Development and validation of methodology for assessment of damage resistance properties of sandwich structures for European space sector.

AO/1-7516/13/NL/KML

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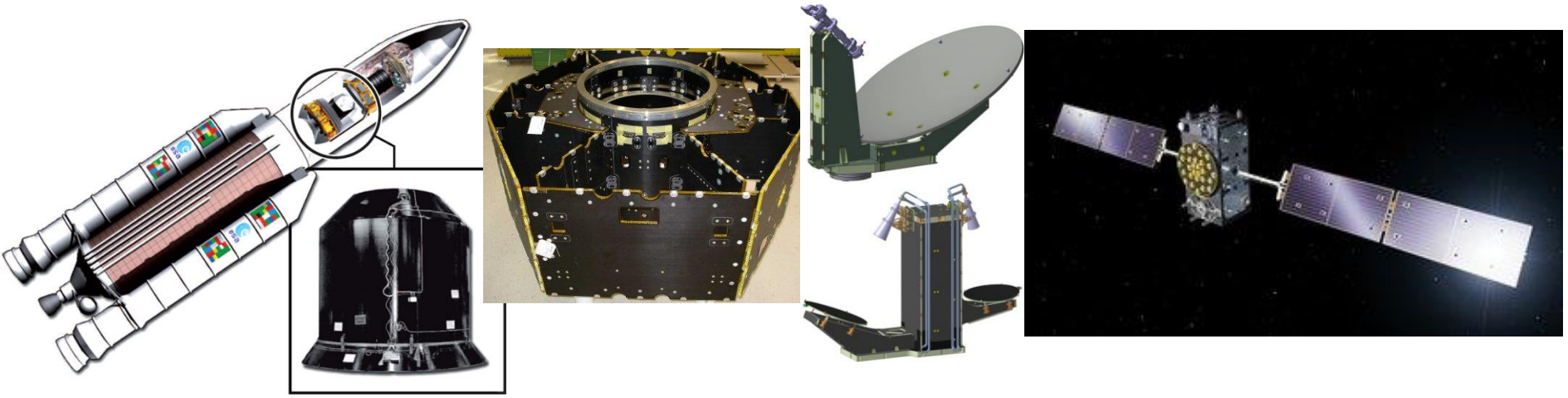
esa European Space Agency

