Laboratory for Lightweight Construction and Durability Performance

29/05/2017

Presentation of the Laboratory for Lightweight Construction and Durability Performance

Giampiero Mastinu

29 May 2017

Outline

- Politecnico di Milano (PoliMi)
- Inter-department Laboratories @ PoliMi
- Laboratory of Lightweight Construction and Durability Performance

POLITECNICO
MILANO 1863

Politecnico di Milano since 1863

The leading University in Italy for
Architecture, Design and Engineering

The Campuses of the Politecnico di Milano

Human Resources, Academic year 2014/2015

Professors and Assistant Professors	1316
Technical and Administrative staff	1207
PhD students	1011
Students	37984

AY 2015/2016 Faculty: 1316 Students: 37984

Architecture

Professors & Researchers	Students
297	6957

Design

Professors & Researchers	Students
94	3542

Engineering

Professors & Researchers	Students
925	27485

21% of architects
graduated from
Politecnico di Milano

16% of engineers
graduated from
Politecnico di Milano

42% of designers
graduated from
Politecnico di Milano

QS World University Rankings by Faculty - Engineering and Technology 2017

	World	EU	Italy
Engineering & Technology	24	7 **(3 after BREXIT)**	1

Politecnico di Milano	**Score**	**World Rank**
Academic Reputation (40%)	86,4	32
Employer Reputation (30%)	88,4	12
Citations per Paper Measures productivity for the last five years (15%)	79.4	301
H-index Citations (15%) Measures both the number of papers produced and the impact of the published work	81,2	87
Overall	**83.7**	**24**

QS World University Rankings by Subject 2017

	World	EU	Italy
Architecture & Built Environment	14	6	1
Art & Design	7	3	1
Computer Science & Information Systems	49	10	1
Chemical Engineering	100	22	2
Civil & Structural Engineering	14	6	1
Electrical & Electronic Engineering	50	10	1
Mechanical, Aeronautical & Manufacturing Engineering	29	7	1
Materials Science	70	15	1
Mathematics	78	23	1
Business & Management Studies	88	29	2
Physics & Astronomy	123	54	5

Giulio Natta

1963 Nobel Prize for his discovery in polymer science

Famous Alumni

Aldo Rossi

1990 Pritzker Architecture Prize

Renzo Piano

1998 Pritzker Architecture Prize

Bachelor and Master of Science Programmes

24 Bachelor of Science Programmes
(1 taught in English)

38 Master of Science Programmes
(33 taught in English)

The 12 Departments of the Politecnico di Milano

Aerospace Science and Technology
Architecture and Urban Studies
Architecture, Built Environment and Construction Engineering
Chemistry, Materials and Chemical Engineering “Giulio Natta”
Civil and Environmental Engineering
Design
Electronics, Information and Bioengineering
Energy
Management, Economics and Industrial Engineering
Mathematics
Mechanics
Physics

Inter-department Laboratories @ PoliMi

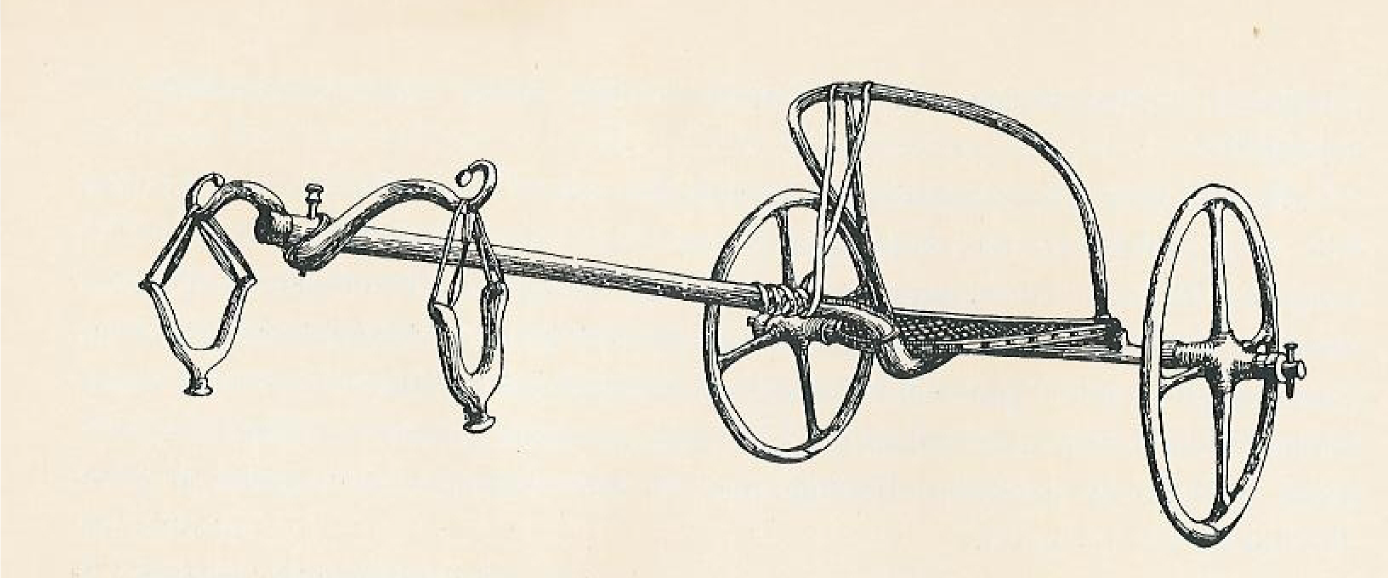
1. AMALA - ADVANCED MANUFACTURING LABORATORY
2. BRAINLAB@POLIMI
3. CECH (CLIMATE AND ENERGY FOR CULTURAL HERITAGE)
4. CFDHUB@POLIMI - LABORATORIO DI FLUIDODINAMICA COMPUTAZIONALE
5. CLIMATE-LAB
6. CREA LAB - LABORATORY OF COMPRESSIBLE-FLUID DYNAMICS FOR RENEWABLE ENERGY APPLICATIONS
7. E4SPORT - ENGINEERING FOR SPORT LABORATORY
8. GEOLAB - LABORATORIO DI GEOMATICA E OSSERVAZIONE DELLA TERRA
9. HYDROINFORMATICS LAB (HIL)
10. I.DRIVE (INTERACTION BETWEEN DRIVER ROAD-INFRASTRUCTURE VEHICLES AND ENVIRONMENT)
11. IN-SITU MICROMECHANICS LABORATORY (ISMICROLAB)
12. INTERNET OF THINGS LAB
13. LAFOS - LABORATORY ON FIBER OPTIC SENSORS
14. **LIGHTWEIGHT CONSTRUCTION AND DURABILITY PERFORMANCE**
15. LUCID LAB
16. MANTOVA LAB
17. MEMS&3D-LAB
18. NANOMEDLAB
19. PHEEL - PHYSIOLOGY, EMOTION AND EXPERIENCE LABORATORY
20. POLICLOUD LABORATORY ON CLOUD, INTERNET OF THINGS AND BIG DATA
21. POLINDT - LABORATORIO PER LA DIAGNOSTICA E IL MONITORAGGIO STRUTTURALE
22. PSVL - POLIMI SOUND AND VIBRATION LABORATORY
23. SISMOSOILLAB
24. SOLID-LIQUID INTERFACE NANOMICROSCOPY LAB (SOLINANO LAB)
25. TEXTILES HUB - LABORATORIO INTERDIPARTIMENTALE DI RICERCA SUI TESSILI E I MATERIALI POLIMERICI
26. UPHOS - ULTRAFAST PHOTOEMISSION SPECTROSCOPY
27. URBANSCOPE LAB

Brief overview – Motivation for a LiDuP Lab

Lightweight construction

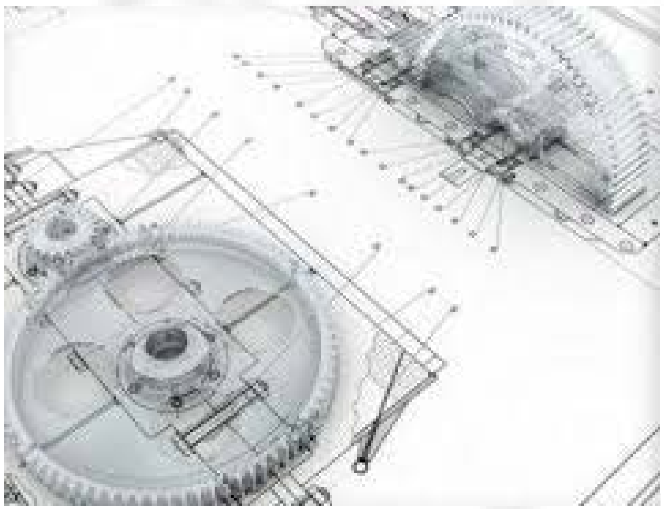
Less is more. Value.

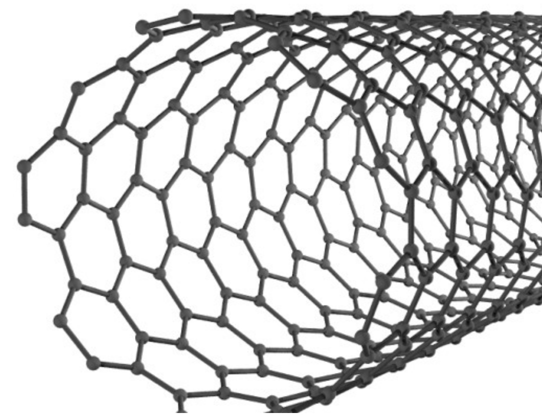
Lightweight Construction and Durability Performance:
a Paradigm of Engineering since ancient times….and still today!



Brief overview – Motivation for a LiDuP Lab

Lightweight Construction and Durability Performance:
Impacting on 100% of companies providing products or services





Brief overview – Motivation for a LiDuP Lab

Lightweight Construction and Durability Performance:

Sustainable growth

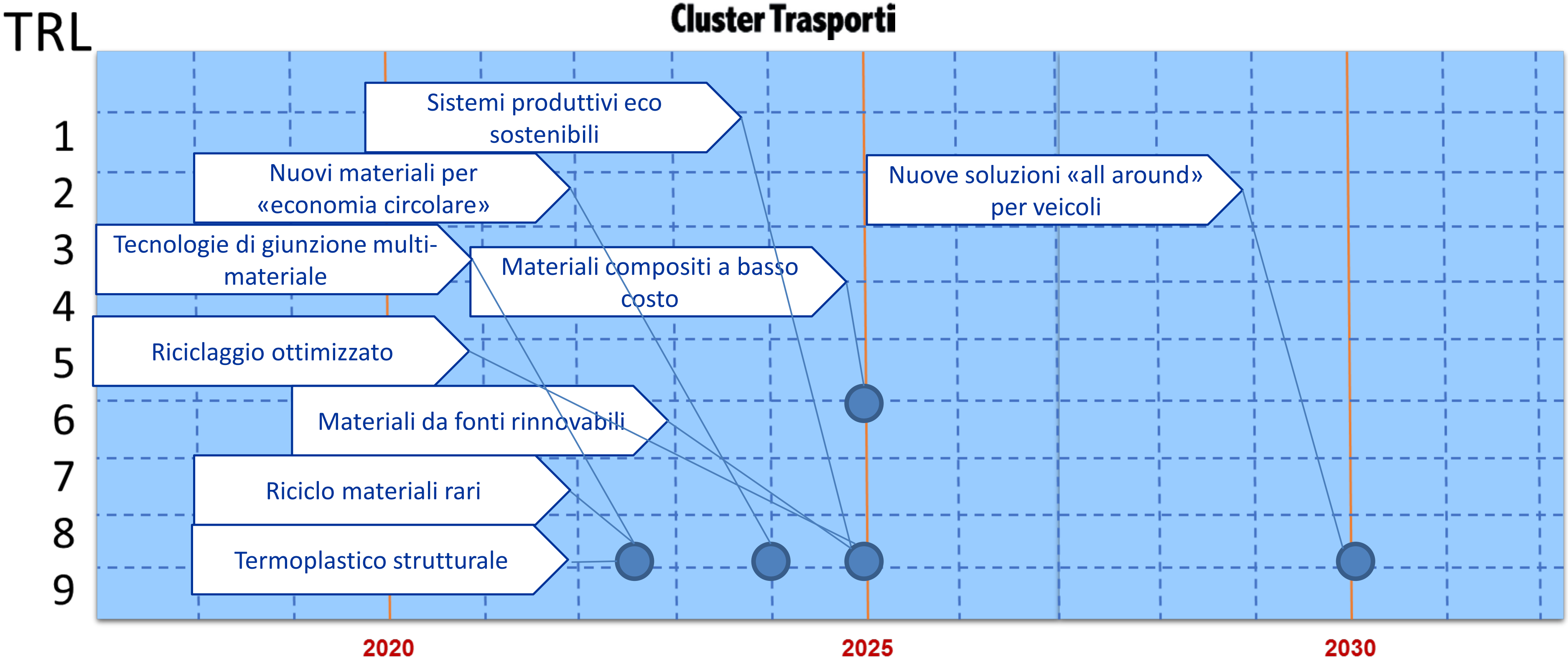
Freight traffic cost proportional to weight,

Freight traffic EU 2200 bln ton*km/year, 7-17% of GDP of developed countries → reducing 10% mass → reducing 10% transport costs → increasing 1% GDP

ROADMAP

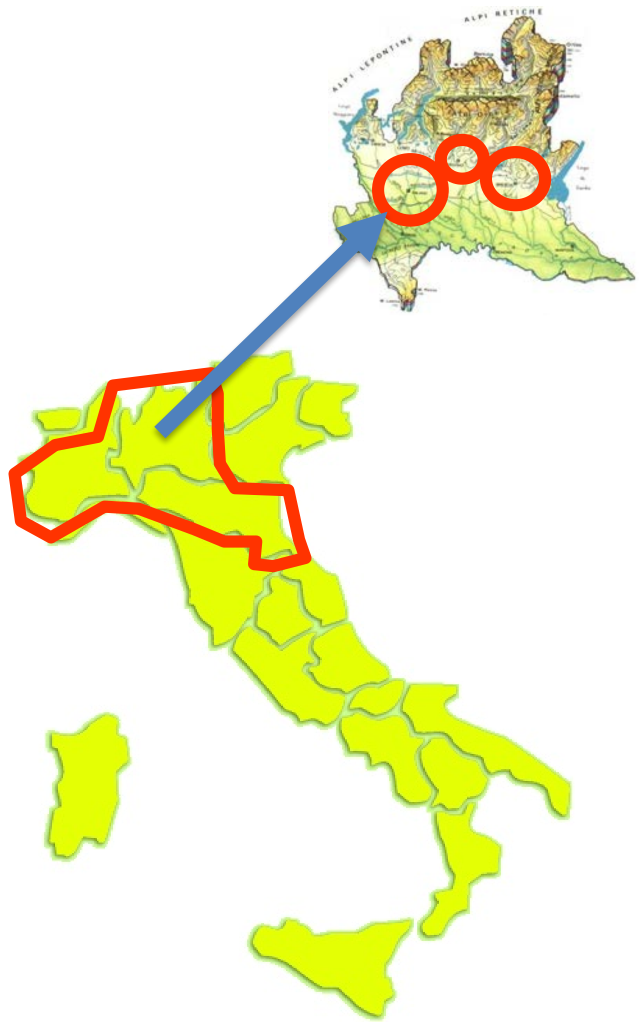
Material and processes referring to «circular economy» and «sustainable vehicles»

Cluster Trasporti

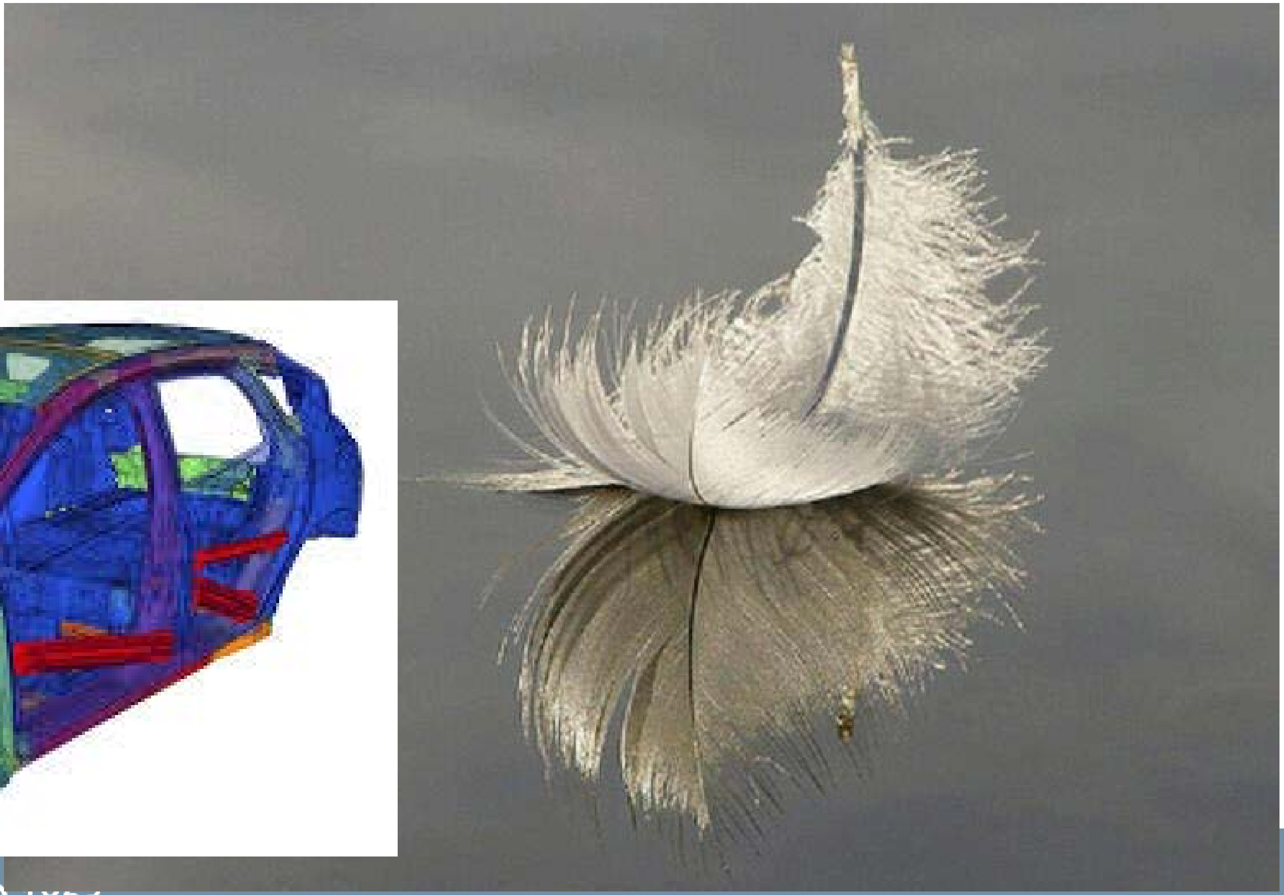


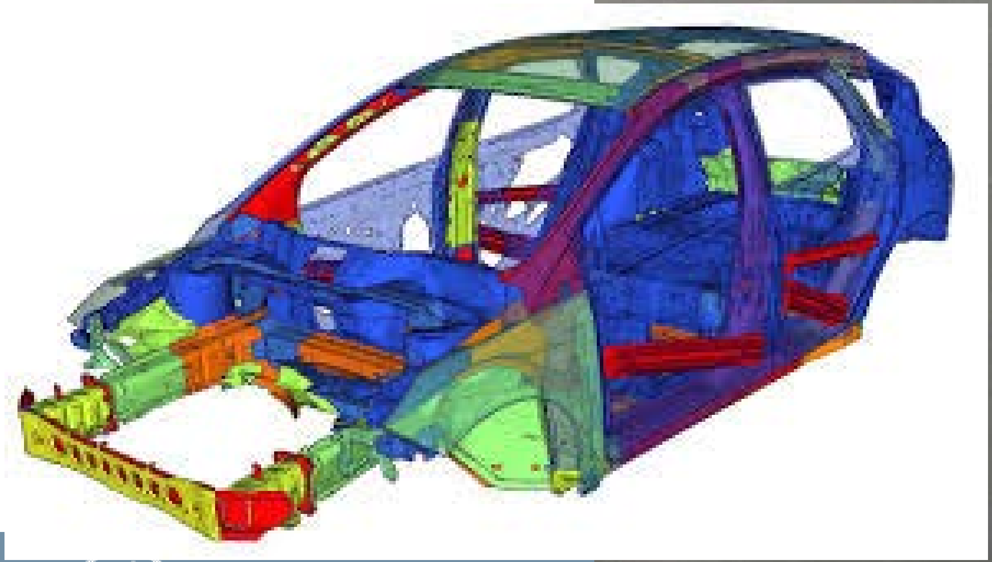
Since 2009: LOMBARDY MOBLITY CLUSTER

CLM
Cluster Lombardo della Mobilità
Lombardy Mobility Cluster



WG 2: LIGHTWEIGHT





WG 6: MATERIALS

Brief overview – Interdisciplinary

Dept. of Mechanical Engineering

LiDuP
Lightweight Construction and Durability Performance

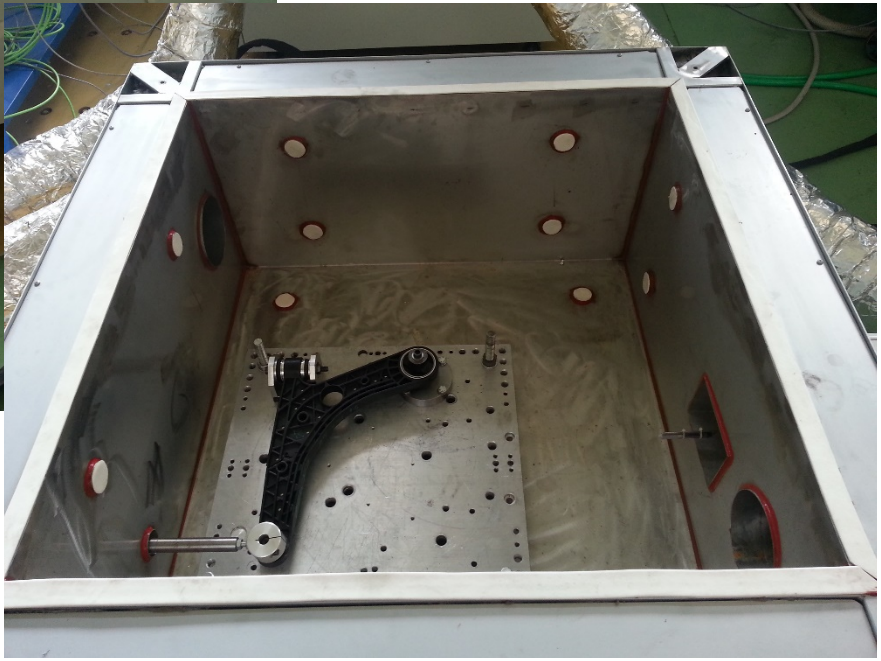
Dept. of Chemistry, Material and Chemical Engineering

Dept. of Civil and Environmental Engineering

Brief overview –LiDuP Lab

1. Climatic machine
2. Functionalization of materials

Climatic machine: Test configuration



Climatc machine: Test configuration

System layout

Chiller

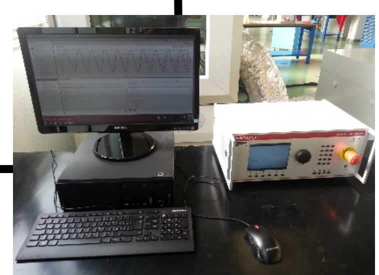
Climatic machine

Climatic machine remote control

Climatic chamber

Actuator(s)

