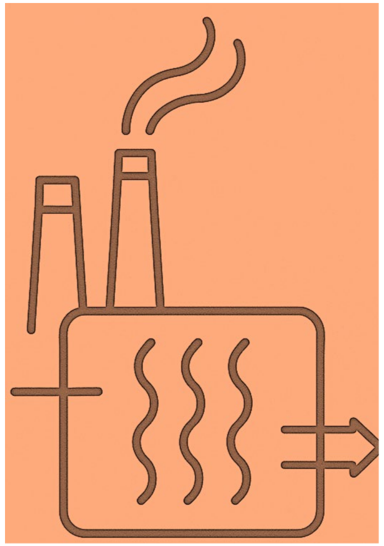
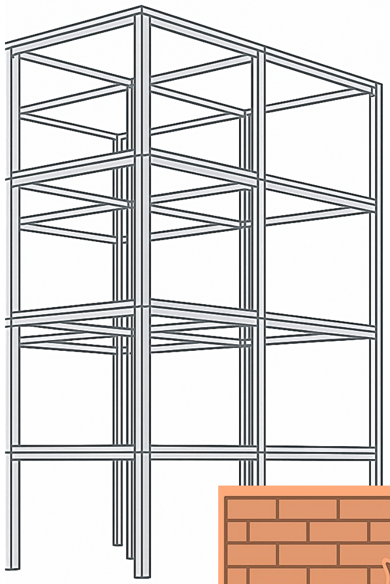
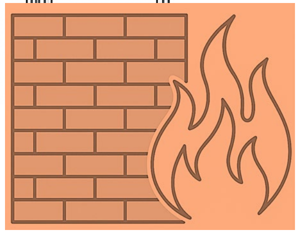
JEC FORUM ITALY 2025
Business Meetings & Conferences
June 11-12, 2025 | CERNOBBIO, LAKE COMO ITALIA

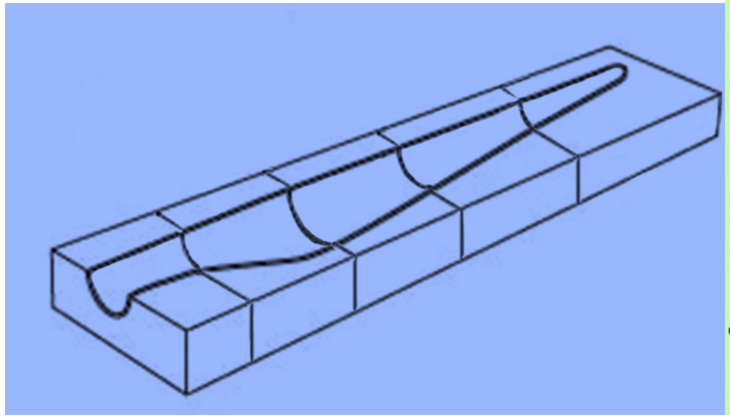


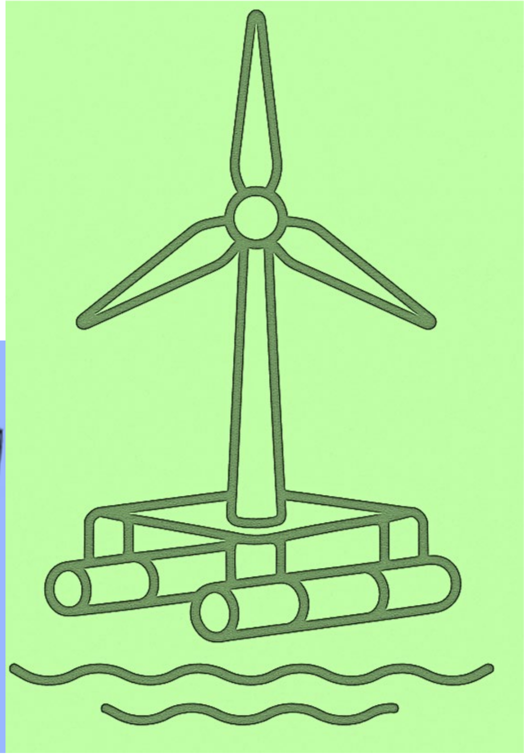
From Steel to Sustainable Composites: Enabling Lightweight Mass Production

Claudio Mingazzini









ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES,
ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

FENICE

Development of high fire-resistant composite materials for safer battery enclosures in electric vehicles.

ECOSISTER

Development of fire-resistant composite separator to enhance battery box safety.

CARBO-PLUS

Industrial reuse of short carbon fibers as secondary raw materials for composites in shipbuilding and construction.

TANTUM ERGO

Research on composite materials suitable for offshore renewable energy applications and marine environments.

CAMPRES

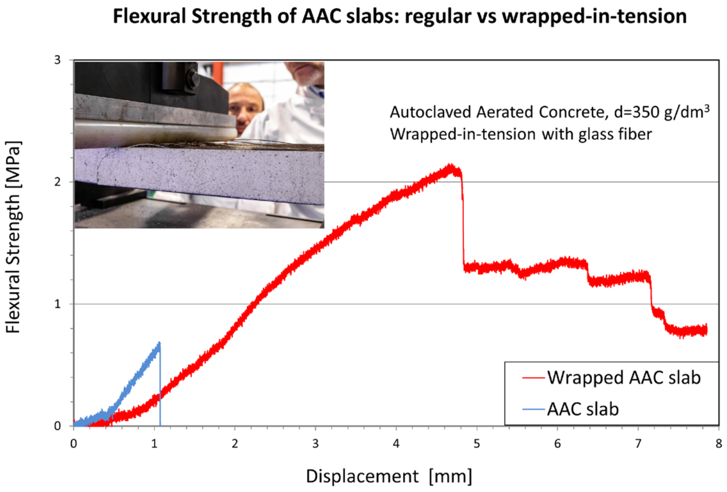
Development of thermoplastic composites for cost-effective battery enclosures.

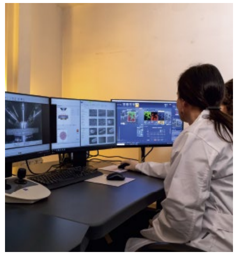
NALUCOAT POC

Development of fiber-metal composites for high-performance battery enclosures in sports cars.

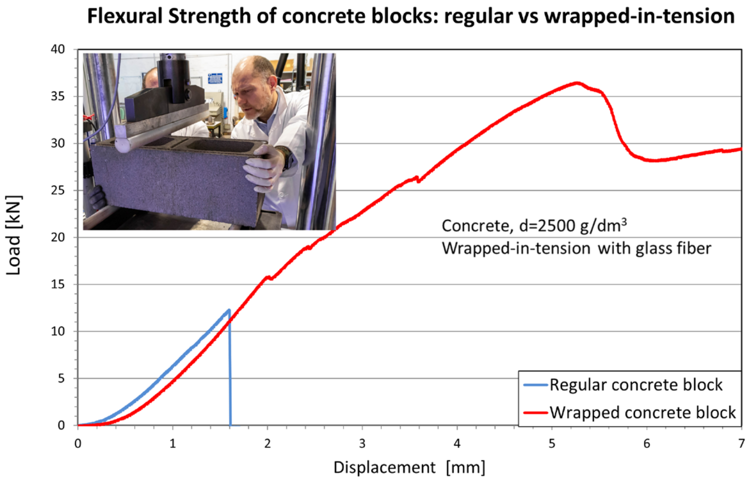
BRILLIANT

Natural fiber composites with recyclable resins.





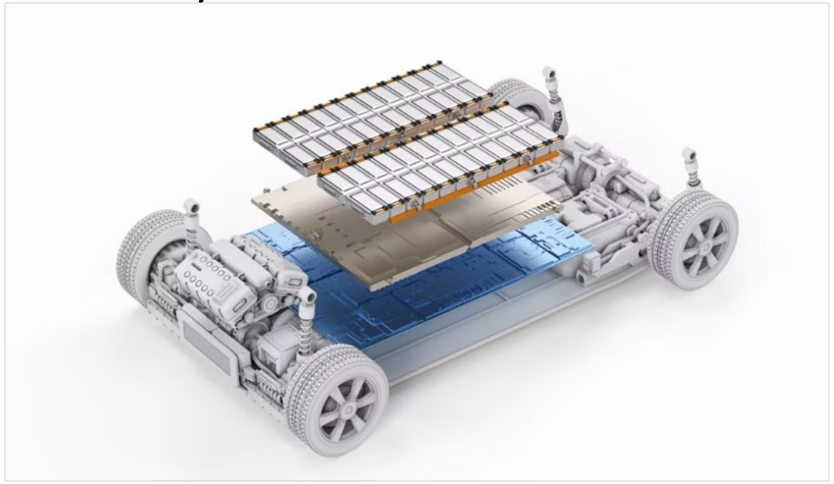
Progetti ENEA Faenza sui materiali compositi



FENICE: Fire Resistant Environmentally Friendly Composites

eit RawMaterials
Connecting matters

The Project is a TRL 6-7 upscaling project that aims at developing recyclable, biobased, fire resistant and robust fibre metal laminates (FMLs) to be used in electric vehicles battery boxes.