Ministry of Education and Science Republic of Latvia

PECS Progress Presentation
11-12 January, 2017

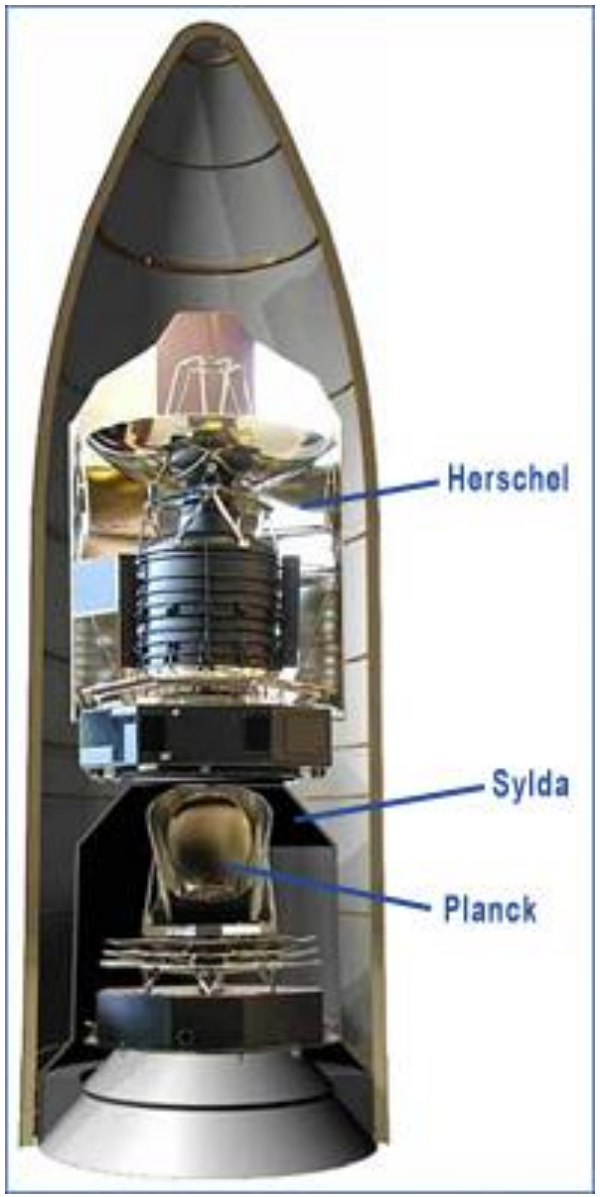
RIGA TECHNICAL UNIVERSITY IMS INSTITUTE OF MATERIALS AND STRUCTURES

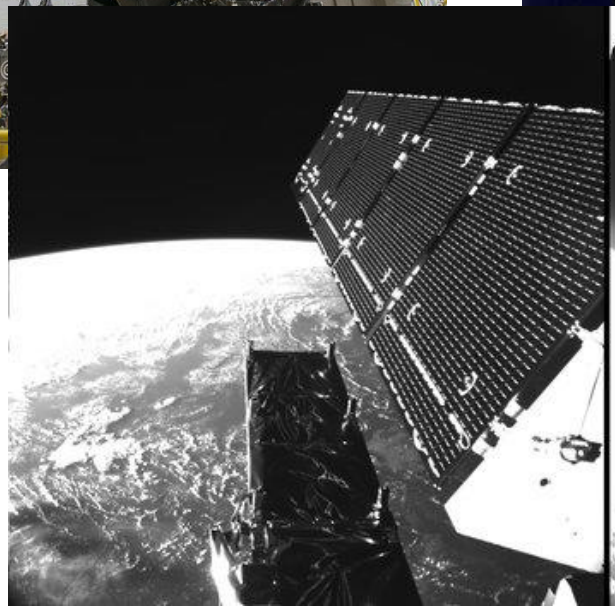
Summary of Objectives

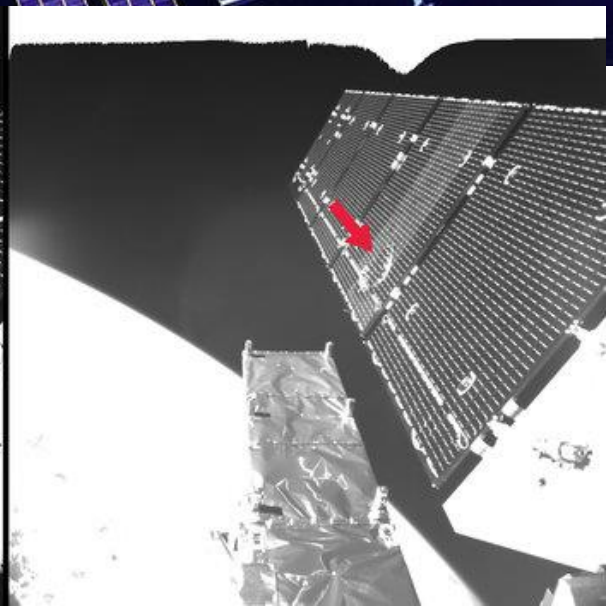


The main objective of proposed research is to develop a methodology and to set a good testing practice guidelines (standard) in order to increase the efficiency in design of launcher and satellite structures, by explicitly demonstrating the risk mitigation practice in form of an assessment of Barely Visible Impact Damage (BVID) resistance properties of ultra-thin wall sandwich structures.

Summary of Objectives

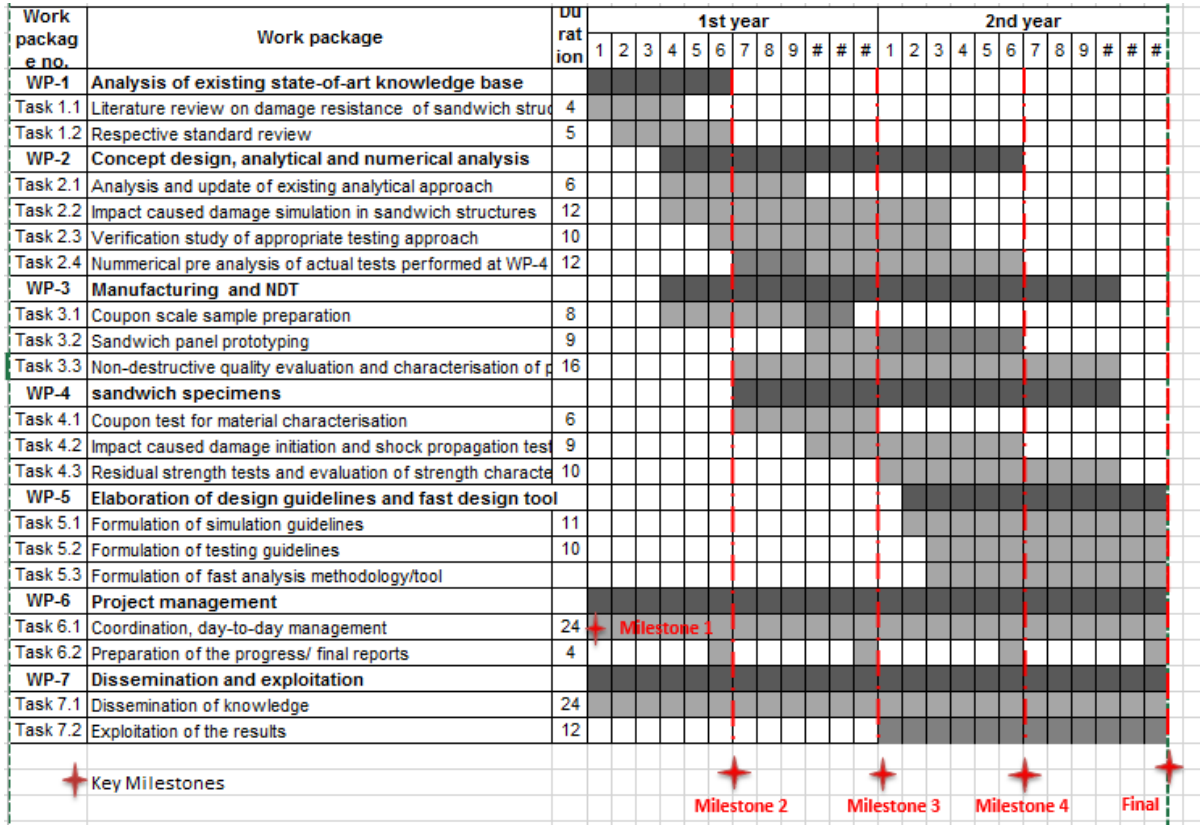






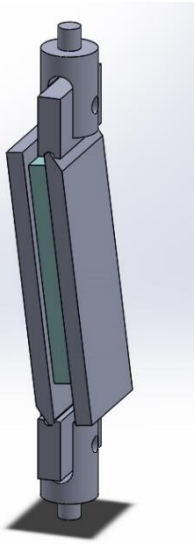
Contract Summary

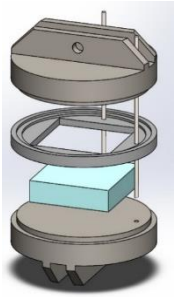
- Kick-of-meeting: 1.11.2015
- Duration: 24 months
- Contract Price: 200 000 eur.