Pump



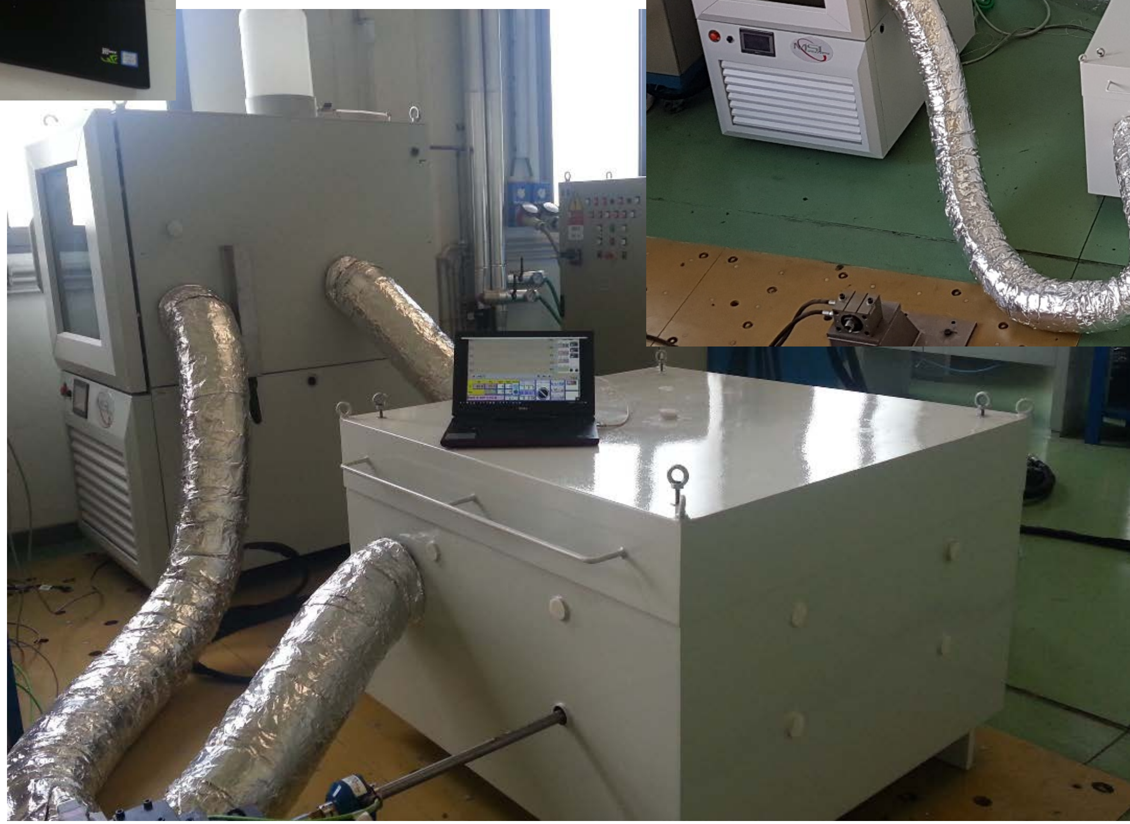
Hydraulic system remote control

Specifications

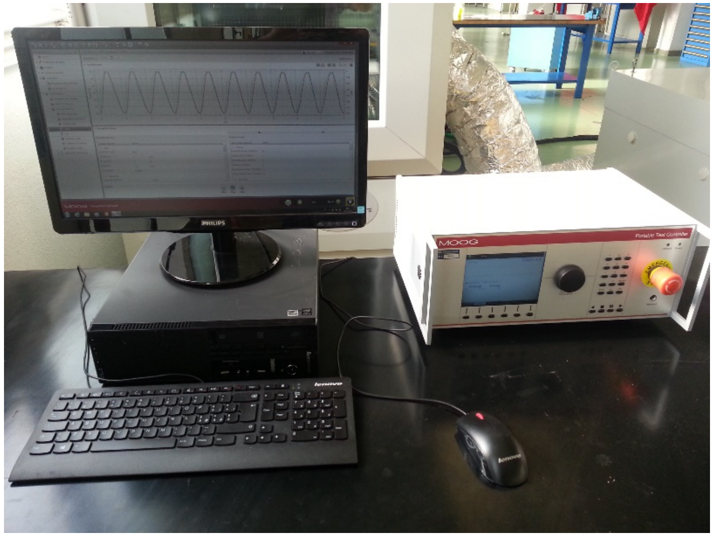
Air conditioning system	
Temperature range	-70°C ÷ 170°C
Control volume	0.5 m^3
Air flow	1000 m^3/h
Temperature control accuracy	± 0.3 °C
Thermal gradient	4°C/min (from -40°C to 120°C) 5°C/min (from 170°C to -40°C)
Relative humidity	20 ÷ 95% (10°C ÷ 90°C)
Heating thermal power	8 kW
Cooling thermal power	16.8 kW
Vapour generation power	2 kW

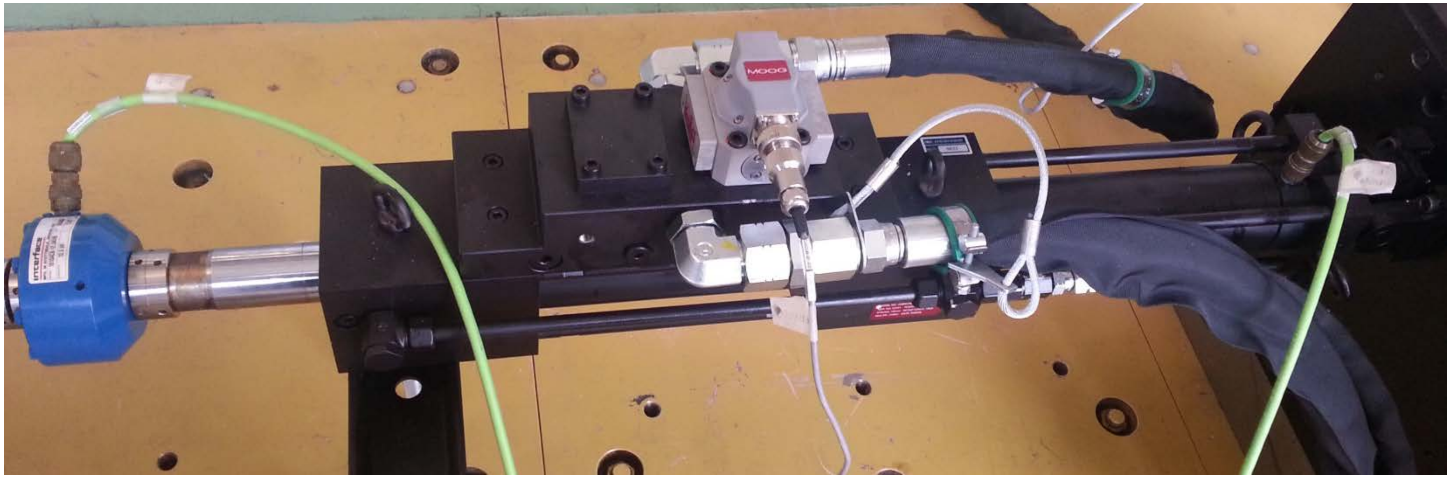
Hydraulic actuation	
Actuation force	up to 170 kN
Actuation frequency	up to 50 Hz
Stroke	up to 250 mm

Air conditioning



Hydraulic system





NanoCarbon Up technology for carbon materials functionalization

A + B / Carbon allotrope

↓

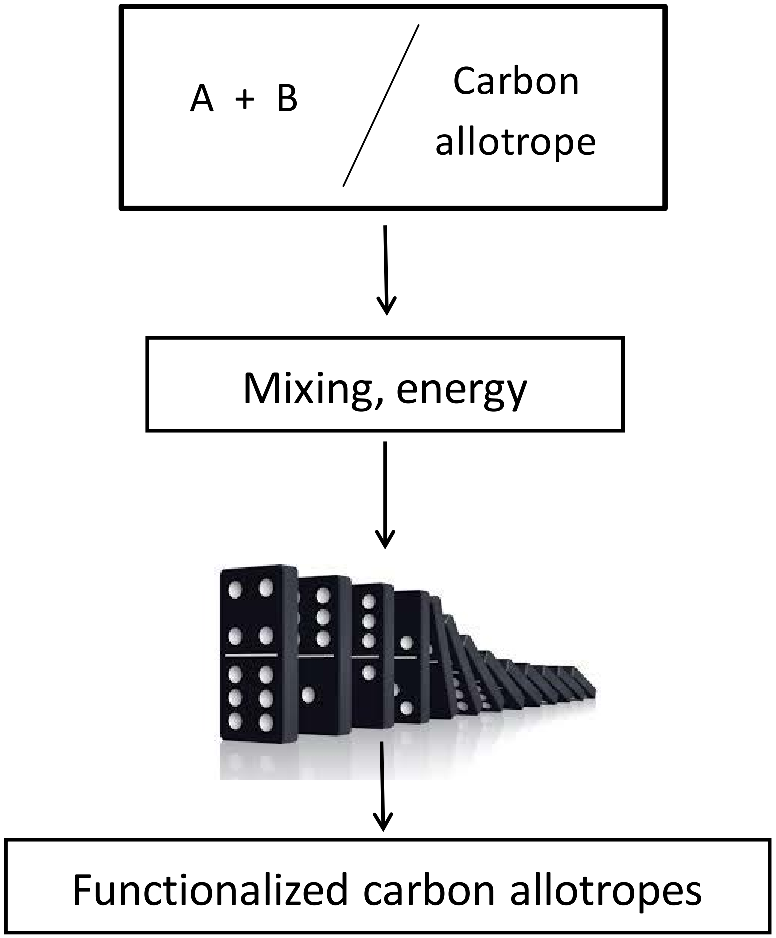
Mixing, energy

↓

↓

Functionalized carbon allotropes

NanoCarbon Up technology for carbon materials functionalization



Agenda of Today

11:45 **Lightweight constructions in the mechanical and automotive field**
A Bernasconi and M Gobbi

12:05 **Lightweight constructions – focus on advanced materials**
R Frassine and M Galimberti

12:25 **Lightweight constructions in civil structures and future perspectives**
M Di Prisco e A Pandolfi

12:45 **Visit to the laboratory and networking lunch**

Acknowledgemtent, event under the patronage of

CLM
Cluster Lombardo della Mobilità
Lombardy Mobility Cluster

Regione Lombardia
Cluster Tecnologici Lombardi

Thank you

29 May 2017

LiDuP
Lightweight Construction and Durability Performance

POLITECNICO
MILANO 1863

Lightweight constructions in the mechanical and automotive field

A. Bernasconi – M. Gobbi

29 May 2017

Lightweighting solutions and architectures, Chassis, Interiors

CTN Tra.It 2020

…….

Lightweighting solutions and architectures

Solutions and architectures for lightweighting of components and systems; Multi material concepts; ...

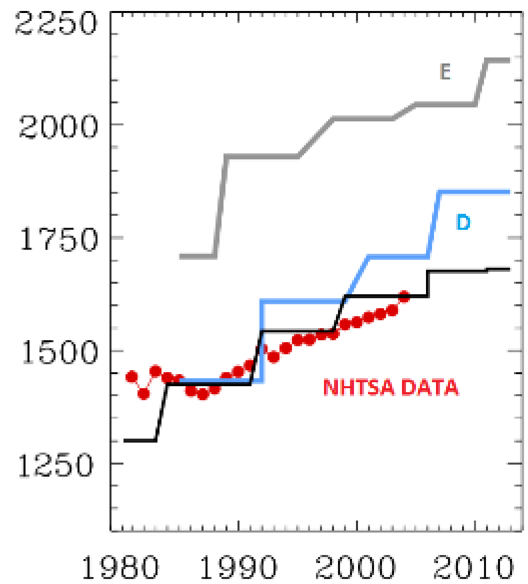
……

Chassis

New materials (metals and plastics) for lightening of the structures (advanced steels, metal alloys, Al, Mg, metal foams, advanced engineering plastics, composites with properties tailored, polymer foams, multilayer); Tyre technologies (according to environmental, economic and social sustainability);

Introduction

Automobile average curb mass (kg)



More

- performance
- comfort
- safety
- electronics

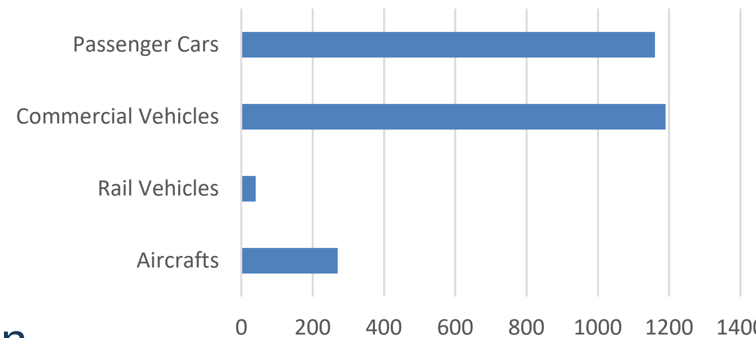
……

Fuel Economy Technologies

-Advances ICE engines
-Advanced transmissions
-Mass Reduction
-Electrification
-Low rolling resistance tires
-Improved aerodynamics
….

Lightweight design

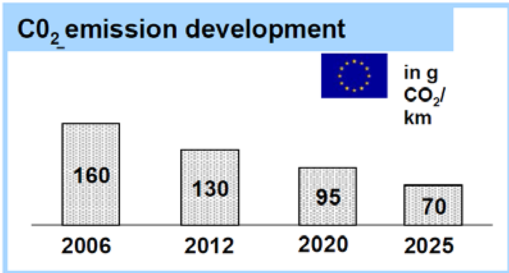
Potential global annual energy saving by lightweight design [PJ]



Int. J. LCA - Case studies – Helms, Lambrecht 2006

life-cycle perspective necessary

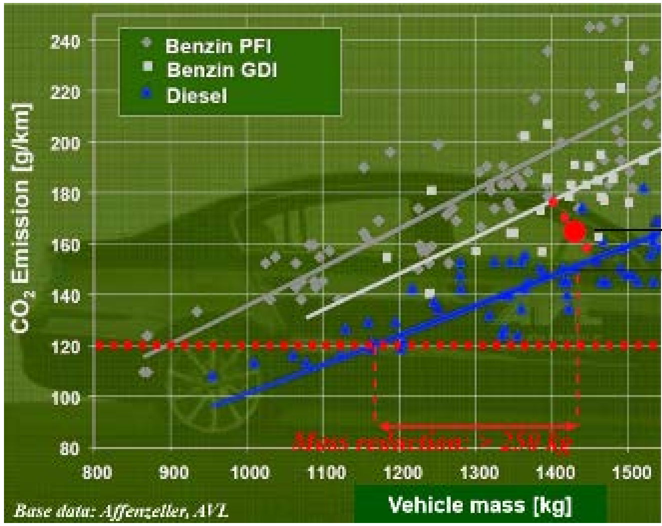
Introduction - Lightweight design



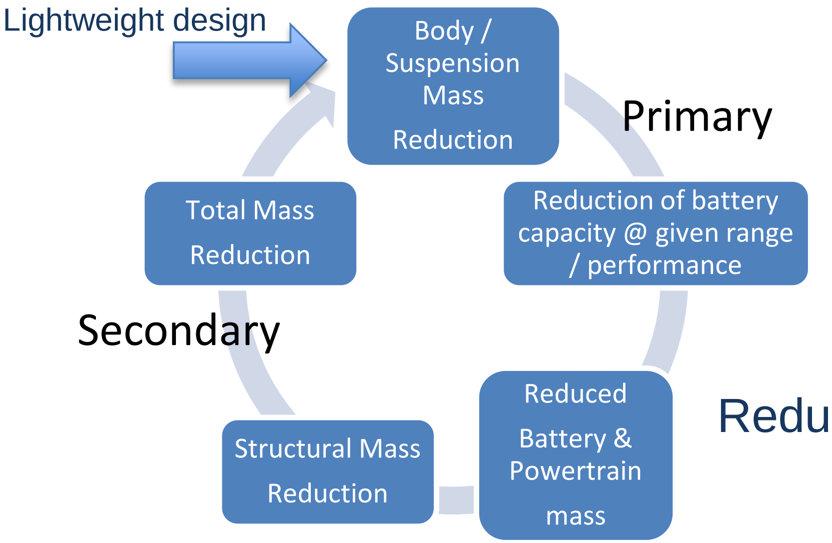
Lightweighting ***necessary*** to meet CO_2 targets of ICE vehicles

-100 kg = 8.5 gCO_2/km

Same level of safety and comfort



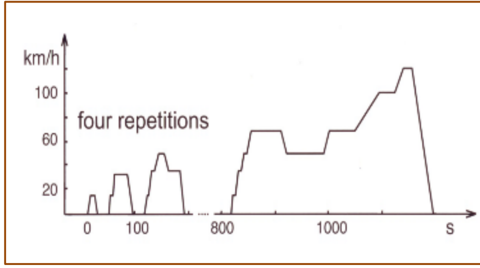
For electric vehicles ***necessary*** to improve the driving range



battery mass ≈ 7-10 * fuel tank (full) mass (0.1 kWh/kg)

Reduce battery size

Mechanical Energy (no recuperation)



vehicle mass

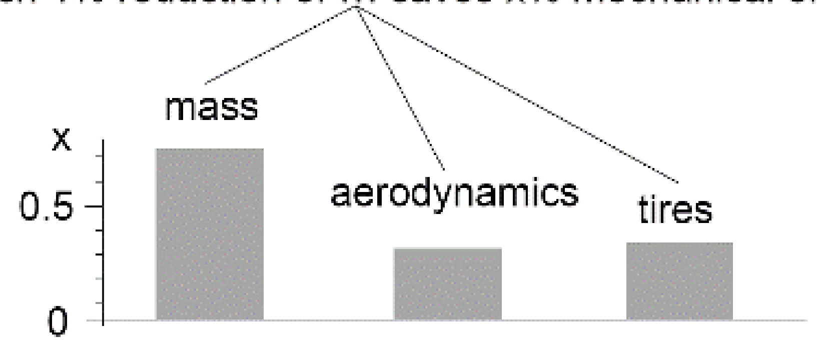
$$E \approx A_f \cdot c_w \cdot 19'000 + m \cdot c_r \cdot 840 + m \cdot 11 \quad kJ/100km$$

tires

aerodynamic shape

frontal area

Each 1% reduction of … saves x% mechanical energy



L.Guzzella, ETH

Drivability

Acceleration time 0→100 km/h

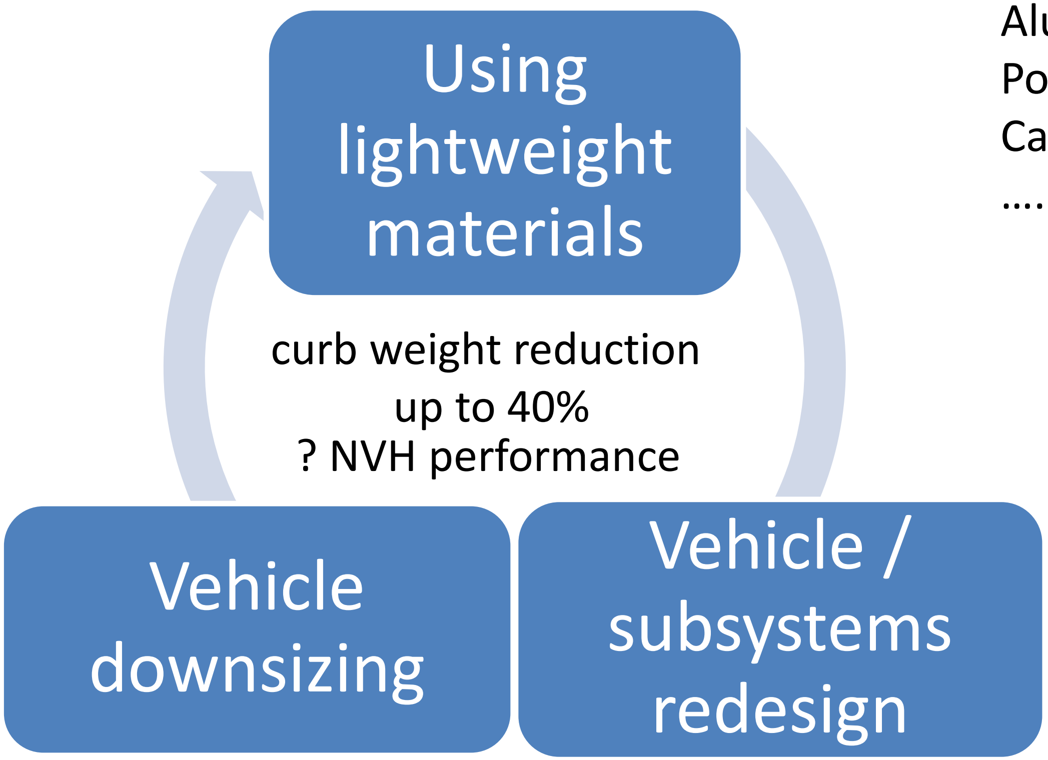
$$t_{0\to100} \approx \frac{770 \cdot m}{P_{\max}}$$

10% mass reduction

-10% time 0→100km/h

Lightweight design

High-strength steel (HSS)
Aluminum alloys
Polymer composites
Carbon fiber composites
….

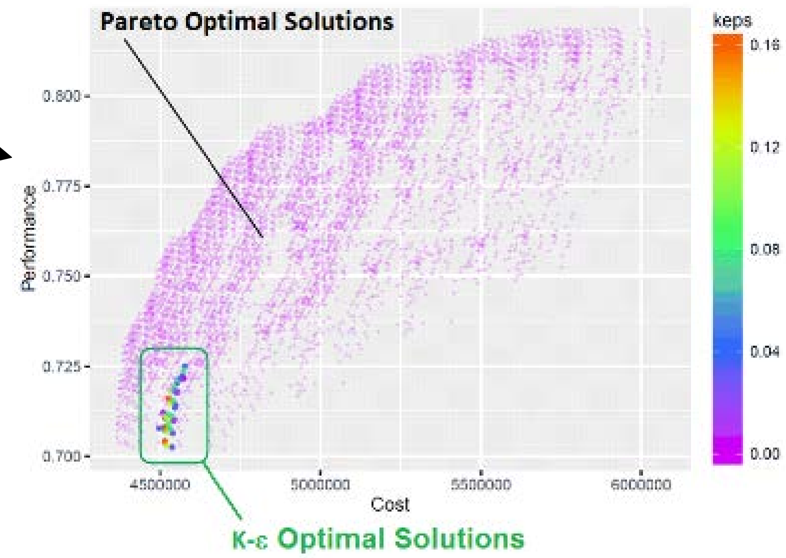


Optimised vehicle design (min mass)
Secondary weight savings
(same power-to-weight ratio)

Complex system multi-objective optimization

VEHICLE LEVEL

Target performance
Vehicle architecture definition



SUBSYSTEMS LEVEL

MULTI-OBJECTIVE OPTIMISATION

Suspension system
- Suspension arms
- Wheel carrier / hub
- Spring
- Damper
- Bump stops
- Bushings
- ……

COMPONENT LEVEL
- Suspension arm
  - Min mass
  - Min compliance
  - …..

Structural Optimisation

Methods

- *lexicographical approach*
- *hierarchical optimization*
- *analytical target cascading*
- *……*

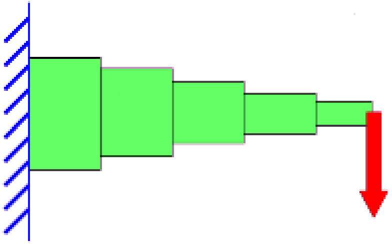
Structural Optimization

Single / multi-objective optimization

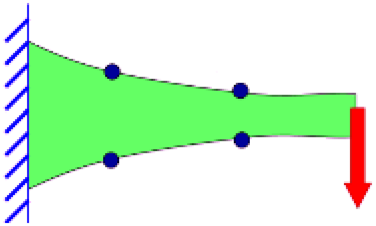
Finding the best "structural" design

Cantilever Beam

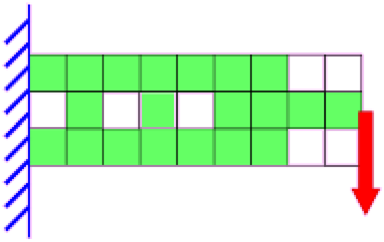
- **Size Optimization**
  DV: beams size



- **Shape Optimization**
  DV: position of control points



- **Topology Optimization**
  DV: density of each cell



Structural Optimisation – beam (size/shape)

Selection of material cannot be separated from the selection of the beam cross section

MULTI-OBJECTIVE OPTIMISATION

$$m = \rho A \quad [kg/m]$$

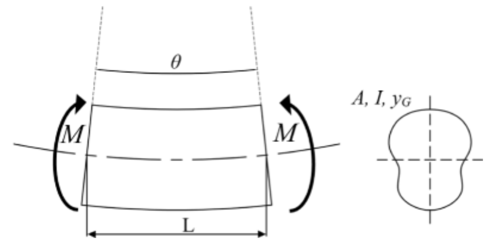
$$c = \frac{\theta}{L} = \frac{M}{EI} \quad [rad/m]$$

DESIGN CONSTRAINTS

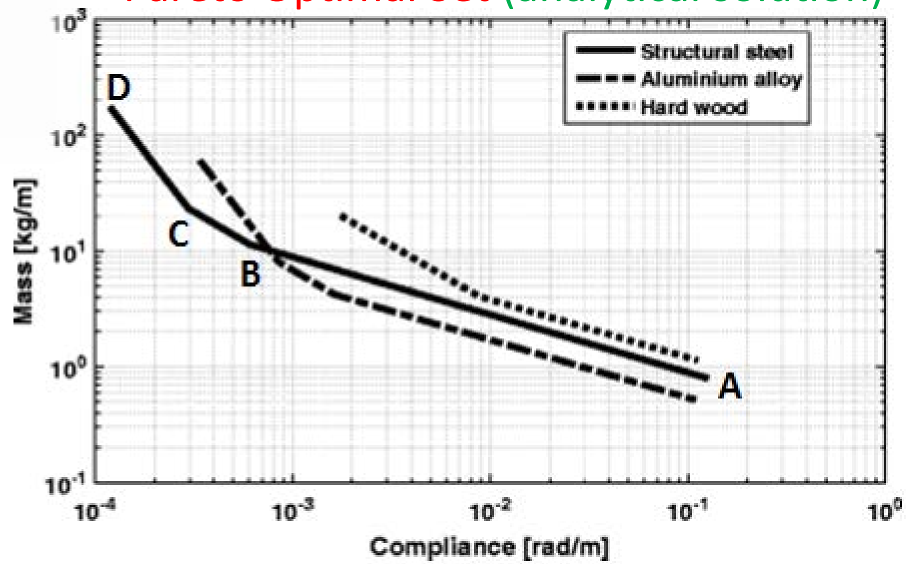
$$\sigma_{max} \leq \sigma_{adm}$$

$$\phi^e \leq \phi^e_{cr} \simeq 2.3\sqrt{\frac{E}{\sigma_{adm}}}$$

Cross section maximum dimensions

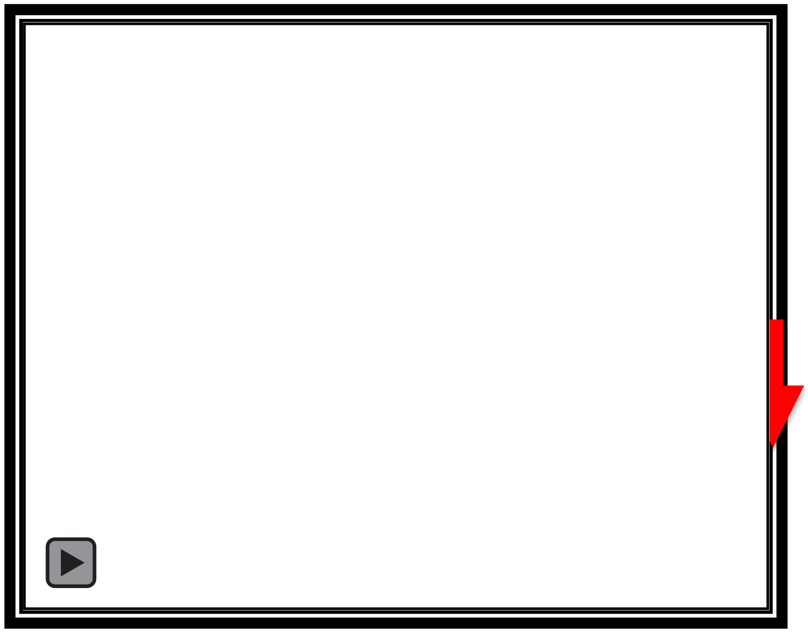


Pareto Optimal Set (analytical solution)

