



CARATTERIZZAZIONE MECCANICA DI COMPONENTI SANDWICH INCOLLATI E SALDATI IN SCHIUMA DI ALLUMINIO

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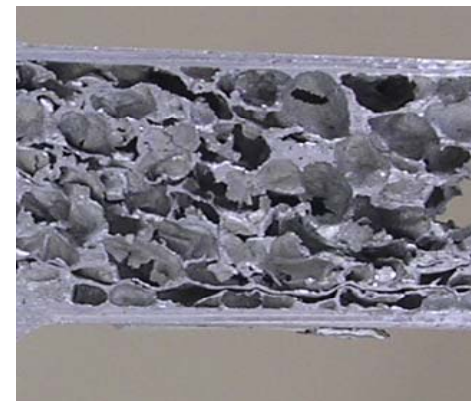
Schiume strutturali - Design and Applications
Vercelli, Il Facoltà di Ingegneria del Politecnico di Torino

Problema tecnico

Aluminum alloy closed-cells foams were recent developed, due to

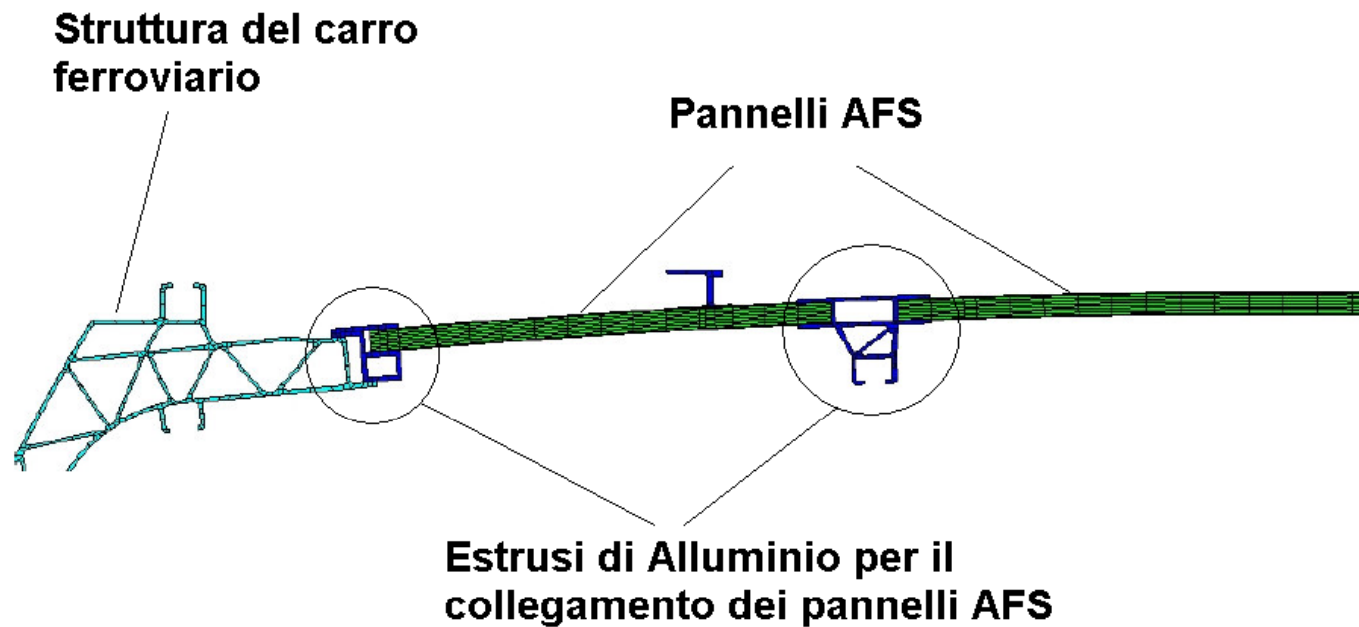
- the high specific rigidity,
- the good capacity of absorption to impact and
- acoustic isolation and
- the exceptional qualities of firebreak.

Usually, these foams are assembled with aluminum skins in sandwich panels for light structural components that must guarantee good resistance of the structure to bending and tension.