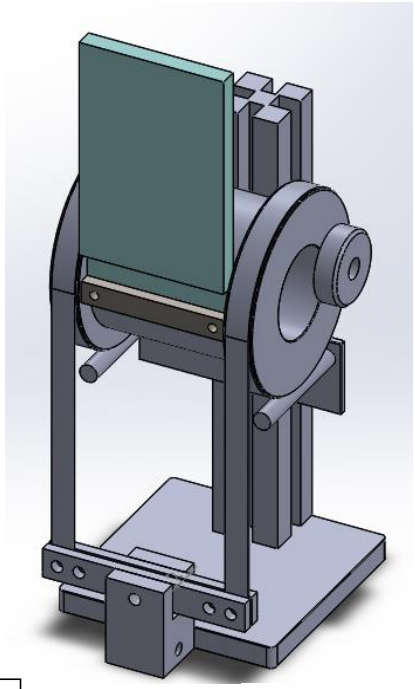


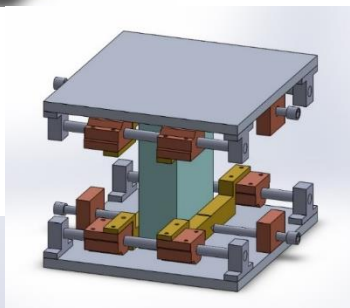
Main Technical Developments

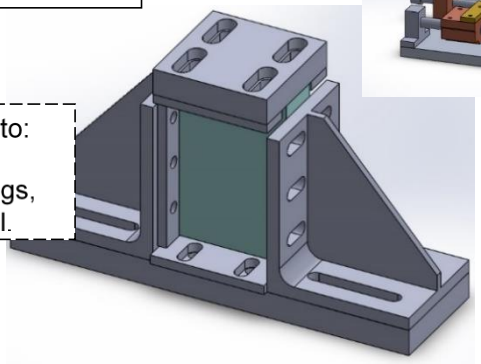
Literature review:











- **Mechanical**
  - **Tensil**
    - Flatwise tension: ASTM C297
    - Node tension: ASTM C363
    - Composite tension: ASTM D3039
  - **Shea**
    - Plate shear: ASTM C273
    - Beam shear: ASTM C393
    - Shear fatigue: ASTM C394
  - **Flexur**
    - Long beam flexure: ASTM C393, ASTM D7249, ASTM D7956
    - Distributed load: ASTM D6416
    - Composite flexure: ASTM D7264
  - **Compression**
    - **Compression**
      - Flatwise compression: MIL-STD-401B (5.2.1) a, ASTM C365
      - Edgewise compression: MIL-STD-401B (5.2.1) b, ASTM D7264
      - Composite compression: ASTM D3410
      - Beam compression: ASTM D3410
    - CAI: SACMA SRM 2-88, NASA 1 092, ASTM D7137
  - **Damage**
    - Impact: ASTM D7766, ASTM D7136
    - QS indentation: ASTM D6264
  - **Other**
    - Climbing drum peel: ASTM D1718
    - Fracture: ASTM D5528

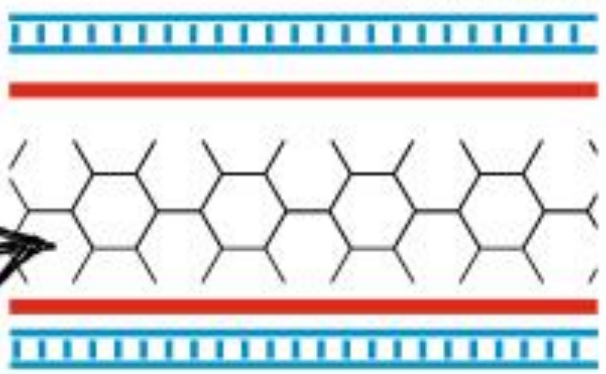
Test is applicable to:
- Honeycomb,
- Composite facings,
- Sandwich panel.

Main Technical Developments

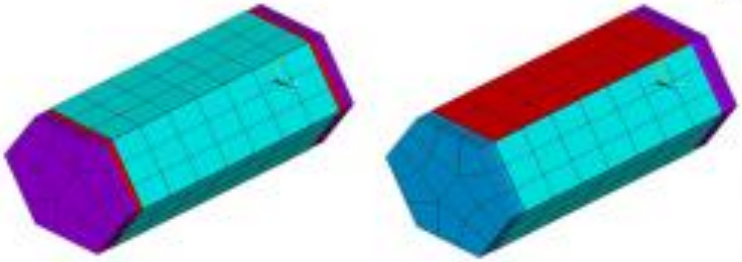
Nummerical analysis:

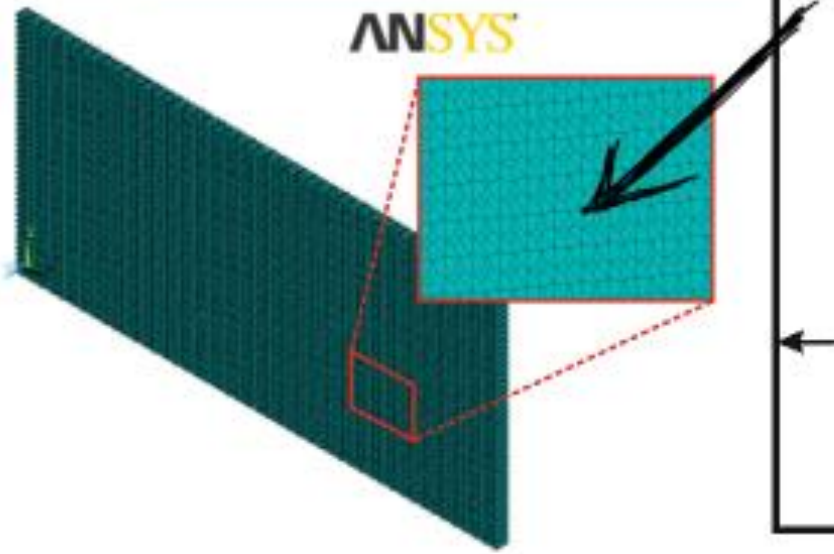
Real sample

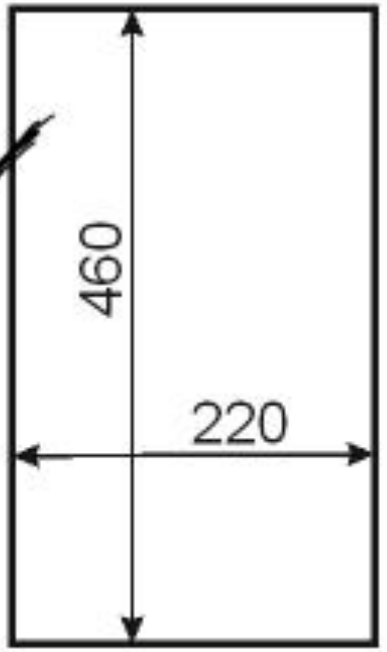
Building blocks



FE ANSYS







Materials

Skin unipreg [-60/0/60]