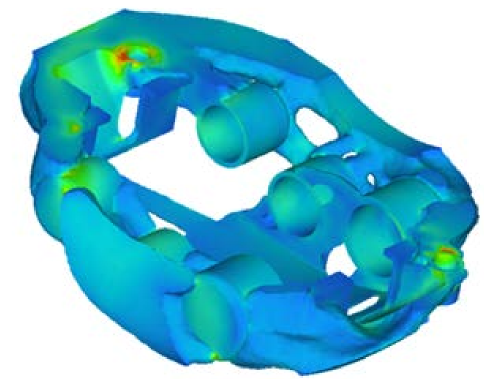


M. Gobbi, G. Previati, F. Ballo, G. Mastinu, Bending of beams of arbitrary cross sections - optimal design by analytical formulae, Structural and Multidisciplinary Optimization, 2017

Topology Optimisation

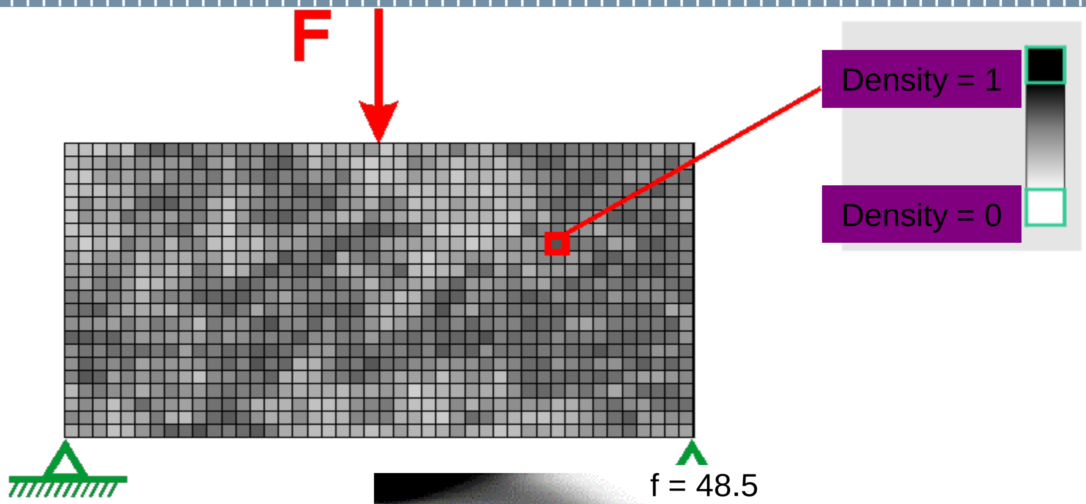


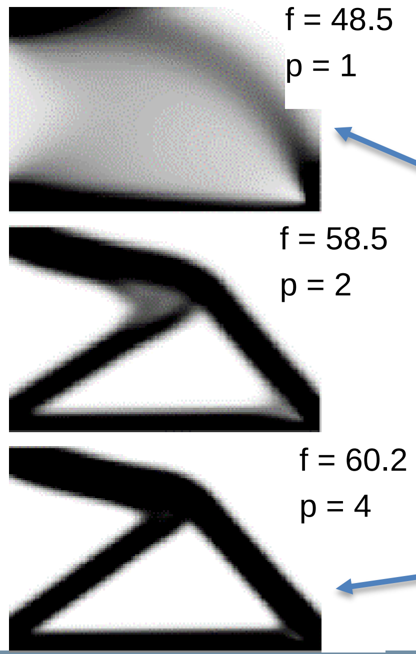
Up to 20% mass reduction



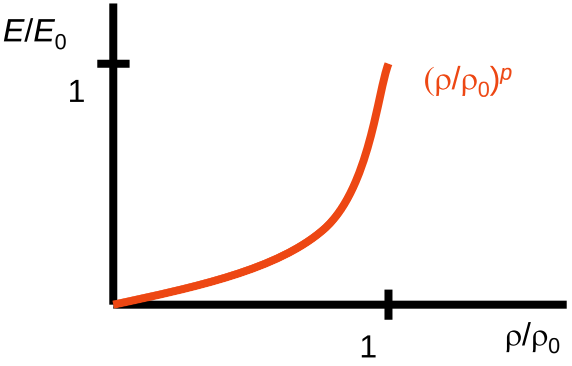
F. BALLO, M. GOBBI, G. MASTINU, A. PISHDAD "LIGHTWEIGHT DESIGN OF A BRAKE CALIPER", 2013 ASME IDETC/CIE 2013 August 4-7, 2013, Portland, Oregon, USA

Topology Optimisation SIMP





SIMP Method

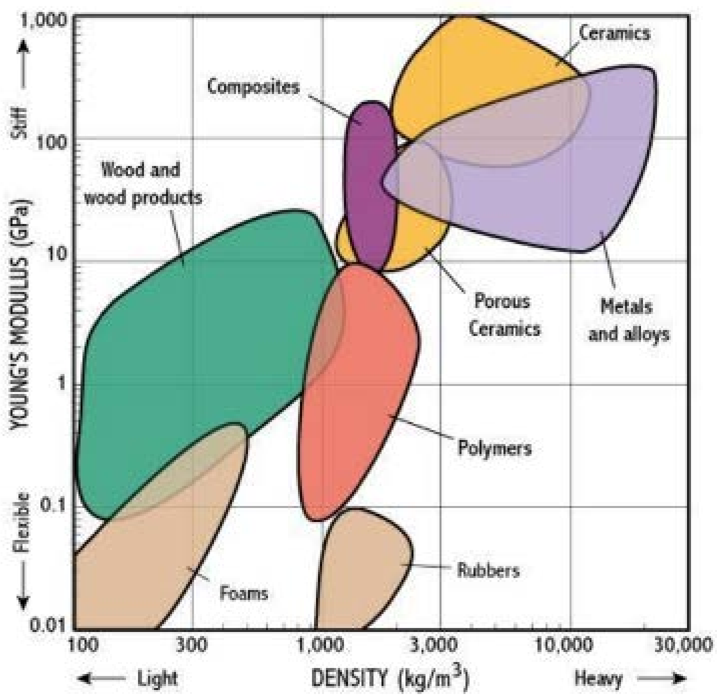


Map intermediate densities to lattice cells (small scale lattice structures - Metamaterial) with different volume fraction

SIMP penalizes intermediate densities (discrete void-solid designs)

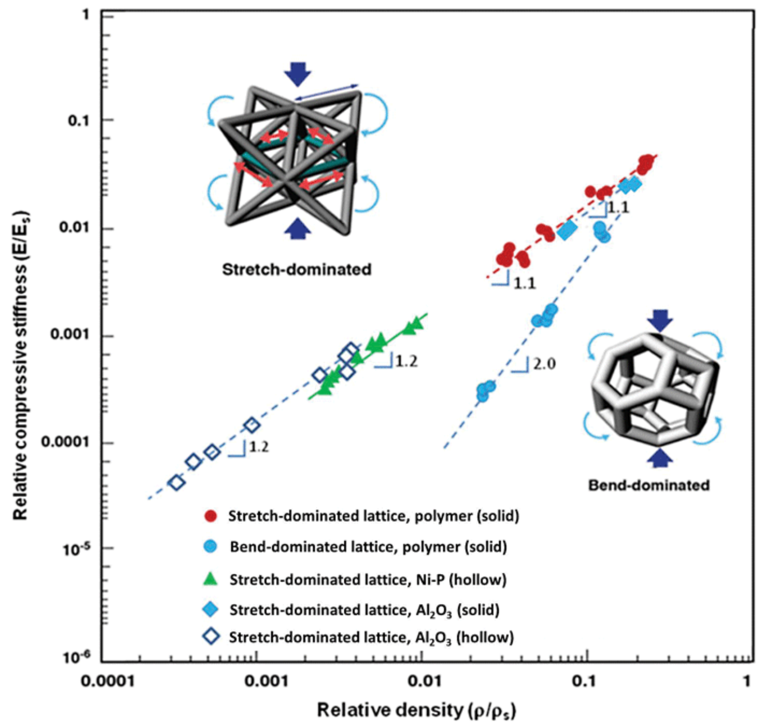
Structural Optimization and Lightweight Materials

Design of Materials vs Design with Materials



Multifunctional Metamaterials/Multimaterial

Develop unique properties not attainable in known materials



Materials for Lightweight solutions:

- Light metal alloys (Al, Mg, Ti,…)
- Composites
  - Continuous fibre reinforced
  - Discontinuous fibre reinforced
- New solutions (metamaterials, multifunctional)

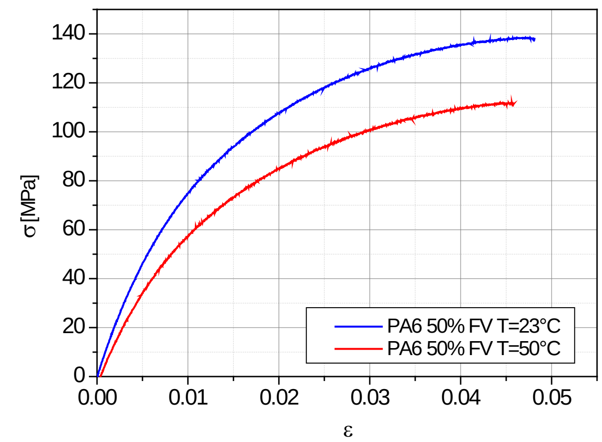
Impact on design:

- Simulation: need of simulation tools, also taking into account the manufacturing process
- Testing: experimental identification of mechanical properties
- Joining: need of solutions different from mechanical joining

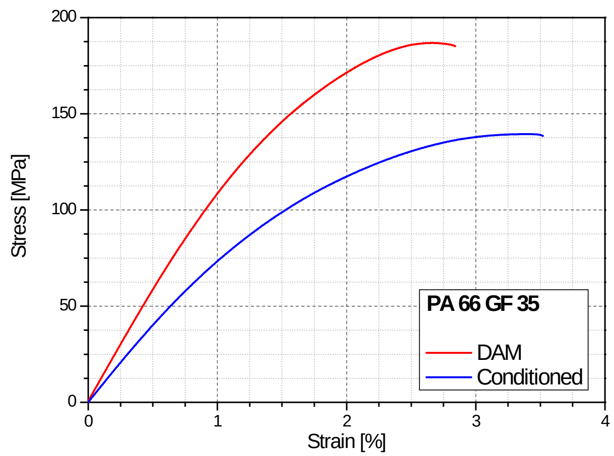
Testing: effect of temperature and humidity

Testing with special equipment is needed due sensitivity of Lightweight materials to:

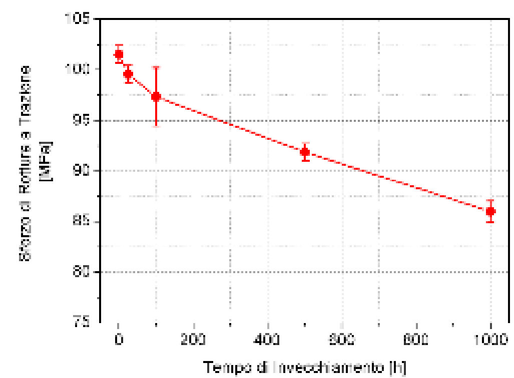
- Temperature



- Humidity

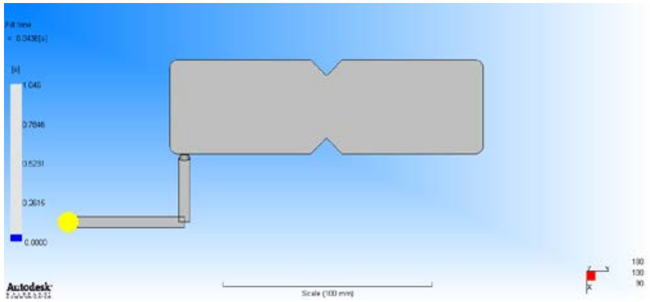


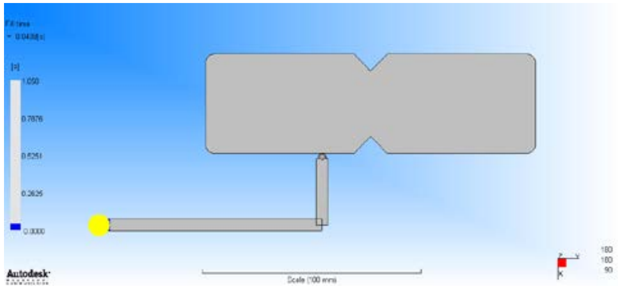
- Time (ageing and creep)

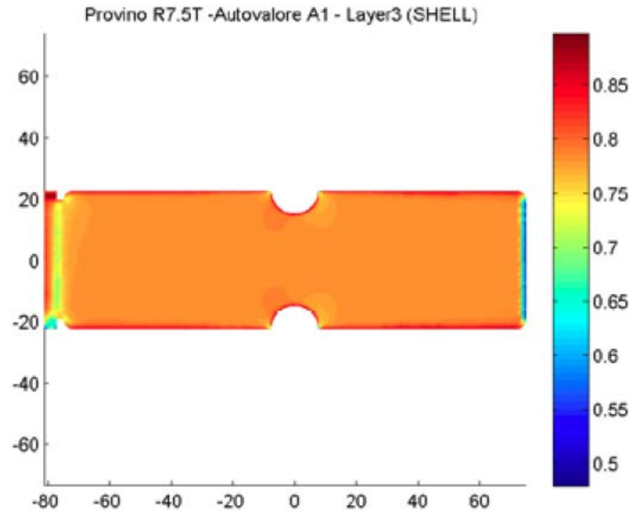


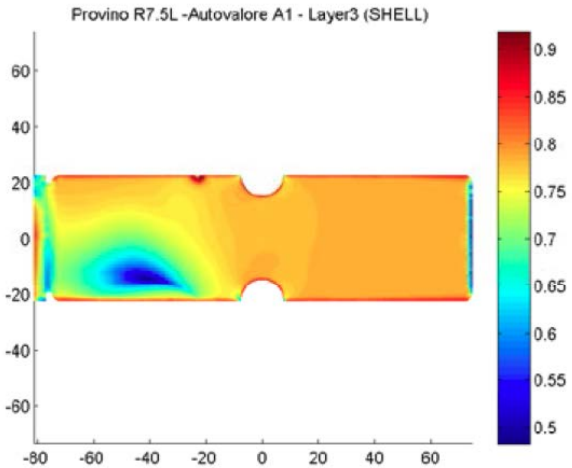
Simulation tools: TPM, Through Process Modelling

Effects of processing (e.g. fibre orientation in injection moulding) need being taken into account by TPM - Through Process Modelling



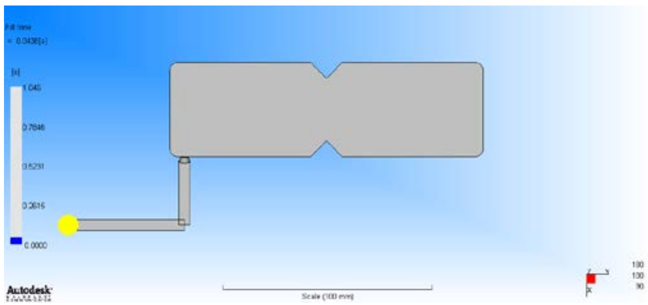


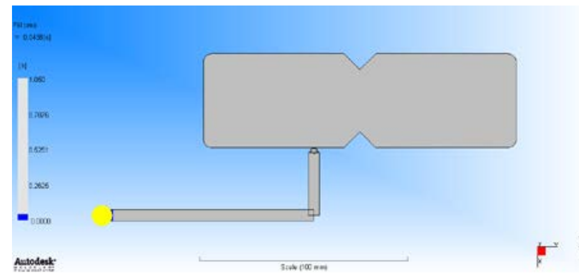


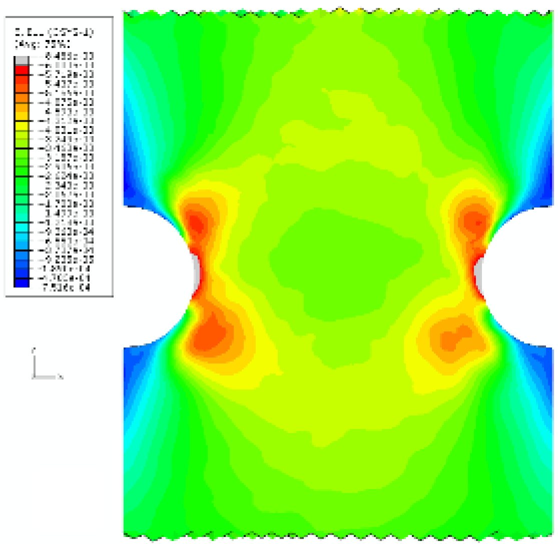


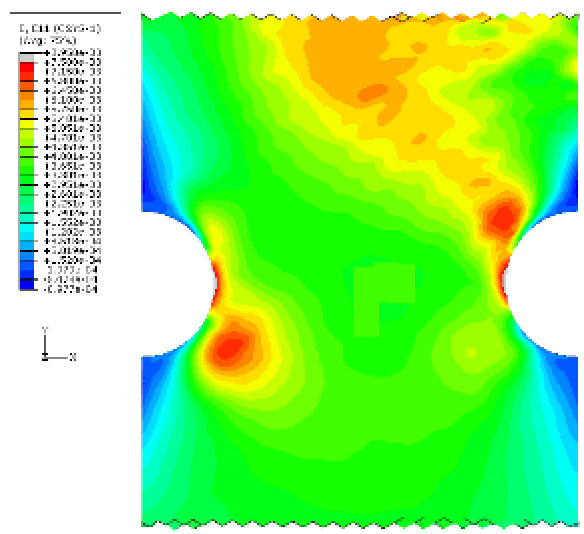
Simulation tools: TPM, Through Process Modelling

Different fibre orientation => different strain pattern (numerical)



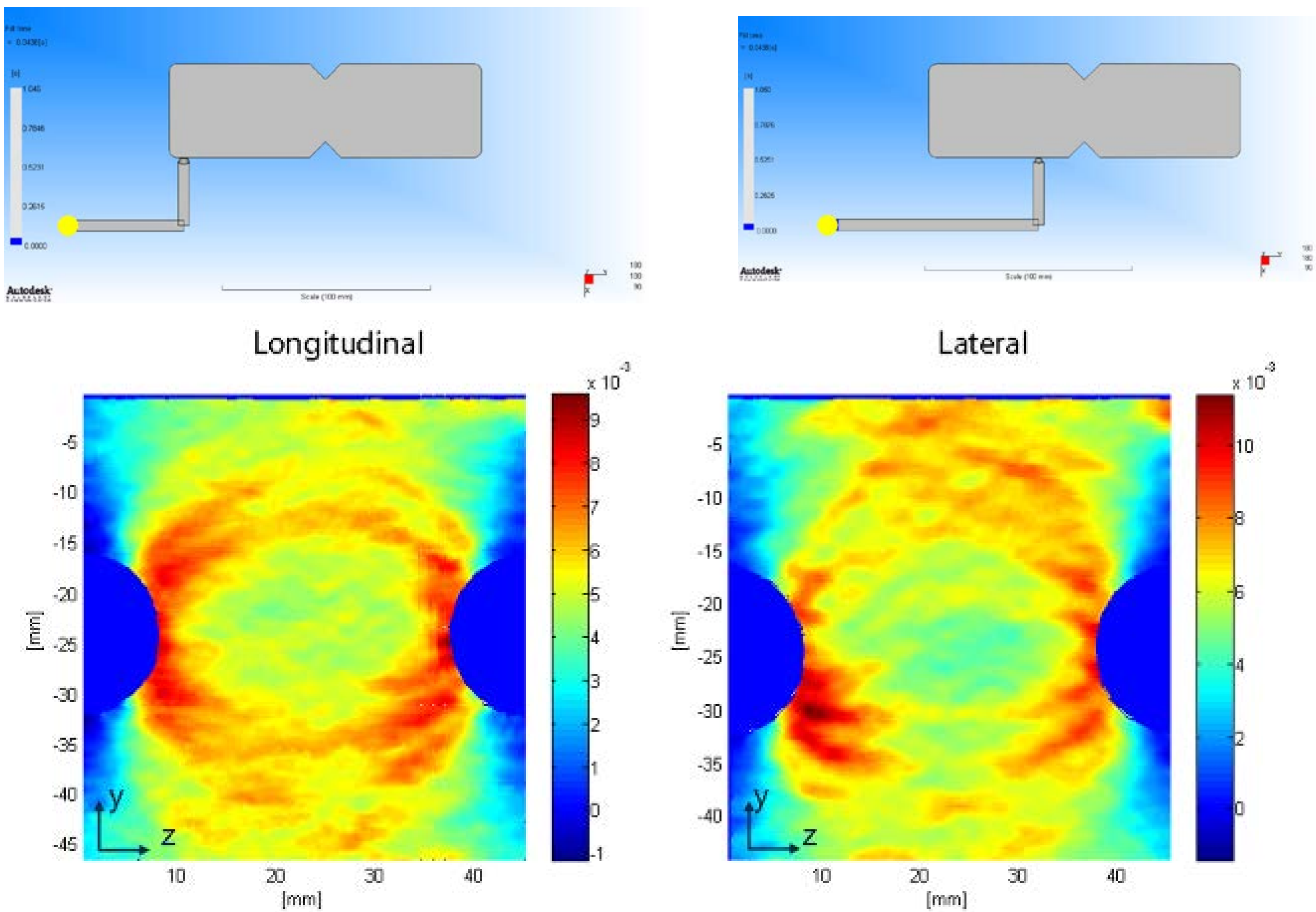




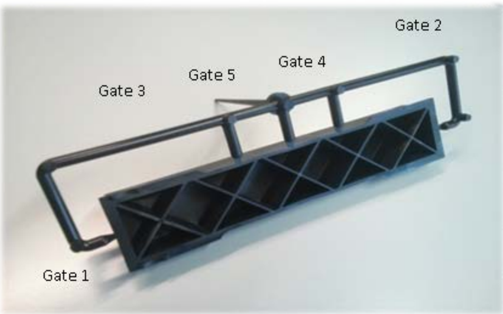


Simulation tools: TPM, Through Process Modelling

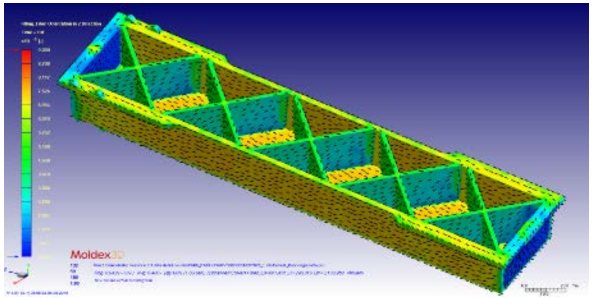
Different fibre orientation => different strain pattern (experimental)



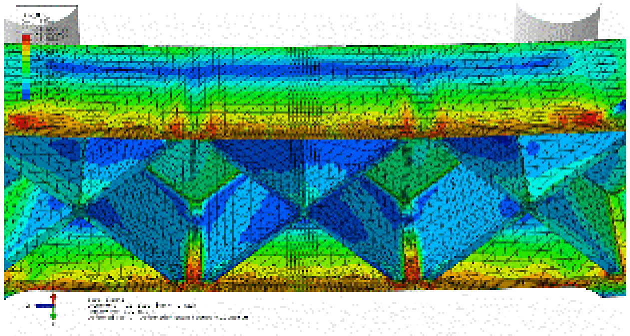
Simulation tools: example of workflow for IM parts