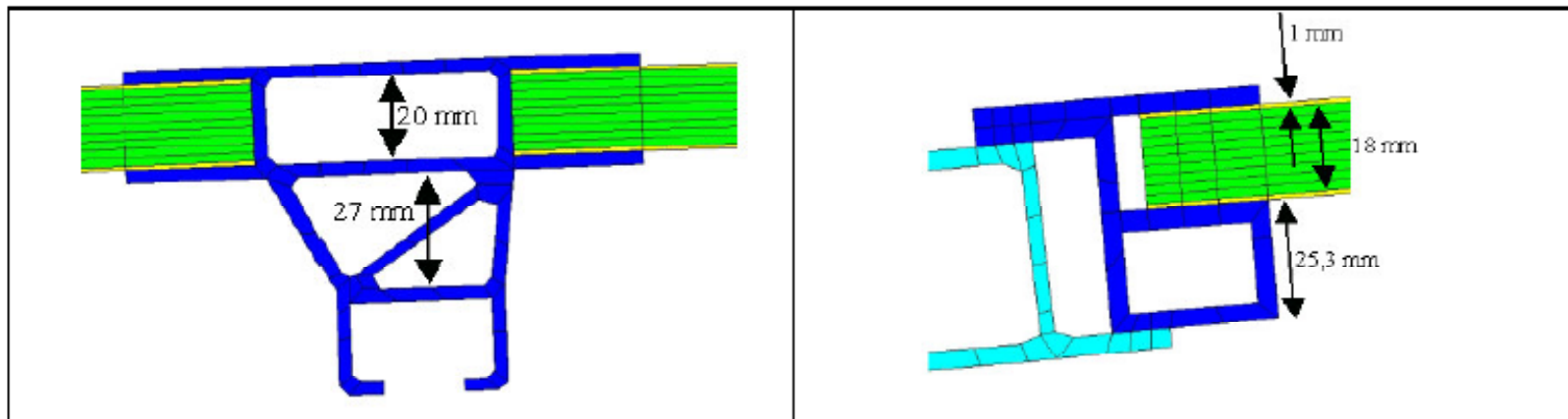
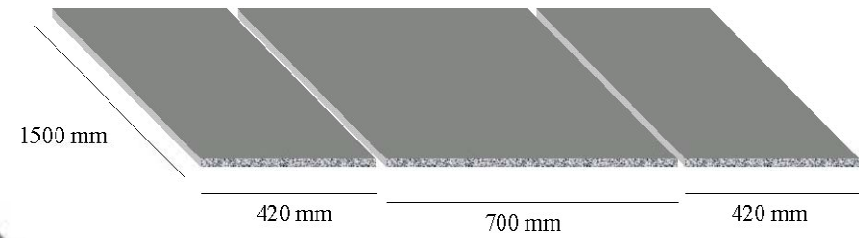
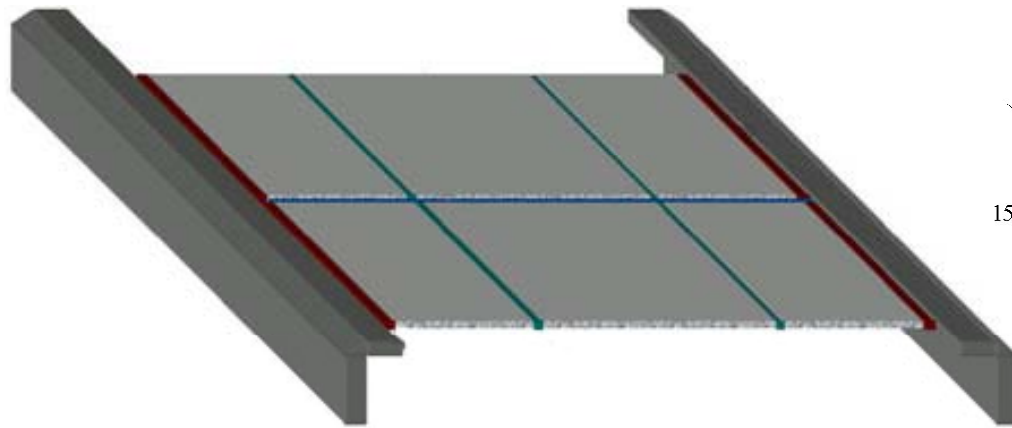


Problema tecnico

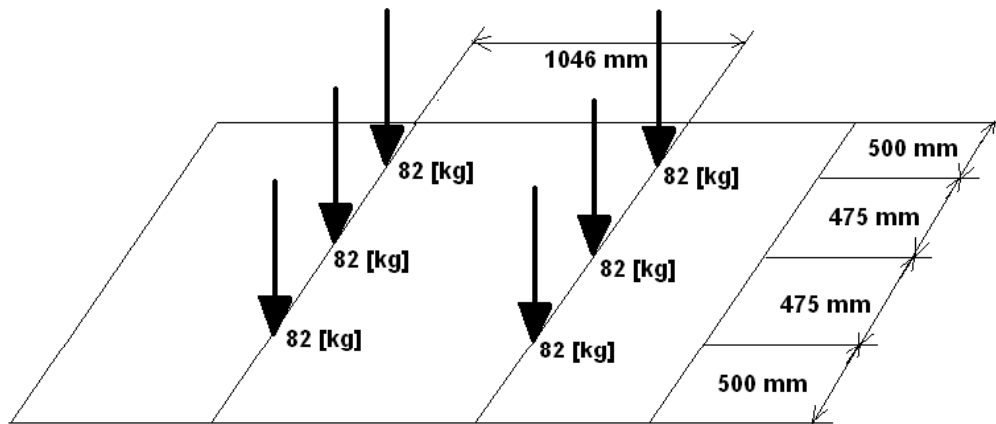
- Progetto di ricerca con il Consorzio CALEF e CRF
- L'imperiale del carro ferroviario può essere realizzato con pannelli sandwich di schiuma di alluminio (AFS).



Problema tecnico

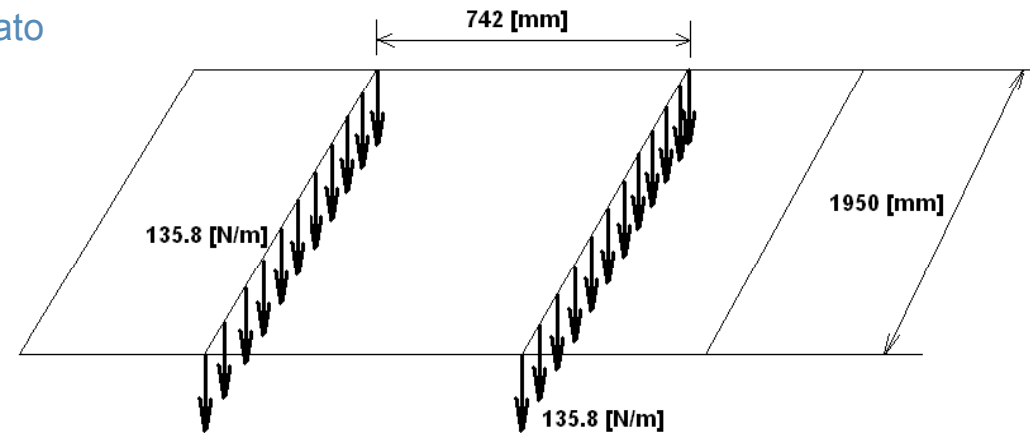


Problema tecnico



Sollecitazioni dovute alla presenza del reostato di frenata ($\approx 4900\text{N}$)

The stress/strain field on the component is rather complex: the structure is hyper static in its wholeness and subject to a tension stress as well as to shear and bending.