Adhesice Permabond ET538

Core AL-HC 3.2/10mm

Section

Top skin

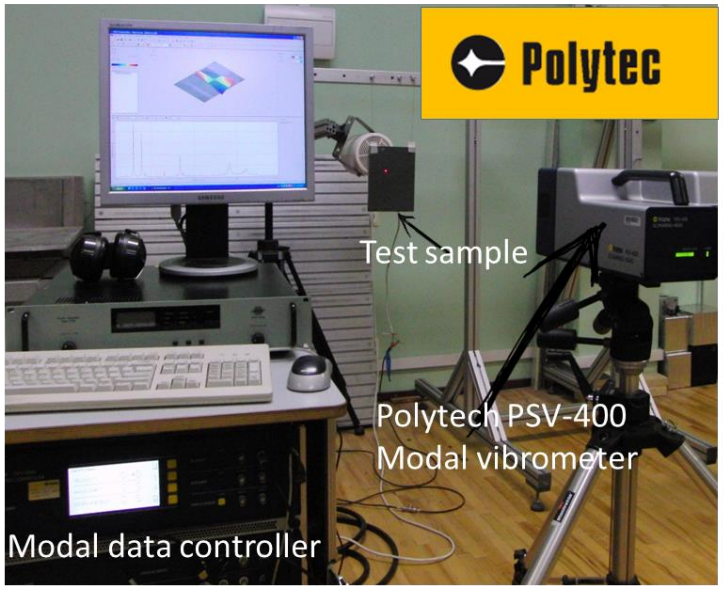
Botton skin

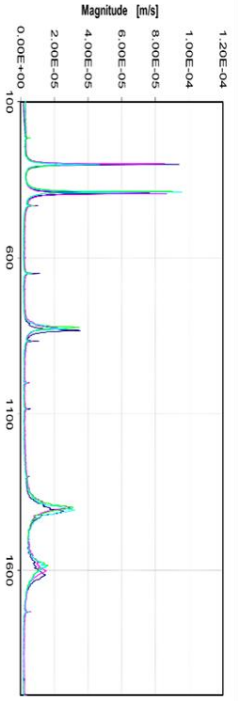
Core joint area

Core

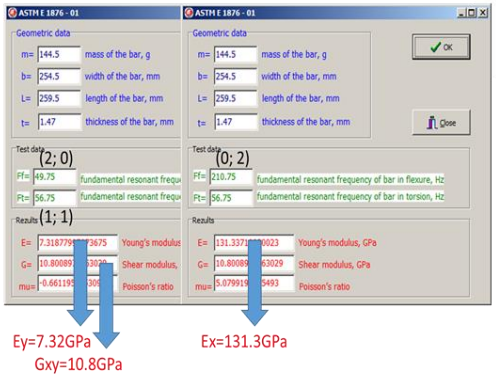
Main Technical Developments

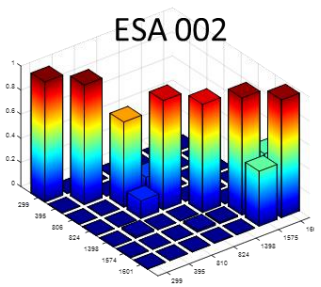
Nummerical analysis:

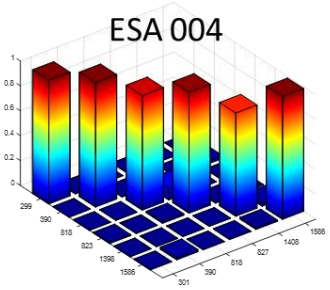




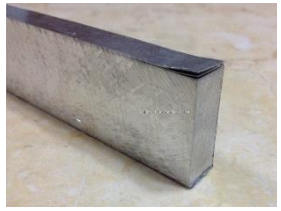
f Hz (m; n)	EXP		FEM		Δ, %
1 (0; 2)	301.25		320.15		-6.27
2 (1; 1)	393.13		406.01		-3.28
3 (1; 2)	811.25	ESA 002	869.02		-7.12
4 (0; 3)	832.50		870.30		-4.54
5 (2; 0)	1388.75		1439.9		-3.68
6 (1; 3)	1410.63		1455.5		-3.18
7 (2; 1)	1573.75		1634.5		-3.86
8 (0; 4)	1615.00		1693.5		-4.86