Process simulation

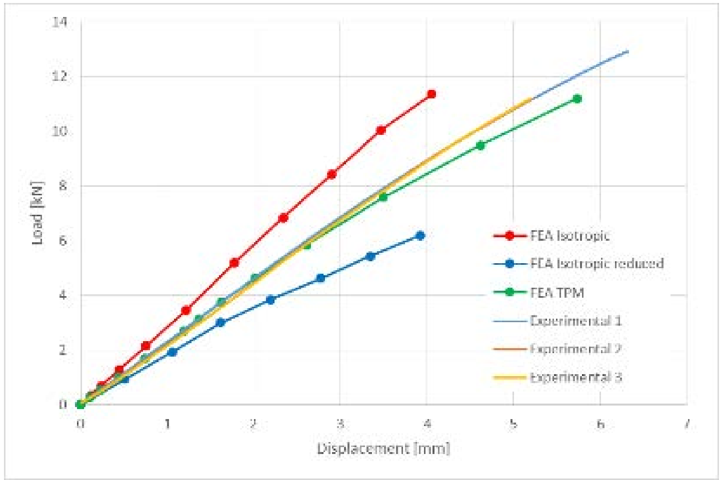


FEA with material's properties defined using process simulation



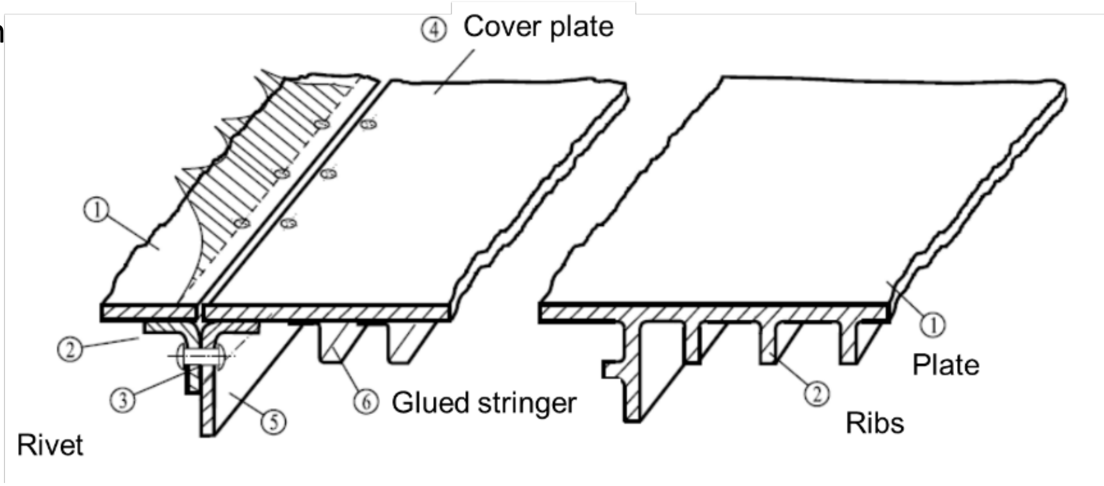
Testing

Testing vs Modelling

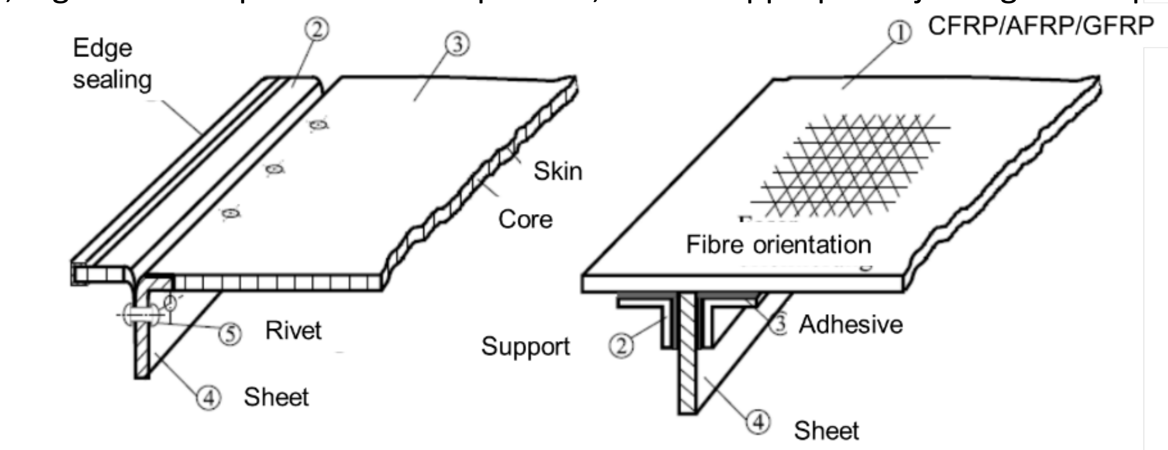


Joining solutions for lightweight design

Multi-part vs Integral Construction



Use of lightweight materials, e.g. sandwich panels and composites ,calls for appropriate joining techniques



Source: B. Klein. Leichtbau-Konstruktion. Vieweg+Teubner, 2009

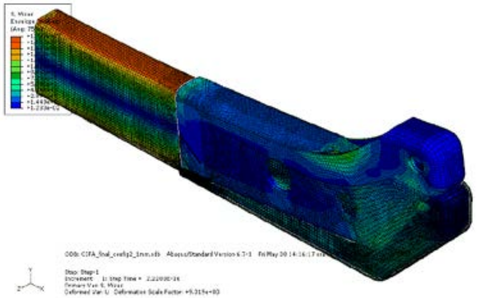
Example: CIFA Carbotech booms

Metal replacement => longer boom, lower weight

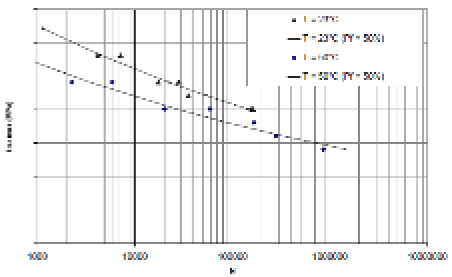
Metal replacement => new design solutions, new joining solutions

Example: metal replacement + adhesive bonding

Simulation

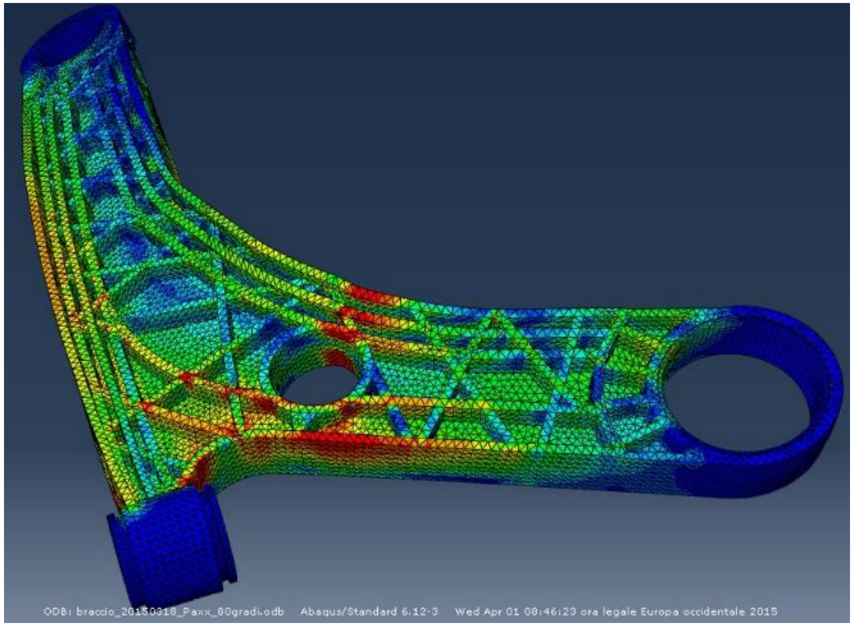


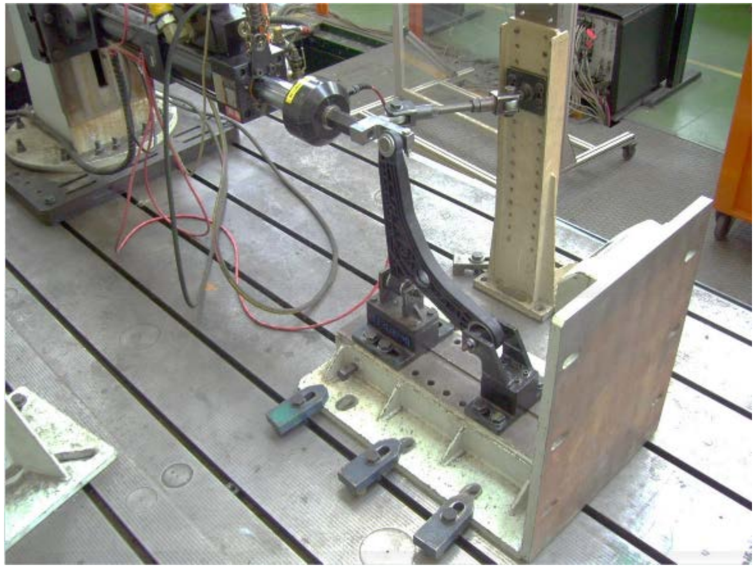
Testing



Manufacturing

“Bando R&S Regione Lombardia *SOSPENSIONI LEGGERE*”





Conclusion

- Lightweight design is currently in the spotlight
- A systematic approach for the development of optimized systems/components is required
- Design with and of new materials possible (*Hybrid, Metamaterial, …)*
- New technical issues. Special testing equipment required.

LiDuP
Lightweight Construction and Durability Performance

LIGHTWEIGHT CONSTRUCTION AND ADVANCED MATERIALS

Roberto Frassine, Maurizio Galimberti
CMIC - G. Natta Department

29 May 2017

COMPOSITE MATERIALS

Roberto Frassine

29 May 2017

Outline

- **Current issues on durability**
- **New developments and applications**
- **Opportunities from nanotechnology**

Durability of composites

- Many **successful applications** for over 60 years;
- Marine, aerospace, transportation and construction;
- Intrinsic **characteristics**: no rust, thermal stability, water resistance;
- Most **threatening** situations: combination of different weathering factors (e.g. Temperature and Humidity);
- **Consequences**: appearance (yellowing, colour fading, blooming, erosion) and performance (loss of strength).

Artificial wheatering

- Indoor/outdoor **accelerated** ageing and **field** testing;
- **Moisture** effects: thickness and integrity, careful material and processing selection;
- Cutting and **drilling** strongly discouraged.

Damage due to weathering

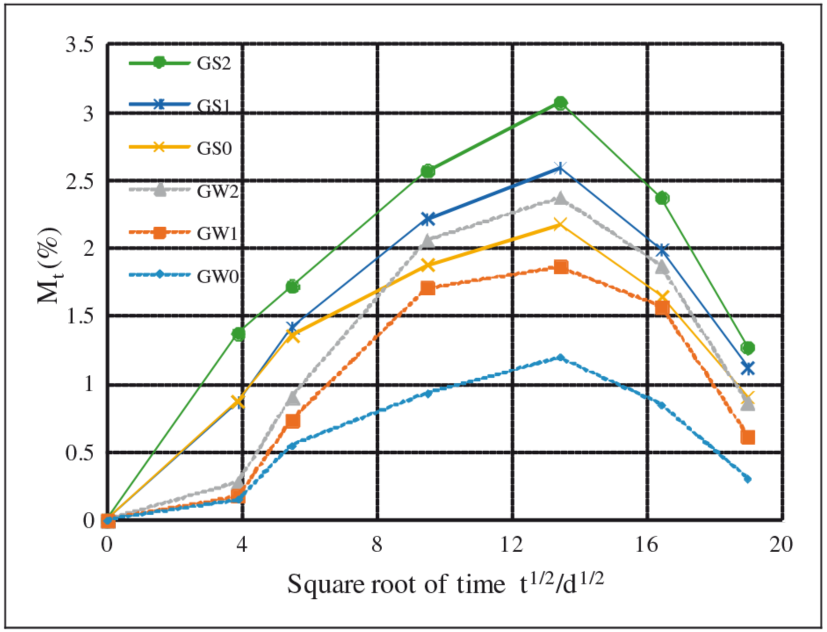


Figure 2. Water uptake curves of GFRP composites under different loading conditions.
GS0: specimens immersed in saltwater without loading, GS1: specimens immersed in saltwater and subjected to 10% ultimate tensile strength; GS2: specimens immersed in saltwater and subjected to 20% ultimate tensile strength; GW0: specimens immersed in tap water without loading; GW1: specimens immersed in tap water and subjected to 10% ultimate tensile strength; GW2: specimens immersed in tap water and subjected to 20% ultimate tensile strength.

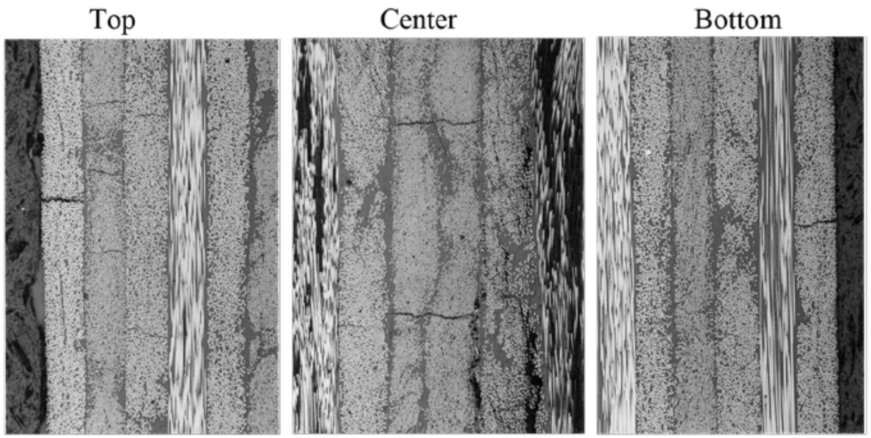


Fig. 7: Microcrack Detection in Aged Polyimide K3B after 3,300 hours (F-FOM1)

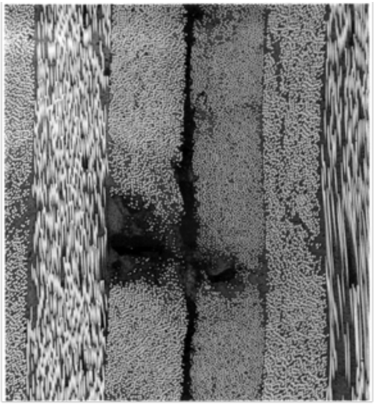


Fig. 10: Resin Matrix Degradation of Cyanate Ester after 2,393 hours (L-TMF3)

Damage and loading

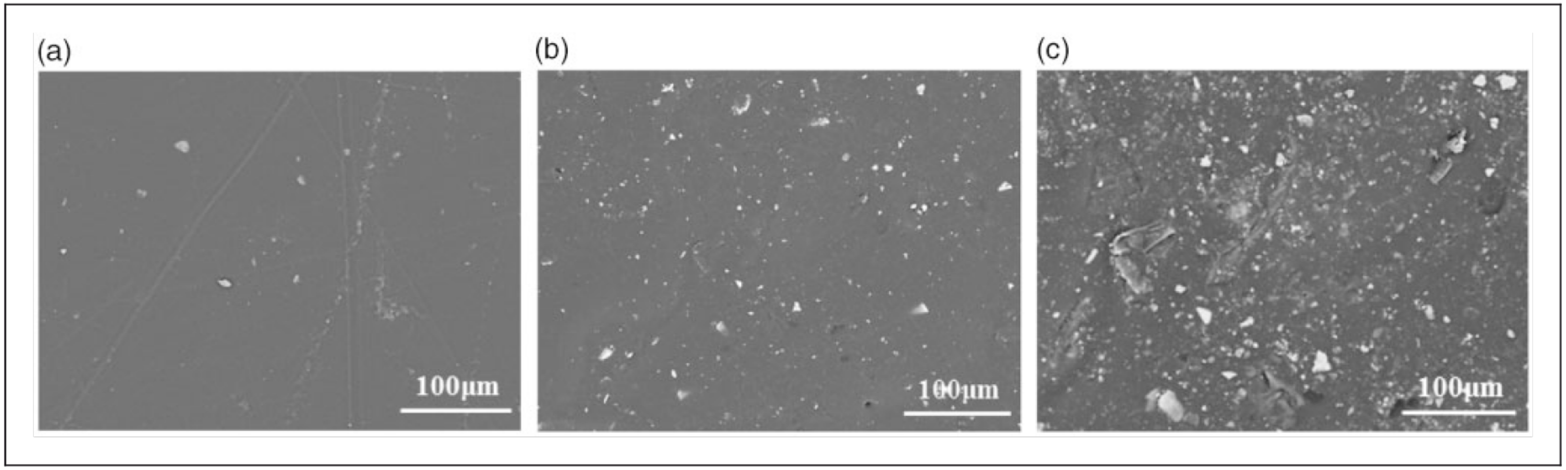


Figure 3. Scanning electron micrographs of the surfaces of specimen: (a) before immersion, (b) after immersion in saltwater for 90 days and subjected to 20% of ultimate tensile strength and (c) after immersion in saltwater for 180 days and subjected to 20% of ultimate tensile strength.

Weathering effects depends on composition

- GFRP strength may be severely affected by **alkaline** exposure;
- Other composites (CFRP) are more sensitive to strong **acids**;
- Stiffness is **less affected** except for very severe damage conditions;
- Strength also decreases at elevated **temperatures**;
- **Combined** sustained loading and environment may lead to very significant loss of strength in relatively **short times**.

Past, present and future

- Composites proved to be reliable, durable and performant since more than 60 years;
- In **5 years**: transportation (+6%) aerospace (+9%) and wind (+4%);
- In **20 years**: consumer goods, oil & gas, medical, civil engineering.

LiDuP
Lightweight Construction
and Durability Performance

LIGHTWEIGHT CONSTRUCTION AND ADVANCED MATERIALS

Maurizio Galimberti
CMIC - G. Natta Department

29 May 2017

☞ Sustainable materials

- Green chemistry

- ☞ Sustainable materials
  - Green chemistry
  - «Circular economy»

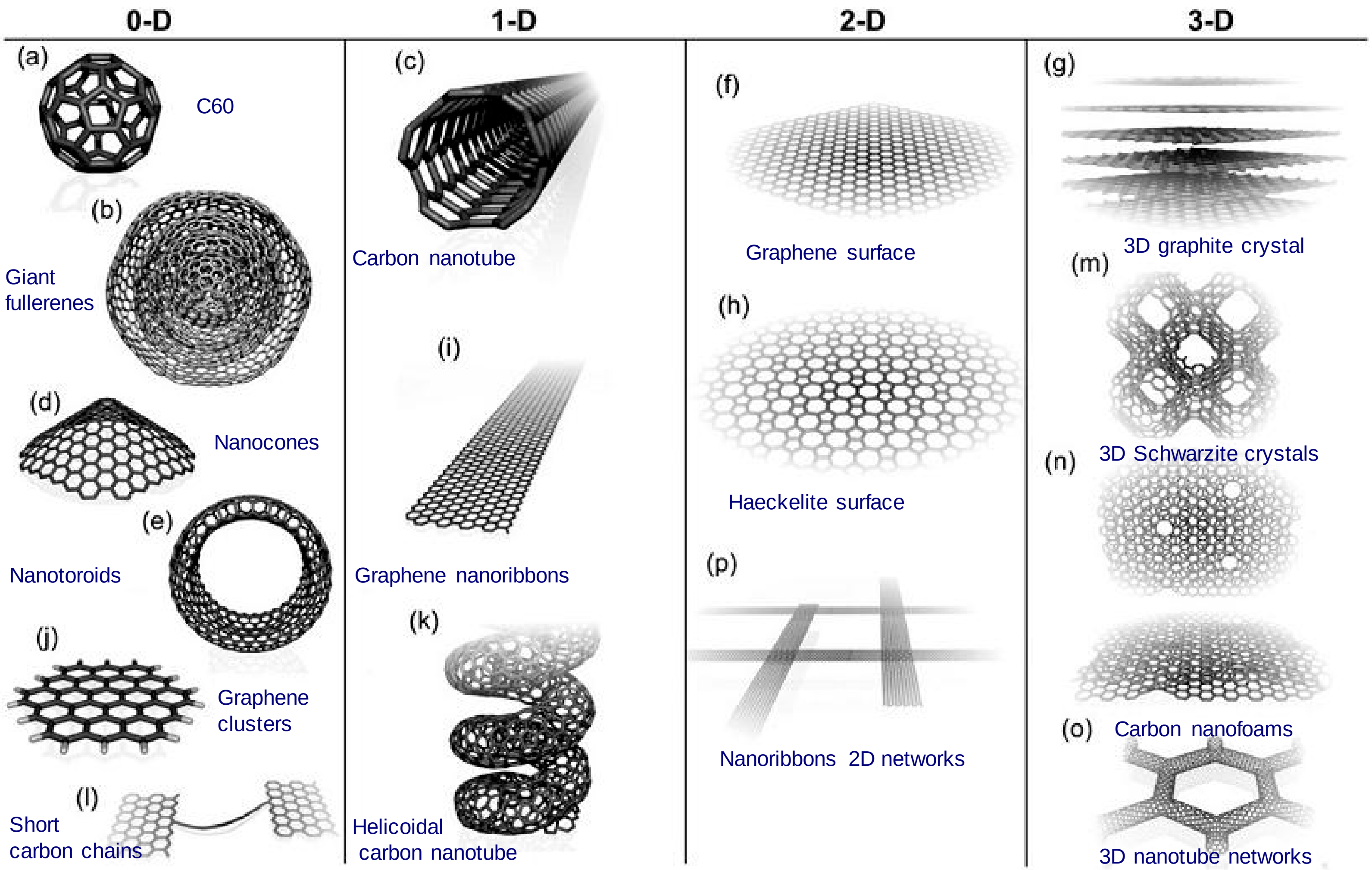
- ☞ Sustainable materials
  - Green chemistry
  - «Circular economy»

- ☞ Nanosize

- sp^2 carbon allotropes
  for the reinforcement of polymer composites

- Functionalization

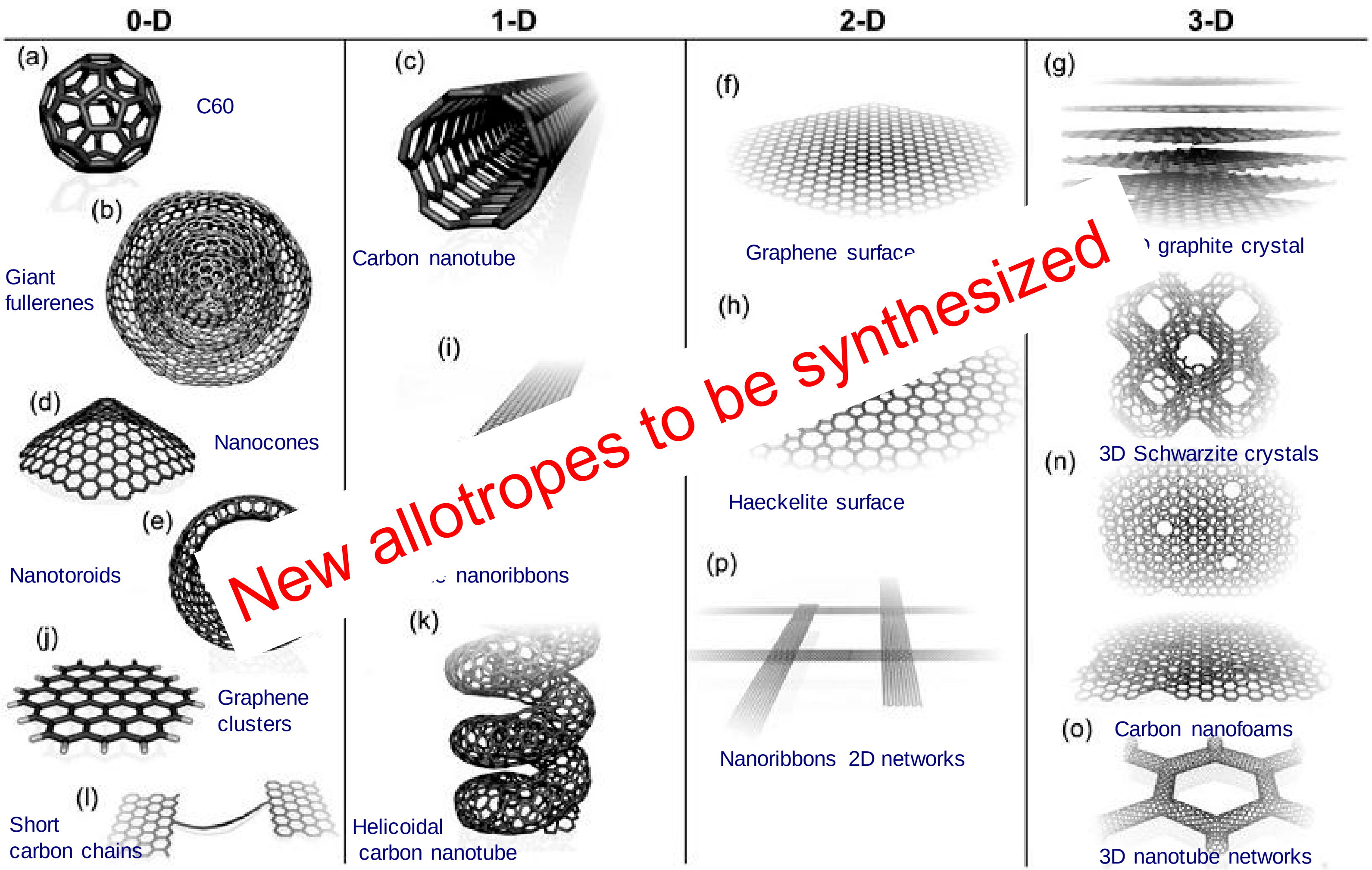
sp^2 carbon allotropes



M. Terrones, et al. Nano Today 5 (4) (2010) 351e372.

Jin Zhang et al, Carbon 98 (2016) 708e732

sp^2 carbon allotropes

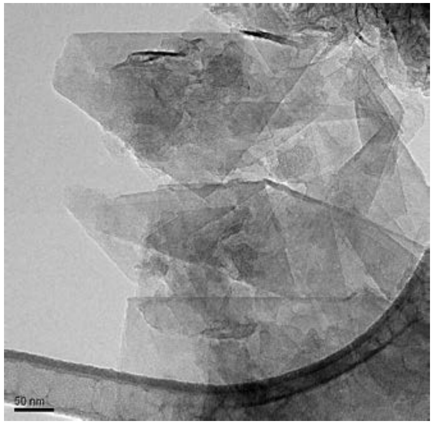


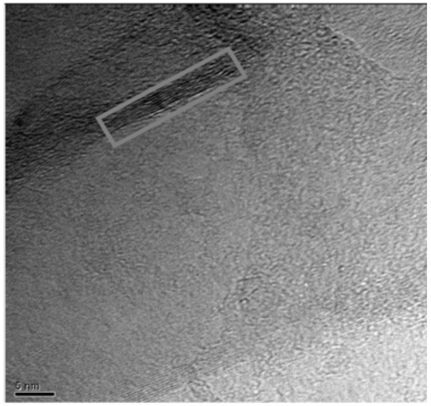
M. Terrones, et al. Nano Today 5 (4) (2010) 351e372.

