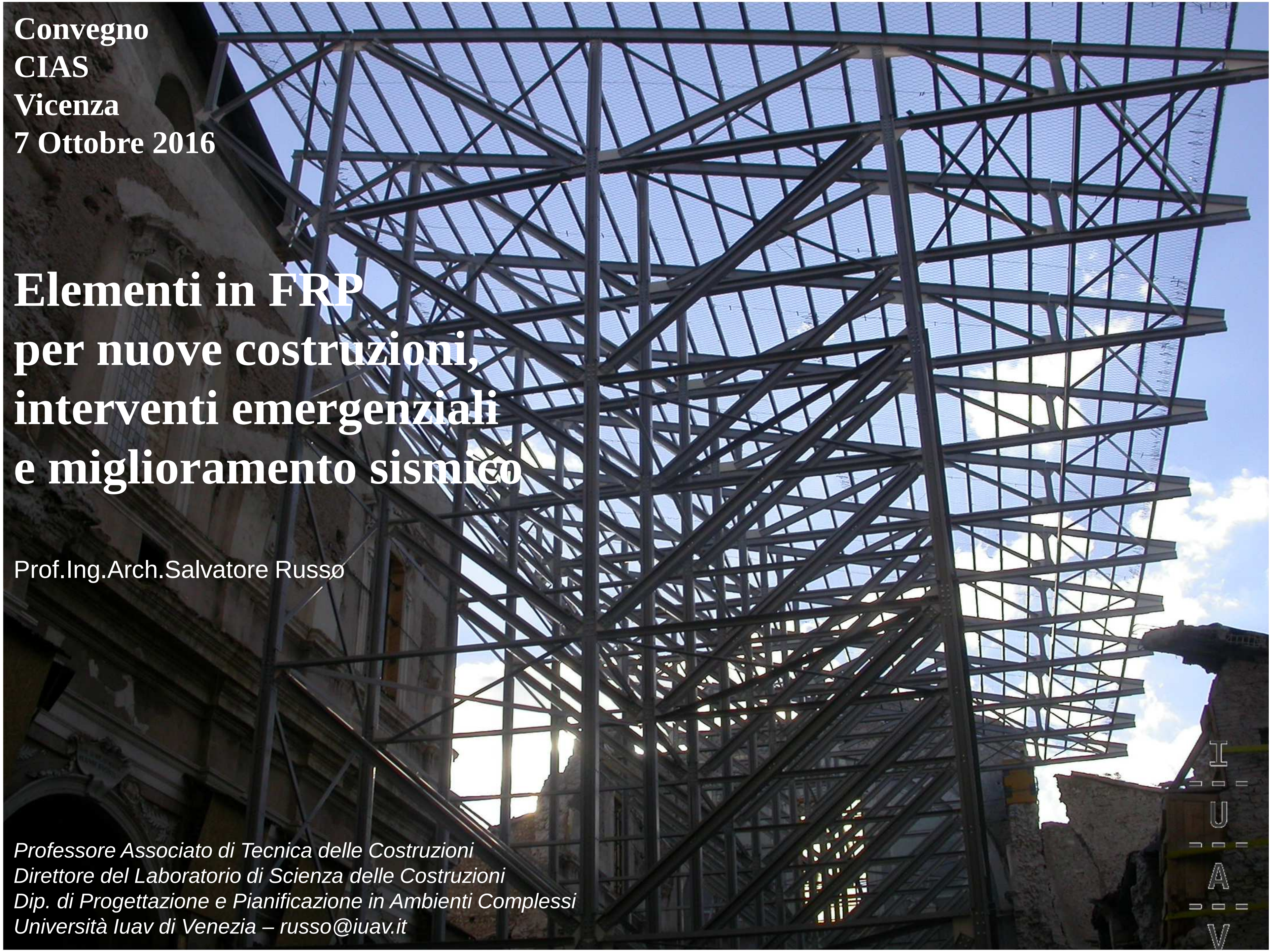

Convegno
CIAS
Vicenza
7 Ottobre 2016

Elementi in FRP per nuove costruzioni, interventi emergenziali e miglioramento sismico

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Dip. di Progettazione e Pianificazione in Ambienti Complessi
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STRUCTURE OF PRESENTATION

1. Le nuove raccomandazioni europee

2. Prestazioni (limiti e benefici)

2. Nuove costruzioni

3. Interventi emergenziali

4. Miglioramento sismico

5. Danno da elevate temperature

I

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V

Le nuove raccomandazioni europee

European Commission
JRC SCIENCE FOR POLICY REPORT

PROSPECT FOR NEW GUIDANCE IN THE DESIGN OF FRP

Support to the implementation, harmonization and further development of the Eurocodes

2016
Joint Research centre
Report EUR 27666 EN

Composition of the Working Group (WG4)

Toward the Eurocode for alle FRP structures

Official members

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6	Frederic Waimer	f.waimer@itke.uni-stuttgart.de	University of Stuttgart, Germany

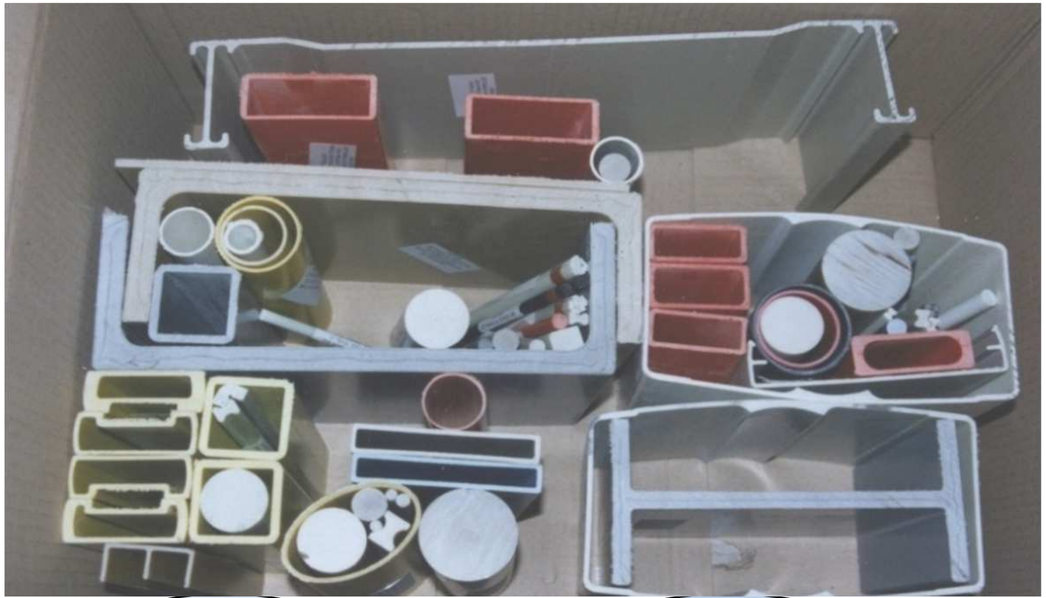
Ephemeral **cathedral** of Creteil, France. Realization of a GFRP gridshell, made with pultruded tubes. Gridshells offer an important freedom of shape for the designer. The covered surface is 350 m^2. 1775m of pultruded tubes were used. The weight of the structure is 5kg/m^2. Design: Navier laboratory. Contractor: Structural engineering company T.E.S.S., 2014.