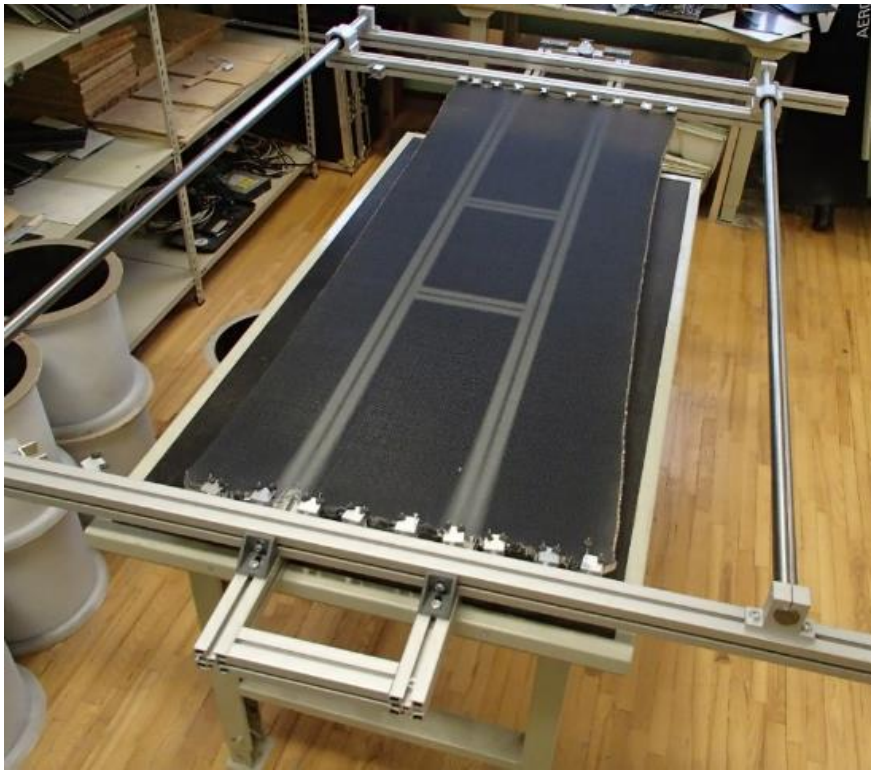


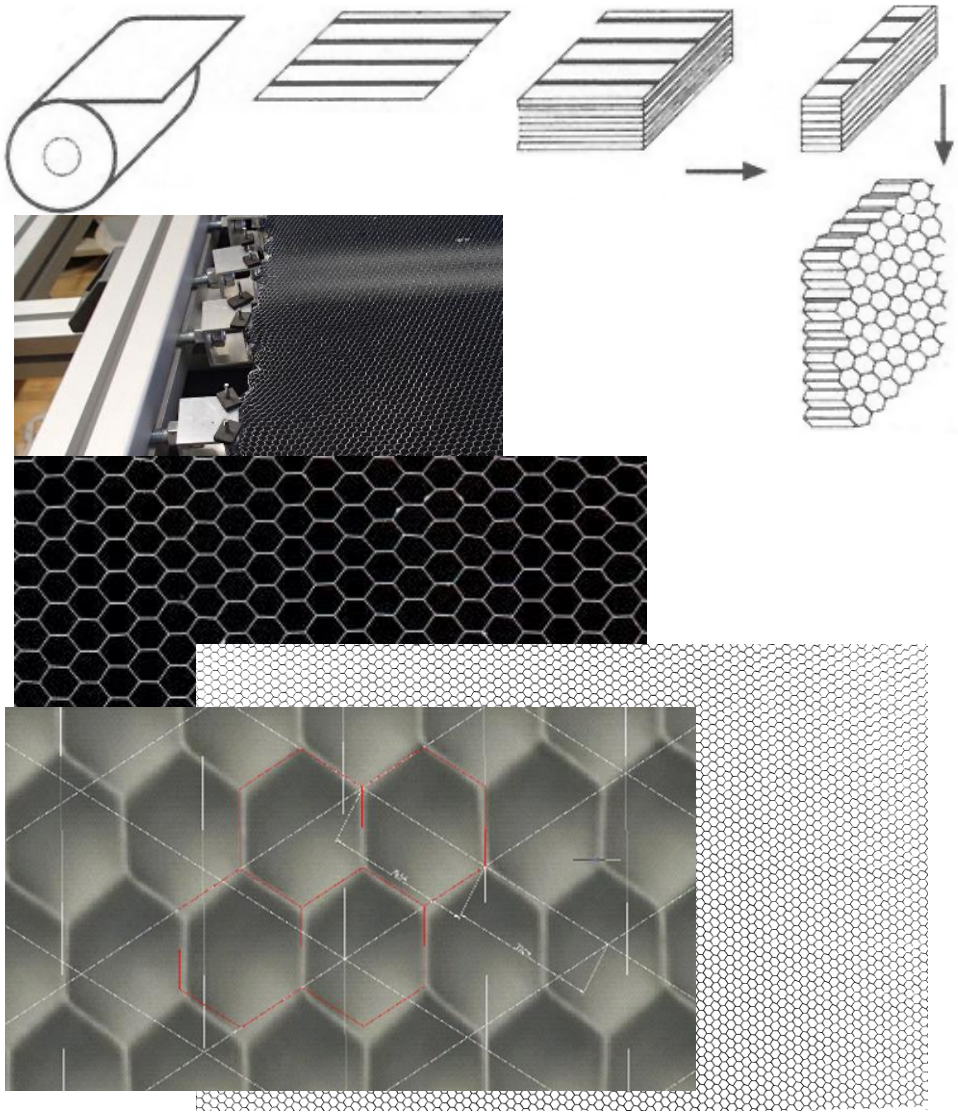


Main Technical Developments



Specimen manufacturing and NDT :



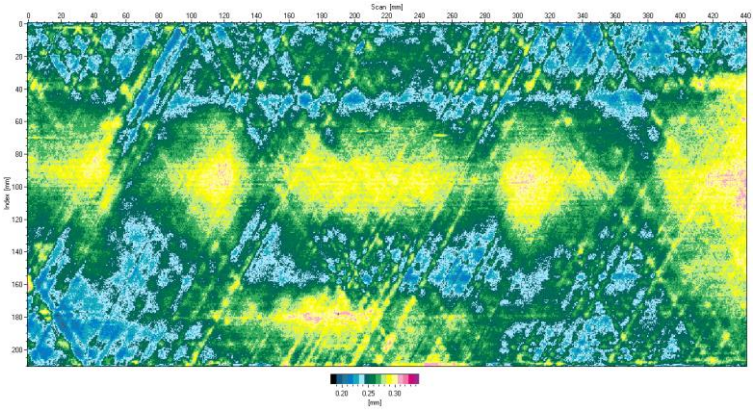


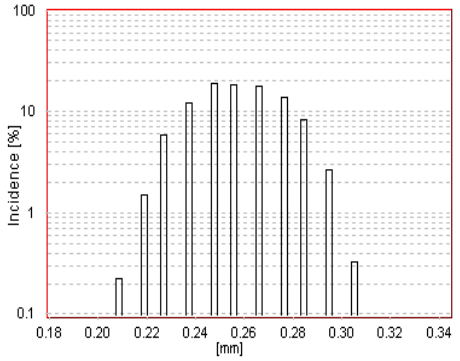
Honeycomb expansion frame was developed and manufactured. Honeycomb expansion quality was monitored by comparative study of cell image geometry correlation with ideal geometry cell.