A battery box must possess numerous characteristics due to the multiple functions it must carry out:

- Elevated **fire resistance**
- Ability to thermally **insulate** the battery modules
- **Elevated mechanical properties** to support the batteries
- Act as an **electromagnetic shield**

It is challenging finding a single material that is able to satisfy all (if not most) of these requirements!

Composites & multimaterial solutions are necessary!

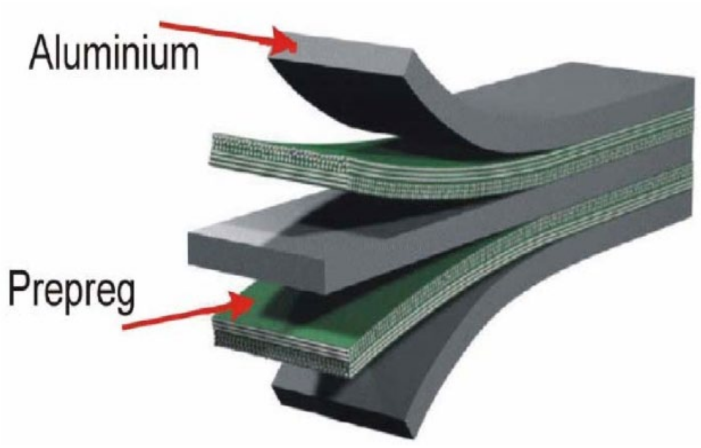
Fiber Metal Laminates (FMLs)

FMLs are a class of materials prepared **alternating pre-pregs to metallic layers.**

www.fenice-composites.com
Cofunded by:

eit RawMaterials
Connecting matters

Upscaling n.21099(2022-2025)



- FML are **sustainable** since they use only low value secondary aluminium and can be either (1) **biobased** or (2) **C2C recyclable** and **zero scrap**. All considered versions are low cost and with a low C footprint.
- The metal layer acts both as a fire and an electromagnetic shield
- Depending on the core, they can be excellent thermal insulators
- Elevated mechanical properties and lower weight compared to steel panels

Mechanical characterization – Sandwich vs monolithic

CrossFire resin
& sandwiches:
Patent application
102024000013807
Of 17/06/24

METHODOLOGY: CONE CALORIMETER

Gaiker
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

Cone calorimeter → according to the standard ISO 5660-1:2015 + AMD.1:2019

- Samples wrapped in aluminium foil to prevent the possible detachment of residues during the test
- Once wrapped, the sample is placed in a sample holder
- Radiation of 60 kW/m^2 on the exposed pase → **Surface temperature around 700ºC**
- Distance between the sample and cone → 25mm
- Test duration: 10 and 20 min; spark placed above the specimen
- One specimen was tested in each exposure time

- Parameters evaluated:
- Ignition and extinction times
- Heat Release Rate (HRR) curve → by measuring oxygen consumption/depletion
- Average Rate of Heat Emission (ARHE)
- Maximum Average Rate of Heat Emission (MARHE)
- MARHE allows to classify materials in railway, according to the standard EN 45545-2
- Qmax: maximum value of Heat Release Rate (HRR) during the test
- Total Heat Released (THR)
- Average mass loss rate
- Total mass loss

www.fenice-composites.com
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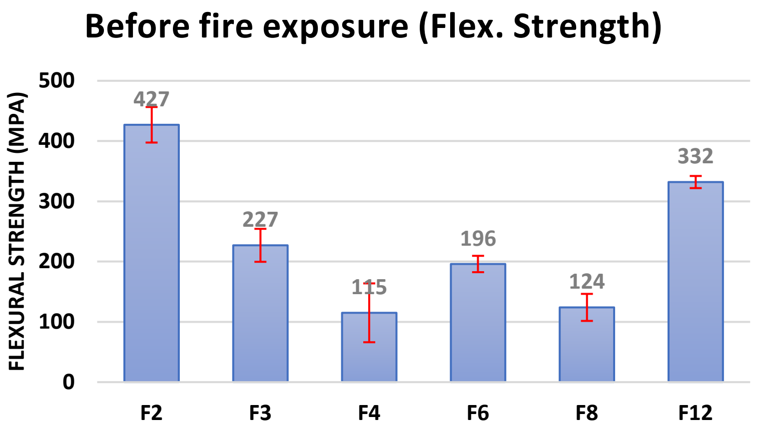
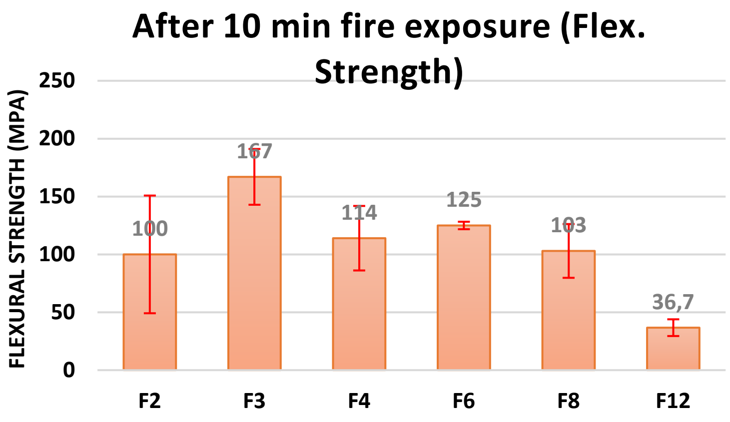
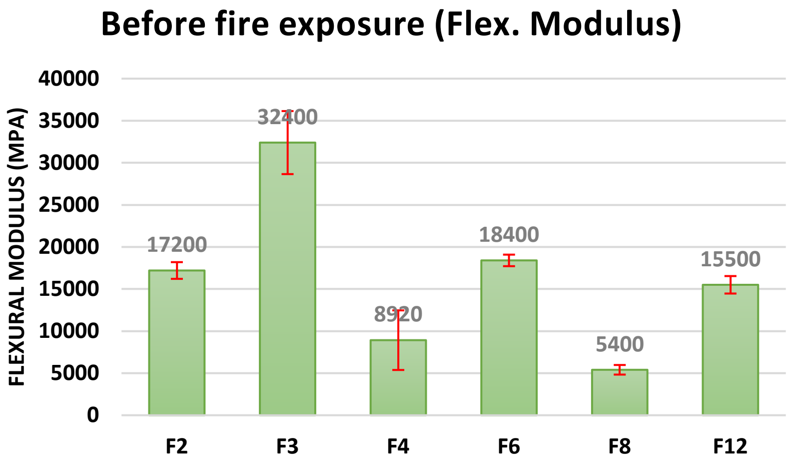
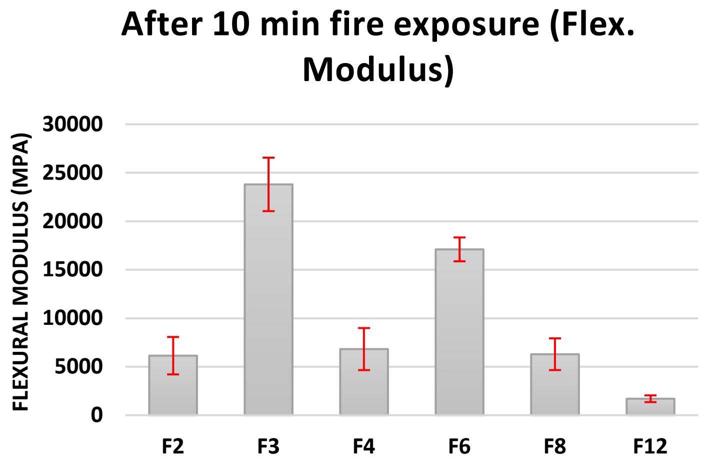
FENICE
Fire Resistant Environmentally Friendly Composites