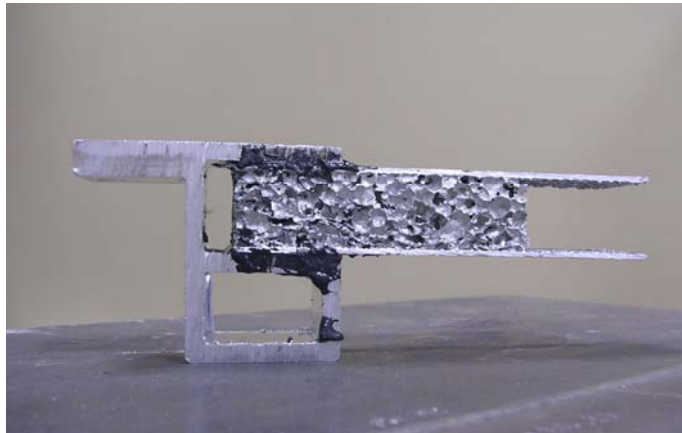


Carichi applicati alla struttura per effetto della presenza delle finiture interne

Obiettivo

valutare sperimentalmente le caratteristiche meccaniche dei componenti in AFS collegati all'estruso di alluminio tramite saldatura o incollaggio

Componenti incollati



Realizzati con adesivo poliuretano (Sikaflex 264)

Componenti saldati

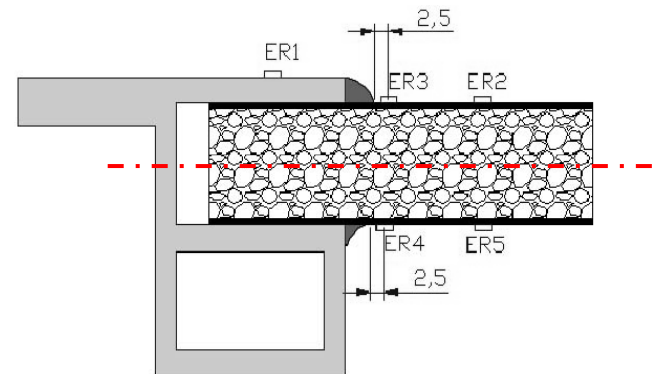


Realizzati con tecnica di saldatura ibrida laser-mig

Metodologia – componente saldato



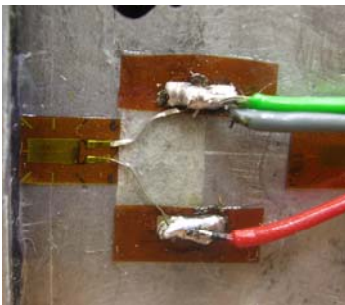
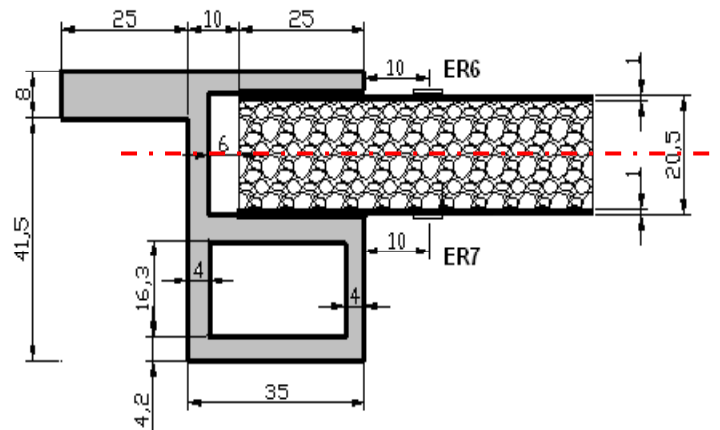
- Sorgente laser Nd:YAG TRUMPF HL 3006 D con potenza massima pari a 3 [kW] nel punto di lavoro;
- generatore MIG/MAG Fronius TransPlus 5000 sinergico, in grado di erogare un valore massimo di corrente di 500 [A];
- testa di saldatura ibrida Fronius che integra la torcia MIG con sistema spingi-filo di tipo push-pull;
- il tutto montato su un robot antropomorfo COMAU.



Il giunto saldato ha sempre un cordone concavo ed uno convesso per esigenze tecnologiche di saldatura.

Si sono incollati estensimetri elettrici a resistenza (base di misura 3mm) per valutare il campo di sollecitazione sul componente (concentrazione al piede del cordone, flessione secondaria)

Metodologia – componente incollato



Polyurethanic adhesives are suitable for a large number of substrates and do not need complicated procedures for their placing.

Sikaflex 264 is a fast-cure structural adhesive

- tensile strength 6.5 N/mm^2 ,
- tear strength $>8 \text{ N/mm}$,
- elongation at break 400%

chosen to bond materials different for mechanical properties and geometry, that is AFS panels and aluminum extruded.

A more uniform stresses distribution on the whole glued surface, with respect to welded AFS, is expected, with consequent reduction in local stress concentration.