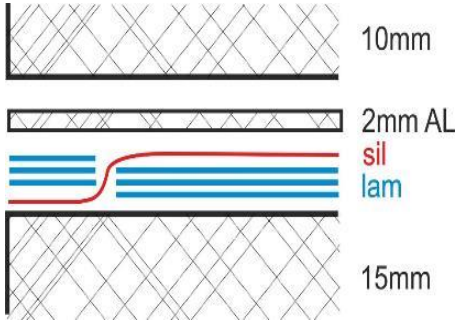
Main Technical Developments

Specimen manufacturing and NDT :

Panel ID	Face ID (+60/0/-60)	Face sheet average thickness, mm	Face sheet weight, g	HC weight, g	Uncured weight, g	Cured component weight, g	Control weight, g (sum of uncured weights)	460 x 210 panel weight, g	Actual adhesive weight, g (norm 50 g/face)	Adhesive thickness, mm
ESA_001	11	0.26	44.4	67.1	98.5	165.8	165.6	237.1	54.1	0.40
	12	0.27	46.5		92.3	258.5	257.9		45.8	0.34
ESA_002	13	0.26	45.1	68.9	94.7	163.8	163.6	240.2	49.6	0.37
	14	0.26	46.9		96.9	260.8	260.5		50.0	0.37
ESA_003	15	0.26	46.3	74.2	94.8	168.9	169	225.7	48.5	0.36
	16	0.26	45.1		79.5	248.5	248.5		34.4	0.26
ESA_004	17	0.26	45.7	73.6	91.1	164.6	164.7	221.0	45.4	0.34
	18	0.25	44.6		79.5	244.3	244.2		34.9	0.26
ESA_005	19	0.26					0		0.0	0.00
	20	0.25					0		0.0	0.00
ESA_006	21	0.25					0		0.0	0.00
	22	0.26					0		0.0	0.00



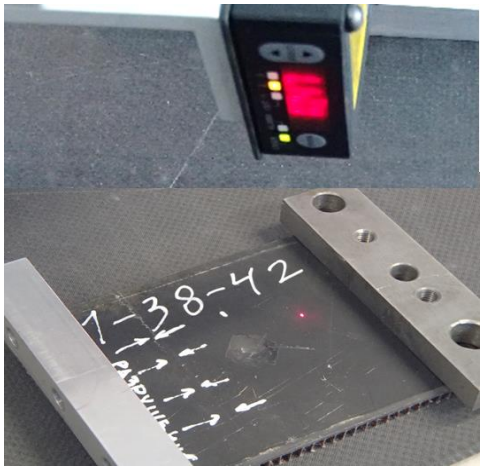


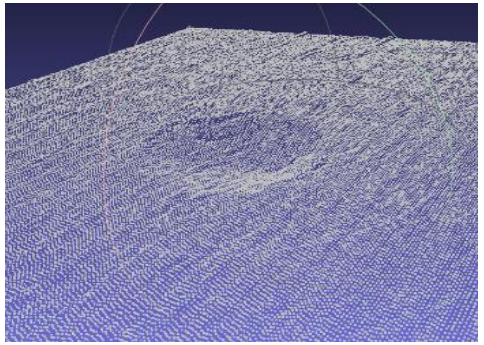


28 skin plates were manufactured at the moment. US inspected for voids and thickness measurements. All corresponding data of all components used to form sandwich panel were gathered in single Excel sheet, with hyperlinks to corresponding US C-scans and thickness histograms.

Main Technical Developments

Specimen manufacturing and NDT :





Each honeycomb panel (460 x 210 mm) was cut to six individual samples (150 x 100 mm). The whole sample series of six samples was scanned by laser based xyz scanner prior and after impacting to calculate impact introduced indentation, with the reason damage zone determination.

Main Technical Developments

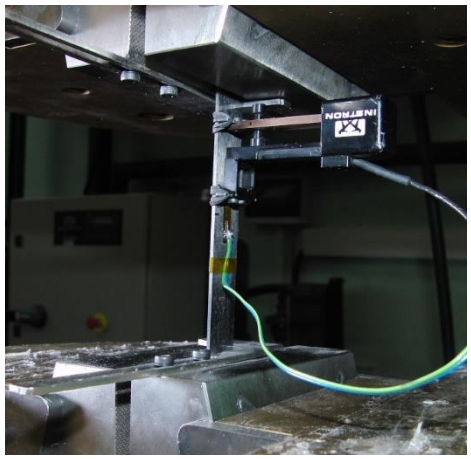
Characterization of the mechanical behaviour of sandwich specimens:

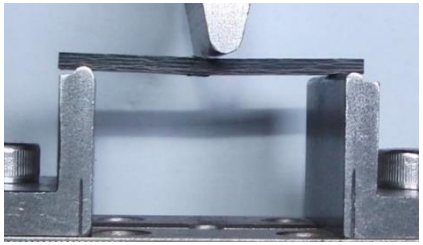
Mechanical tests of carbon fiber reinforced laminate for sandwich skin plates

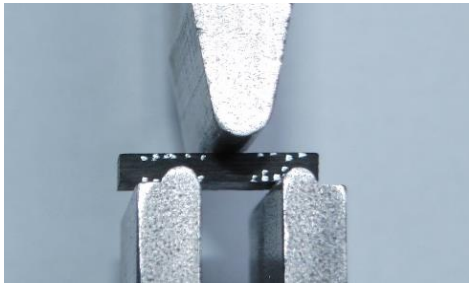
Unidirectional laminate plates for tests

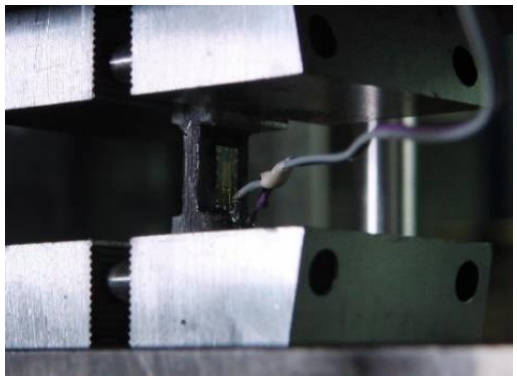
Performed mechanical tests

- Tensile test
- Compression test
- 45º shear test
- Flexure test
- Short beam shear test





