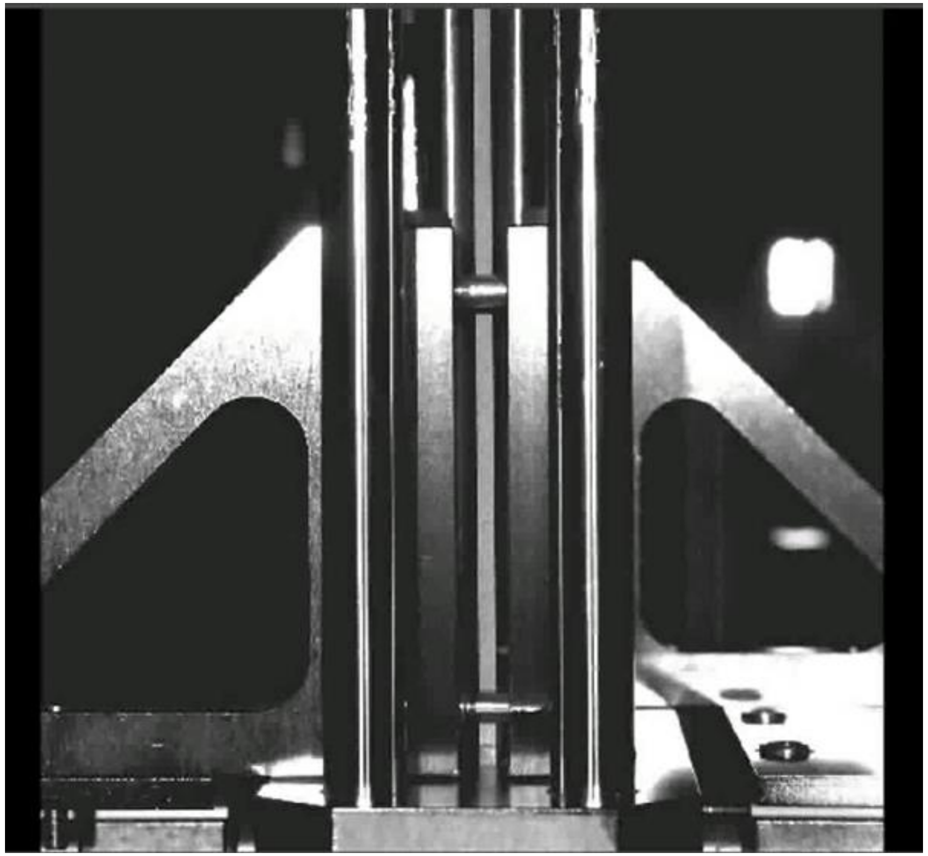
Results

Sub-component Test

Structural Element Test



5 mm unsupported height



35 mm unsupported height

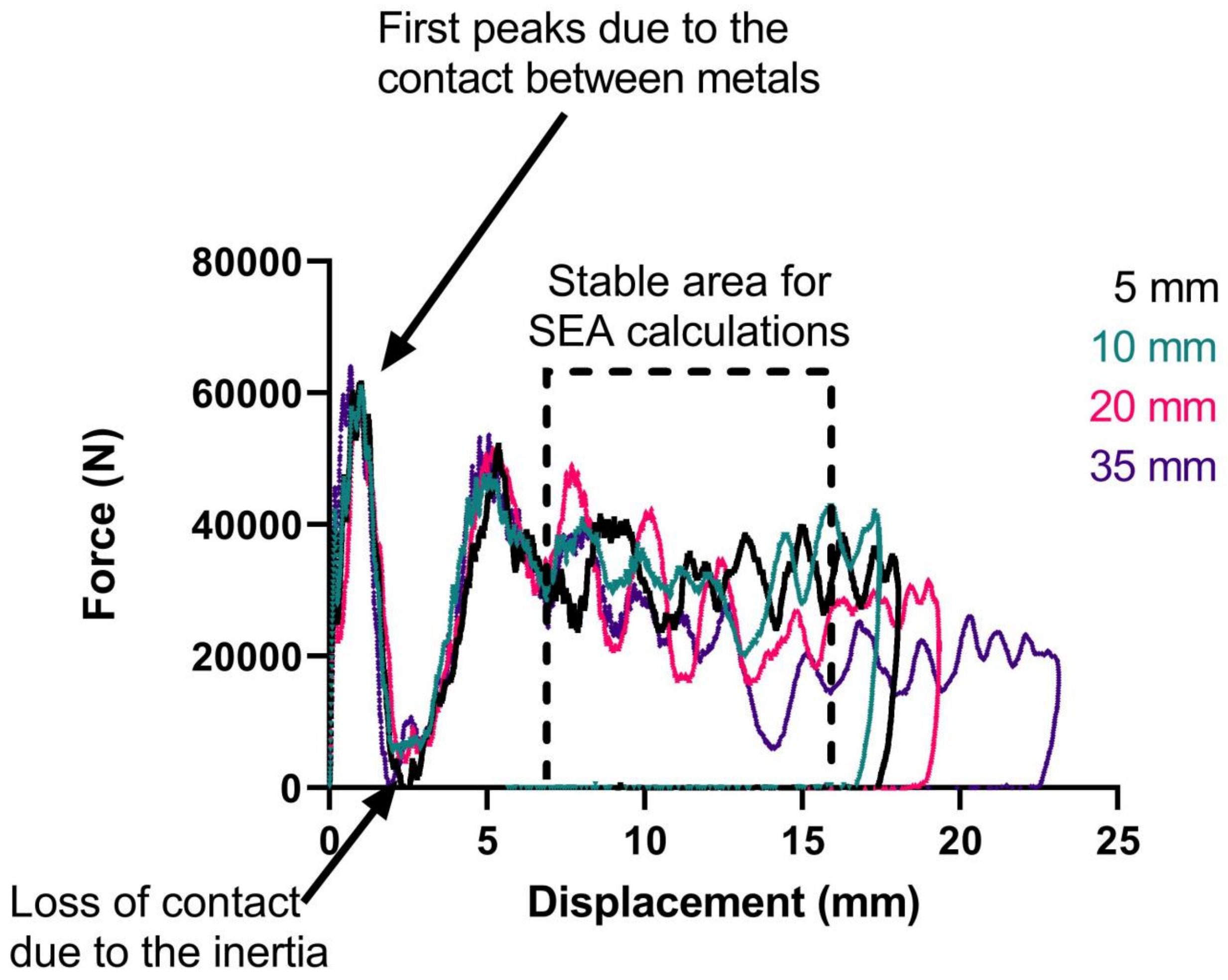
Results

Sub-component Test

Structural Element Test

- Effects of unsupported height

Unsupported Height (mm)	Mean Force (kN)	SEA (kJ/kg)
5	32.383 ± 0.76	52.167 ± 0.91
10	31.633 ± 0.77	51.316 ± 0.79