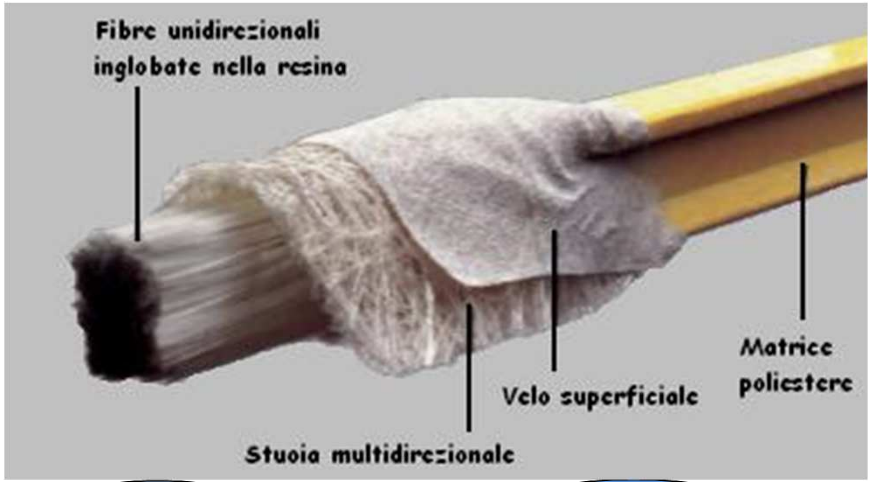
Salerno (Italy). **Pedestrian bridge** at the University of Salerno. Length: 148 m; main span: 37 m. GFRP pultruded I-beam. The deck is made of GFRP sandwich panels. Designer: prof. Luciano Feo, 2014 (In construction).

Moscow, Russia. Construction of the **deck of a pedestrian** bridge with GFRP pultruded profiles. Length: 79.5 m; width: 3.72 m. Contractor: APATECH, Russia, 2010.

Prestazioni (limiti e benefici)