RESULTS: Flexural Strength and Modulus before and after 10 min Fire Exposure (Monolithic)









Samples tested during 10 min in the cone calorimeter:

Flexural Strength:

→ **F2 highest** strength (427 MPa) **before** fire exposure

→ **F4 lowest** strength (115 MPa) **before** fire exposure

→ After fire→ F3 shows the highest strength

Flexural Modulus

→ **F3 highest** modulus (32400 MPa) **before** fire exposure

→ **F8 lowest** modulus (5400 MPa) **before** fire exposure

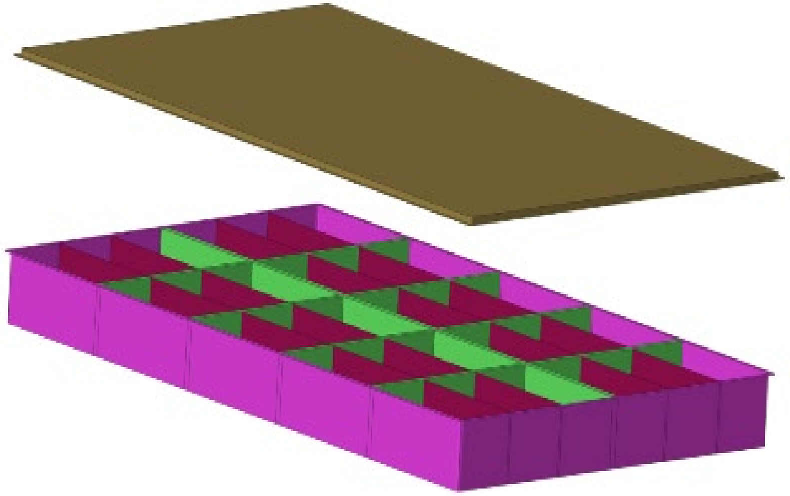
→ After fire→ same behaviour showed in the modulus values → F3 highest modulus

All solutions keeps enough flexurral properties even after fire exposure for 10 minutes

FENICE Business/Commercial Case

What is the market for your product/service?	Battery boxes for the automotive marine and renewable energies EP Patent, owned by CFR-ENEA. about FML for battery cell spacers

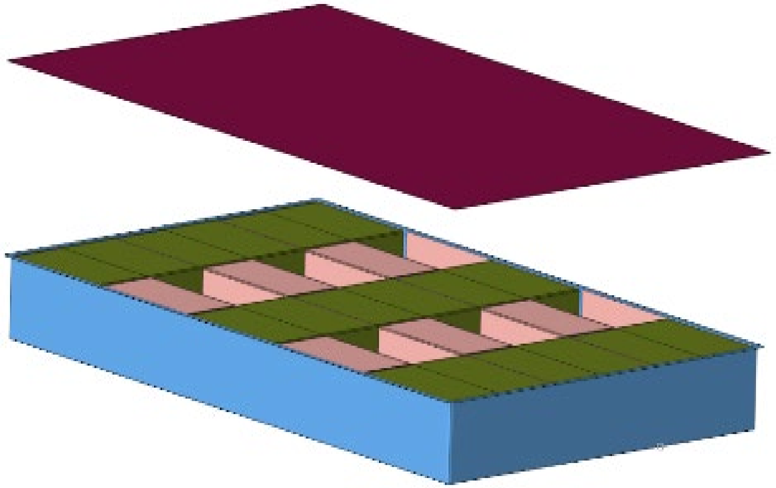
Battery case in steel



Weight Reduction

40 %

Battery case in FML



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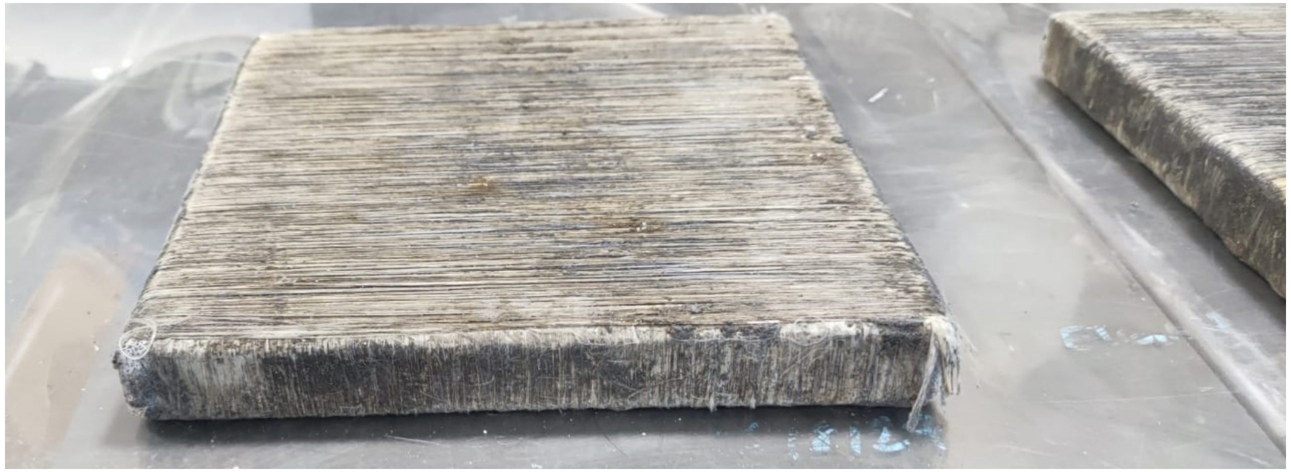
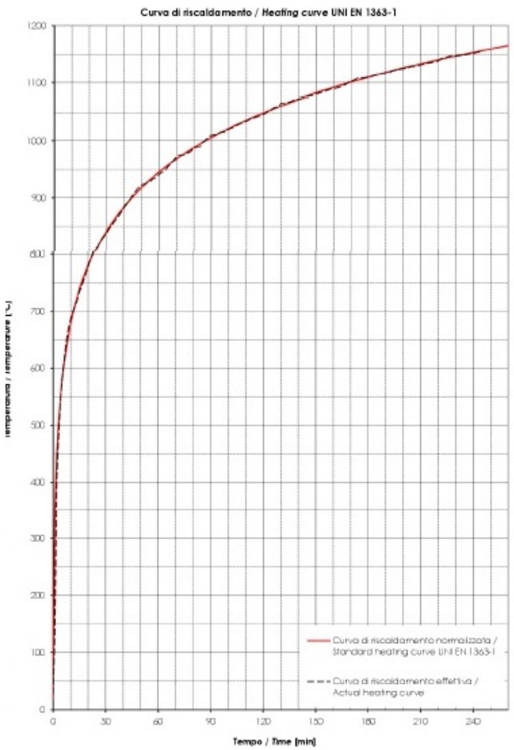
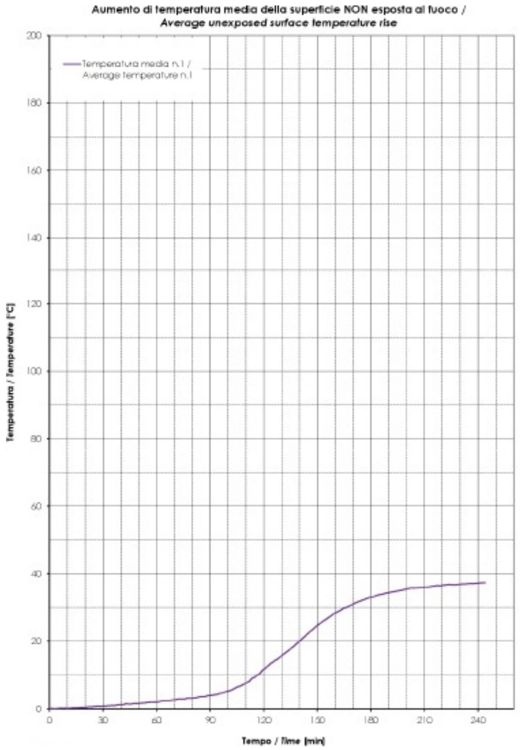
Fire Resistant Environmentally Friendly Composites

How to stop fire better than steel, for example in ships?
New standards for automotive battery boxes: 2h at 1300°C







The low density porous inorganic core
ensures the thermal insulation and fire resistance

Fiber wrapping ensures flexural strength and blast resistance

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CARBO PLUS

FENICE
Fire Resistant Environmentally Friendly Composites

CARBO-PLUS: End-Users

1) Ferretti Spa (www.ferrettigroup.com), about the marine applications. In particular the composite technologies (fire-resistant and recyclable FMLs, Fiber Metal Laminates, and FML sandwich structures) have to be adapted and certified by RINA for the nautical sector. The experimental and demonstrative part of the work will follow a modelling study, up to MUSP.