20	30.635 ± 3.81	49.861 ± 5.33
35	22.350 ± 3.85	37.618 ± 6.70

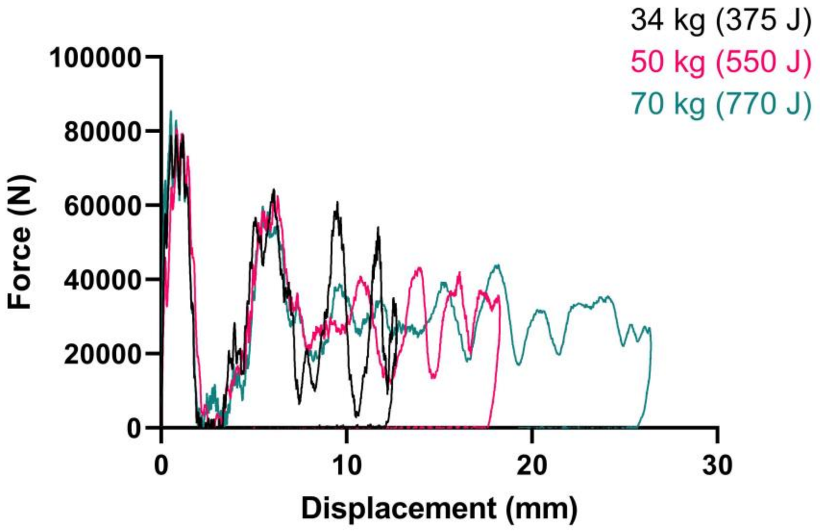


Results

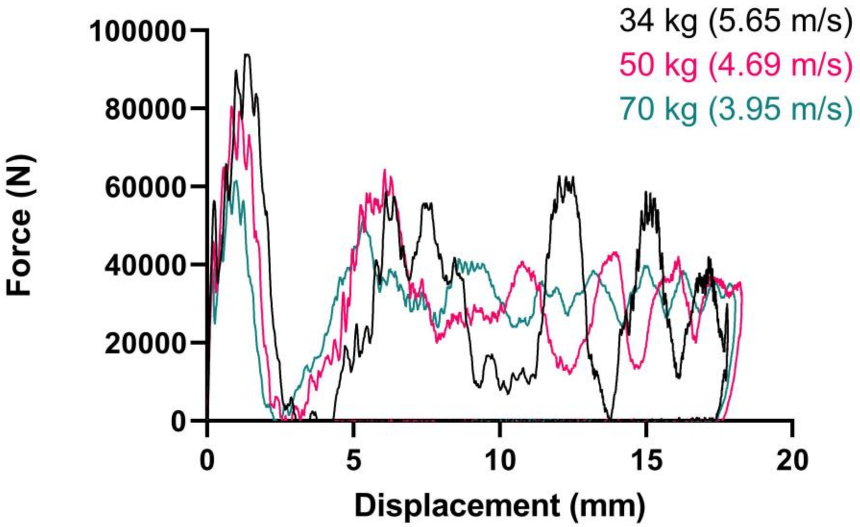
Sub-component Test

Structural Element Test

• Effects of impact mass



Impact velocity = 4.67 m/s



Impact Energy = 550 J

Results

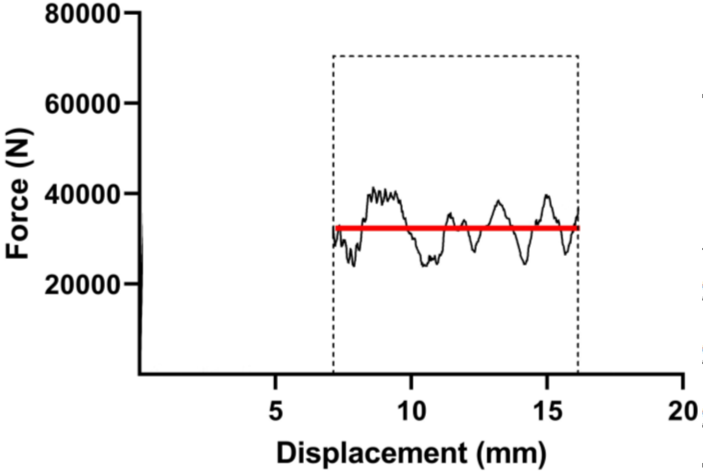
Sub-component Test
Structural Element Test