Si sono incollati estensimetri elettrici a resistenza (base di misura 3mm) per valutare il campo di sollecitazione sul componente

Piano sperimentale

Tipo di componente	N. componenti	Test
AFS incollato	13	Trazione statica
AFS saldato	10	Trazione statica
AFS saldato	14	Fatica $R=-1$
AFS saldato	9	Fatica $R=0,1$

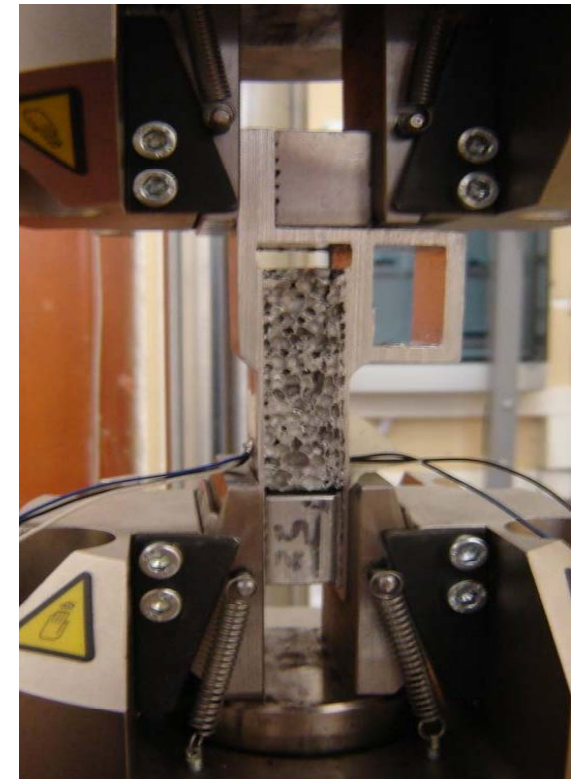
All tests were executed at room temperature, on a bi-axial servo-hydraulic machine.

Strain gages measurements were recorded by System 5000 (Micro Measurements – USA)

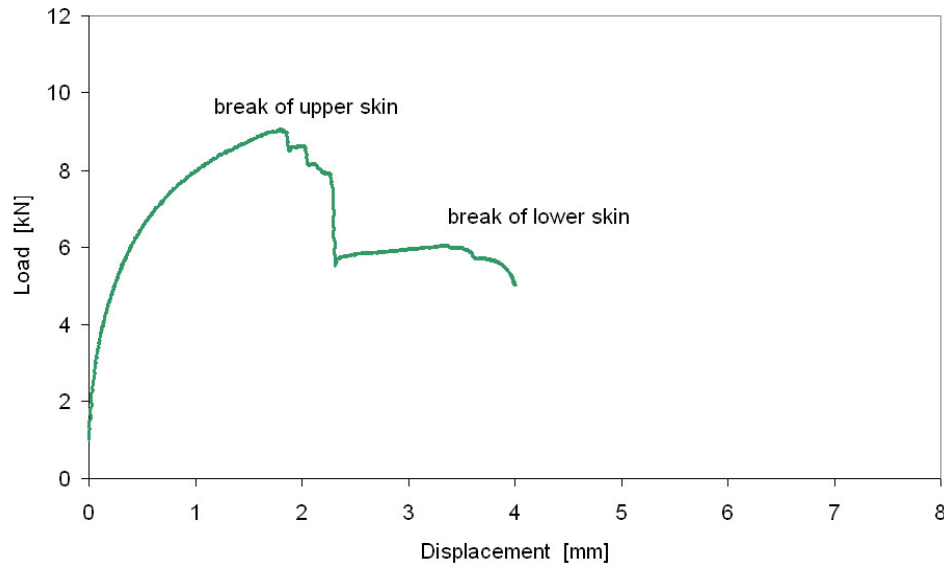
A special device was utilized

- to align the specimen long axis with the axis of testing machine and
- to obtain an eccentric direction of the pull in order to reproduce the working condition of the component.

In order to compare experimental results on welded and bonded AFS, in both cases test parameters were chosen considering the suggestions of ASTM D3528.



Risultati – test trazione su AFS saldati



The failure criterion adopted for the component was “the first skin broke”.

The graph reports, as example, one experimental tensile curve (load versus displacement) and describes this failure mode: the first skin broke in the heat affected zone at about 9200N (specimen n.2S), then the crack propagates into the foam till reaching the second skin which broke at about 6000N.

Specimen	Width [mm]	Breaking load [N]	σ_c [MPa]
1S	29.70	9000	169.76
2S	30.10	9200	146.24
3S	30.30	9900	192.76
4S	29.90	10600	176.82
5S	30.00	7200	130.79
6S	30.40	7200	122.08
7S	30.40	6500	100.38
8S	29.90	8600	132.85
9S	30.10	9000	191.67
10S	30.10	8200	134.86

σ_c is the “reference” stress values calculated according to Eurocode 9 on the basis of normal and shear stresses operating on the surface referred to the weld throat thickness.

Risultati – test trazione su AFS saldati

The **scattering** of experimental results on welded AFS may be attributed to the elevated number of variables that influence the phenomena, principally connected to the quality of welding process and to foam characteristics.