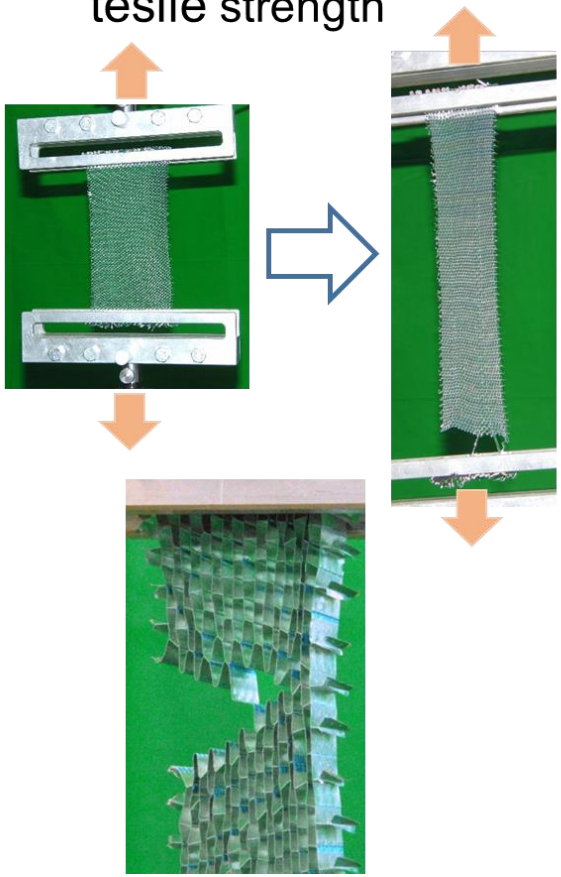




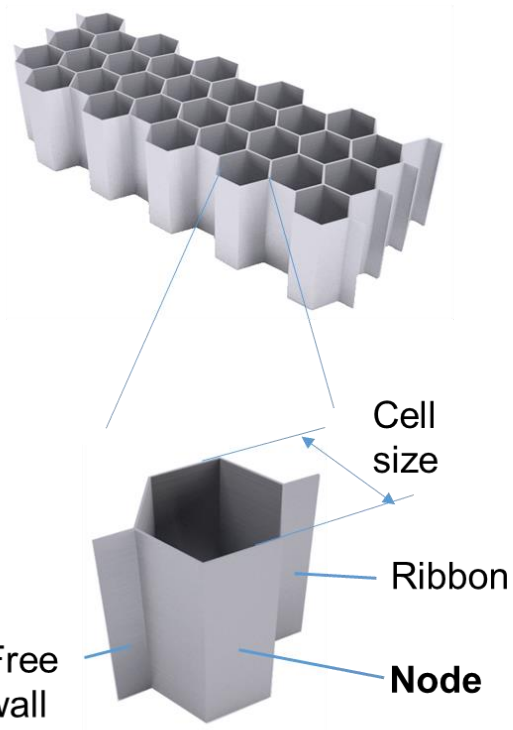
Main Technical Developments

Characterization of the mechanical behaviour of sandwich specimens:

Honeycomb node tesile strength



Aluminium honeycomb core tests



Compression

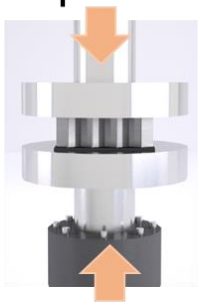
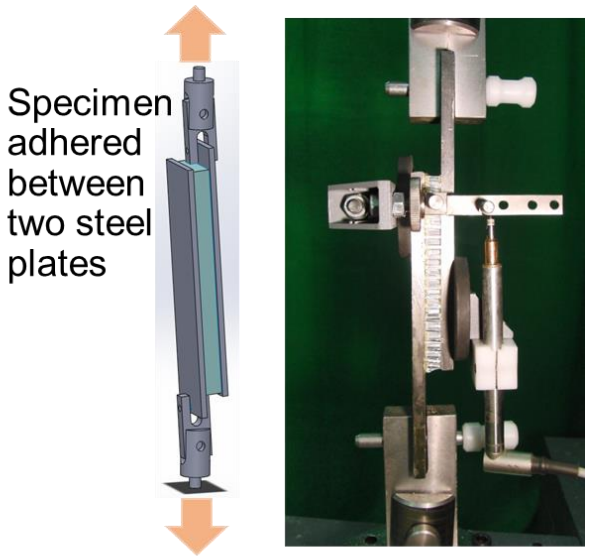


Plate shear test



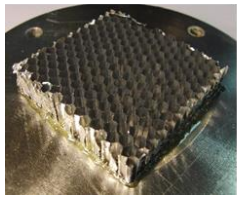
Main Technical Developments

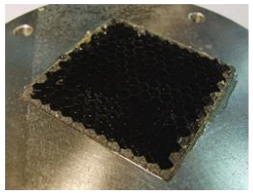
Characterization of the mechanical behaviour of sandwich specimens:

Sandwich panel tests

Flatwise tension test

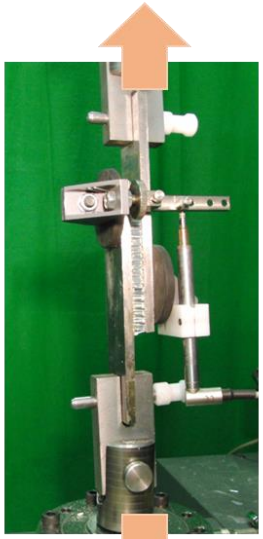
- Specimen adhered between two steel plates
- Finds weakest adhesive bond in construction