2) Laterlite (www.laterlite.com) about the applications in the constructions field specially production of **geogrids**. In particular, ENEA and Certimac will develop the production of FRP, Fiber Reinforced Plastic, to reinforce concrete.

3) Both the solutions cited above (FML and FRP) are currently using **only glass fibres**, but CARBO-PLUS will enquire, for the same applications **secondary C fibre.** In Emilia Romagna Region the main industrial reference in the field is Curti Costruzioni Meccaniche (www.curti.com) who has developed the **industrial recycling** of C fibre obtained by **pyrolysis,** in collaboration with HERA and UniBo.

In the last 80 years, **composites** applications have been only slightly expanding but they are **still a very small niche** vs the totality of what the current society is manufacturing.

WHY?

In most cases structural elements are sustaining normal (positive=tension and negative) and tangential stresses. **Composites (fibers) are structurally efficient only in tension!**

How composites can contribute to mass production of low cost structures?

Steel reinforced concrete is a great composite that costs less of 0.8 Euro per Kg for a product that yield above 440 MPa. Glass rebars are considered only if a longer service life is needed.

HOW CAN WE GO BEYOND?

Using composites (fibers) in combination with materials with high compression strength, inducing `compression stresses in strategic positions, **enables structural elements, with lower initial cost, longer service life, lower energy and carbon footprint.**

MASS APPLICATIONS: COMPOSITES ARE ASKING FOR IT!!

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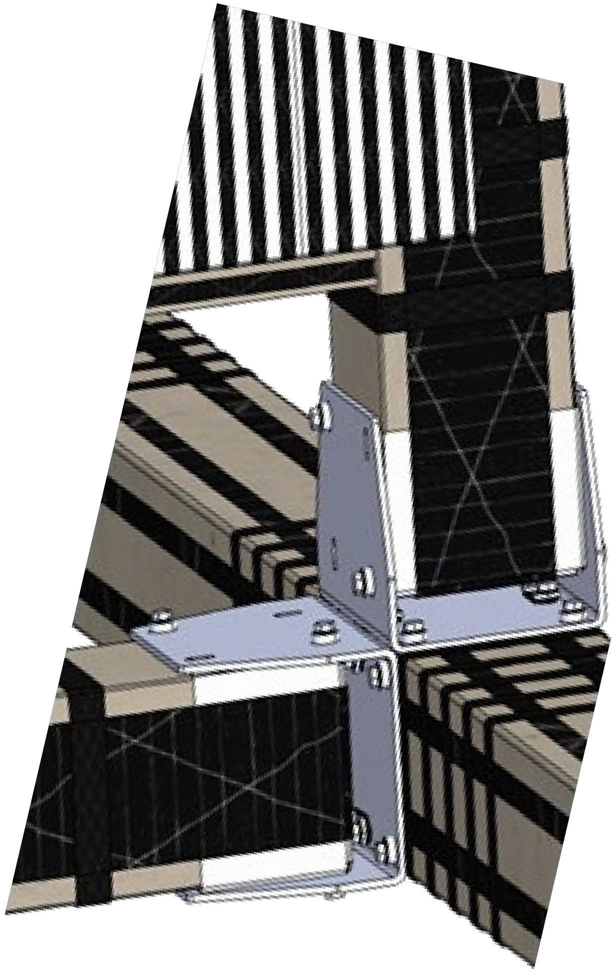
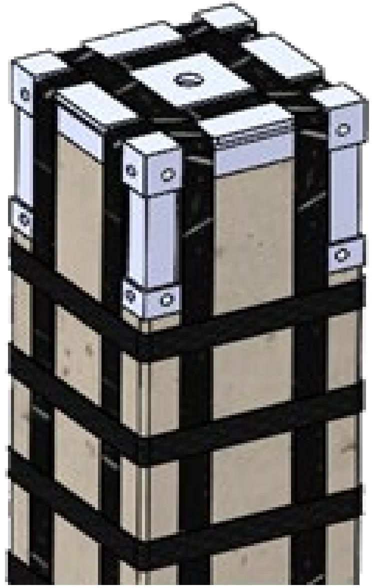
WRAPPED-IN-TENSION FIBERS:

A GAME CHANGER APPROACH

FSC TECH



Wrapping in tension disruptive change: Applications to Constructions batteries and H_2 storage



HORIZON-CL5-2024-D4-02-04

Under evaluation: submitted on 04/02/25

Enabling technology: concrete wrapping-in-tension with glass fiber, fully avoiding embedded steel

Examples of what a new class of fiber reinforced materials can do

ENEA coordinated:
Claudio Mingazzini

ENEA

WRAPPED-IN-TENSION FIBERS: A GAME CHANGER APPROACH

FSC TECH

Project FSC-TECH: steel-free constructions

Making buildings:
- modular, adaptable and demountable
- 1000 years lasting with close loop recycle of all materials
- with drastically lower (90% less) C-footprint and costs
- full resilience to earthquakes and extreme events
- huge structures possible
- lighter structures (=30% weight reduction in a typical multustorey building)
- avoiding exceptional transports and unlocks electrification in constructions

The project FSC-TECH will also:
- change how construction modules are used and reused before recycling
- produce band new long-lasting modules using 100% recycled aggregate
- make ceramic tiles production carbon neutral
- pave the way to international standardisation

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WRAPPED-IN-TENSION FIBERS: A GAME CHANGER APPROACH

FSC TECH

Application to Constructions

Gli edifici così realizzati risultano:

- **modulari, adattabili e smontabili**;
- con una **durabilità 10 volte superiore** (ovvero 1000 anni, come il **Pantheon** ha dimostrato) e una **riciclabilità al 100%**;
- con costi ed emissioni **ridotti del 90%;**
- resilienti in caso di terremoti e altri eventi catastrofici;
- anche di grandi dimensioni e generalmente più leggeri (**-30% in peso** rispetto al tipico edificio a più piani);
- niente trasporti eccezionali e si può sbloccare l'elettrificazione del settore.

Tabella 1	**Column (0.3x0.3x3.0 m)**	**Beam (0.30x0.38x5.7 m)**	**Frame (6.0x6.0x3.0 m)**
Risparmi % emissioni CO_2	84%	85%	84%

Application to Constructions

- L’acciaio viene usato solo nei giunti e mai incluso nel calcestruzzo
- L’applicazione del montaggio in situ di elementi prefabbricati riduce di più del 90% i tempi di costruzione
- A differenza delle strutture tradizionali, queste sono riparabili a seguito di un terremoto

	Colonna (0.3x0.3x3.0 m)	Trave (0.30x0.38x5.7 m)	Struttura (6.0x6.0x3.0 m)
Aggregato da riciclo (kg)	1310	545	7400
Cemento (kg)	250	105	1430
Fibra di vetro (kg)	17	12,7	120
% Fibra di vetro	1,1	1,9	1,3

Cement re-carbonation mechanism

$$2(3CaO \cdot SiO_2) + 3CO_2 + 3H_2O \rightarrow 3CaO \cdot 2SiO_2 \cdot 3H_2O + 3CaCO_3$$