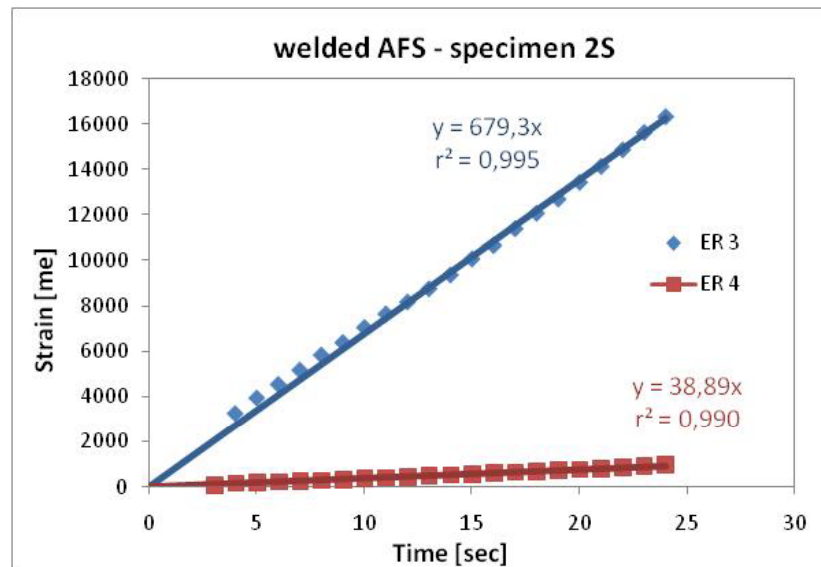
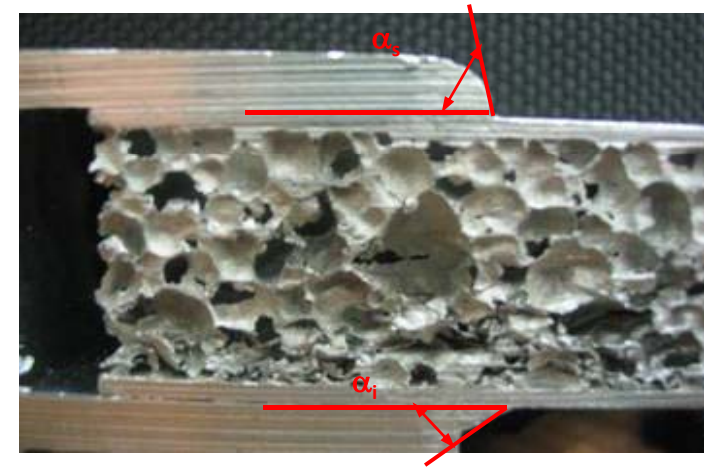
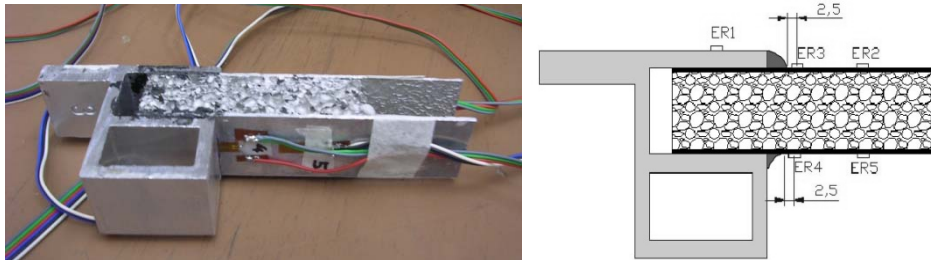


Section of fracture with some gas inclusion and different thickness in skin.

Components with low breaking load revealed these welding defects.

Risultati – test trazione su AFS saldati

Strain gages values were registered for all tested specimens: in all cases, ER3 describes an higher strain field than ER4, ER2 and ER5 reveal a secondary bending.



Due to technological needs, weld cords are different on the two side of the specimen: the upper cord is always convex (α_s), the lower is concave (α_i) and it is well known that the stress concentration is high where the a angle is large.

The final break, in fact, often occurs where the cord is convex.

Risultati - test trazione su AFS incollati

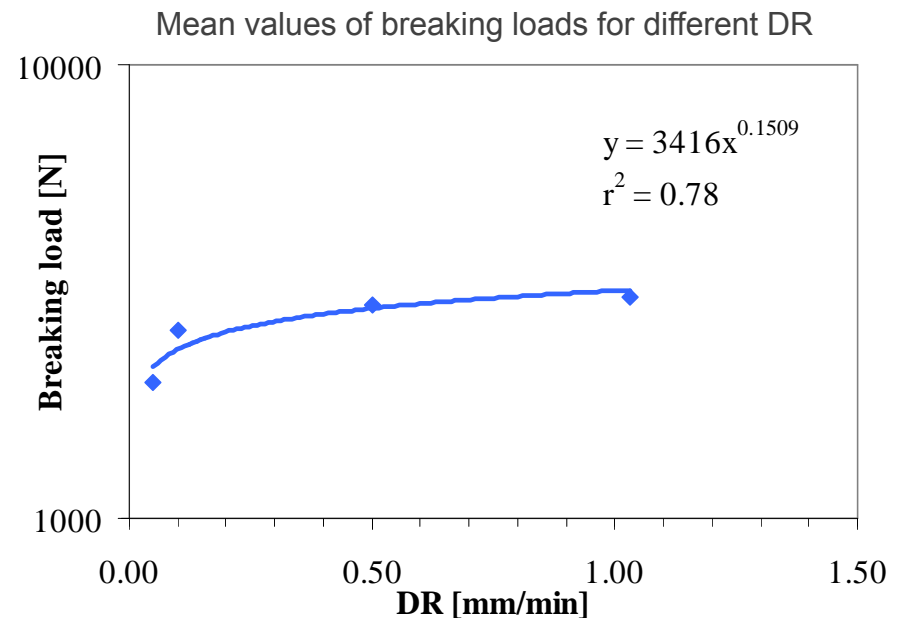
Specimen	DR [mm/min]	Breaking load [N]	τ_{mean} [MPa]
37	1.3	2144	1.79
46	1.3	3866	3.03
55	1.3	3226	2.67
Mean values			2.49
39	0.5	2100	1,72
54	0.5	3810	3,03
60	0.5	4510	3,70
Mean values			2.82
32	0.1	3500	2,83
43	0.1	2430	2,07
47	0.1	1490	1,25
49	0.1	925	0,75
52	0.1	2386	1,90
58	0.1	3138	2,57
Mean values			1.89
56	0.05	2000	1.65

The **bonded area** was calculated considering twice the specimen width for the glue line length.