First framework





60-65 % Matrix

γ = 1600-1800 kg/mc

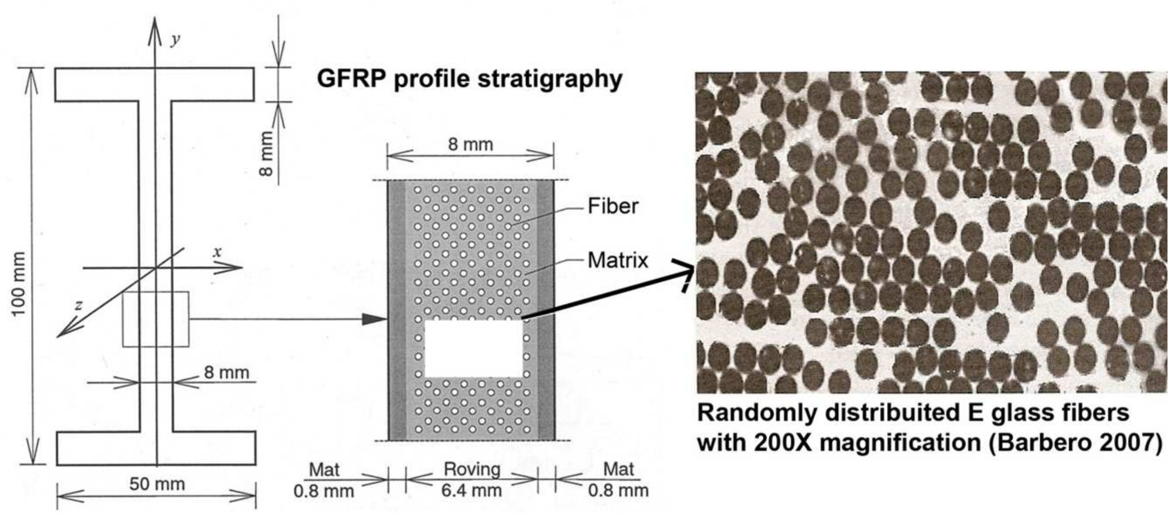
Mechanical perfromances

Matrix<<Fiber

Elastic-brittle behaviour

E_{11}- E_{12}

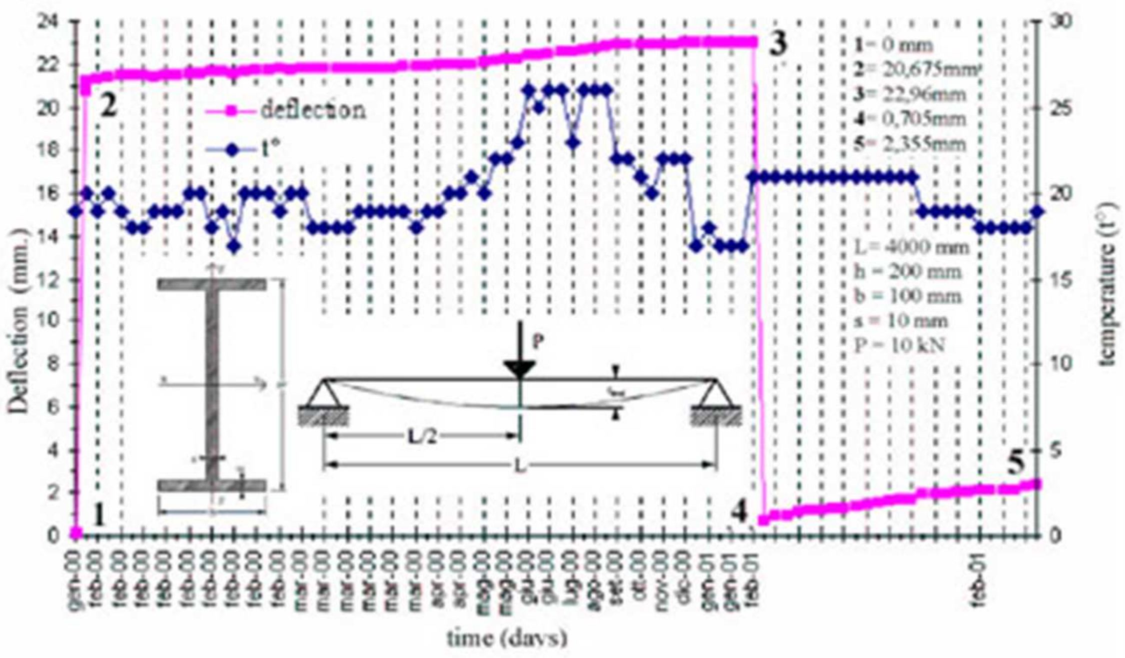
E_c< E_t



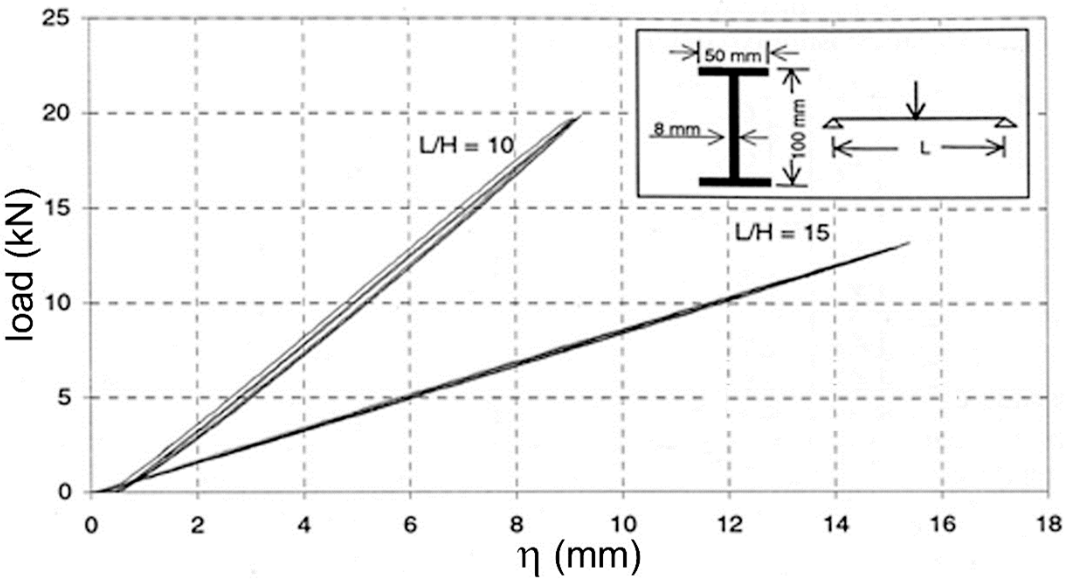
Randomly distribuited E glass fibers with 200X magnification (Barbero 2007)