- Effects of impact mass
  - GFRP specimens

Impact Mass (kg)	Mean Force (kN)	Standard Deviation (kN)	SEA (kJ/kg)
34 kg	30.853 ± 1.76	17.685 ± 2.12	50.892 ± 4.02
50 kg	30.646 ± 2.09	10.044 ± 1.27	50.452 ± 2.54
70 kg	31.296 ± 1.06	5.206 ± 0.65	50.663 ± 1.85

  - CFRP specimens

Impact Mass (kg)	Me	SEA (kJ/kg)
34 kg	17.3	45.537 ± 1.30
50 kg	18.1	44.976 ± 1.99
70 kg	16.6	45.945 ± 2.96

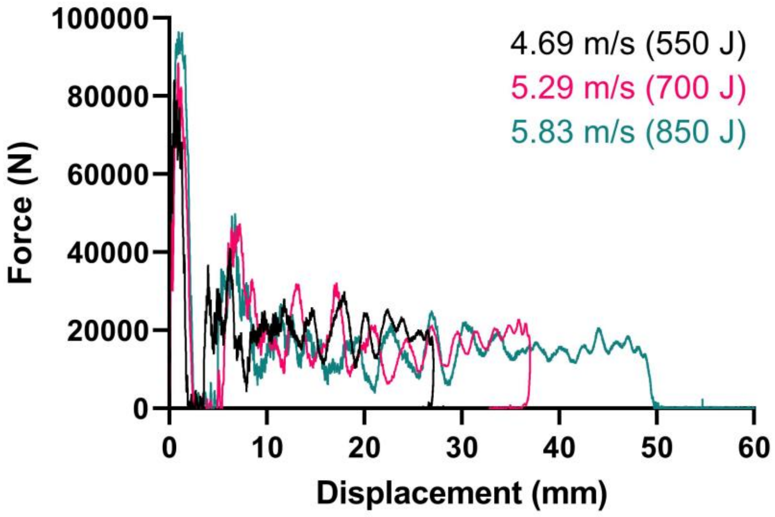


Results

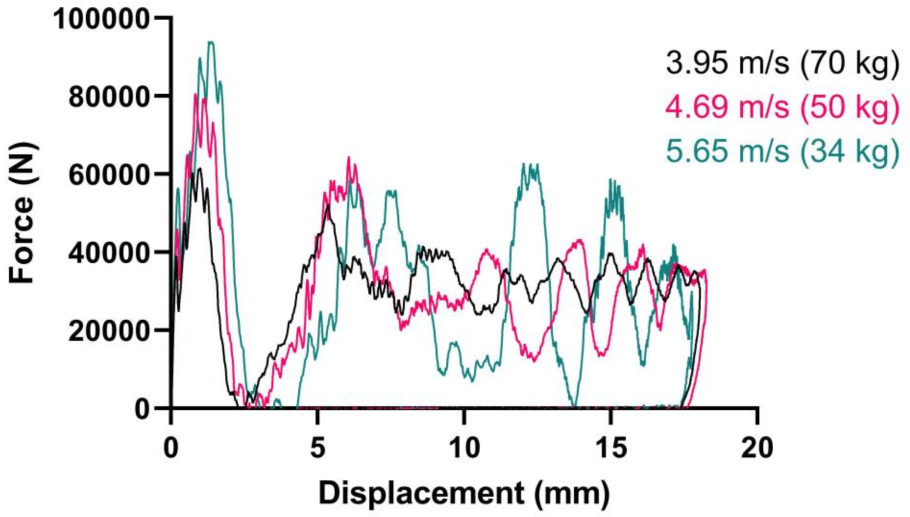
Sub-component Test

Structural Element Test

- Effects of impact velocity



CFRP, impact mass = 50 kg



GFRP, impact energy = 550 J

Results

Sub-component Test
Structural Element Test

- Effects of impact velocity
  - GFRP specimens

Impact Velocity (m/s)	Peak Force (kN)	Mean Force (kN)	SEA (kJ/kg)
3.96	62.261 ± 0.77	31.633 ± 0.77	51.316 ± 0.79
4.73	81.873 ± 2.80	30.947 ± 1.89	50.729 ± 3.52
5.65	93.814 ± 0.01	29.951 ± 0.28	50.599 ± 0.68

  - CFRP specimens

Impact Velocity (m/s)	Peak Force (kN)	Mean Force (kN)	SEA (kJ/kg)
4.69	77.309 ± 4.38	17.585 ± 1.65	46.208 ± 3.08
5.29	86.286 ± 2.65	17.101 ± 1.85	45.350 ± 2.46
5.83	99.703 ± 3.42	17.108 ± 0.65	45.002 ± 1.83

Results

Sub-component Test

Structural Element Test

- Reproducible and reliable results
- No jamming or tearing
- Helped tuning the modelling steps for better prediction of composite component behavior

applied sciences

MDPI

Article

Newly Developed Anti-Buckling Fixture to Assess the In-Plane Crashworthiness of Flat Composite Specimens

Iman Babaei [1,*], Ravin Garg [1], Lorenzo Vigna [1], Davide Salvatore Paolino [1], Giovanni Belingardi [1], Lucio Cascone [2], Andrea Calzolari [3] and Giuseppe Galizia [3]

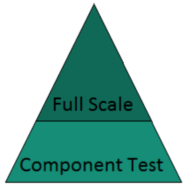
1 Department of Mechanical and Aerospace Engineering, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Turin, Italy; ravin.garg@polito.it (R.G.); lorenzo_vigna@polito.it (L.V.); davide.paolino@polito.it (D.S.P.); giovanni.belingardi@polito.it (G.B.)