Jin Zhang et al, Carbon 98 (2016) 708e732

sp^2 carbon allotropes: few layers graphene and carbon nanotubes

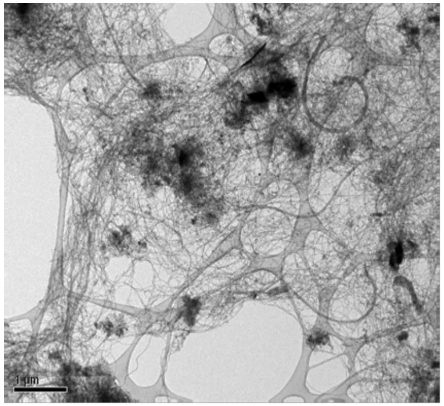
Few layers graphene

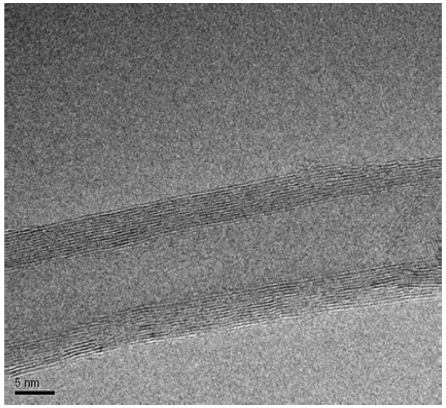




Carbon purity ≈ 98% (TGA), Surface Area (m^2/g) = 300 (BET)

Carbon nanotubes CNT

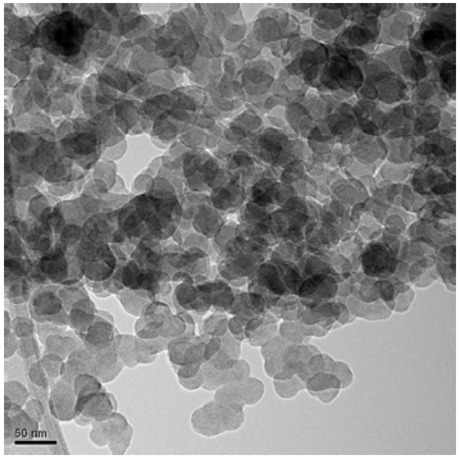


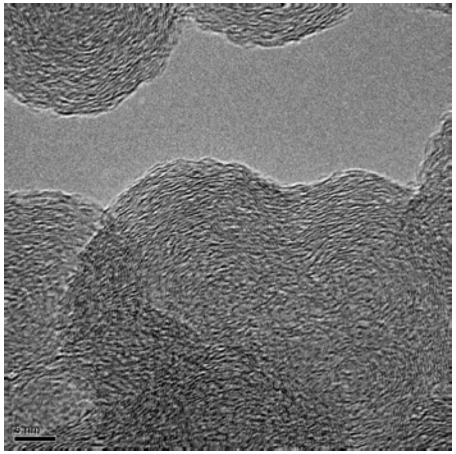


Carbon purity ≈ 90% (TGA), Surface Area (m^2/g) = 275 (BET)

sp² carbon allotropes: few layers graphene

Carbon black
CB





Carbon purity ≈ 98% (TGA) , Surface Area (m^2/g) = 77(BET)

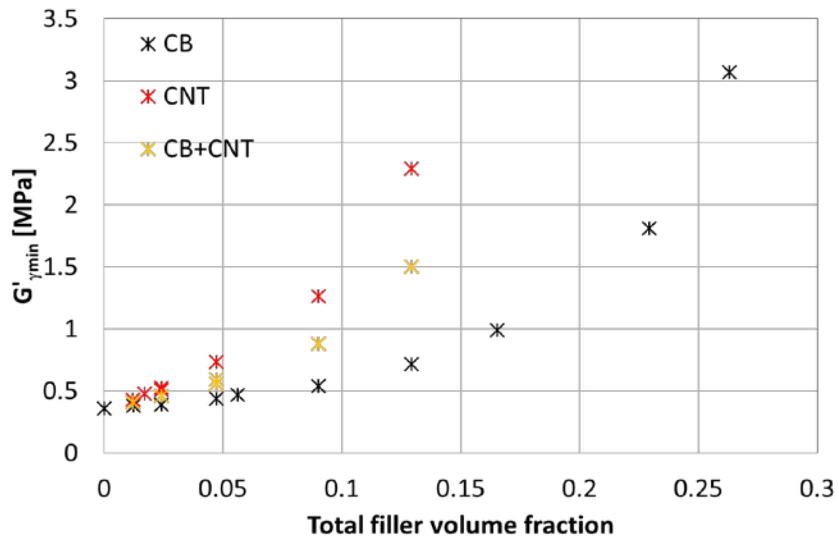
CB and CNT for the mechanical reinforcement of rubber

Isoprene rubber

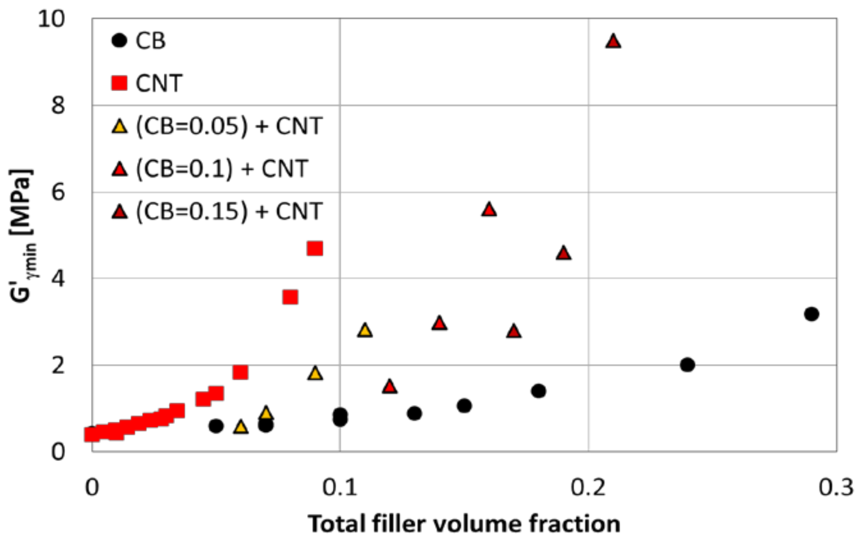
Styrene-butadiene rubber

CB and CNT for the mechanical reinforcement of rubber

Isoprene rubber



Styrene-butadiene rubber



Data from shear stress tests, 50°C

CB and CNT for the mechanical reinforcement of rubber

$$\text{Specific interfacial area} = A \cdot \rho \cdot \Phi$$

filler properties

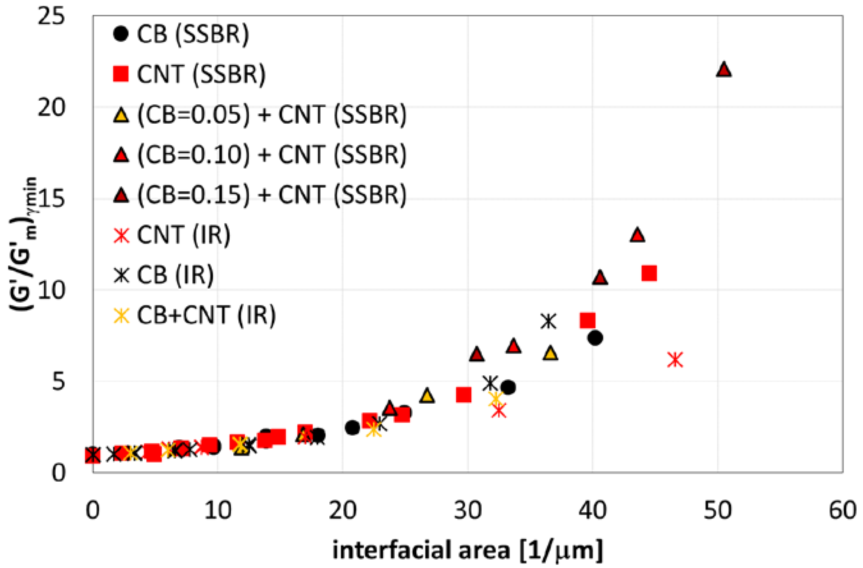
- A = BET surface area
- ρ = density
- Φ = volume fraction

measure unit: m^2 / m^3

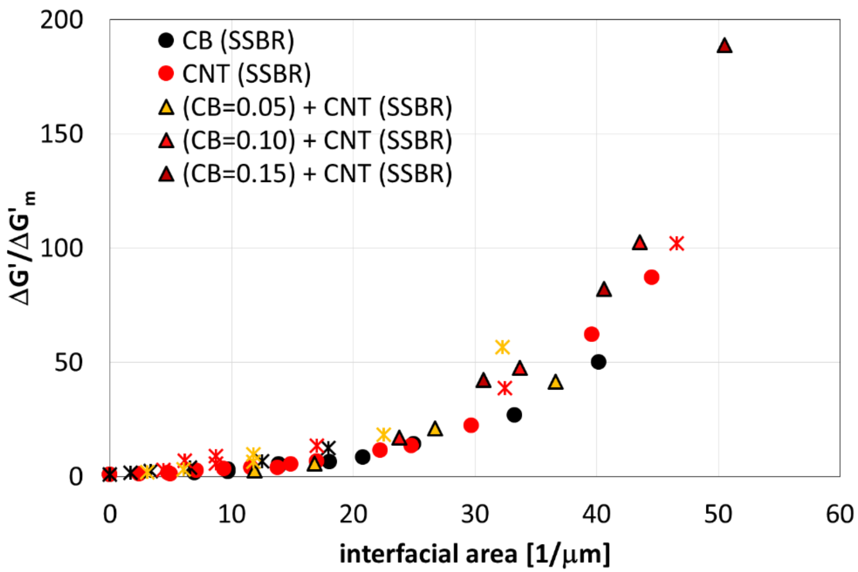
Surface / volume in the composite

Master curves for the mechanical reinforcement of rubber

G'



ΔG'

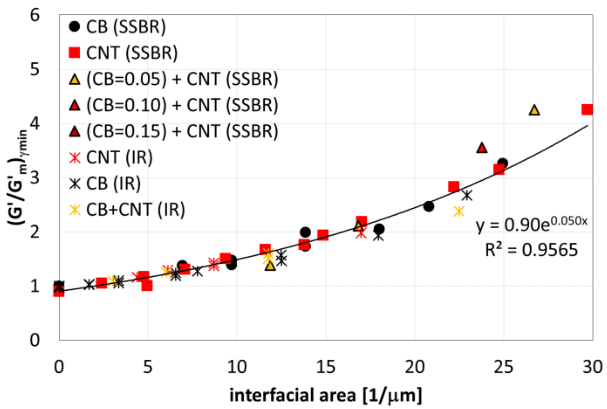


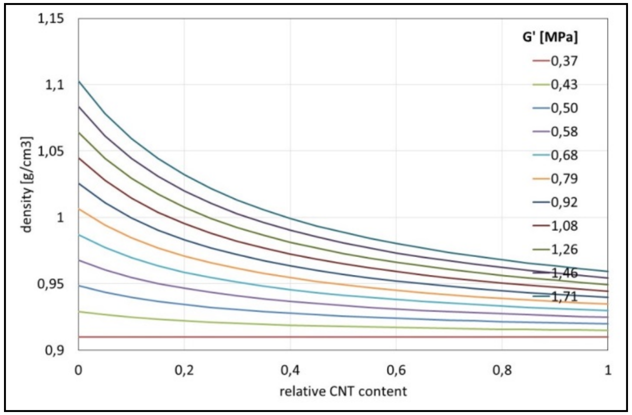
S. Agnelli, V. Cipolletti, S. Musto, M. Coombs, L. Conzatti, S. Pandini, T. Riccò, M. Galimberti, *eXPRESS Polymer Letters 8(6)* (2014) 436

S. Musto, V. Barbera, V. Cipolletti, A. Citterio, M. Galimberti, *eXPRESS Polymer Letters* Vol.11, No.6 (2017) 435–448

M. Galimberti, V. Cipolletti, S. Agnelli, S. Pandini, Rubber World, February 2017, 28-37

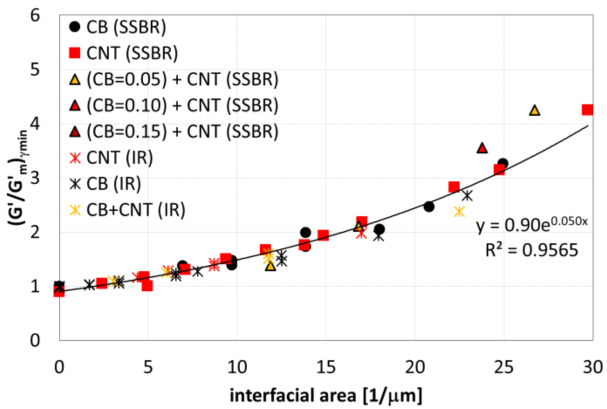
From master curves to lightweight materials



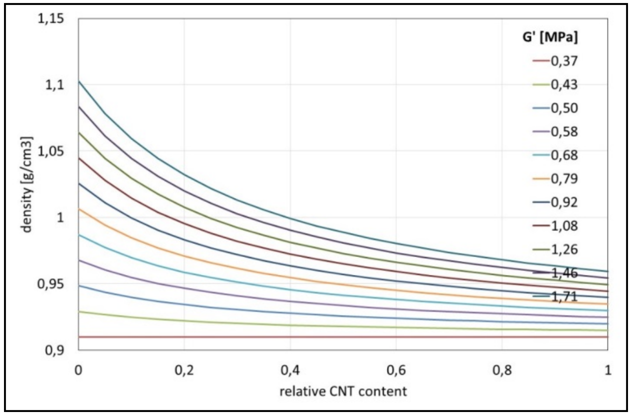


Relative CNT content $= \phi_{CNT}/(\phi_{CB}+\phi_{CNT})$

From master curves to lightweight materials



→



Relative CNT content = $\phi_{CNT}/(\phi_{CB}+\phi_{CNT})$

Target G' = 1,46 Mpa

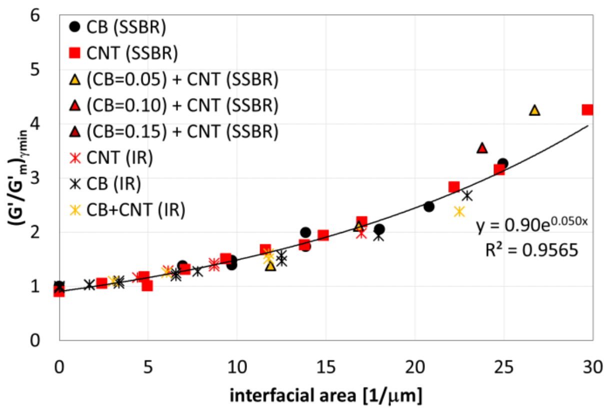
↓

% CNT in CB/CNT = 0

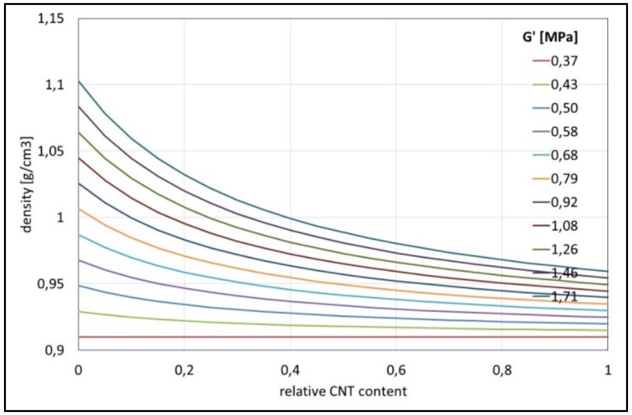
↓

density = 1.08

From master curves to lightweight materials



→



Relative CNT content = $\phi_{CNT}/(\phi_{CB}+\phi_{CNT})$

Target G' = 1,46 Mpa
↓
% CNT in CB/CNT = 0
↓
density = 1.08

Target G' = 1,46 Mpa
↓
Target density = 1
↓
% CNT in CB/CNT = 30

NanoCarbon Up

Politecnico technology for carbon materials functionalization

V. Barbera, A. Citterio, M. Galimberti, G. Leonardi, R. Sebastiano, S. U. Shisodia, A. M. Valerio WO 2015/189411 A1

M. Galimberti, V. Barbera, A. Truscello, R. Sebastiano, A. M. Valerio WO 2016/023915 A1

M. Galimberti, V. Barbera, R. Sebastiano, A. Citterio, G. Leonardi, A.M. Valerio WO 2016 050887 A1

M. Galimberti, V. Barbera, S. Guerra, L. Conzatti, C. Castiglioni, L. Brambilla, A. Serafini, RSC Adv., 2015, 5, 81142-81152

NanoCarbon Up technology for carbon materials functionalization

A + B / Carbon allotrope

↓

Mixing, energy

↓

↓

Functionalized carbon allotropes

NanoCarbon Up technology for carbon materials functionalization

- ☞ Sustainable
- ☞ Versatile: all types of carbon allotropes
- ☞ Tuning of solubility parameters of carbon allotropes
- ☞ Simple functionalization process
- ☞ Functionalization *in situ*, during composite preparation
- ☞ Five families of Patents

NanoCarbon Up technology for carbon materials functionalization

A + B / Carbon allotrope

↓

Mixing, energy

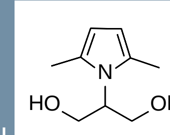
↓

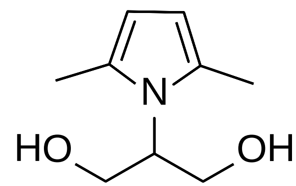
↓

Functionalized carbon allotropes

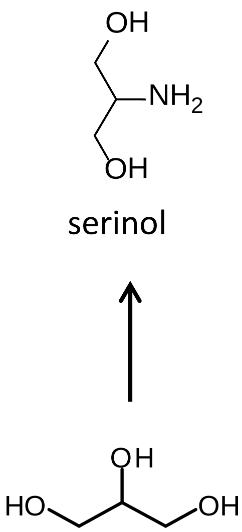
- Functional group:
  from few % to 20%
- Functionalization yield:
  from 85% to quantitative
- Covalent bond
  between functional group
  and graphene layer
- Bulk structure of graphitic materials:
  unaltered

Example: serinol pyrrole





Source



glycerol

Synthesis

Atom economy: 83%

Only byproduct: water

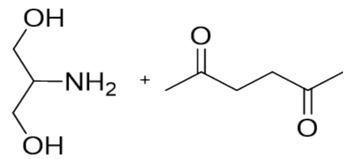
Yield: 95 - 99%

No solvent, no catalyst

In situ,

on the carbon allotrope

Example: serinol pyrrole

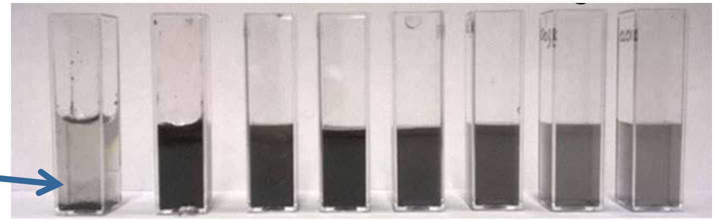


Carbon allotrope

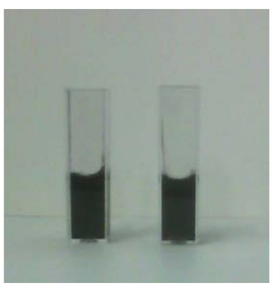
Mixing, energy

Functionalized carbon allotropes

without SP

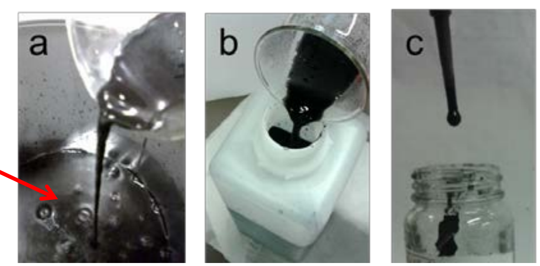


freshly prepared

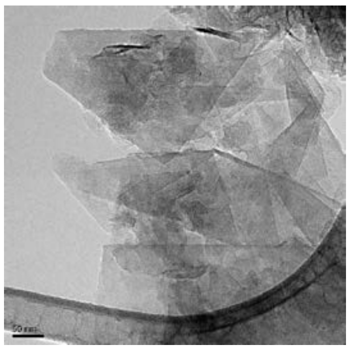


after 30 min centrifugation at 2000 rpm

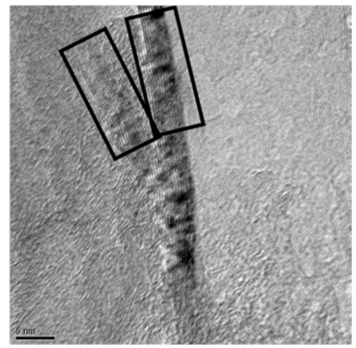
Large scale preparation



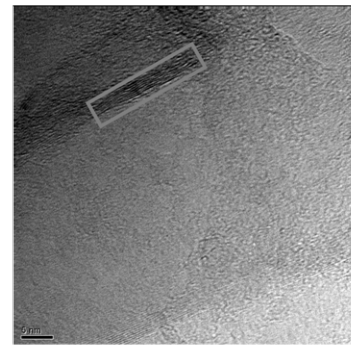
Conc (g/L): 10 g/L, 30 g/L 200 g/L.