materiali	σ/γ
GFRP	4.4
Steel	0.9
Aluminium	2.2

3. Structural approach / static loads



Time-dependent behaviour

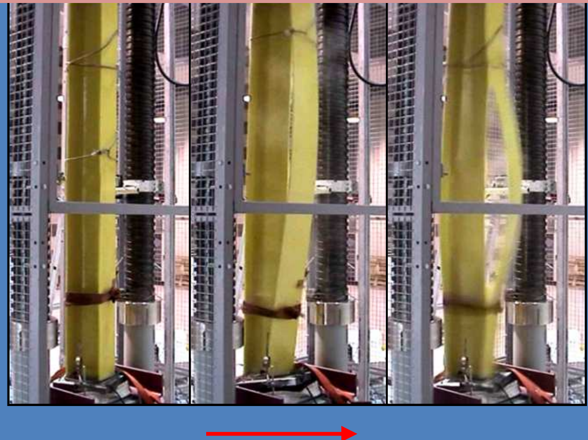


Cyclic behaviour

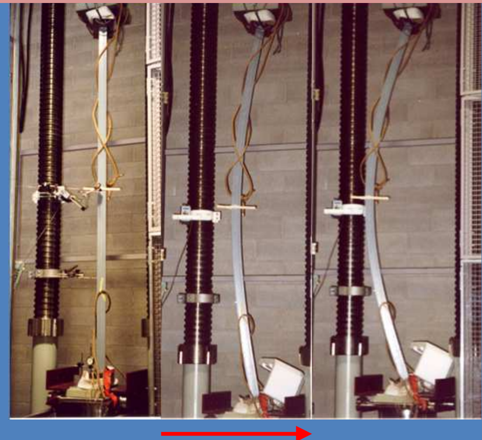
Russo et al.,1998

3. Structural approach / static loads

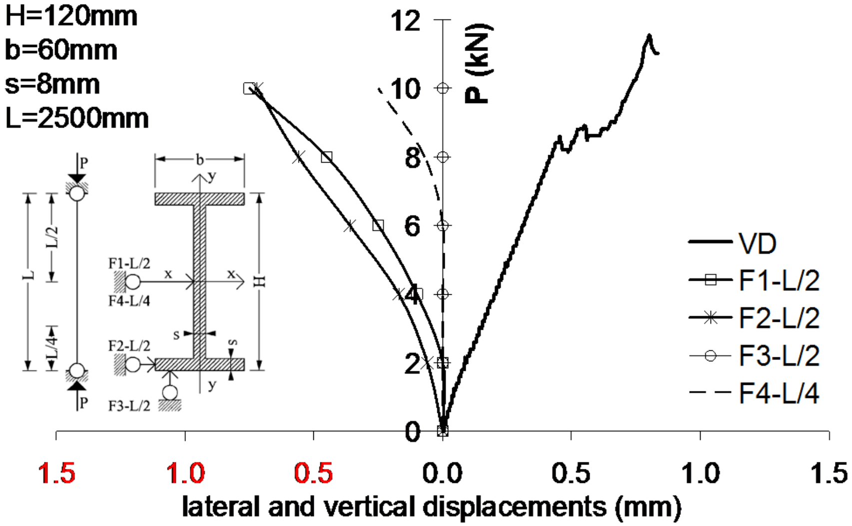
“H”(200x200x12mm) – h = 2800 mm

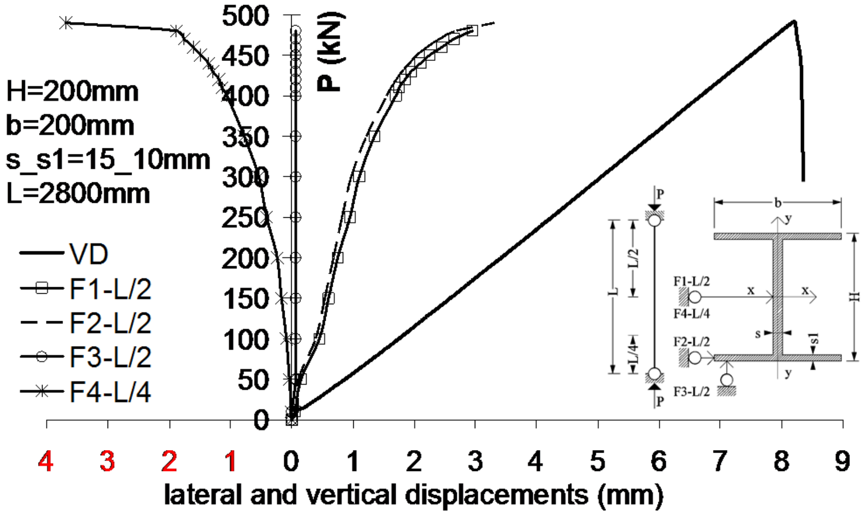


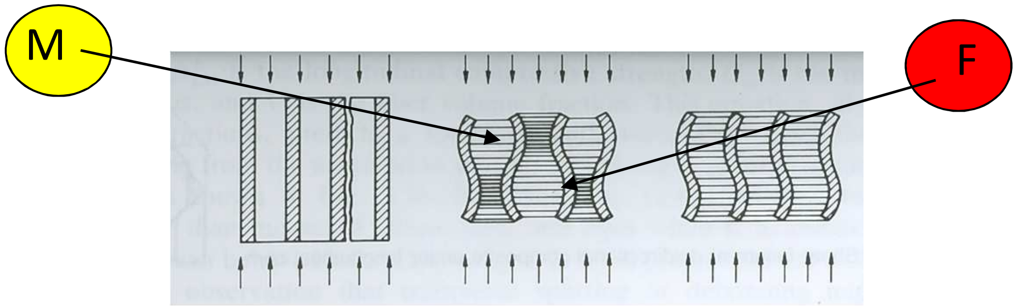
“H” (200x200x12mm) -h = 2000 mm



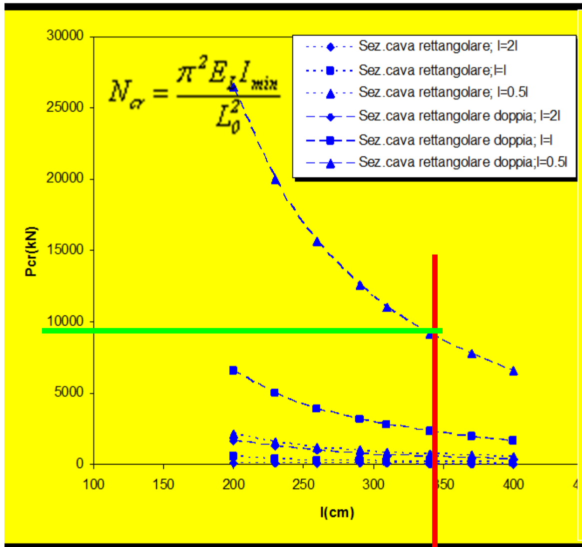
“I” (60x120x8 mm)– h = 2000 mm



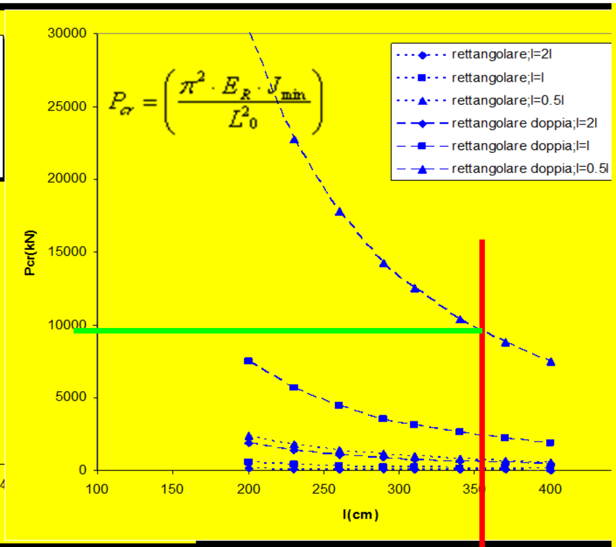




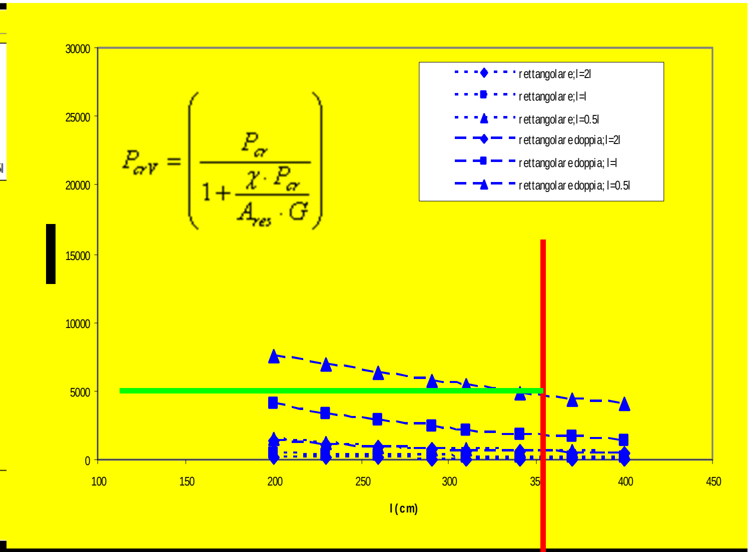
Russo et al.,2001



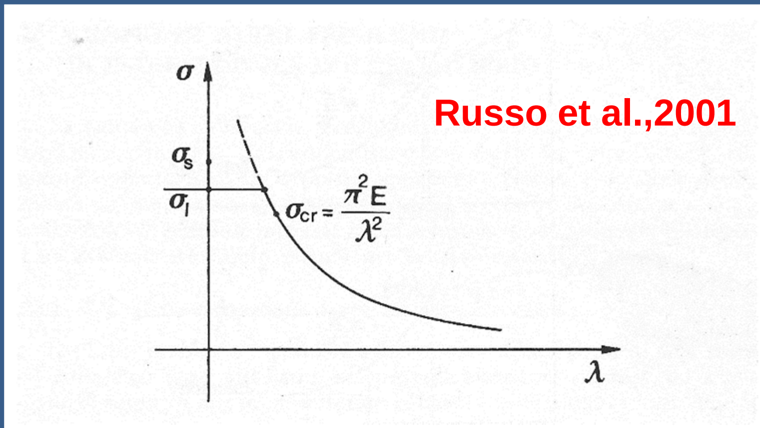
$N_{cr} = \frac{\pi^2 E_L I_{min}}{L_0^2}$
Sez.cava rettangolare; l=2l
Sez.cava rettangolare; l=l