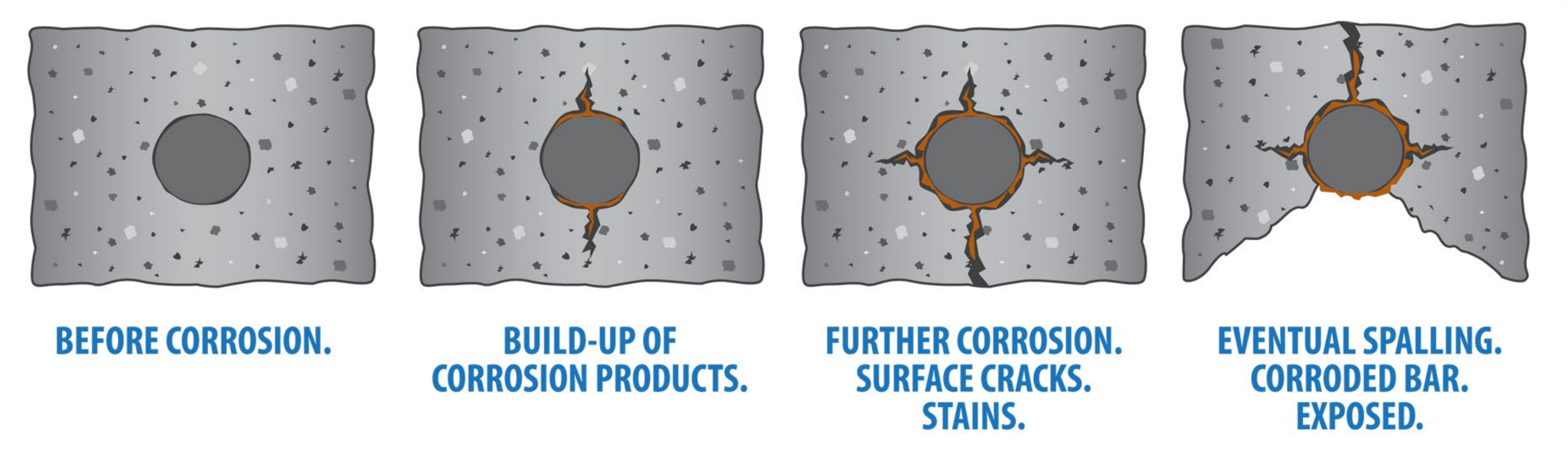
$$2(2CaO \cdot SiO_2) + CO_2 + 3H_2O \rightarrow 3CaO \cdot 2SiO_2 \cdot 3H_2O + CaCO_3$$

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

$$3CaO \cdot 2SiO_2 \cdot 3H_2O + 3CO_2 \rightarrow 3CaCO_3 + 2SiO_2 + 3H_2O$$

Cement re-carbonation: why not possible up to now?

High concrete pH is what protects steel frame from rusting. When naturally occurring (over 50-100 years) it brings to the structure collapse…



Durability & Performance in steel free beams

50% of the produced steel goes into constructions: most could be avoided, with constructions which would last at least 3 times longer (Pantheon lasted 2000y…) cost less, withfire and earthquake resistance, adaptability through modularity, better energy efficiency. In short, at least:

-lower C footprint (- 84%)

-lower production cost (- 92%)

CO_2 & Costs reduction in steel free concrete

- **The adoption of FSC-TECH technologies allows both CO_2 weight and economical savings.**
- **Reduced weight also saves energy consumptions, NOx emissions and costs for lorries and cranes.**

% CO_2 savings	**Column (0.3x0.3x3.0 m)**	**Beam (0.30x0.38x5.7 m)**	**Frame (6.0x6.0x3.0 m)**
Concrete prefabricate production	39%	48%	39%
Production (P) + Carbonation (C)	52%	56%	53%
P + C + Increased 3x Lifespan	84%	85%	**- 84%**

% Cost savings	**Column (0.3x0.3x3.0 m)**	**Beam (0.30x0.38x5.7 m)**	**Frame (6.0x6.0x3.0 m)**
Concrete prefabricate production	33%	58%	74%
Production (P) + Carbonation (C)	87%	61%	76%
P + C + Increased 3x Lifespan	96%	87%	**- 92%**

The expected savings for a frame are:
- - 84% if we consider CO_2
- - 92% if we consider costs

Additional advantages: full modularity (which can be demounted nd reused), lower time for building, resilience to earthquakes, better thermal insulation, much reduced need of mining and water, closed loop recycling

Possible symbiosis with ceramics production

	Cement produced (Mton/y)	Ceramic tile produced (Mm^2/y and Mton/y)	Ceramic tile CO_2 emission (Mton/y)	CO_2 absorbed by Cement (Mton/y)	CO_2 absorbed by Cement at early age (Mton/y)
Worldwide	4100	15937 Mm^2/y = 598 Mton/y	400	1025	738
In EU	182.5	1267 Mm^2/y = 47.5 Mton/y	19	46	33

Concrete prefabricates production can use ceramic tiles emission to speed up its curing, while <u>making ceramic tiles Carbon neutral</u>

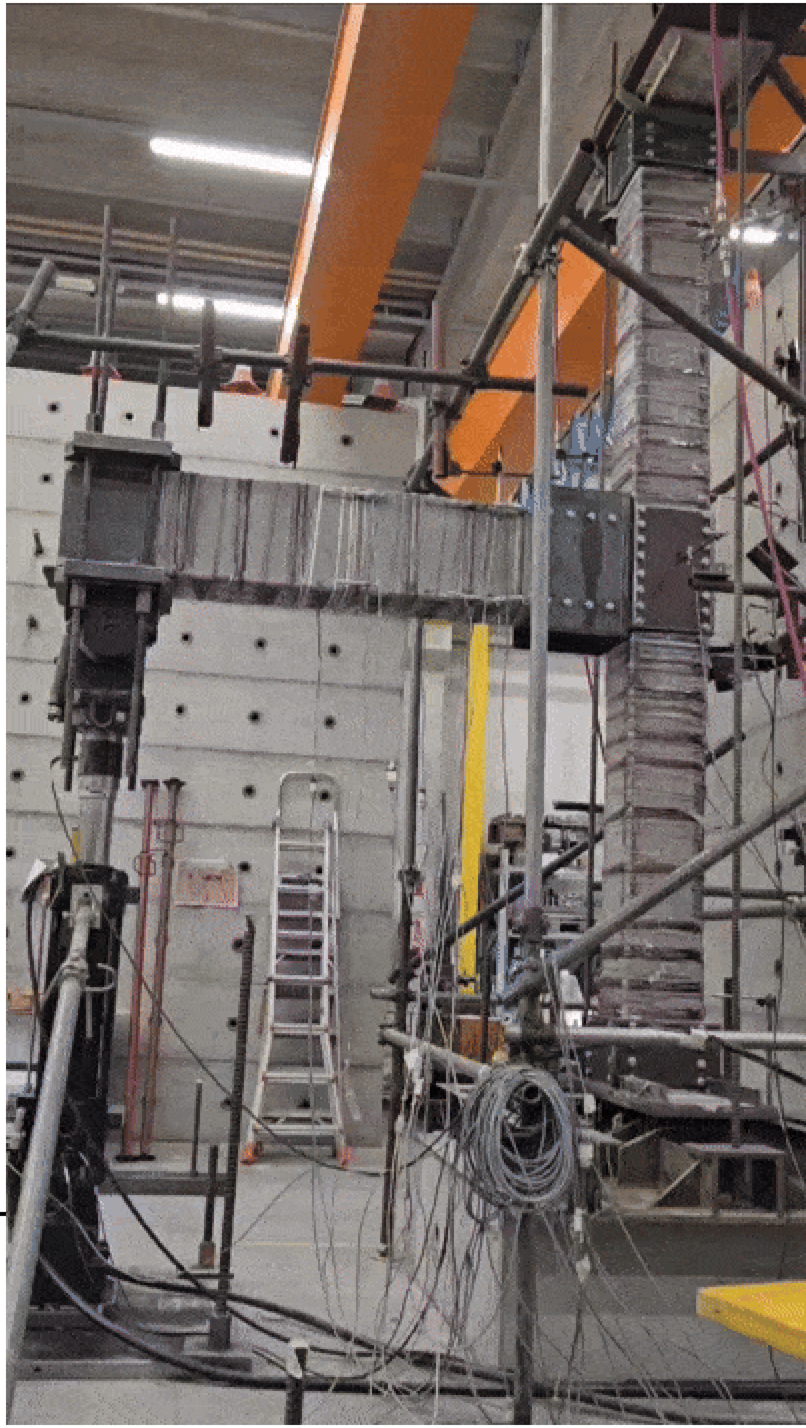
Potential synergy with ceramics production			
Tiles thickness	**mm**	7	10
Mass production	**ton/h**	5.3	7.5
CH4 consumption	**m^3/h**	82	117
CO2 Emissions	**kg/h**	150	210
Cement need to abs	**ton/h**	0.8	1.2

Weight reduction and antiseismic advantages in constructions

	Wet on-site constructions (kg)					FSC-TECH (kg)			
typical struct. Element	**Natural aggregate**	**RCA**	**Cement**	**Steel**	**Tot weight**	**Glass fibre**	**Cement**	**RCA**	**Tot weight**
Beam	1670	560	540	133	2903	17	250	1310	**1577 (-45%)**
Column	410	140	130	36	716	12.7	105	545	**662.7 (-7.4%)**