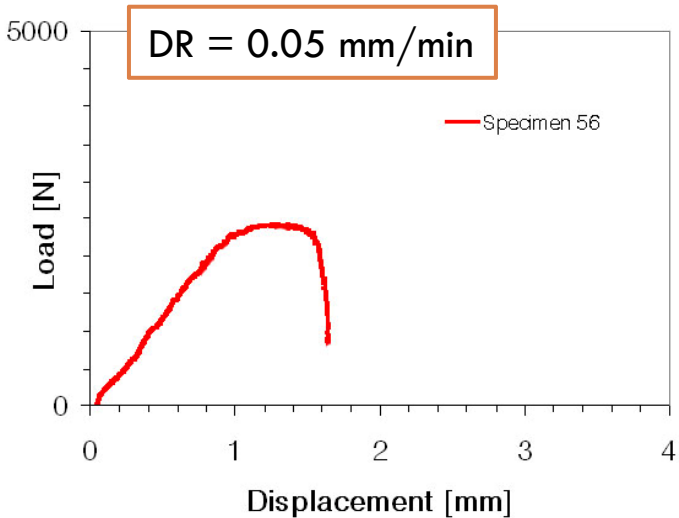
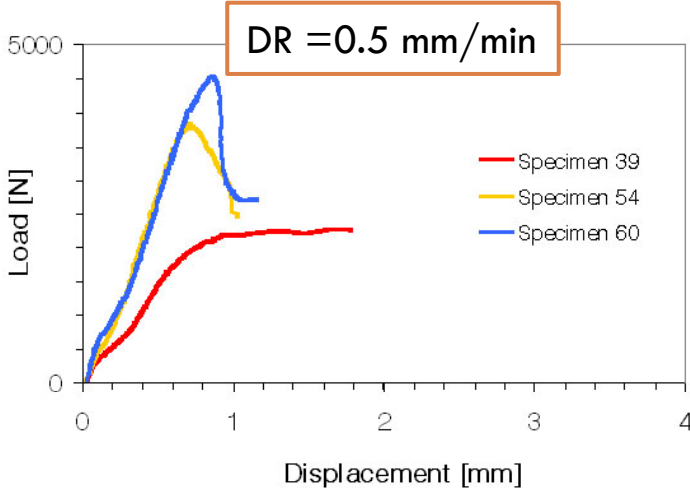
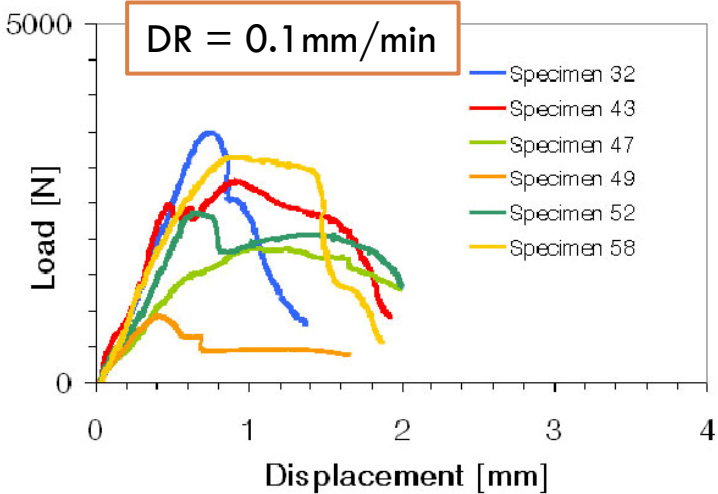
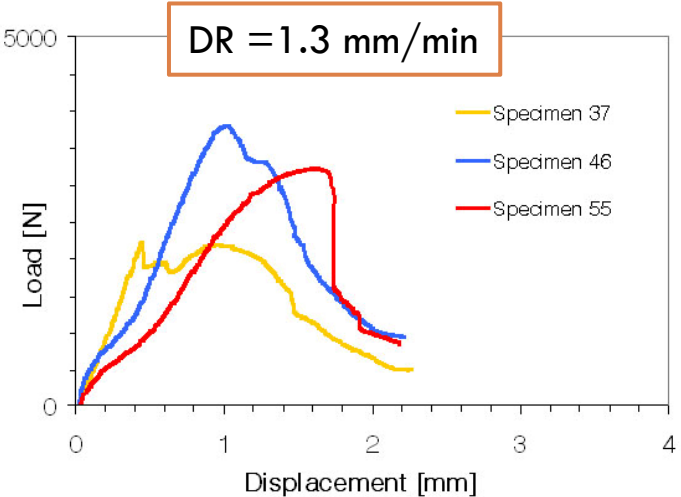
Ultimate shear strength τ of the component was calculated from the ultimate breaking load and the bonded area.

This value could be compared with the tensile shear strength of Sikaflex 264.