2 Group Materials Labs—Polymers, Centro Ricerche Fiat, Via Ex Aeroporto sn, 80038 Pomigliano d'Arco (Na), Italy; lucio.cascone@crf.it

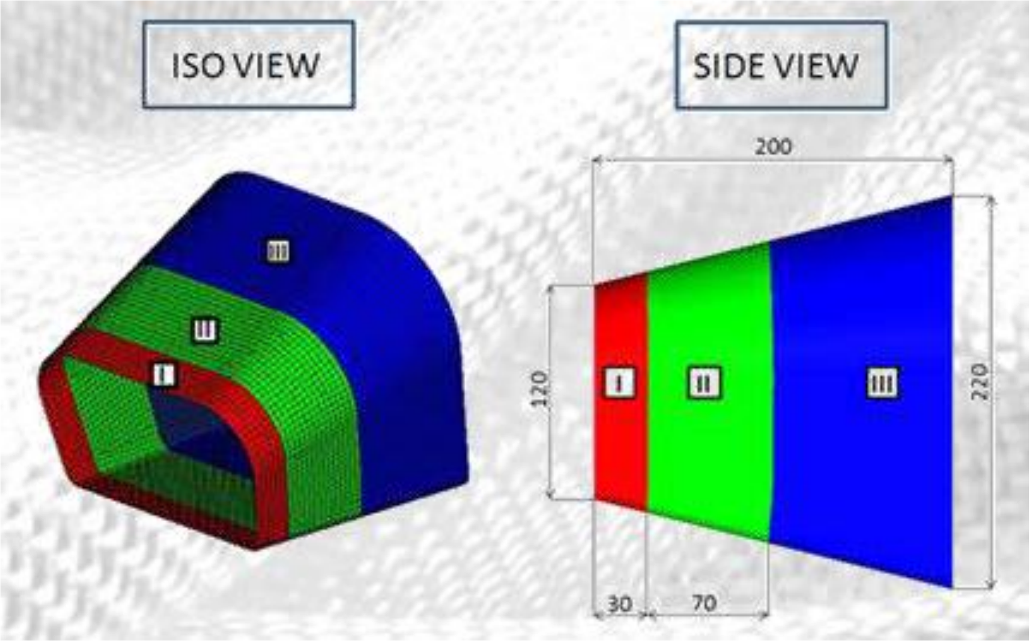
3 IWT Test and Measurement Italy, Instron CEAST, Via Airauda, 12, 10044 Pianezza TO, Italy; andrea_calzolari@instron.com (A.C.); giuseppe_galizia@instron.com (G.G.)