The existing patents protecting all this:

[1] EP3143321B1, “Reinforced concrete pipe”, FSC TECH LCC, expiry 2035
[2] EP3470595A1, "A structural element for constructions", FSC TECH LCC, expiry 2038
[3] WO 2024/025790, "Postcompressed concrete flooring element", FSC TECH LCC, expiry 2042
[4] EP4402324A1, “Prefabricated building structure”, CSCON srl, expiry 2041



Tabel 2.3: Steel Frame Weight on 6X6 mt building mesh (H=3mt)...		
Labor requirement per ton	40	Hours/Ton
Painting cost	1000	Euro/Ton
Paint amount per grid	5	Kg
CO_2 emitted per Kg of paint	6	Kg/Kg
Recycled aggregates cost per Ton	10	Euro/Ton
Columns Steel Connector Mass	40	Kg
Steel Connectors Beams Columns Mass (Entire Mesh)	240	Kg
Steel CO_2 Emission per Ton	1800	Kg/Ton of Steel
Steel Plates / profiles Cost per Kg	0,85	Euro/Kg
General Labor cost	15	Euro/Hour
Tecnician Labor cost	22	Euro/Hour

...vs corresponding 6X6 mt post compressed structural members (H=3mt)		
Beams Cement Mass	1008	Kg
Beams Aggregate Mass	5230	Kg
Beams Aggregate Cost	209	Euro
Beams total cost	591	Euro
Beams Total CO_2 Emitted	983	Kg
Columns Cement Mass	419	Kg
Columns Aggregate Mass	2173	Kg
Columns Aggregate Cost	22	Kg
Column Total Cost	349	Euro
Columns Total CO_2 Emitted	560	Kg
CO_2 absorbed naturally for recarbonation by Cement	75	Kg
Beams Total CO_2 Emitted (considering recarbonation)	485	Kg
Steel Connector Raw Material Cost	204	Euro
Steel Connector Labor Cost	24	Euro
Steel Connectors CO_2 Emitted	432	Kg

Assuming a CO_2 cost of 100 eur/ton		
Total CO_2 Emitted (Raw material + paint)		
Steel Frame Weight on 6X6 mt building mesh (H=3mt)	**5823**	**Euro**
6X6 mt Post Compressed structural members (H=3mt)	**1339**	**Euro**

Total CO_2 Emitted		
Steel Frame Weight on 6X6 mt building mesh (H=3mt)	**3630**	**Kg**
6X6 mt Post Compressed structural members (H=3mt	**1718**	**Kg**

Assuming a CO_2 cost of 150 eur/ton		
Total CO_2 Emitted (Raw material + paint)		
Steel Frame Weight on 6X6 mt building mesh (H=3mt)	**6005**	**Euro**
6X6 mt Post Compressed structural members (H=3mt)	**1425**	**Euro**

Assuming a CO_2 cost of 200 eur/ton		
Total CO_2 Emitted (Raw material + paint)		
Steel Frame Weight on 6X6 mt building mesh (H=3mt)	**5460**	**Euro**
6X6 mt Post Compressed structural members (H=3mt	**1168**	**Euro**

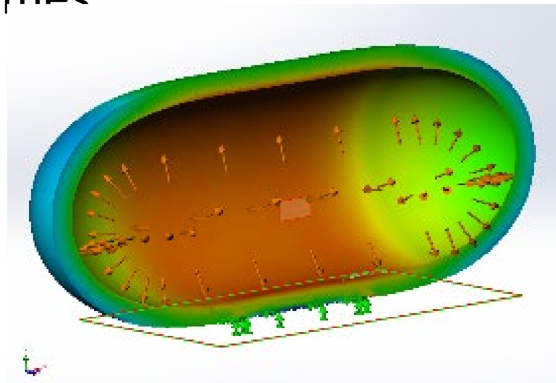
CHALLENGES	FSC-TECH SOLUTION(S)
Traditional construction elements are overly resource-intensive, emission producing, unavailable for recycling, dependent on mining for raw materials and generate significant waste and pollution.	New patented **post-compression concrete composite constructive elements** optimizing concrete, steel and glass fiber that: i) radically extend service life (1000 yr) by eliminating steel reinforcement and associated chemical degradation, ii) enable the use of 100% recycled or biobased aggregates and iii) are engineered to optimize the function of each material into a structural element (beam, column, wall, floor, frame) which are C-footprint and structurally optimized, using less steel.
Multistorey constructions don't allow for adaptability, re-use of structural elements or deconstruction. Moreover, they aren't resilient to earthquakes, requiring total reconstruction after major events.	New patented **full moment metal joints** that connect together the new composite constructive elements. These full moment joints enable lego-like construction, carry both moment and shear, enable efficient assembly and disassembly and limit damage in extreme load scenarios by dissipating energy at the joints which are easy to replace. The end results are resilient adaptable structures ready for deconstruction and re-use, which can be repaired to new after any earthquakes.
Traditional construction methods of monolithic cast-in-place structures awarded to lowest-cost bidders aren't adaptable, structurally inefficient, time-consuming, higher C footprint, face labor shortages, have safety concerns and are lifecycle higher cost.	The new elements unlock **new construction methods** that maximize off-site prefabrication in automated plants that i) improves efficiency, quality control, and labour safety, ii) reduces reliance on manual labor and promotes upskilling of the construction workforce, iii) significantly lowers construction time and costs on site, and iv) results in much lower emissions, pollution and waste (closed loop recycling after >300y expected lifespans and lower use of raw materials. The end result is a categorical shift toward adaptability, circularity, and re-use in construction.

Current solution: STEEL H_2 vessel (type-1)

FSC TECH EU INNOVATIVE CONCRETE H_2 VESSEL

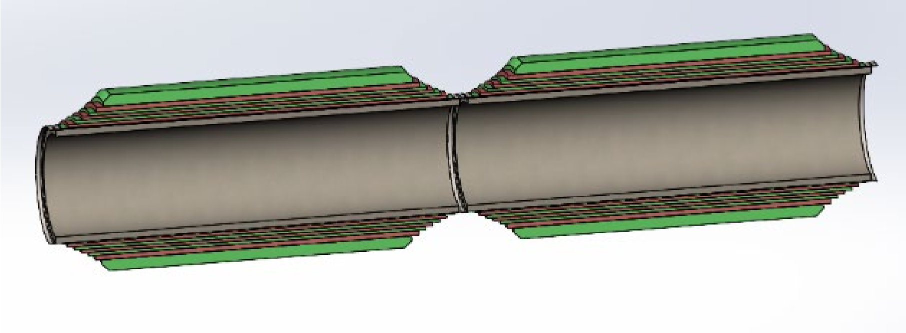
A vessel for 400kg of H_2:
Pressure: 700 bar
Internal diameter: 1500 mm
Length: 6 m
Not considering the domes:

Weight= 64 ton
Cost= 300,000 €



Corresponding FSC vessel:
Pressure: 700 bar
Internal diameter: 1500 mm
Length: 6 m
Not considering the domes:

Weight= 30 ton
Cost= 35,000 €



Concrete core are the only sustainable ones!