Sez.cava rettangolare; l=0.5l
Sez.cava rettangolare doppia; l=2l
Sez.cava rettangolare doppia; l=l
Sez.cava rettangolare doppia; l=0.5l
Pcr(kN)
l(cm)



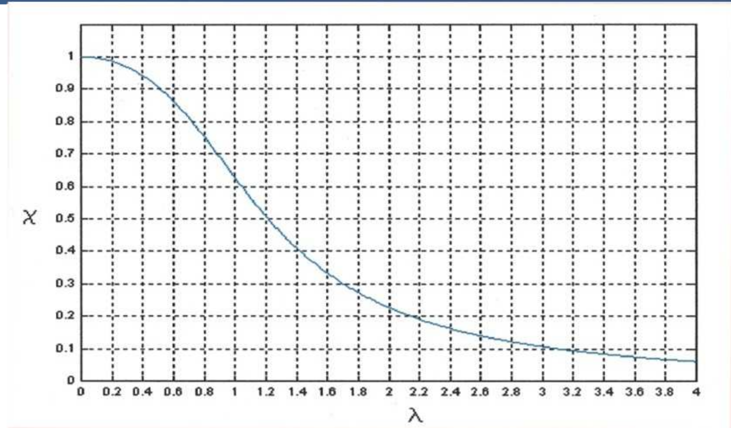
$P_{cr} = \left(\frac{\pi^2 \cdot E_R \cdot J_{min}}{L^2_0} \right)$
rettangolare; l=2l
rettangolare; l=l
rettangolare; l=0.5l
rettangolare doppia; l=2l
rettangolare doppia; l=l
rettangolare doppia; l=0.5l
Pcr(kN)
l(cm)



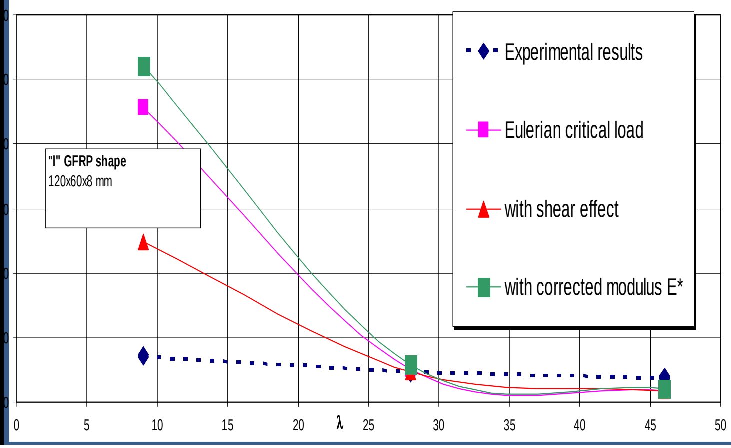
$P_{crV} = \left(\frac{P_{cr}}{1 + \frac{\chi \cdot P_{cr}}{A_{res} \cdot G}} \right)$
rettangolare; l=2l
rettangolare; l=l
rettangolare; l=0.5l
rettangolare doppia; l=2l
rettangolare doppia; l=l
rettangolare doppia; l=0.5l
l (cm)



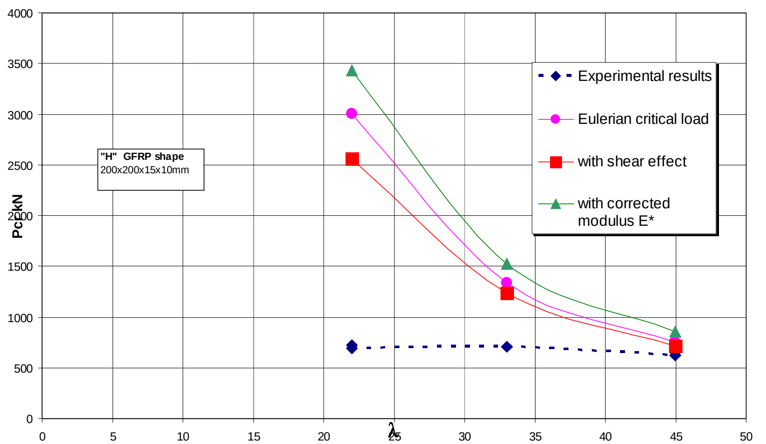
Russo et al.,2001
σ
σ_s
σ_l
$\sigma_{cr} = \frac{\pi^2 E}{\lambda^2}$
λ