TEM micrograph



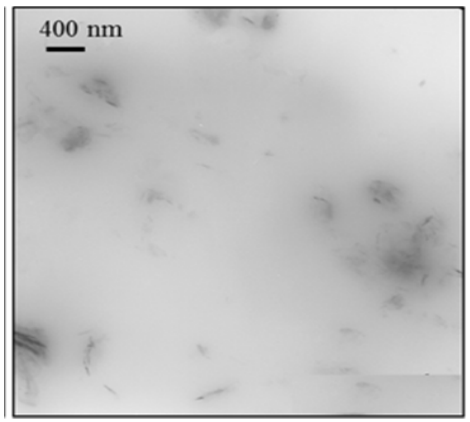
about 10-12
graphene layers

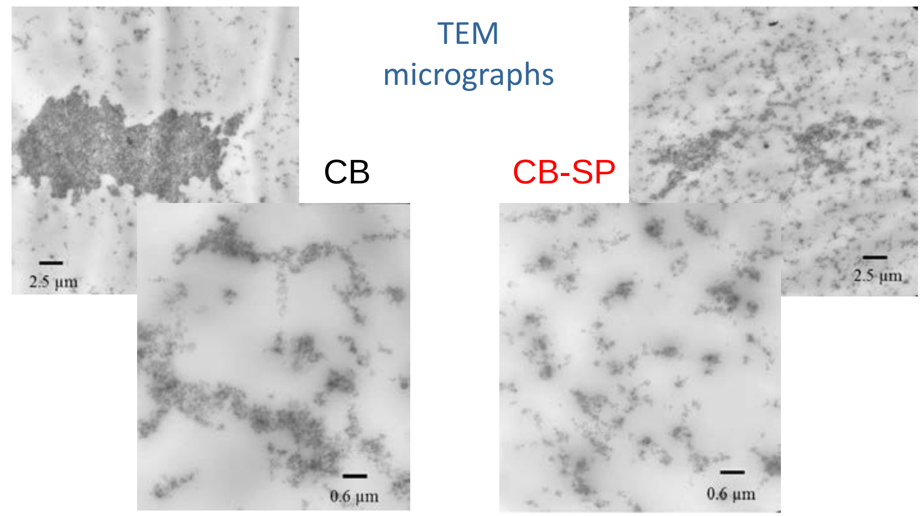


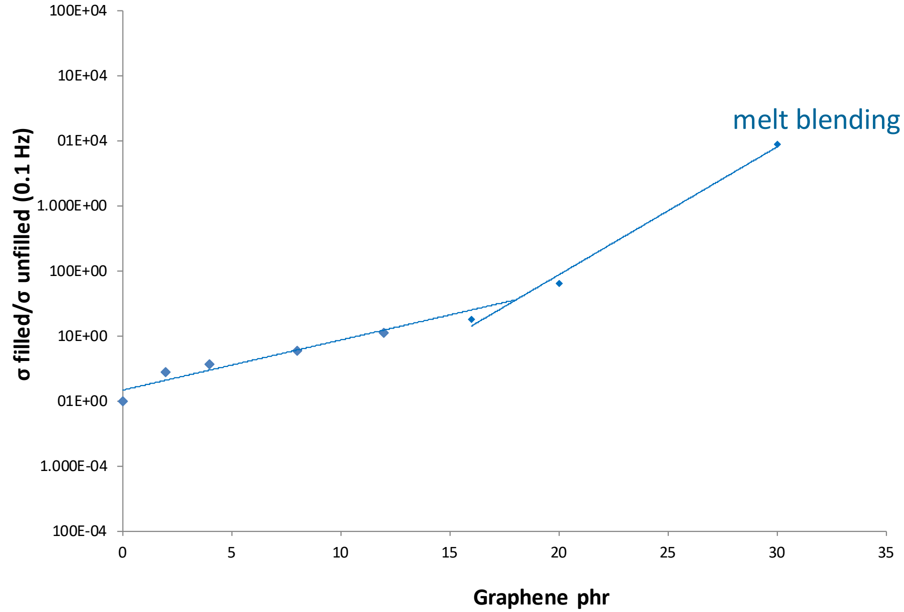
about 8
graphene layers

HR-TEM micrographs

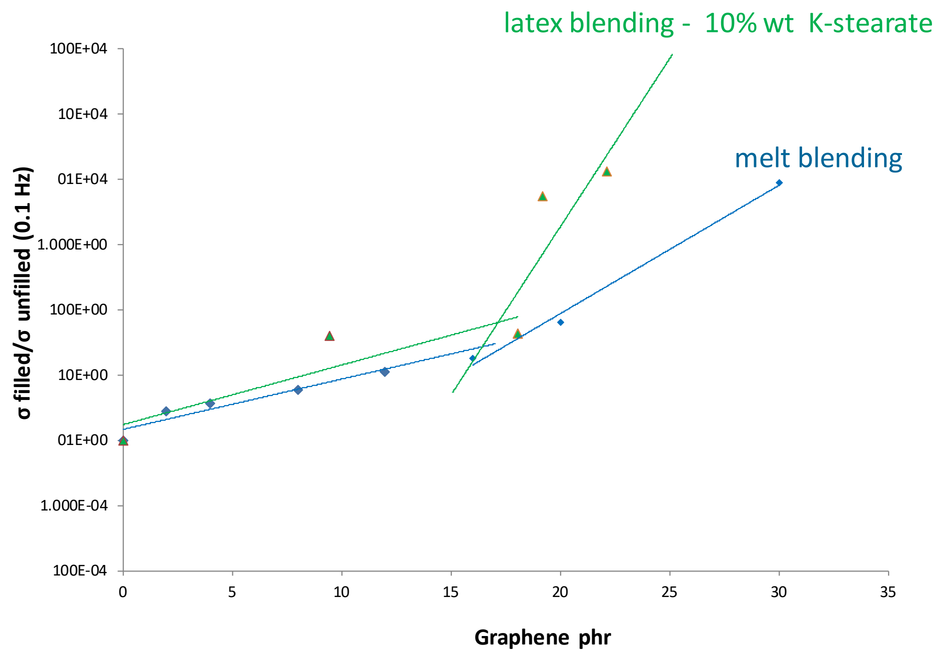
Nano-graphite + SP

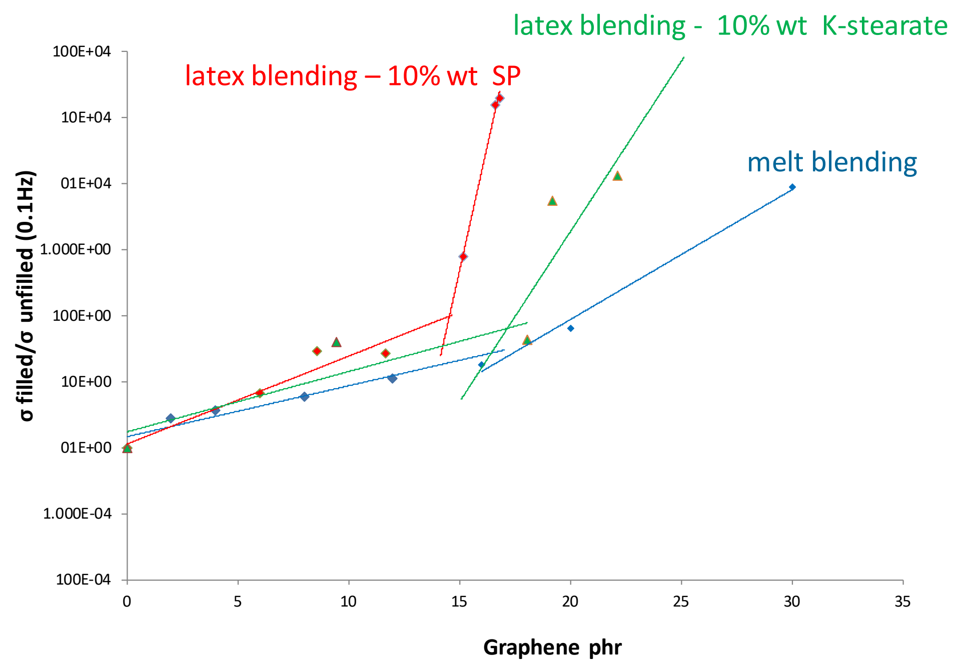






100E+04
10E+04
01E+04
1.000E+00
100E+00
10E+00
01E+00
1.000E-04
100E-04
σ filled/σ unfilled (0.1 Hz)
0
5
10
15
20
25
30
35
Graphene phr
melt blending


latex blending - 10% wt K-stearate
melt blending
σ filled/σ unfilled (0.1 Hz)
100E+04
10E+04
01E+04
1.000E+00
100E+00
10E+00
01E+00
1.000E-04
100E-04
0
5
10
15
20
25
30
35
Graphene phr



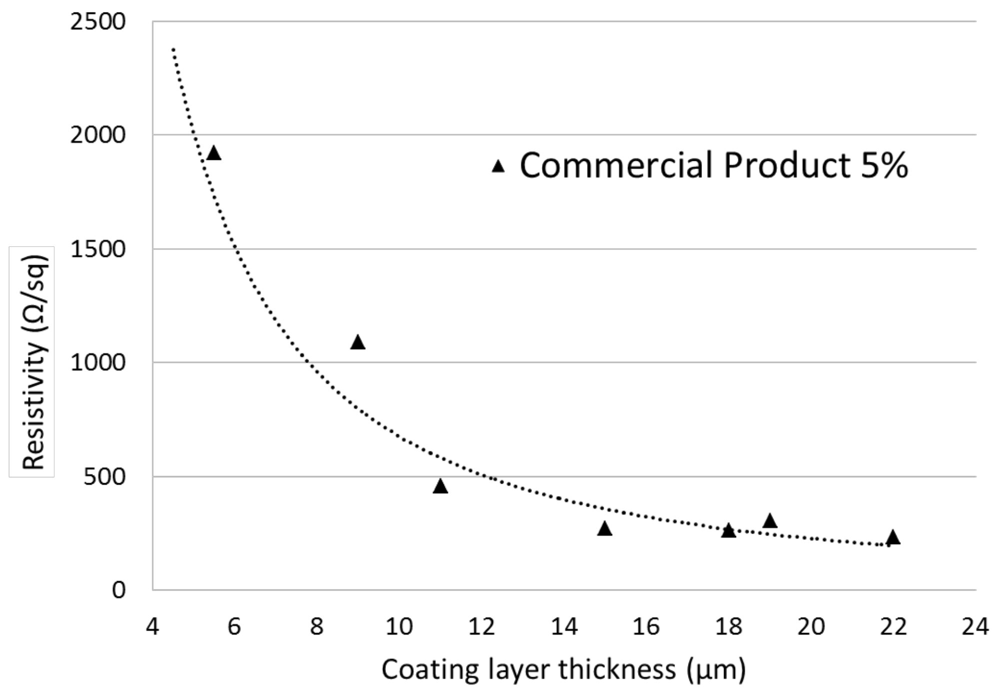
latex blending - 10% wt K-stearate
latex blending – 10% wt SP
melt blending
100E+04
10E+04
01E+04
1.000E+00
100E+00
10E+00
01E+00
1.000E-04
100E-04
0
5
10
15
20
25
30
35
σ filled/σ unfilled (0.1Hz)
Graphene phr

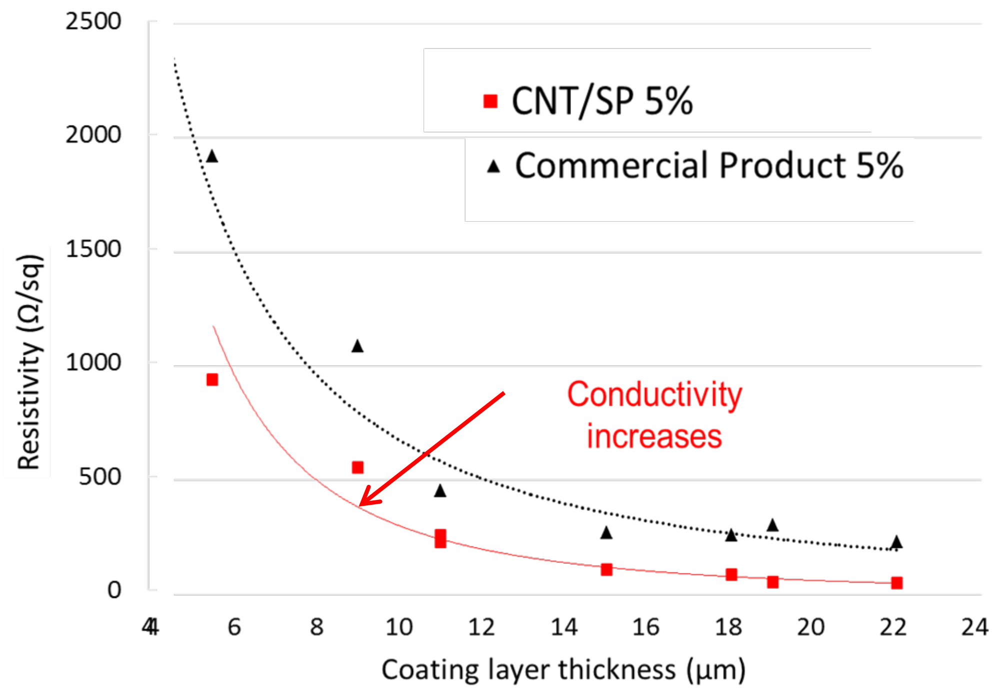
Large scale preparation

Nanographite-SP

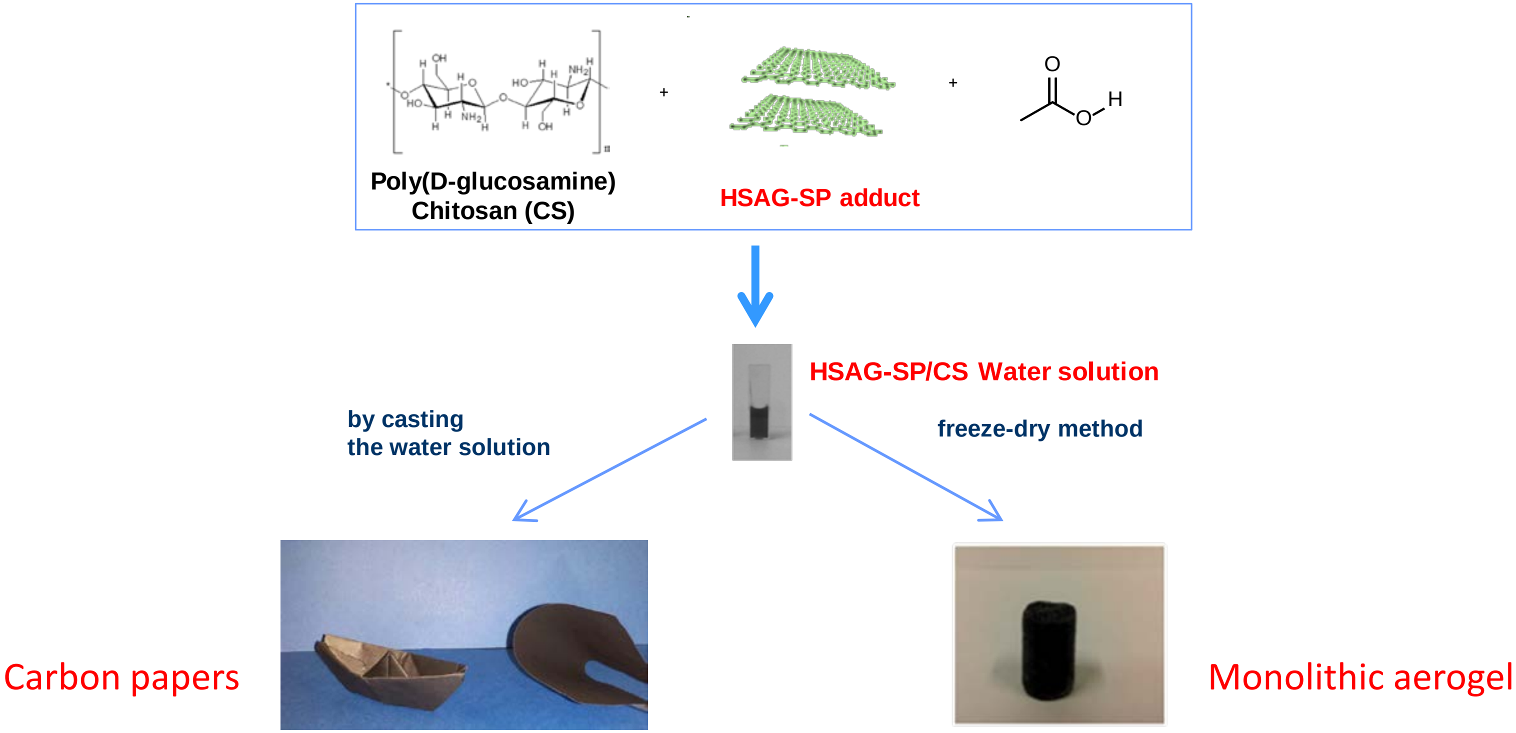
2% by mass in polyol

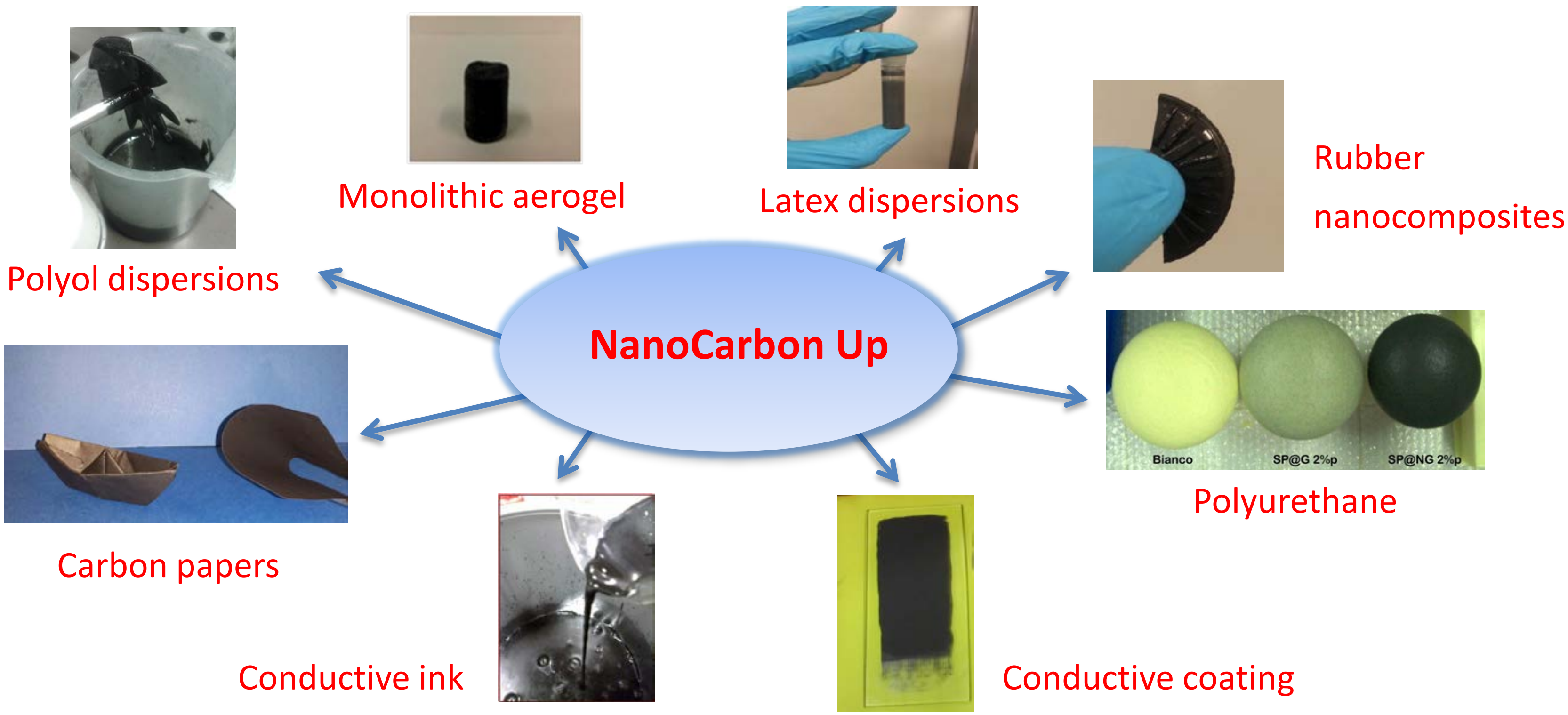
no nanoG nanoG nanoG-SP

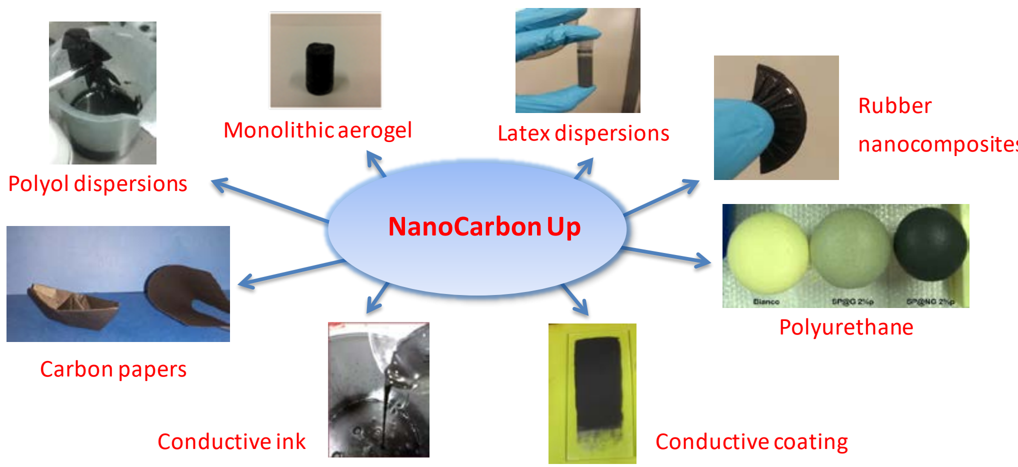

2500
2000
1500
1000
500
0
4
6
8
10
12
14
16
18
20
22
24
Resistivity (Ω/sq)
Coating layer thickness (μm)
Commercial Product 5%

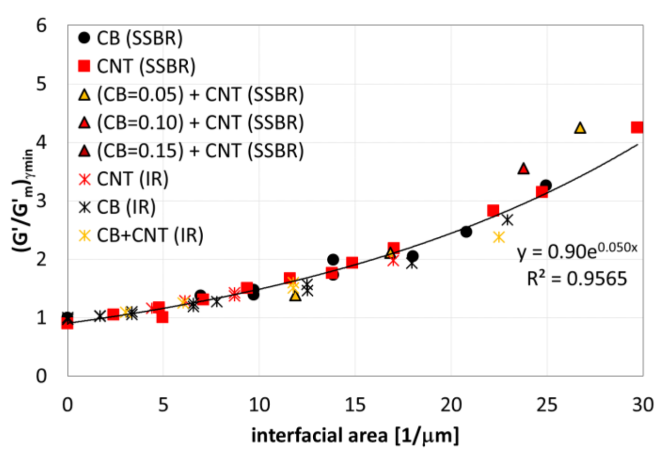


CNT/SP 5%
Commercial Product 5%
Conductivity
increases
Resistivity (Ω/sq)
2500
2000
1500
1000
500
0
4
6
8
10
12
14
16
18
20
22
24
Coating layer thickness (µm)


Poly(D-glucosamine)
Chitosan (CS)
HSAG-SP adduct
HSAG-SP/CS Water solution
by casting
the water solution
freeze-dry method
Carbon papers
Monolithic aerogel


NanoCarbon Up
Polyol dispersions
Monolithic aerogel
Latex dispersions
Rubber nanocomposites
Polyurethane
Bianco
SP@G 2%p
SP@NG 2%p
Carbon papers
Conductive ink
Conductive coating


NanoCarbon Up
Polyol dispersions
Monolithic aerogel
Latex dispersions
Rubber nanocomposites
Polyurethane
Carbon papers
Conductive ink
Conductive coating


CB (SSBR)
CNT (SSBR)
(CB=0.05) + CNT (SSBR)
(CB=0.10) + CNT (SSBR)
(CB=0.15) + CNT (SSBR)
CNT (IR)
CB (IR)
CB+CNT (IR)
$y = 0.90e^{0.050x}$
$R^2 = 0.9565$
$(G'/G'_m)_{\gamma min}$
interfacial area [1/μm]
0
1
2
3
4
5
6
0
5
10
15
20
25
30

LiDuP
Lightweight Construction and Durability Performance

POLITECNICO
MILANO 1863

CIVIL AND ENVIRONMENTAL ENGINEERING DEPARTMENT

Marco di Prisco & Anna Pandolfi

29 May 2017

Introduction

1) Prefabricated light-weight sandwich panels for façades: a energy performance improvement of residential buildings

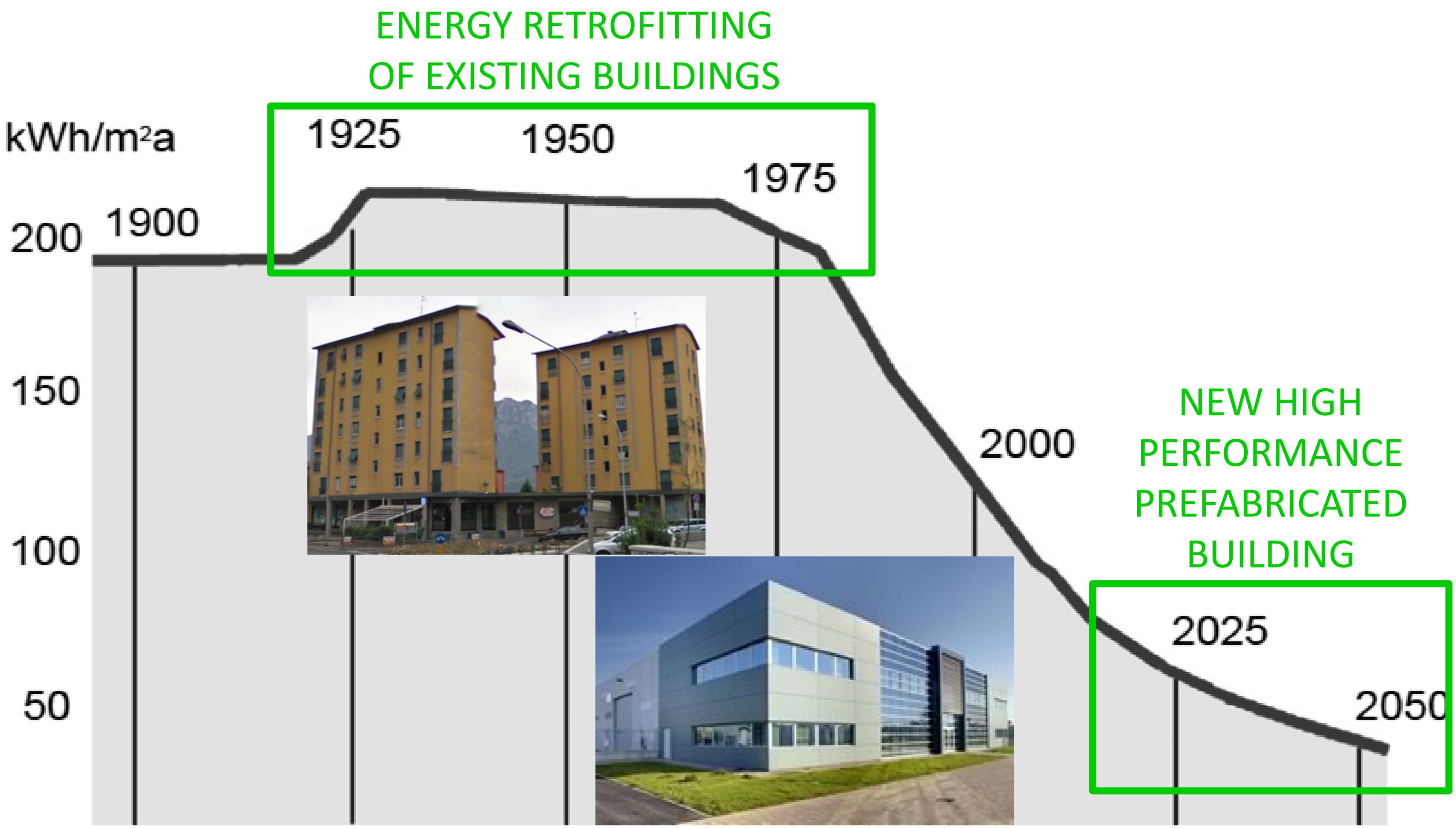
2) Prefabricated light-weight HPFRC roofing: a synergic retrofitting of commercial/industrial building

3) FRCM for seismic retrofitting: which durability?