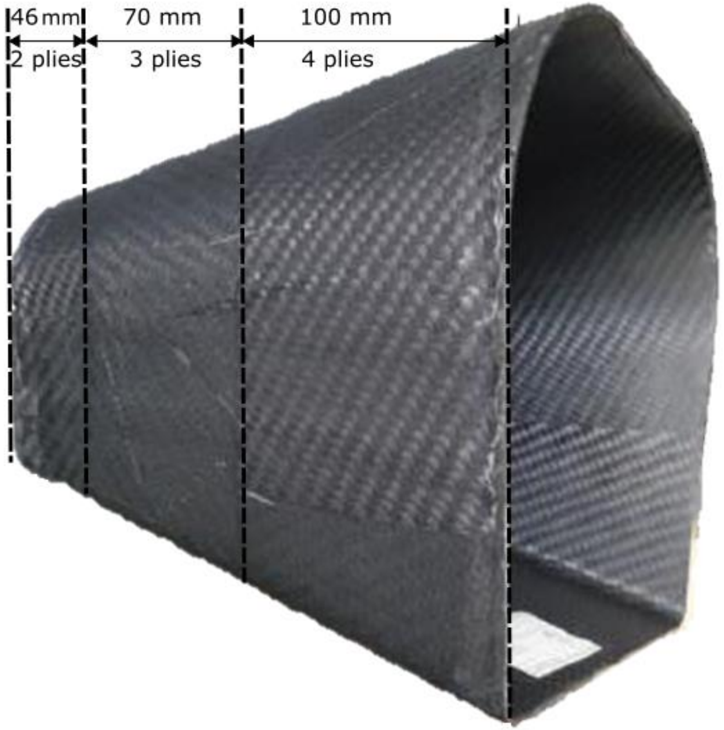
* Correspondence: iman.babaei@polito.it

Results

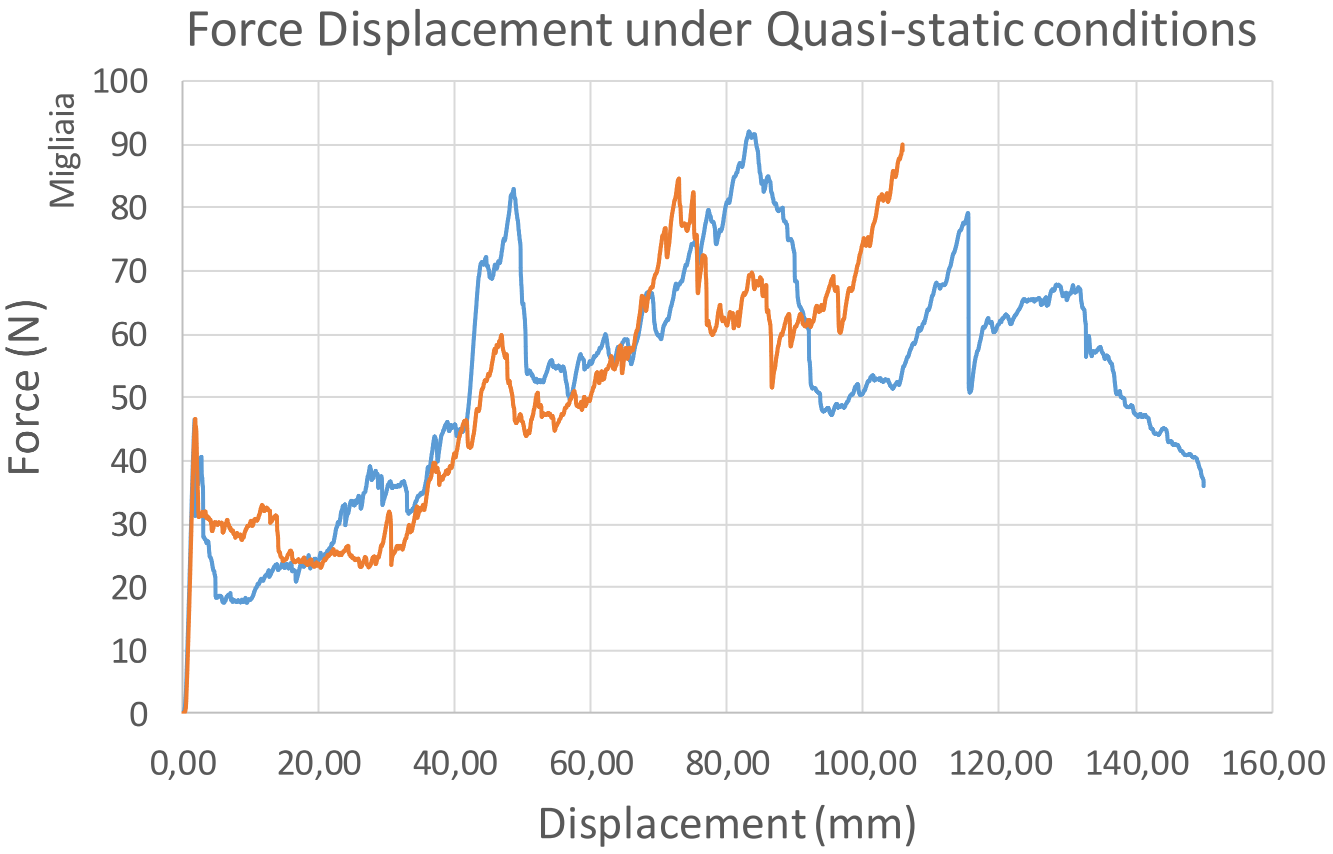


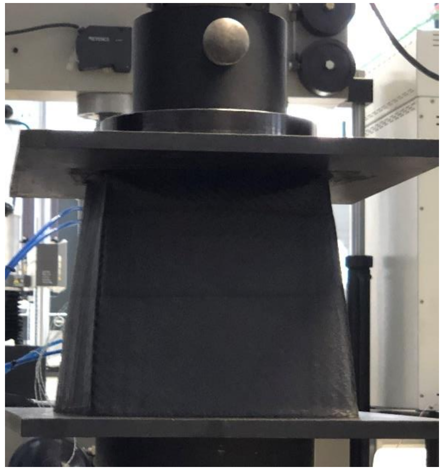
- Crash demonstrator and facilities to perform the tests are selected

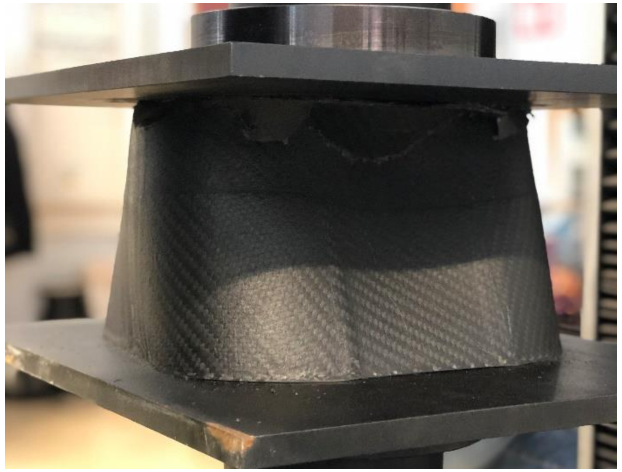




Results


Force Displacement under Quasi-static conditions
Migliaia
Force (N)
100
90
80
70
60
50
40
30
20
10
0
0,00
20,00
40,00
60,00
80,00
100,00
120,00
140,00
160,00
Displacement (mm)