χ
λ



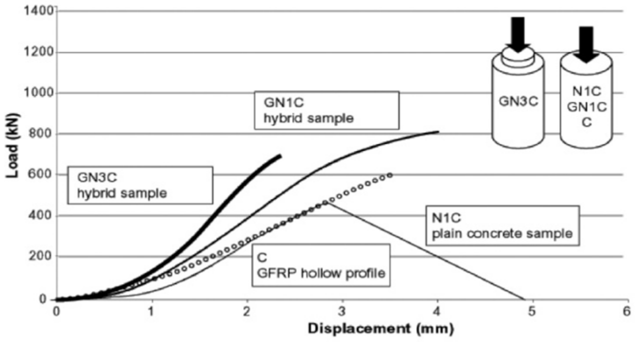
Experimental results
Eulerian critical load
with shear effect
with corrected modulus E*
"I" GFRP shape
120x60x8 mm
λ



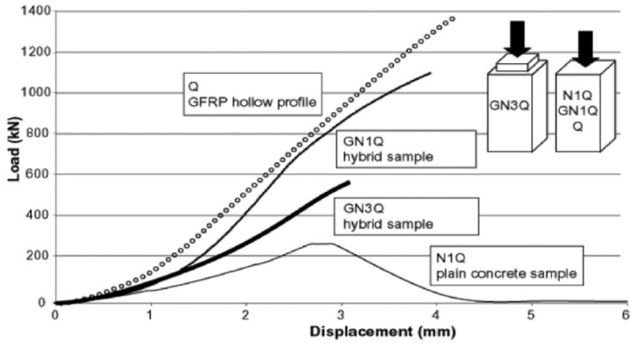
Experimental results
Eulerian critical load
with shear effect
with corrected modulus E*
"H" GFRP shape
200x200x15x10mm
PckN
λ

EXPERIMENTAL RESULTS ON HYBRID COLUMNS (GFRP + Concrete)

Typical local buckling of GFRP hollow profile induced by crashing of concrete
Brittle failure



Circular sample. Curves of plain concrete, hollow GFRP profile and hybrid columns with two different type of load



Square sample. Curves of plain concrete, hollow GFRP profile and hybrid columns with two different type of load

Collapse of hybrid short column

Type	Dim. (mm)	λ	Thick. of GFRP (mm)	Load Sample (kN)	E_{exp} (MPa)	$P_{max-exp}$ (kN)	Type of collapse
GN1C	∅ 110 h 220	3.89	5	0.056	23751	814.0	Loss of stress bond + instability of Hollow profile
GN2C	∅ 119 h 220	3.61	5	0.056	/	591.8	Loss of stress bond + crush of concrete and vertical break of GFRP without instability
GN3C	∅ 120 h 115	1.87	5	0.040	49327	680.1	

Experimental results for circular samples CONCRETE+GFRP. Short Columns

Type	Dim. (mm)	λ	Thick. of GFRP (mm)	Load Sample (kN)	E (MPa)	$P_{max-exp}$ (kN)	Type of collapse
GN1Q	(99×99) h 160	2.61	10	0.034	16887	1120.0	Loss of stress bond + vertical break in the corner
GN2Q	(99×99) h 160	2.61	10	0.033	/	550.1	Crush of concrete + vertical break in the corner
GN3Q	(99×99) h 160	2.61	10	0.034	/	569.2	
GN4Q	(99×99) h 106	1.73	10	0.023	/	569.2	

Experimental results for square samples CONCRETE+GFRP. Short Columns

Russo et al.,2002

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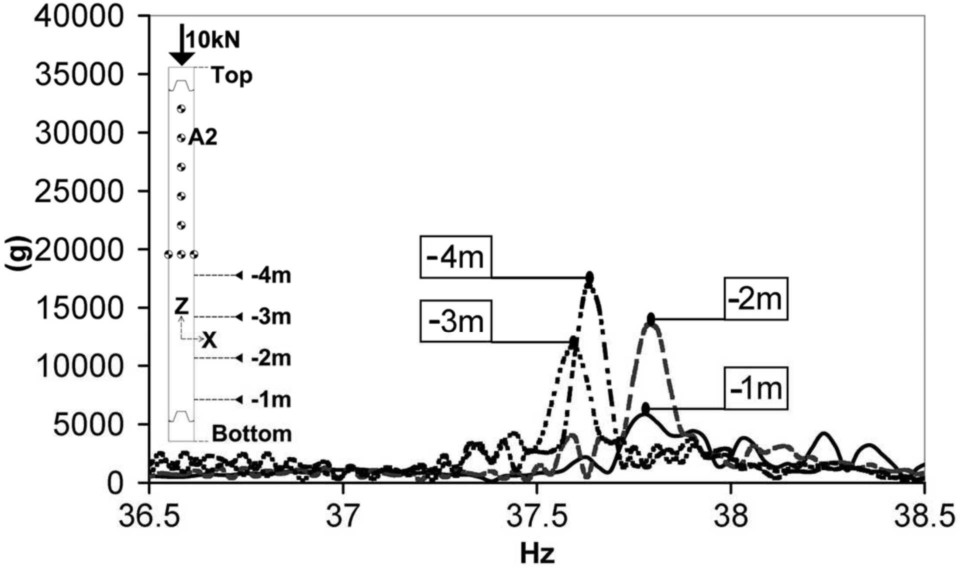
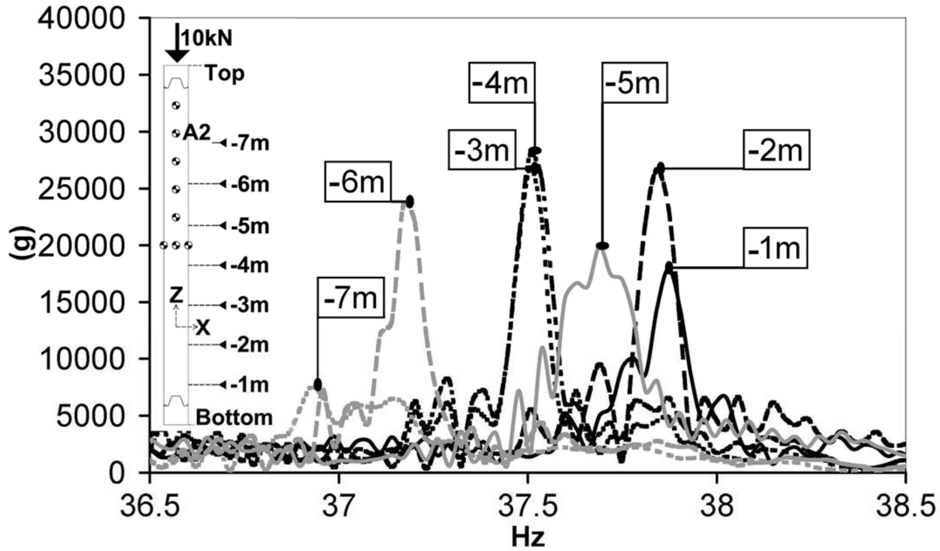
VENICE'S LAGOON