4) Metaconcrete: a resonant metamaterial with enhanced performance under dynamic loading with has been developed, tested and patented (In collaboration with Caltech).

1. Energy performance improvement by sandwich panels

TRC prefabricated façade sandwich panel for energy retrofitting of existing buildings



1. Energy performance improvement by sandwich panels

Politecnico di Milano ⟷ Research institutes ⟷ 18 partners (9 countries) ⟷ Enterprises ⟷ Magnetti Halfen Stam

ABC

EASEE

Envelope Approach to improve Sustainability and Energy efficiency in Existing multy-storey multy-owner residential buildings

- Inner insulation layer
- Cavity wall insulation layer
- <u>Outer insulation layer</u>

Prefabricated prefinished and insulated modular panels, keeping the original appearance of the façade

1. Energy performance improvement by sandwich panels

<u>Inner insulation layer</u>:

Single layer - Improved perlite board

Multi-layer – Aerogel insulating wallpaper and laminated solution

<u>Cavity wall insulation layer</u>:

Expanded natural perlite hydrophobized (SandB)

Expanded synthetic perlite (NTUA)

<u>Outer insulation layer</u>:

Precast TRC sandwich panel

1. Energy performance improvement by sandwich panels

Cinisello Balsamo (Italy)

Madrid (Spain)

Gdansk (Poland)

1. Energy performance improvement by sandwich panels

Envelope retrofitting strategies

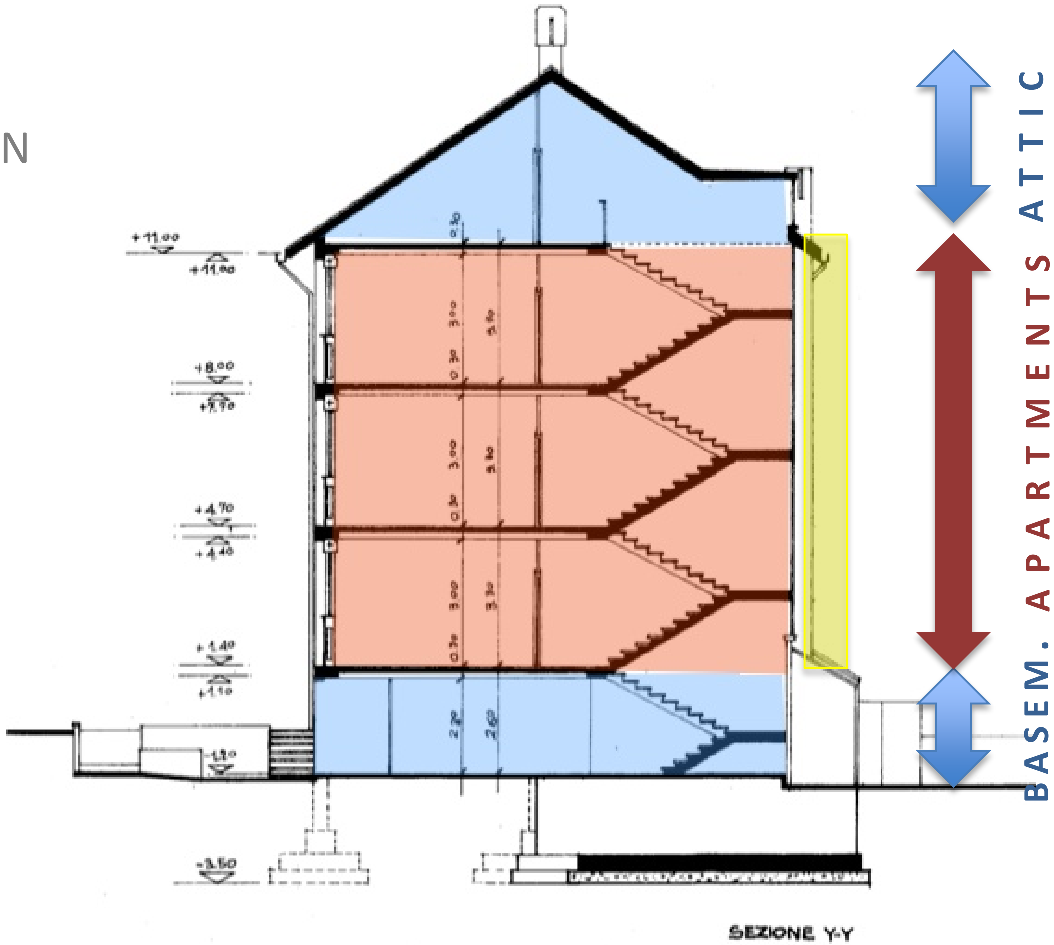
EASEE OUTER ENVELOPE SOLUTION

U-value of opaque envelope

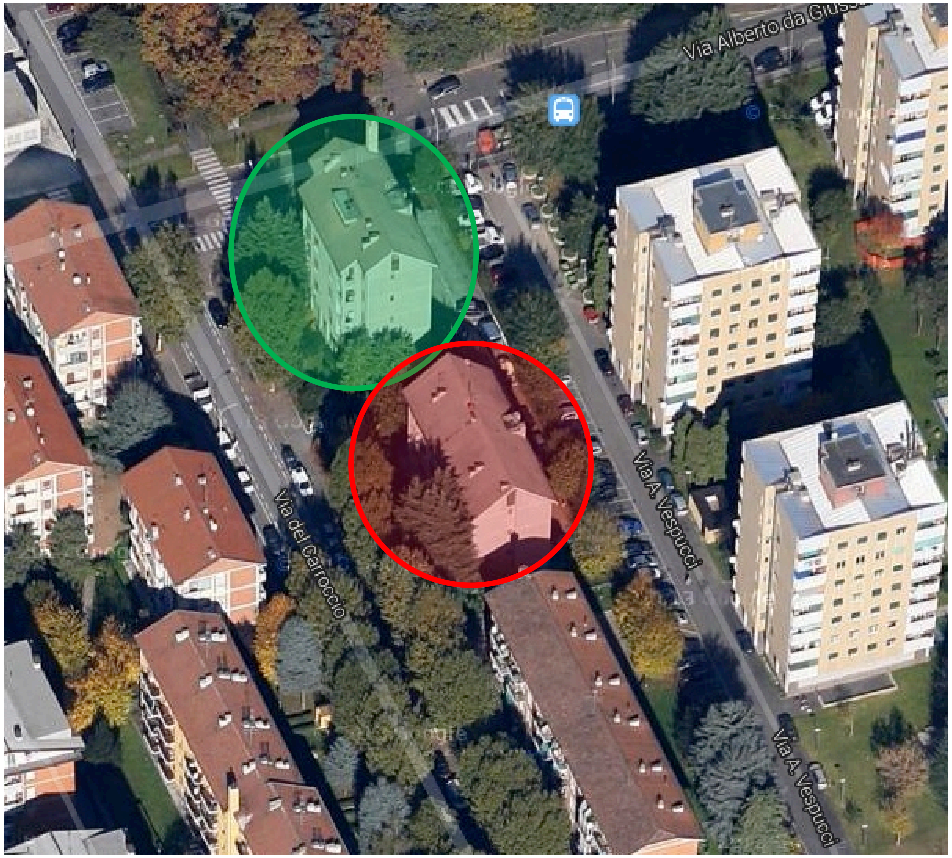
2,184 W/m²K

0,293 W/m²K

- 86%



1. Energy performance improvement by sandwich panels

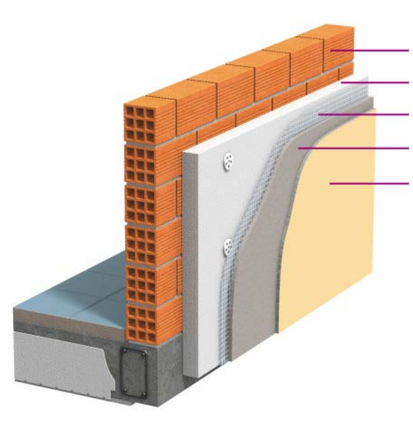


1. Demo for internal envelope solutions
2. Demo for external envelope solutions

1. Energy performance improvement by sandwich panels

ETICS

1. Masonry wall
2. Insulation layer
3. Glass fabric
4. Primer
5. Rendering mortar



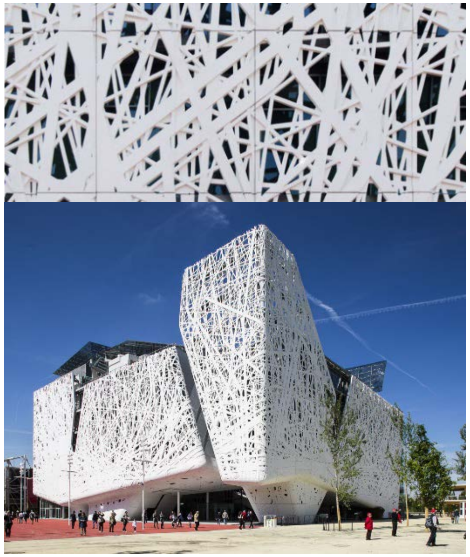
(www.bfcartongessomodena.it)

EASEE panel

Main features:

- low impact on occupant life;
- customized finishing (e.g. possible reproduction of the original façade);
- high quality;
- durability.

Advanced cementitious façades



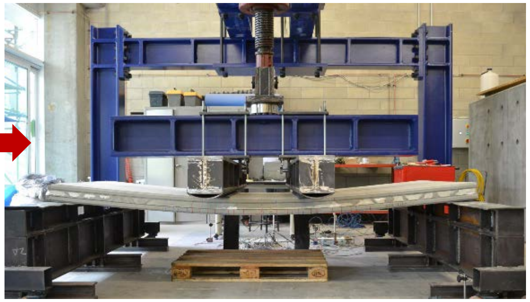
(http://www.domusweb.it)
(inhabitat.com)

1. Energy performance improvement by sandwich panels

SUMMER CONDITIONS

Effect of the sun radiation on the panel:

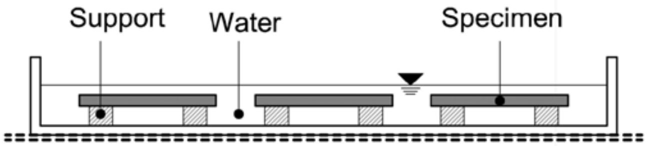
- full-scale panels exposed to real environment conditions will be tested after 1 year of exposure



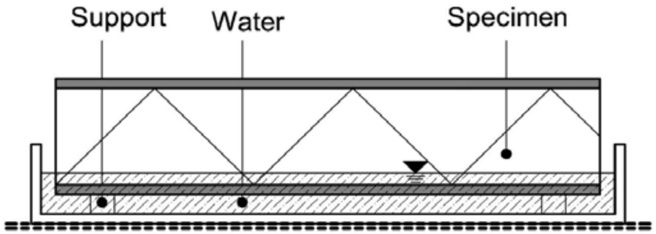
WINTER CONDITIONS

Freezing-thawing cycles according to ASTM C666 procedure A up to 500 cycles between +4 °C (+39.2°F) and -18°C (-0,4°F)

- on TRC specimens:



- on sandwich beams:

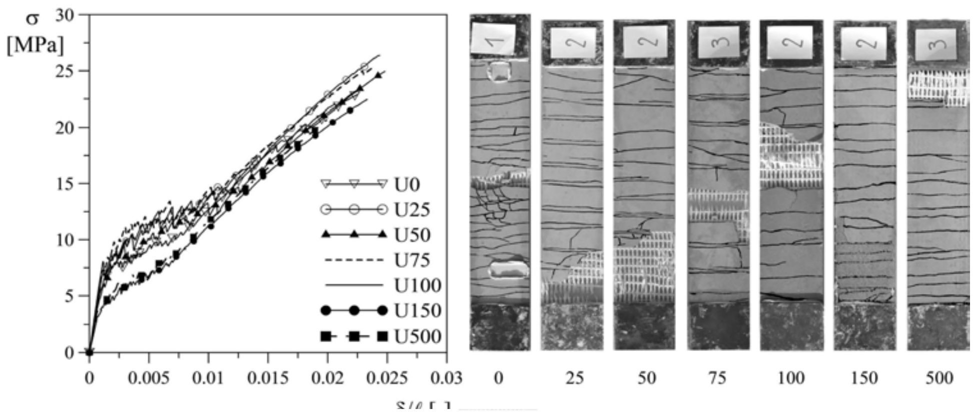


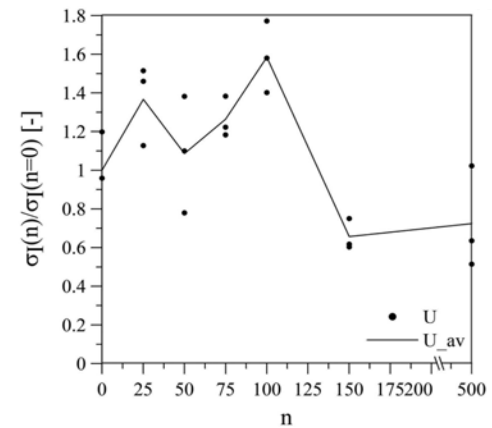
1 cycle = 5 hours

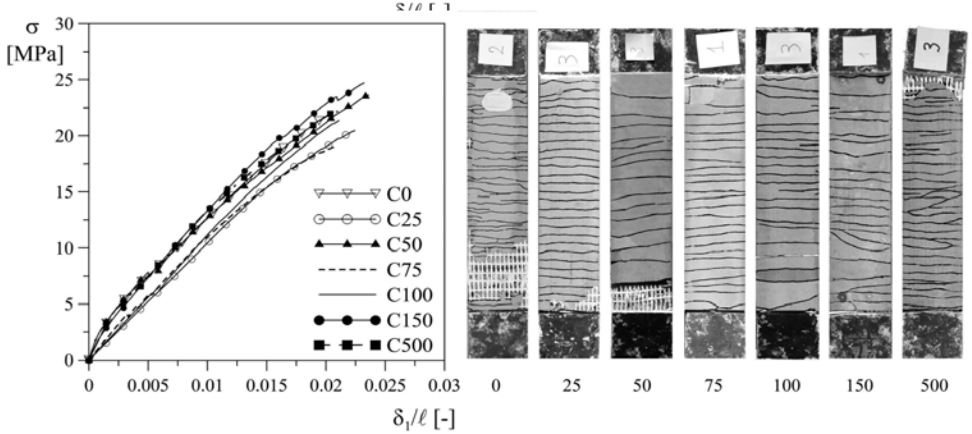
1. Energy performance improvement by sandwich panels

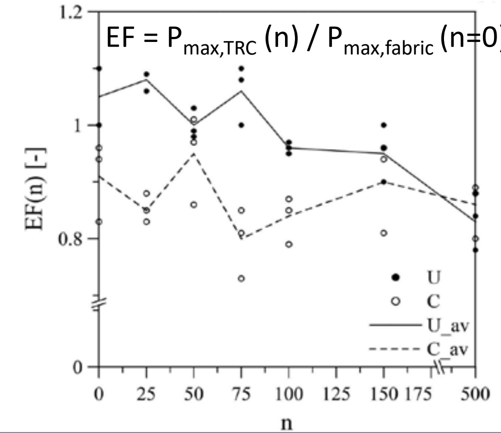
DURABILITY UNDER WINTER CONDITIONS

TENSILE TESTS ON 400 x 70 X 6 mm^3 (15.75 x 2.76 x 0.24$in.^3$) SPECIMENS





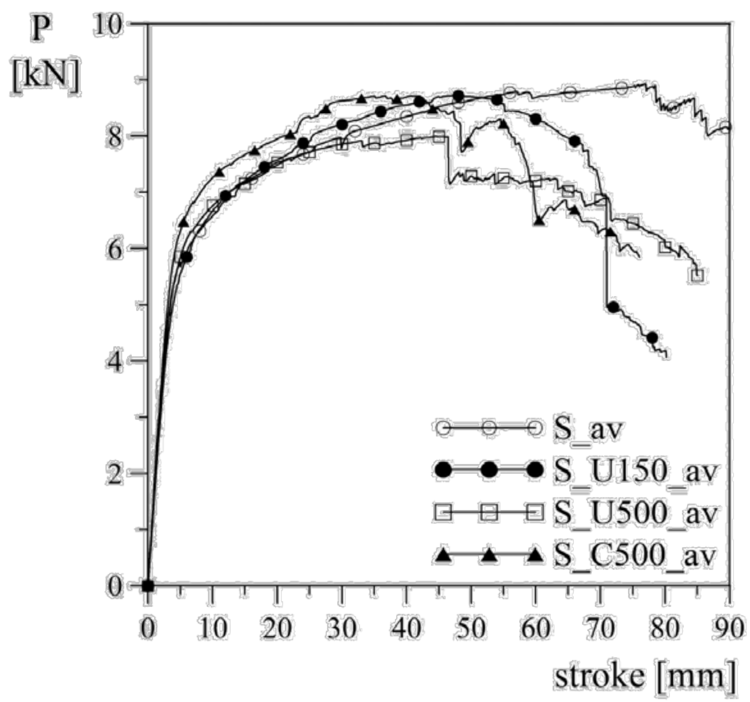




1. Energy performance improvement by sandwich panels

DURABILITY UNDER WINTER CONDITIONS

4 POINT LOAD TESTS ON 550 x 150 mm^2 (21.65 x 5.91 in.^{2}) BEAMS AFTER FREEZING-THAWING CYCLES



S = small specimens

S_U150 = small specimens exposed to150 freezing-thawing cycles in un-cracked (U) condition before testing;

S_U500 = small specimens exposed to 500 freezing-thawing cycles in un-cracked (U) condition before testing;

S_C500 = small specimens pre-cracked (C) exposed to 500 freezing-thawing cycles before testing.

2. Synergic retrofitting of roofings

Roof systems are in important component of the building envelope, since they are specifically designed to separate the living spaces from the natural environment.

They should ensure:

- adequate mechanical performances;
- energy efficiency;
- sound insulation;
- durability;
- aesthetics.

HOW CAN WE MEET THE REQUIREMENTS OF THE REVISED NATIONAL CODES?

A retrofitting strategy that might be successfully applied to several precast structures in northern Italy is represented by the substitution of the unsafe tertiary roofing elements with innovative multilayer panels characterized by lightness and remarkable structural performances.

S.IN.E.RG.I.E ATTI.V.E.

SISTEMA INTEGRATO SOSTENIBILE ENERGETICAMENTE ATTIVO PER IL RINNOVO DEGLI EDIFICI INDUSTRIALI ATTRAVERSO COPERTURE COMPOSITE

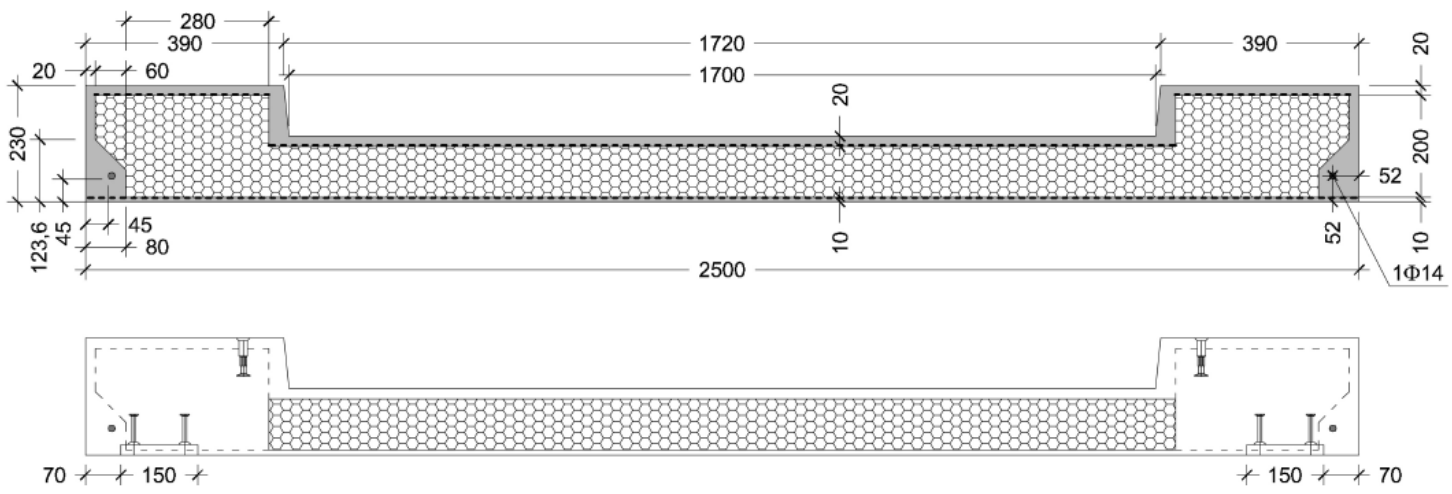
UNIONE EUROPEA
Ministero dell'Istruzione dell'Università e della Ricerca
RegioneLombardia
POR COMPETITIVITÀ 2007-2013

2. Synergic retrofitting of roofings

The proposal

2.5 m wide and 5 m long secondary prefabricated elements.

Main features: **lightness** (self-weight of about 1.2 kN/m^2); remarkable **thermal insulation** (U = 0.42 W/m^{2}K), **waterproof quality**, **ease of assembly**, **fire safety** (> R30) and effective **integration of photovoltaic systems**.