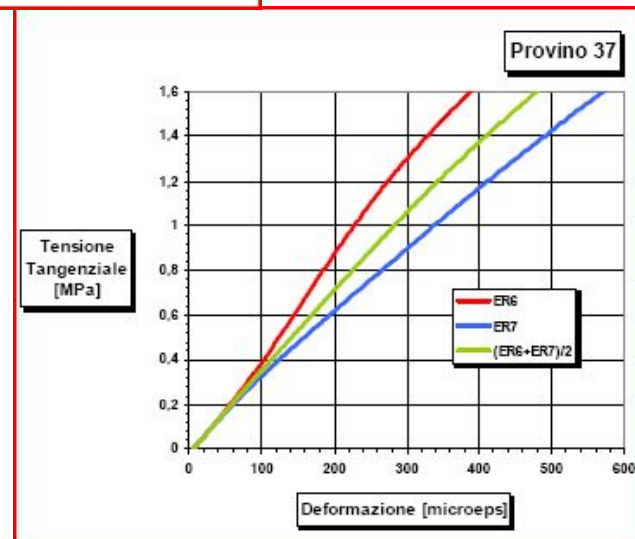
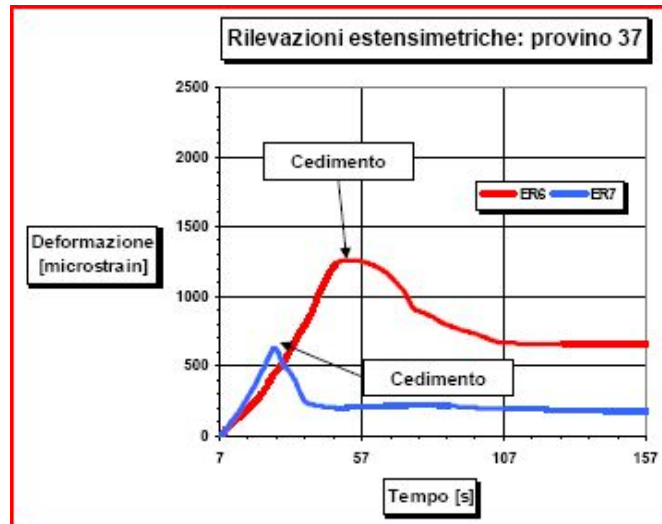
Also in this case the failure criteria adopted was to consider the tensile test done when the first bonded area broke.



Risultati - test trazione su AFS incollati

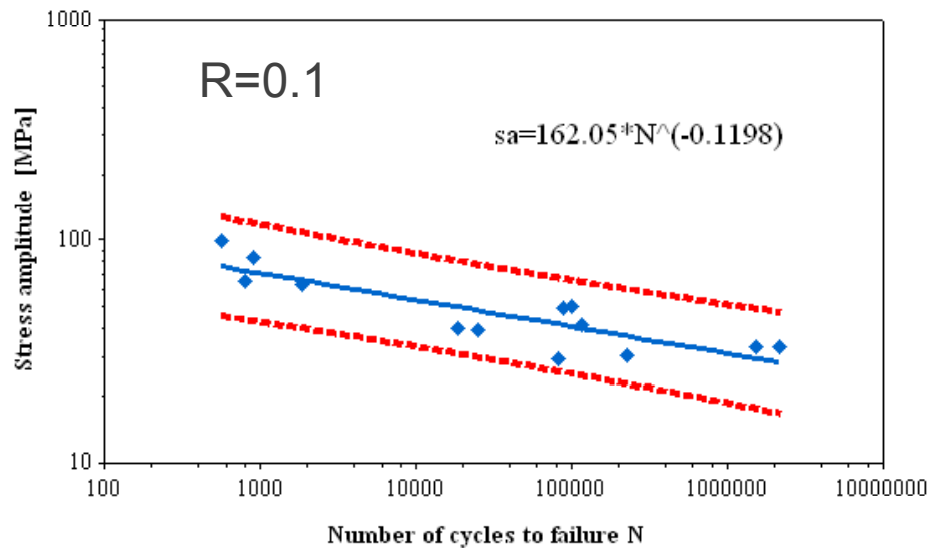


Risultati - test trazione su AFS incollati



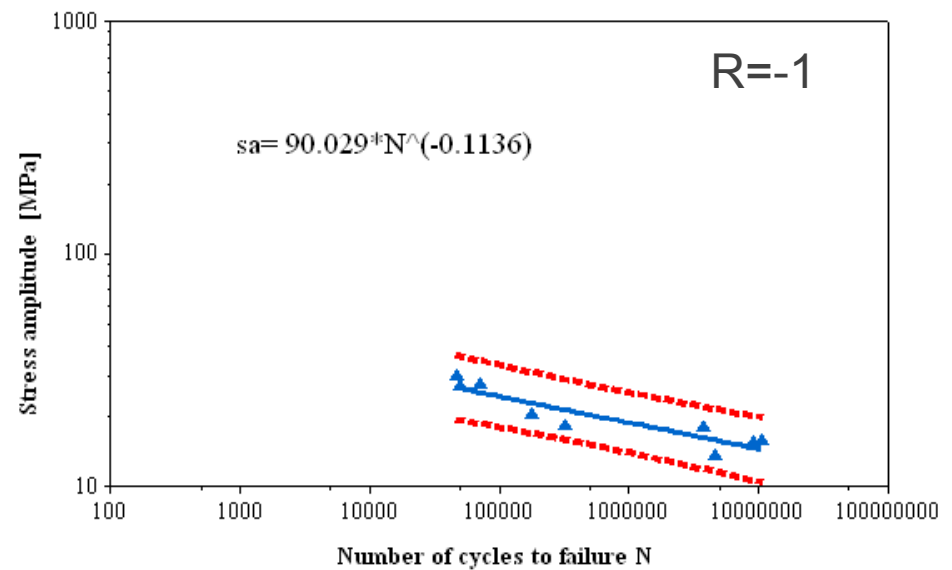
All specimens showed cohesive failure modes

Risultati – test di fatica

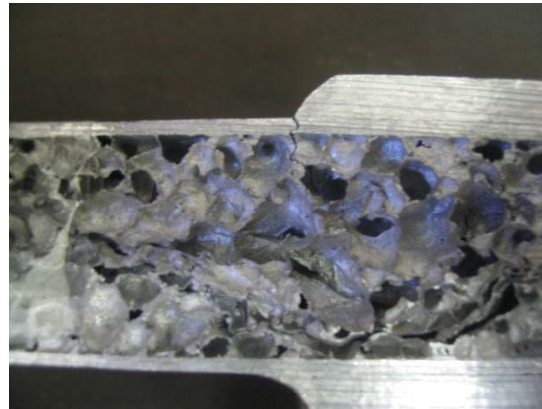


Also in this case, the test was considered done when the first skin broke, because from this moment on the component could not work correctly anymore.