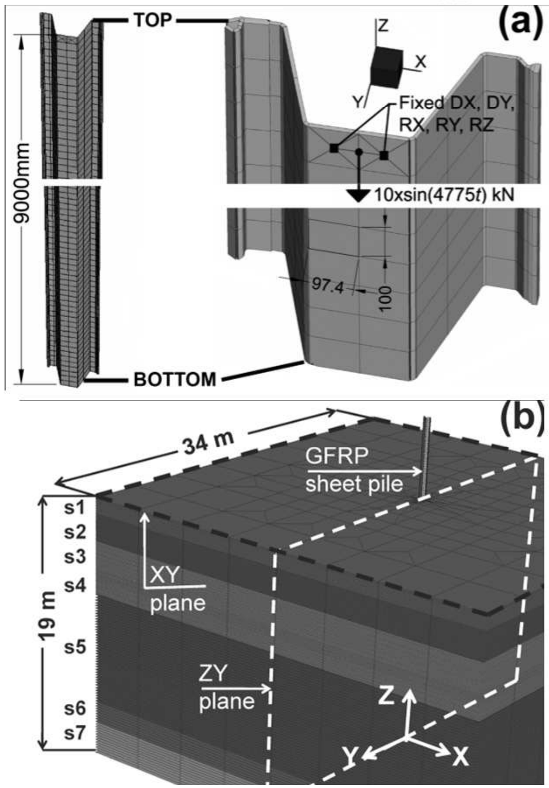
Protection of the Lagoon sites with FRP sheet piles to avoiding any adverse/ nocive effect on the very fragile lagoon' environment due to steel degradation in the medium and long time

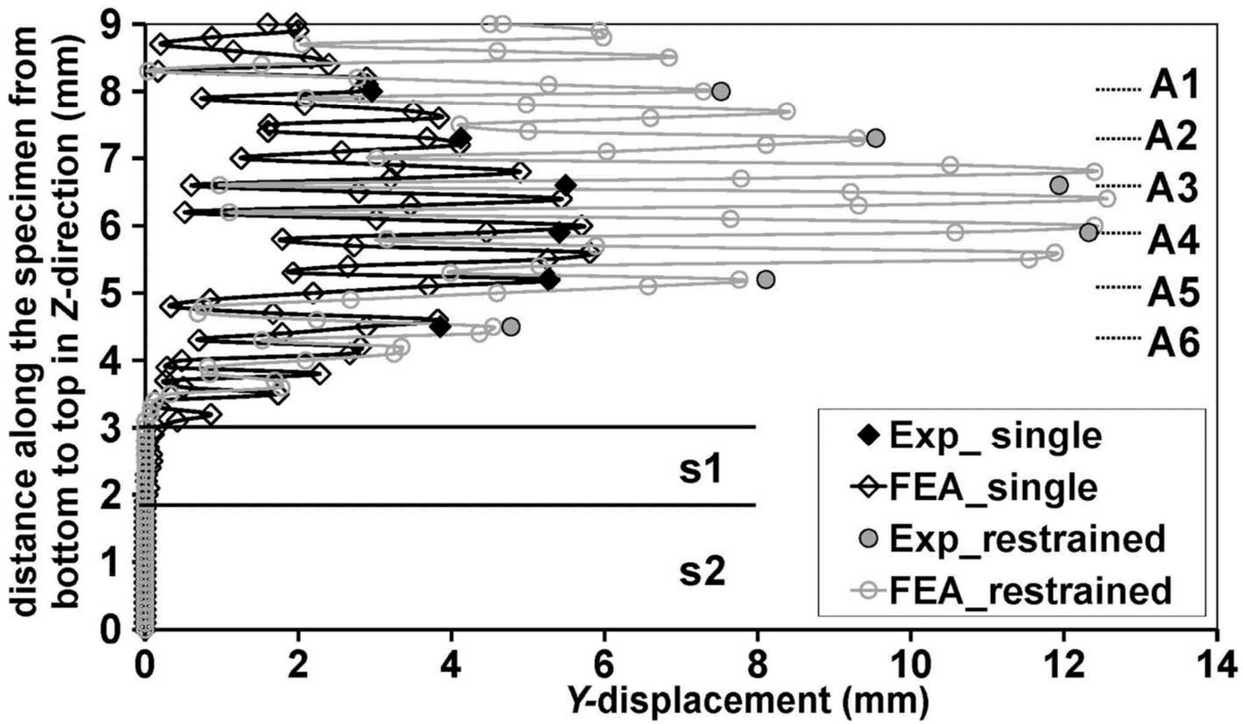
Russo et al. 2007

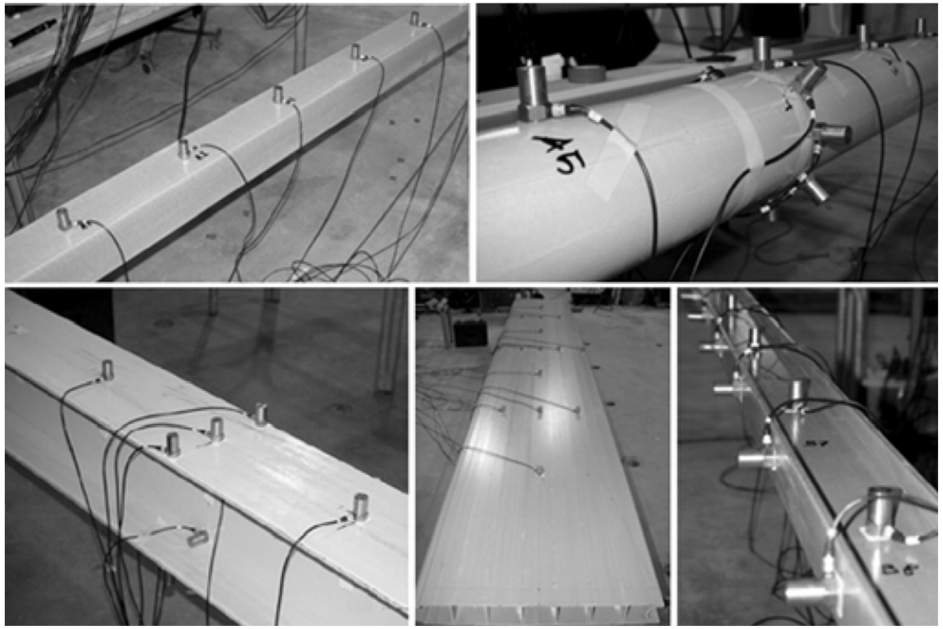
Dynamic behaviour of sheet piles with different configurations