2. Synergic retrofitting of roofings

Prototype

2.5 m wide, 5 m long

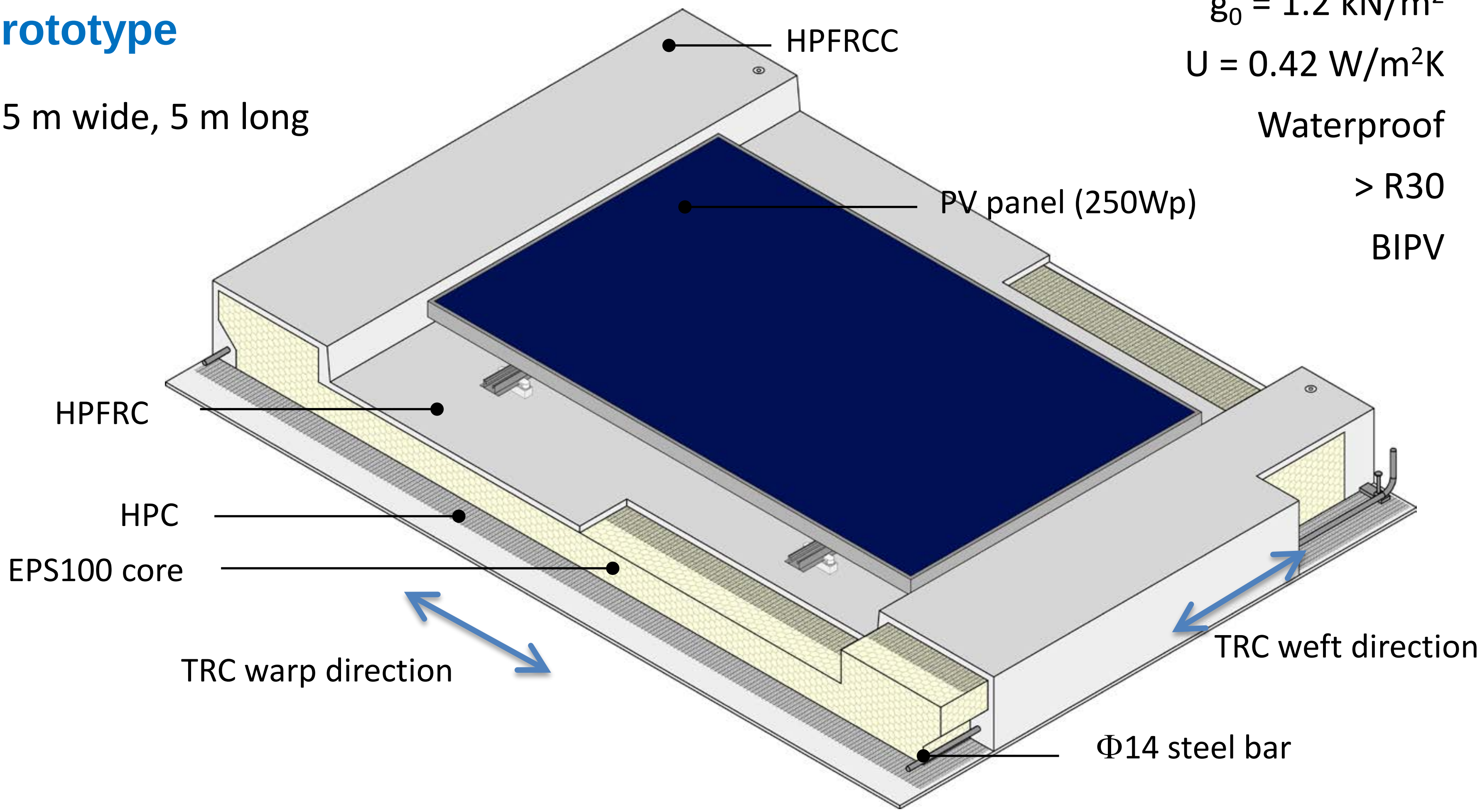
$g_0 = 1.2\ kN/m^2$

$U = 0.42\ W/m^2K$

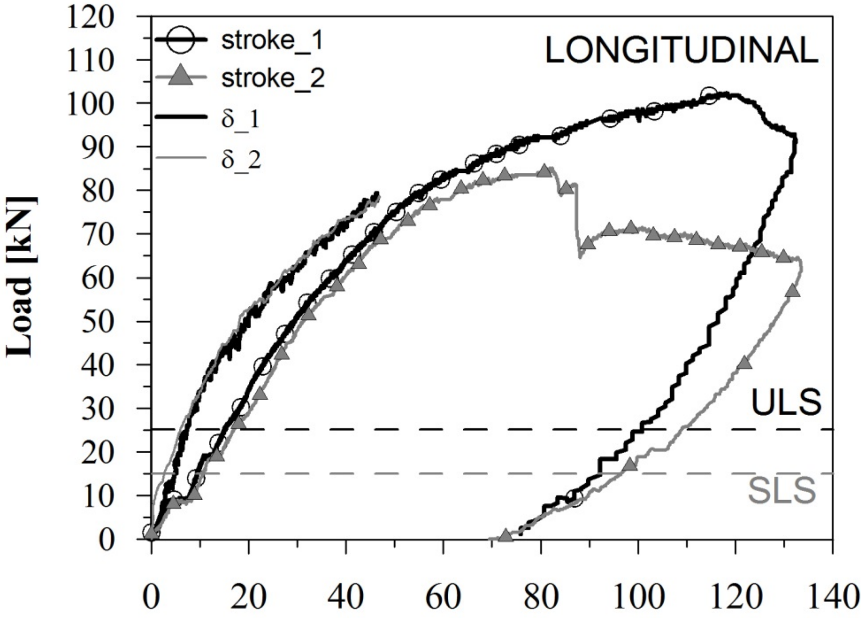
Waterproof

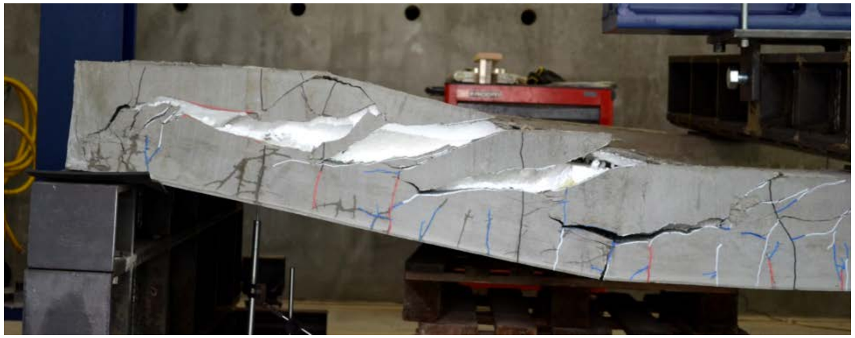
> R30

BIPV

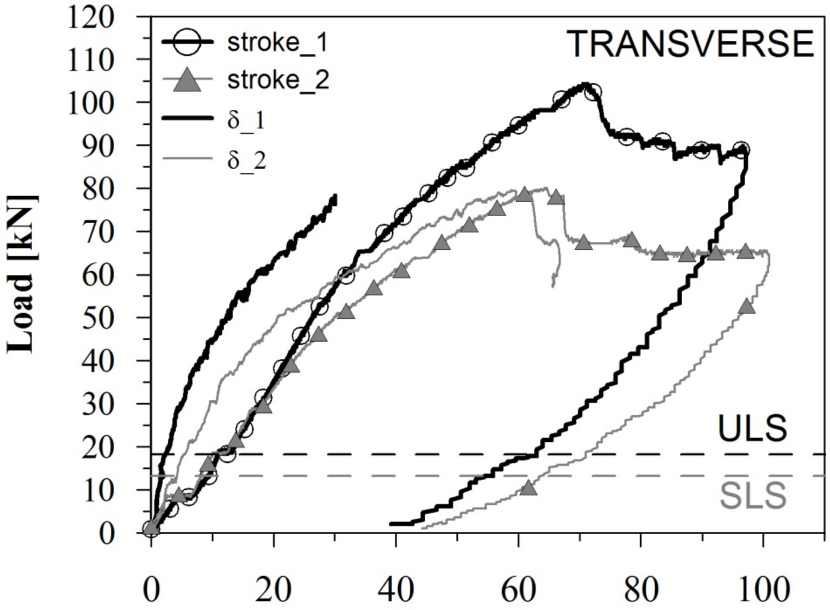


2. Synergic retrofitting of roofings

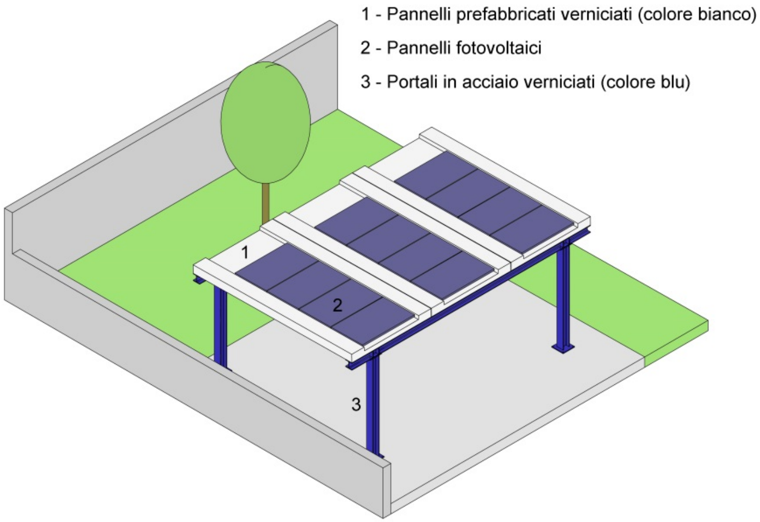




2. Synergic retrofitting of roofings



2. Synergic retrofitting of roofings



FRCM for seismic retrofitting: which durability?


a) Prepared reinforced concrete structure

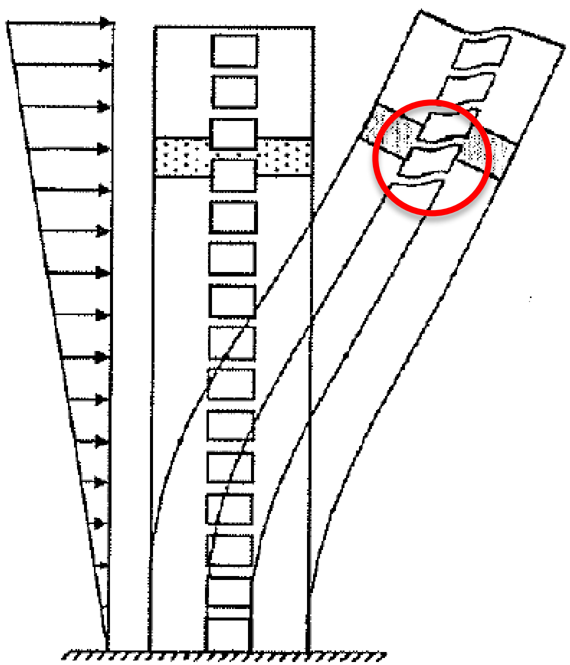

b) Spraying a fine grained concrete layer [20]

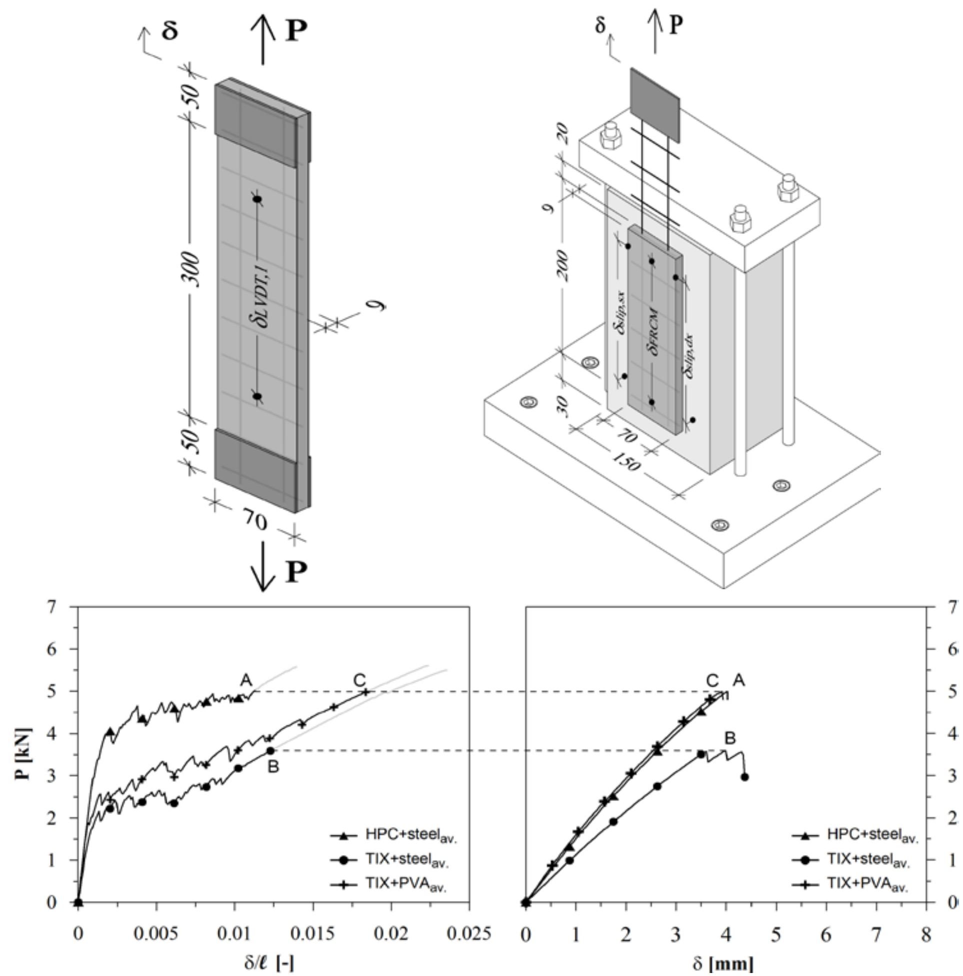

d) Ready TRC surface


c) Application of carbon fabric into the fine concrete (right photo: [20])

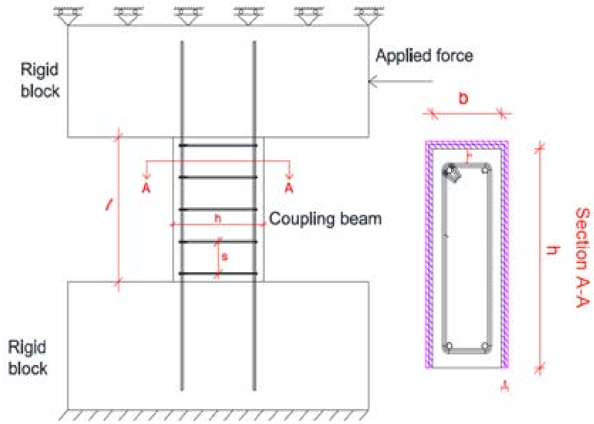

e) Roof structure after reopening of the building

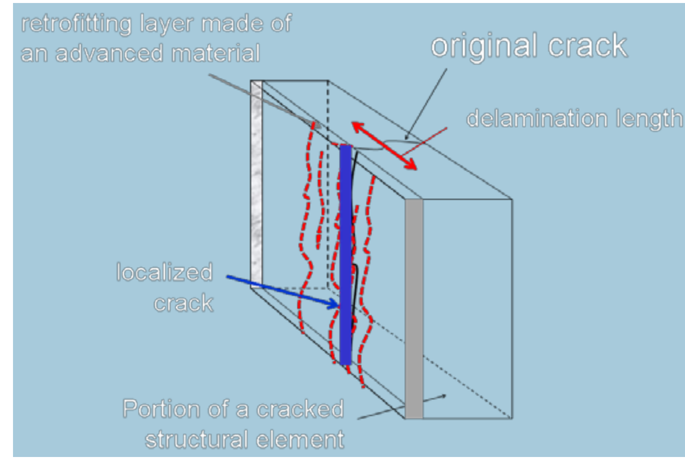
FRCM for seismic retrofitting: which durability?

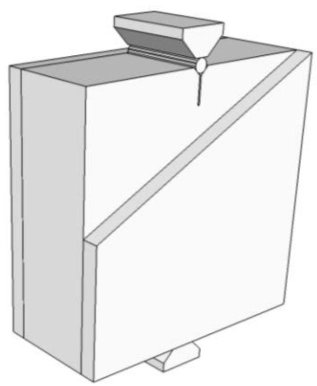


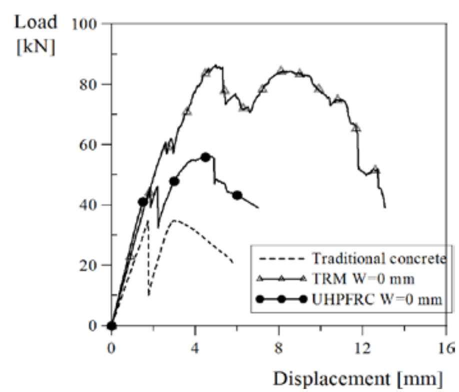


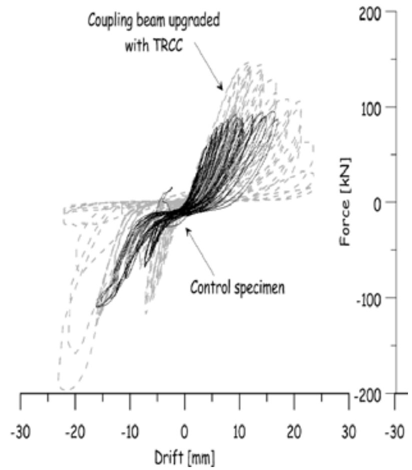
FRCM for seismic retrofitting: which durability?







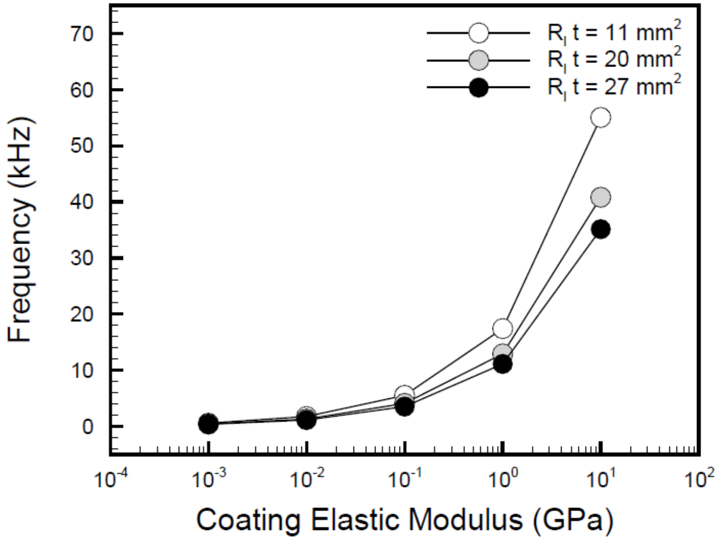




Metaconcrete

Metaconcrete is a new concept for a modified concrete where traditional aggregates are replaced by "resonant" engineered inclusions

- Resonant inclusions consist of:
  - A heavy core (e.g. high density material such as lead)
  - A compliant outer layer (e.g. silicone, rubber, or nylon, a few millimeters in thickness)
  - Resonant frequency depends on materials and sizes



Applications for Metaconcrete: Blasts and Impacts

Blast Shielding and Impact Protection

Blast shielding

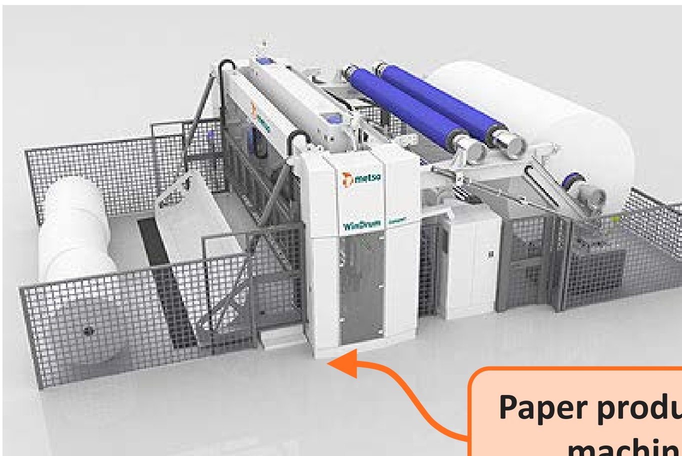
Seismic isolation and earthquake protections

Protective slab for impact resistance

Tuned damping protections

Applications for Metaconcrete: Vibrations

Foundations of Vibrating Machinery



Paper production machine

Rotary press machine

Fuel/Coal Extraction Support

Support of coal screening machines

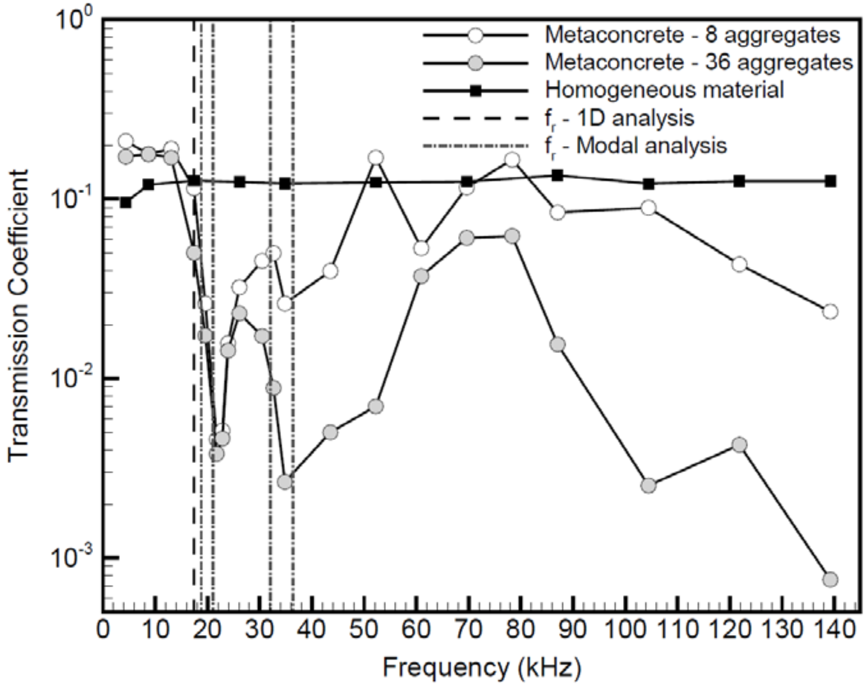
Support of gas/oil drilling rig

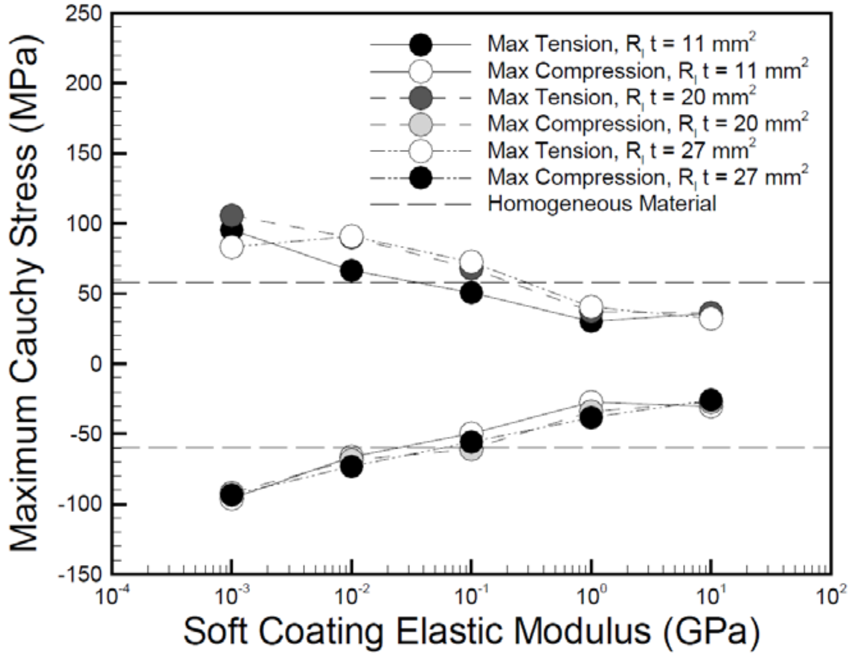
Numerical validation: energy and stress attenuation

Transmission Coefficient

$$T = \frac{E^{\mathrm{RA}}}{\sum_{j=1}^{N} E^j}$$

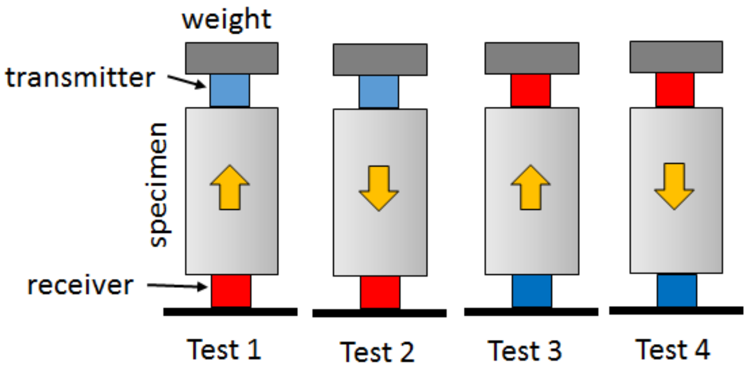
E^j = j[th] inclusion time-averaged mechanical energy
N = total number of inclusions
E^{RA} = Farthest inclusion energy



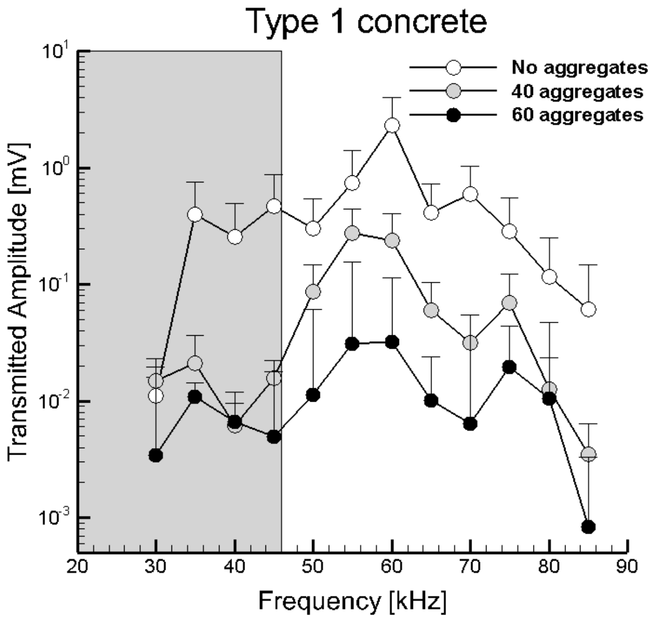


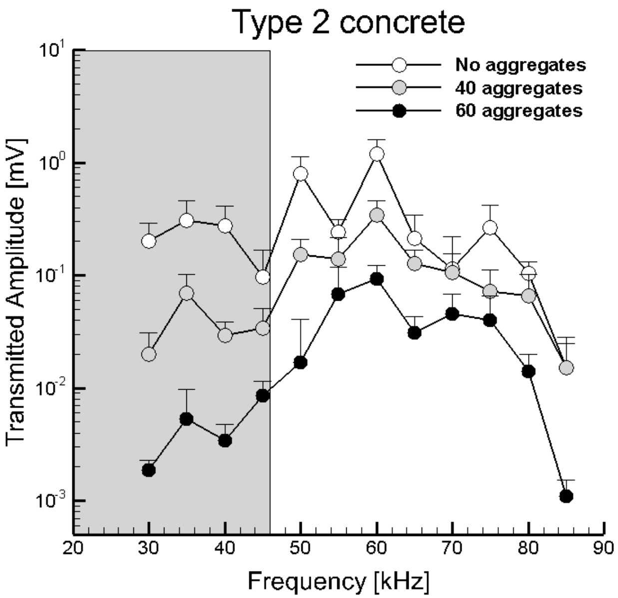
Maximum longitudinal tensile and compressive stress over the duration of the dynamical analysis

Experimental validation: signal transmission attenuation



- Two types of concrete (without and with fibers)
- Three arrangements (0, 40 and 60 aggr)
- 4 tests for each sample





Conclusion

1) ✓ Interface behaviour for sun radiation cycles
2) ✓ Structured recicled material to substitute EPS as insulation material
3) ✓ Maintenance of finishing performance with RH and temperature cycles … during load application

4) Mechanical strength, stiffness, durability and temperature performance of metaconcrete shall be investigated in the next years at LIDUP.