Expected need in Italy in next three years: 14’000 (84 km)

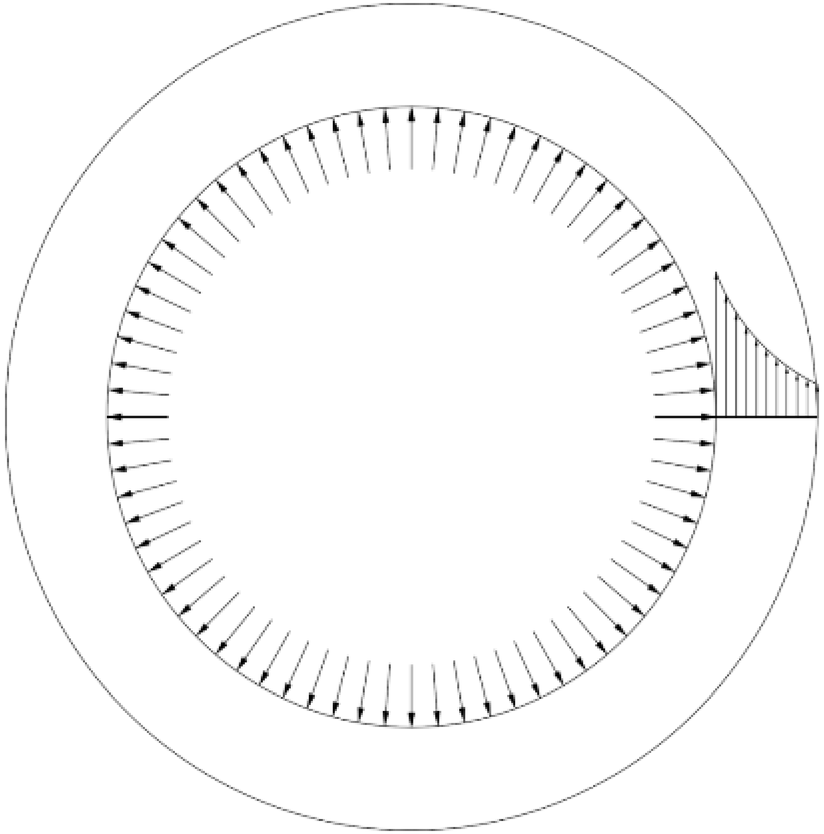
ENEA

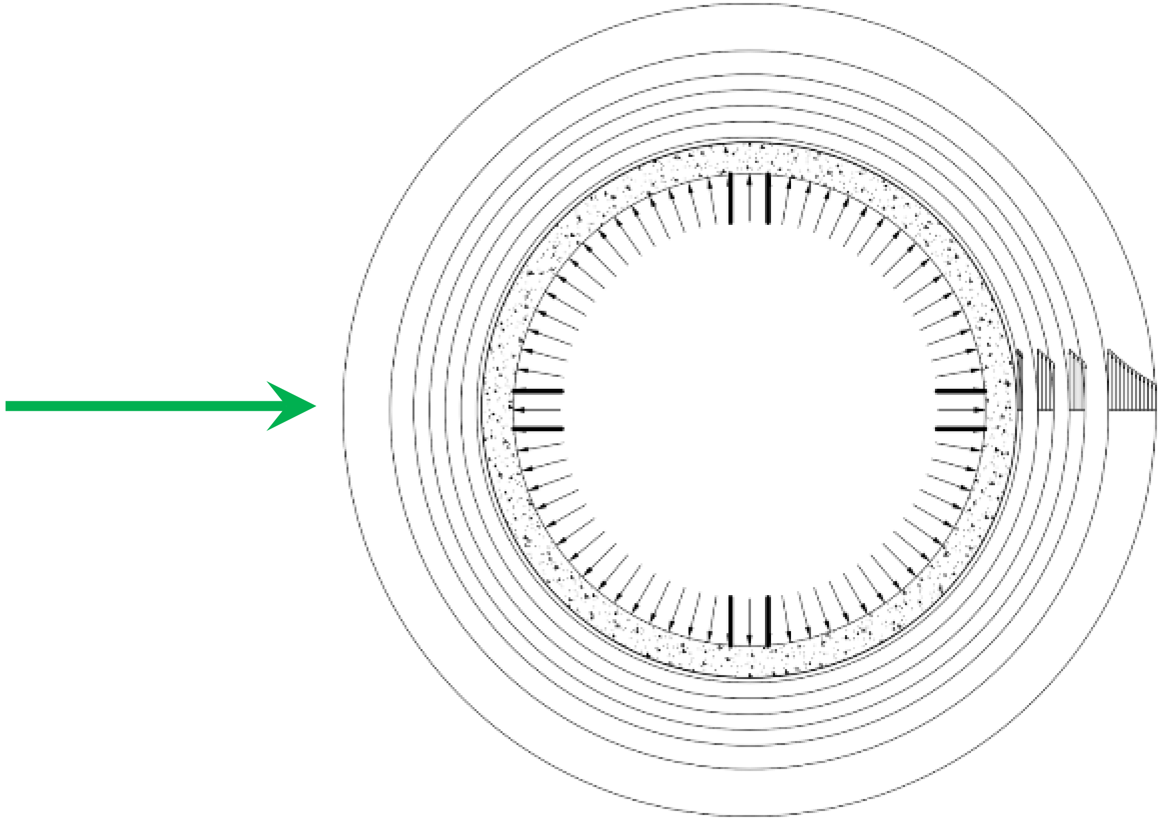
WRAPPED-IN-TENSION FIBERS:
A GAME CHANGER APPROACH

FSC TECH

The traditional stress distribution in a thick wall composite vessel: the stress is concentrated in the inner layers, limiting the storage capacity and long term reliability

FSC solution: allows an **even stress distribution across wall thickness**, optimizing the performances and preventing fatigue problems





Standards (relevant for H_2 storage)

ISO 11119-3 specifies the requirements for the design, construction, and testing of composite cylinders intended for the storage and transport of compressed gases, including hydrogen. Specifically, ISO 11119-3 focuses on fully wrapped fibre reinforced composite gas cylinders with a non-metallic liner. It details the types of tests that must be conducted to verify the cylinders' compliance with the standard, including Proof pressure test, Hydraulic elastic expansion test, Cylinder burst test, Ambient cycle test, Vacuum test, Environmental cycle test, Environmentally assisted stress rupture test, Flaw test, Drop/impact test, High velocity impact (gunfire) test, Fire resistance test, Permeability test, Torque test on cylinder neck boss, Salt water immersion test, Leak test, Pneumatic cycle test, Liner burst test, Resin shear strength, Glass transition temperature. Specifies the conditions under which the tests must be carried out to ensure they accurately reflect the performance of the cylinders under real-world conditions. Includes requirements for prototype testing, batch testing, and periodic requalification to ensure ongoing compliance and safety.

ISO-TS-15869 specifies the requirements for lightweight refillable fuel tanks intended for the onboard storage of high-pressure compressed gaseous hydrogen or hydrogen blends on land vehicles. It is applicable for fuel tanks of steel, stainless steel, aluminium or non-metallic construction material, using any design or method of manufacture suitable for its specified service conditions.

FML, a good solution also for renewable and biobased composites

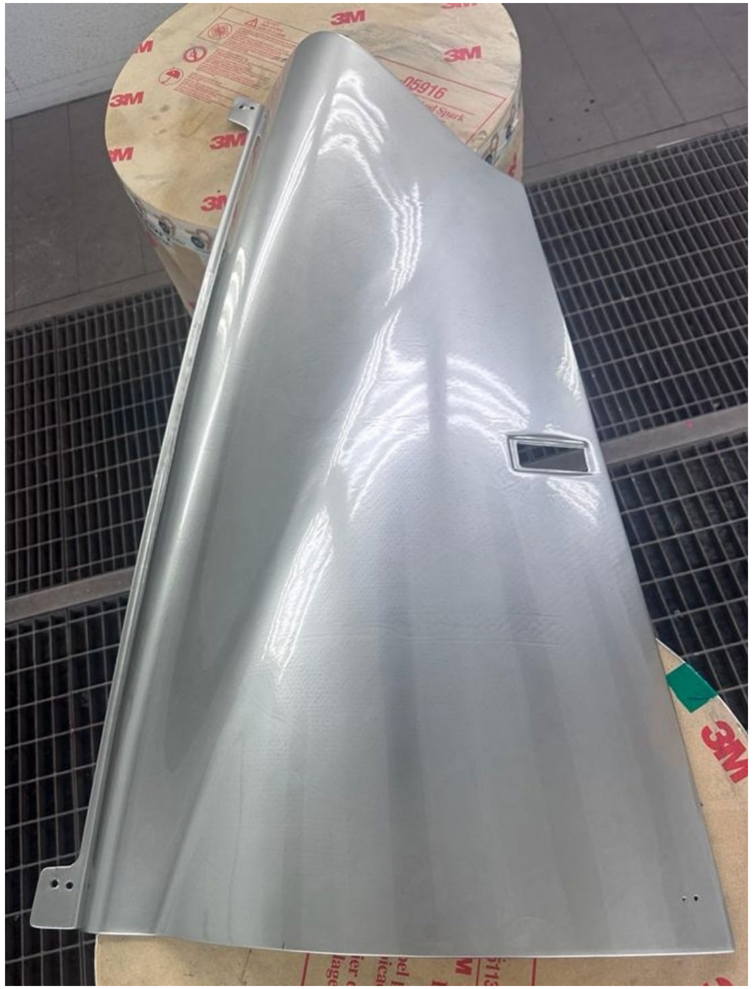
Environmental friendly solution to the problems of:

-**Microplastics** (produced from gelcoats (58% of microplastics in food-chain coming from paints!) **<u>avoiding aluminium Cr-plating</u>**

-biobased raw materials exploitation: Aluminium as **<u>antiosmotic barrier</u>**

-Al on top can **<u>increase impact and erosion resistance</u>** performances

-Allow substituting fiberglass-reinforced vinylester (affected by the carynogenic styrene) with **<u>100% closed-loop recyclable composites</u>**



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Producing huge composite and FML components, at high T: necessary for exploiting C2C recyclable resins

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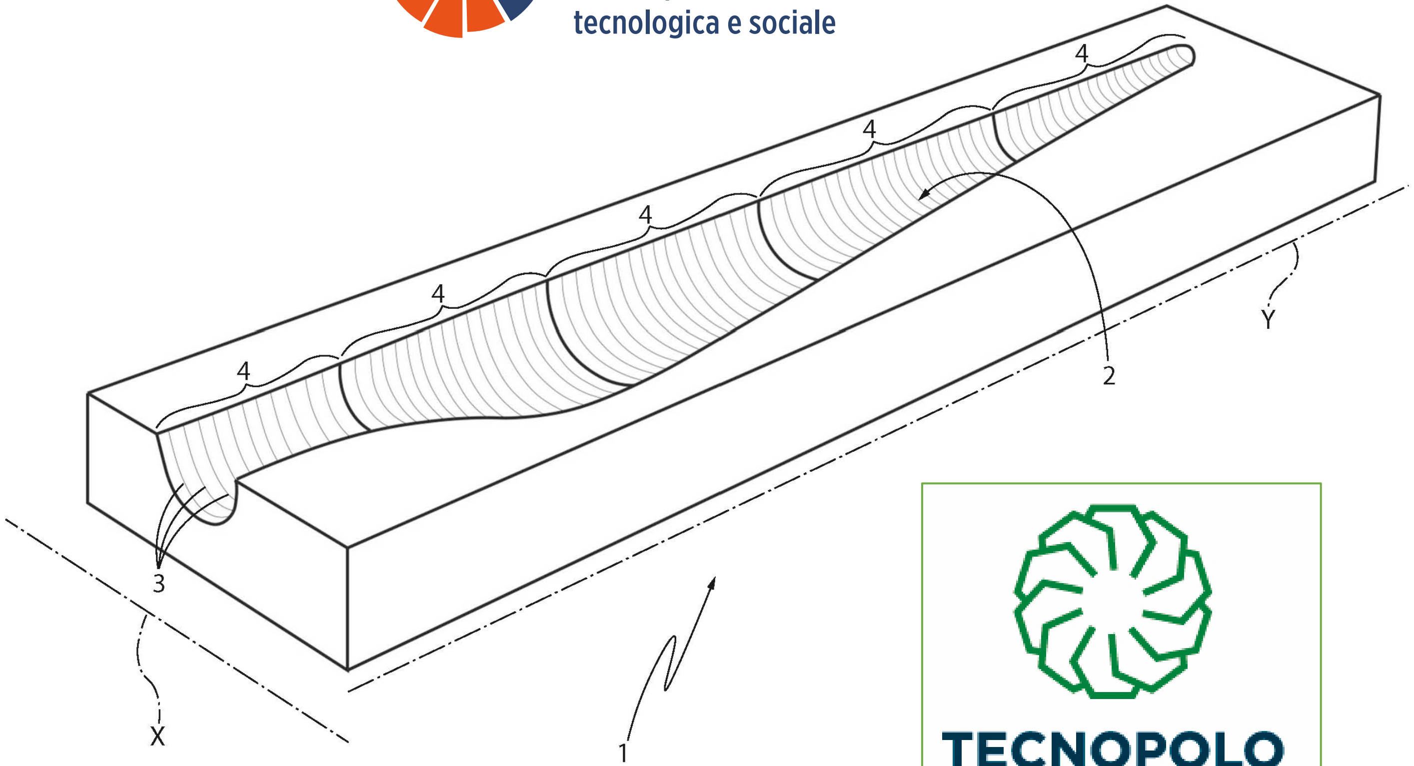
METHOD FOR THE MANUFACTURE OF A LARGE COMPOSITE MATERIAL COMPONENT
Domanda n. 102025000009861 del 5/5/25
Inventori C. Creonti, C.Mingazzini

Proprieta' ENEA-CROSSFIRE



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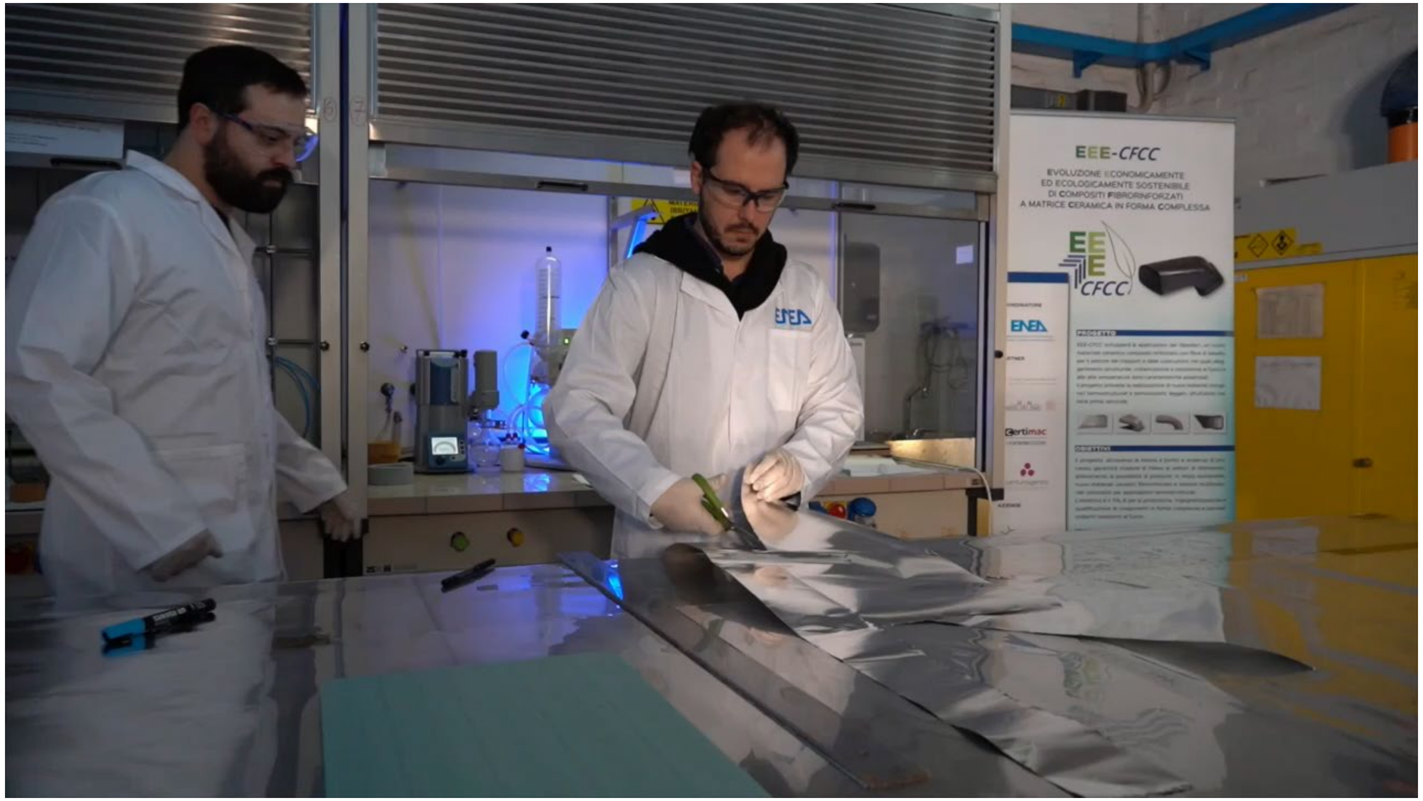

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- 9 Regional Clusters
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associazione BigData from volume to value

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More info at: [Tecnopolo di Ravenna - Dove la ricerca incontra l'impresa]()

Thanks for your kind attention!!

Questions??

Booth D04!!!

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