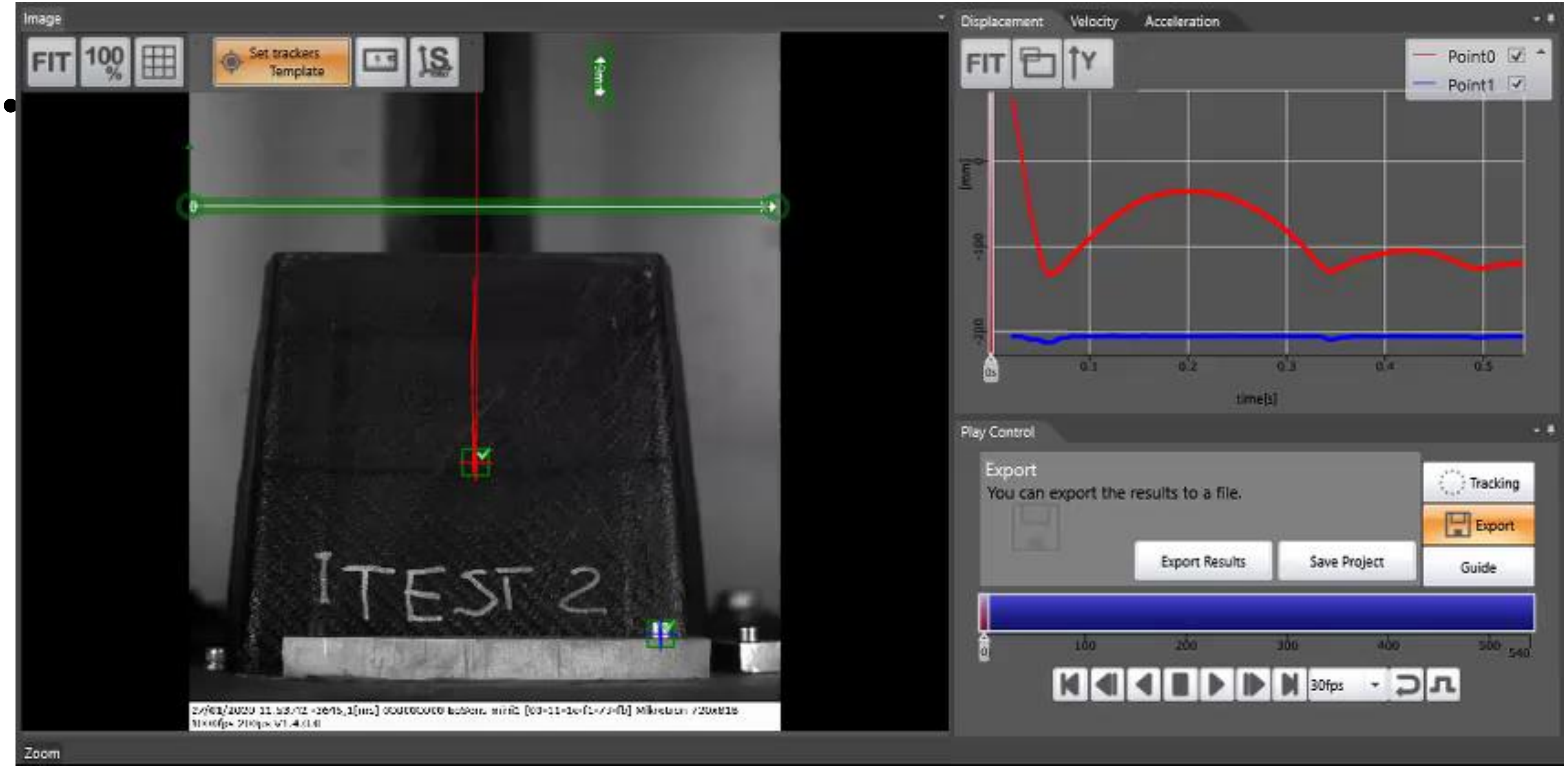
Results

Full Scale
Component Test

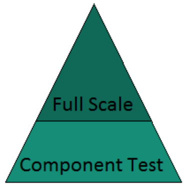
	Impact Velocity (m/s)	Impact Energy (J)
1	7.097	7555
2	7.101	7563
3	7.77	9055
4	8.04	9696