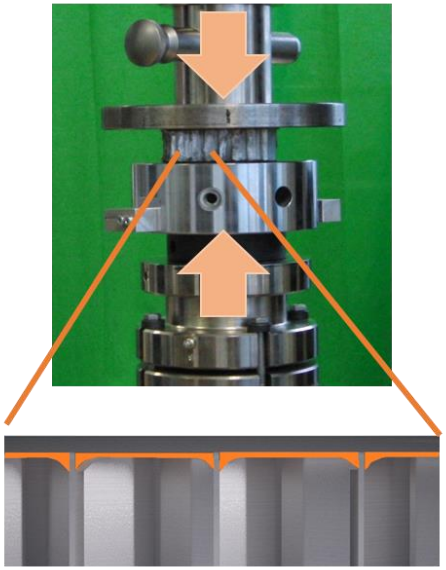
Core to facing adhesive failure

Plate shear test



Finds panel's component which is least stable to shear stress

Flatwise compression test

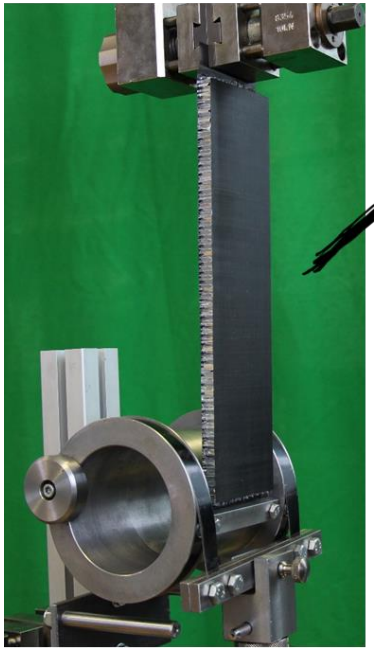


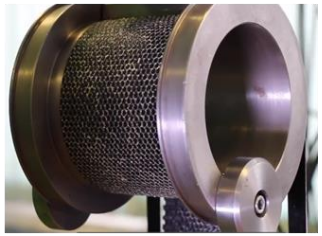
Adhesive fillets stabilizes honeycomb and increases it's shear strength

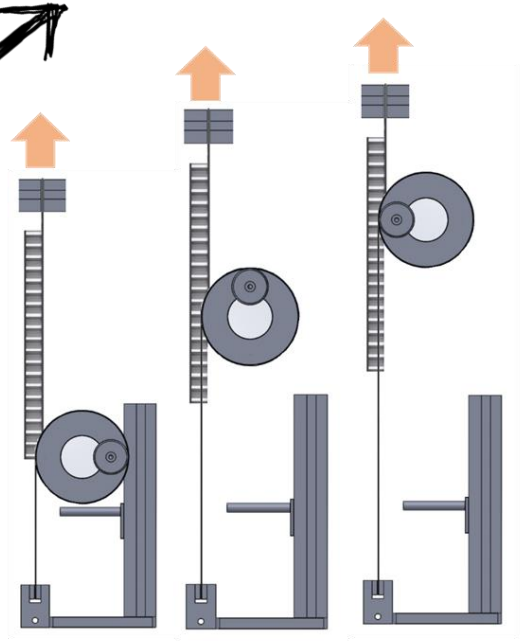
Main Technical Developments

Characterization of the mechanical behaviour of sandwich specimens:

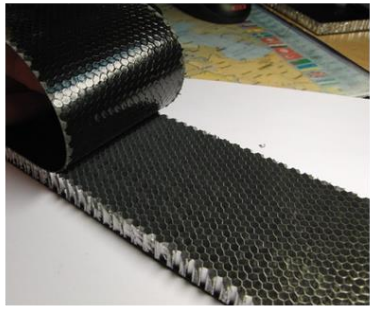
Seeking for appropriate adhesive by using
CLIMBING DRUM PEEL TEST



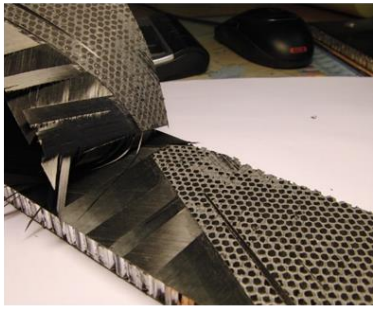




Adhesive destruction
Bad



Cohesive destruction
Good



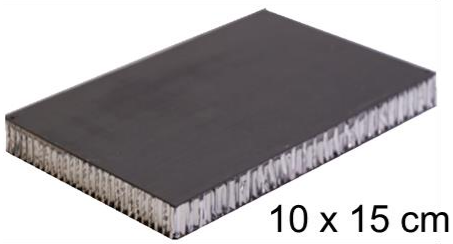
Epoxy adhesives

Main Technical Developments

Characterization of the mechanical behaviour of sandwich specimens:

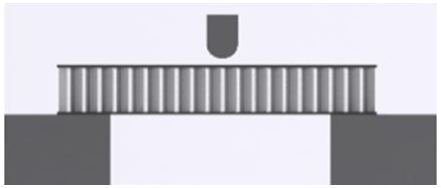
Residual strength esimation by mechanical tests

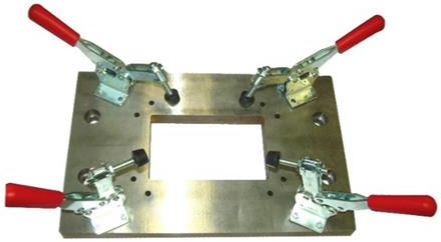
Reference panel



10 x 15 cm

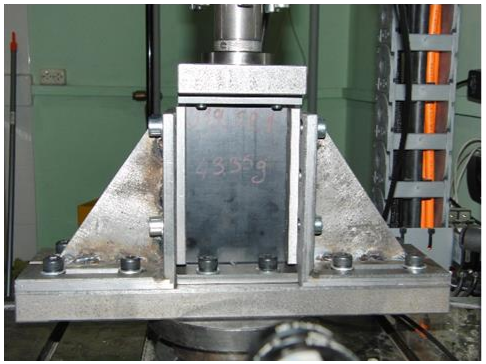
Impact
or
indentation





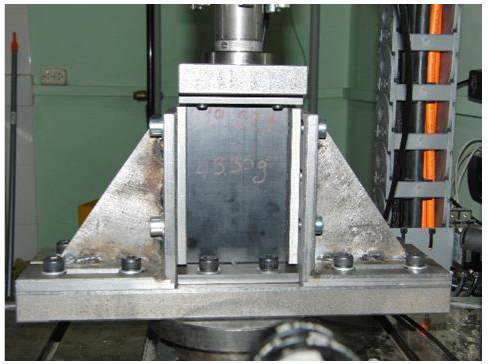
Damaged panel

Edgewise compression



Anti-buckling test fixture

Copression after impact



Development and validation of methodology for assessment of damage resistance properties of sandwich structures for European space sector.

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