So, the number of cycle N comprehends the nucleation of the fatigue crack and partially its propagation.



Risultati – test di fatica



Fracture at weld toe: typical fracture at the weld toe, in the heat affected zone.



Fracture of the weld cord: some incorrect failures occurred along the weld cord (Fig. 14), indicating a poor quality welding and revealing that bonding in a satisfactory way is easier than obtaining good quality welding cord, particularly on AFS components.

Conclusioni

AFS components obtained by the roof of a railway carriage were studied in order to obtain mechanical properties, both under static and fatigue loads. Particularly, two different technological solution for connecting the foam sandwich to the extruded of aluminium alloy were considered, that is hybrid welding and bonding.

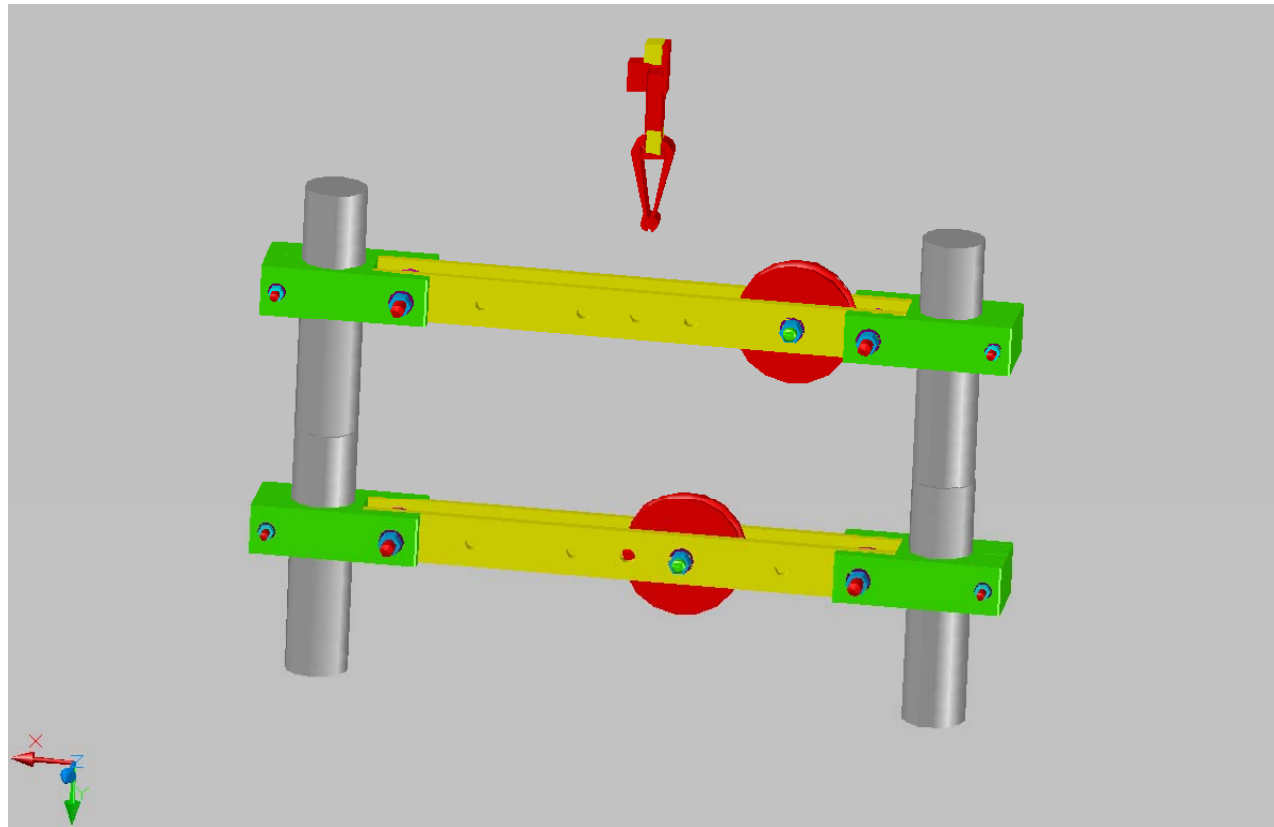
Static tensile tests were performed both on welded and bonded AFS.

Experimental results suggest the following observations:

- breaking load values for bonded AFS seems to be affected by the displacement rate adopted during tests;
- anyhow, mean value of breaking load experienced on bonded AFS is lower than 3000 N, but satisfactory for working requirements of the AFS panel;
- all bonded components showed cohesive failures;
- mean value of breaking load for welded AFS is about 8500N and 149MPa is the reference stress amplitude;
- welded specimens revealed some welding defects as gas inclusions and thickness irregularities.

Fatigue tests were done on welded AFS and fatigue curves were drawn for load ratio -1 and 0.1. All experimental data fall within scatter band with 95% confidence level.

Sviluppi futuri



Realizzazione di un sistema di carico che tramite pulegge consenta di sottoporre i componenti a un carico misto di trazione e taglio

Ringraziamenti



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