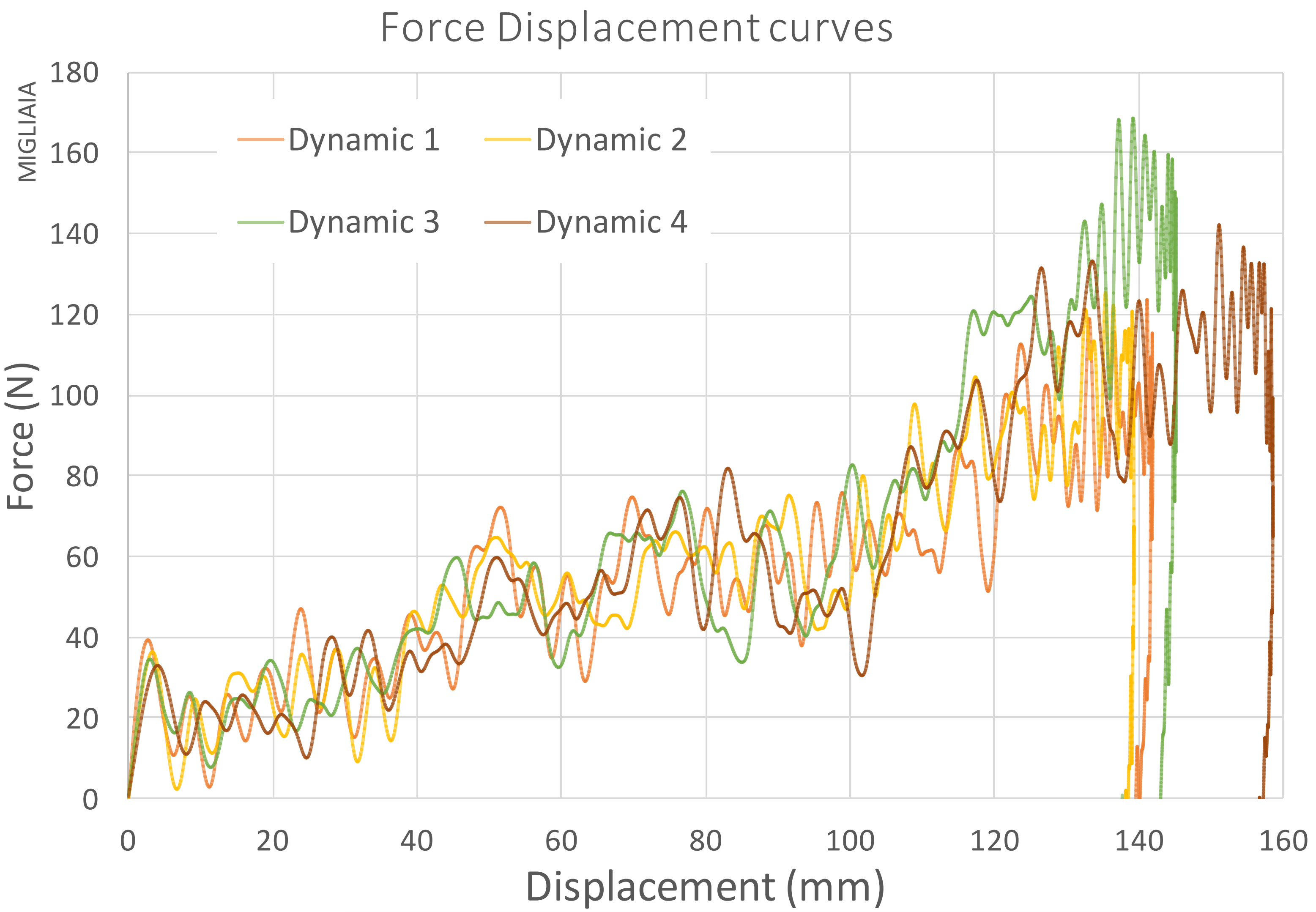
Results

Full Scale
Component Test



Results





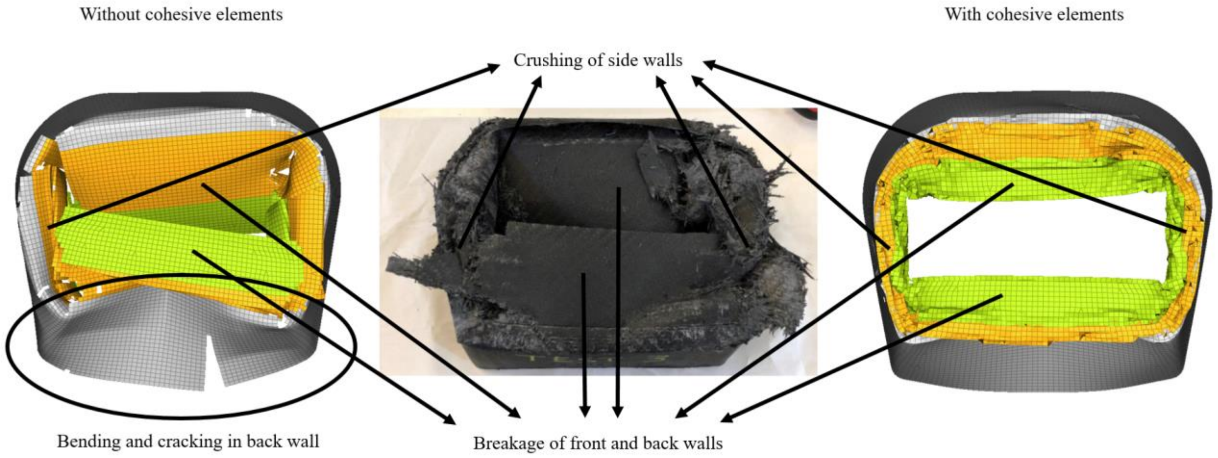
	Impact Velocity (m/s)	Impact Energy (J)
1	7.097	7555
2	7.101	7563
3	7.77	9055
4	8.04	9696

Results

- Final stage component level tests

- Reference for modelling validation
  Quantitively and visually

- Proof of concept



Thank You

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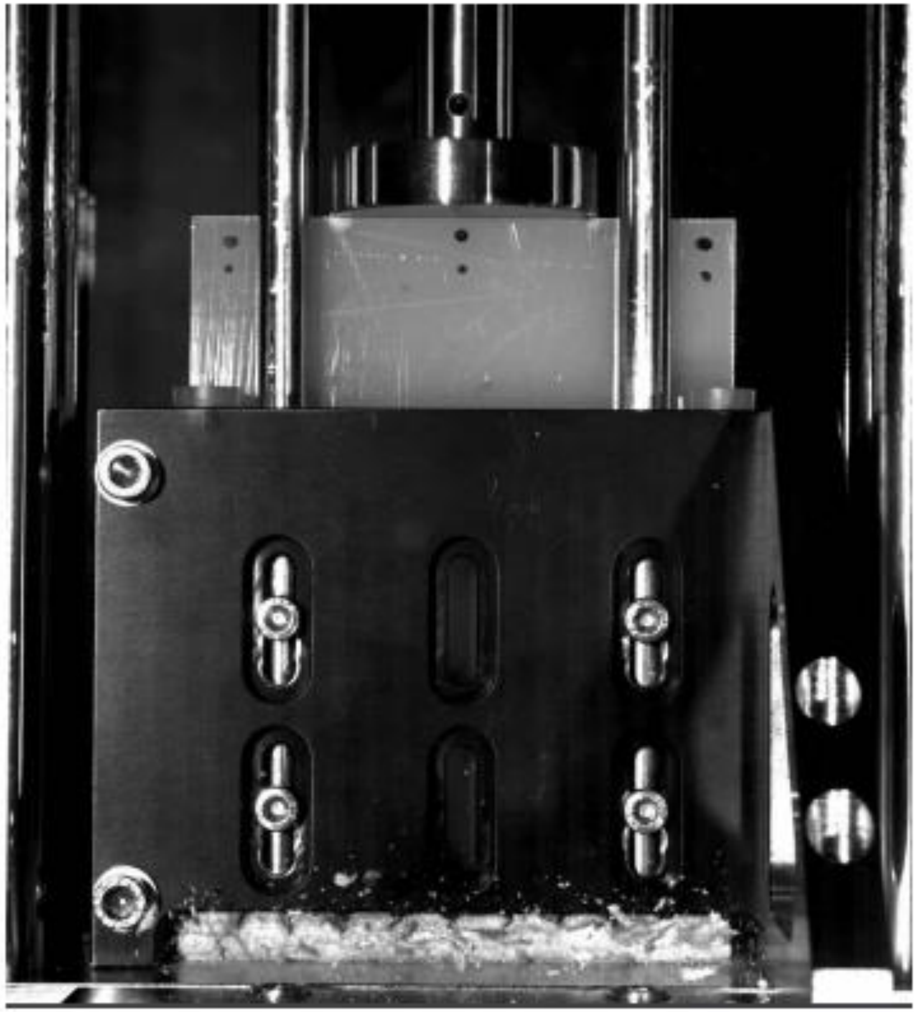
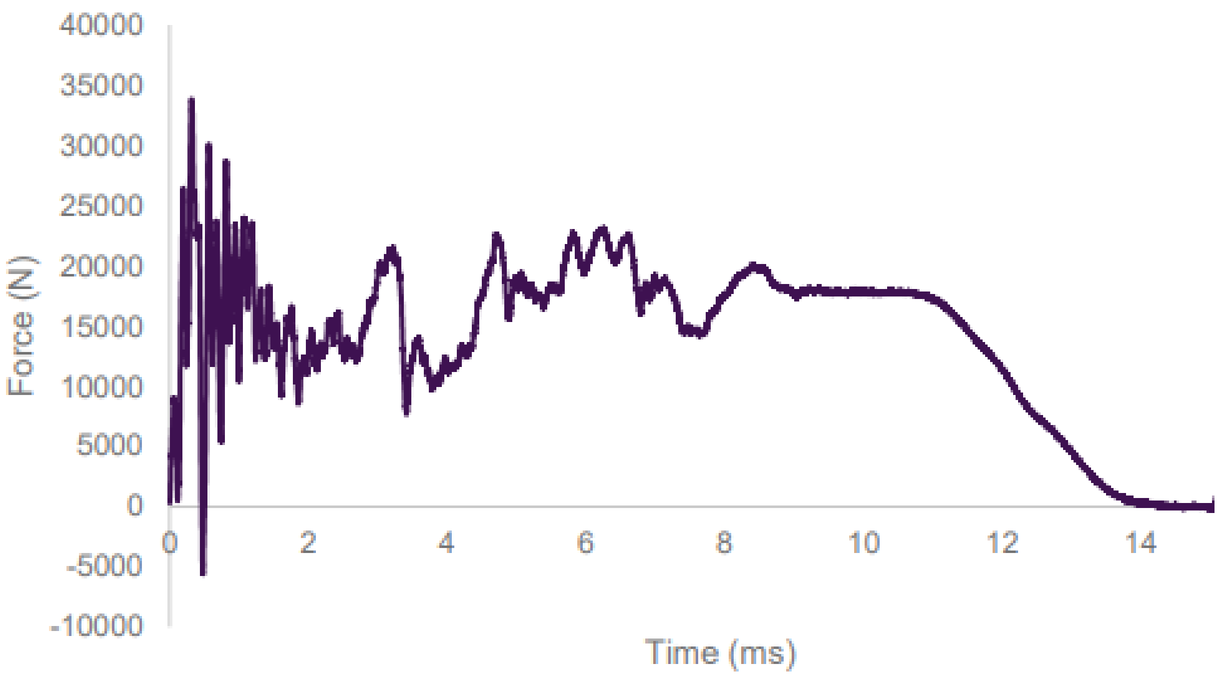
Backup Slides





Backup Slides