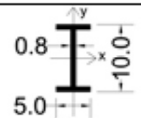
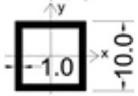
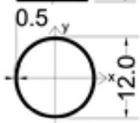
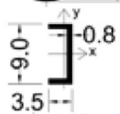
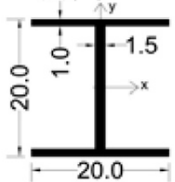
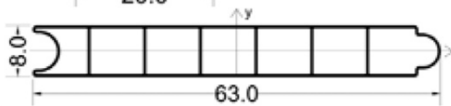










Structural elements (cm)		J (cm^4)	L (cm)	Area (cm^2)	Weight (kg)
	"I", J_{max}	209.22	300	14.72	8.65
	"I", J_{min}	17.02			
	"Q"	492	240	36	14.87
	"O"	299.20	240	18.06	7.85
	"C", J_{max}	121.45	200	11.52	4.2
	"C", J_{min}	11.27			
	"H", J_{max}	4342.3	500	67	62
	"H", J_{min}	1338.4			
	"P"	808.66	420	74.57	57.3

Element	Cross section dimensions (cm)	L (cm)	J_{max} (cm^4)	A_S (cm^2)	DL_S (kg)	DL_S/ DL_{GFRP} (%)
“I”	5.75x2.9x0.46	300	22.89	4.87	11.46	**132**
“H”	11.5x11.5x0.86x0.58	500	475.5	22.17	87	**140**
“Q”	5.75x5.75x0.575	240	53.88	11.91	22.44	**150**
“P”	36.2x4.6x0.23	420	88.56	24.59	81.06	**139**

Steel-GFRP comparison

Element	Cross section dimensions (cm)	L (cm)	J_{max} (cm^4)	A_A (cm^2)	DL_A (kg)	DL_A/ DL_{GFRP} (%)
“I”	7.6x3.8x0.6	300	69.69	8.49	6.87	**79**
“H”	15.2x15.2x1.1x0.76	500	1447.	38.68	52.2	**84**
“Q”	7.6x7.6x0.76	240	163.9	20.78	13.46	**90**
“P”	48x6x0.3	420	269.5	43.05	48.8	**84**

Aluminum-GFRP comparison

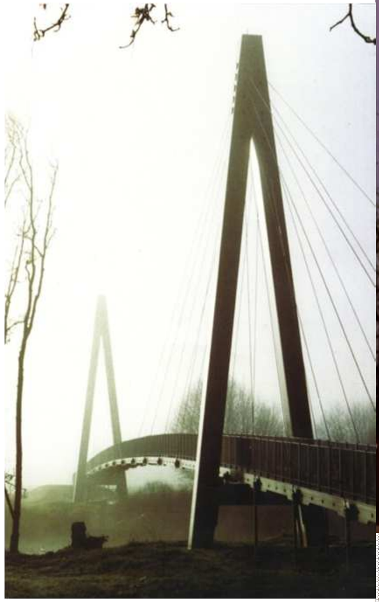
Structural element	Material	Fundamental frequency (Hz)
“I”, J_{max}	GFRP	**24.41**
	Aluminum	26.79
	Steel	20.72
“H”, J_{max}	GFRP	**16.47**
	Aluminum	20.04
	Steel	15.5
“Q”	GFRP	**35.09**
	Aluminum	41.77
	Steel	32.31
“P”	GFRP	**11.9**
	Aluminum	11.7
	Steel	9.07

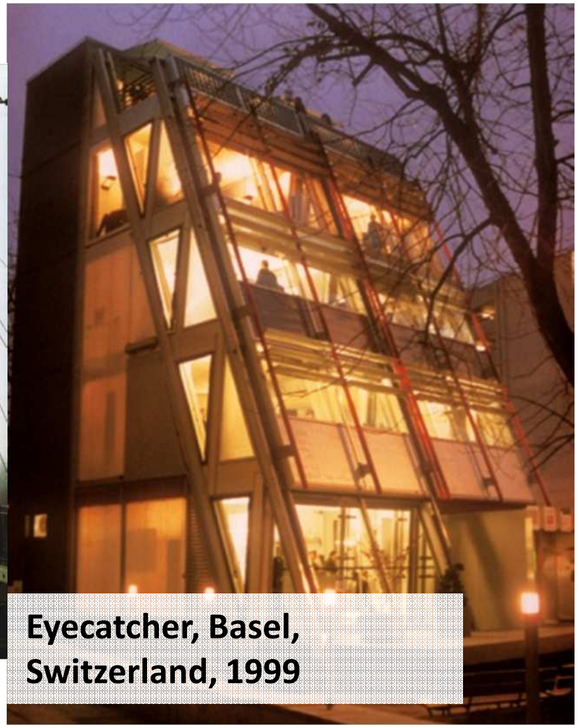
TYPICAL DAMPING COEFFICIENTS

Structure typologies and boundary conditions	ξ
Structures with elements below of 50% than elastic limit	
RC Structures with first cracks *RC Prestressed Structures* *Welded steel structures*	*2-3%*
RC Structures cracked	*3-5%*
Bolted or nailed steel structures *Bolted or nailed wood structures*	*5-7%*
Structures with elements near to elastic limit	
RC Prestressed Structures without pretension loss *Welded steel strutures*	*5-7%*
RC Prestressed Structures *RC Structures*	*7-10%*
Bolted or nailed steel structures *Bolted wood structures*	*10-15%*
Nailed wood structures	*15-20%*
Masonry structures	
Normal masonry structures	*3%*
Reinforced masonry structures	*7%*
GFRP elements and structures	
Structural elements simply supported, Jmax	***2.26-3.4%***
Bolted GFRP structures *Bonded GFRP structures* *Bolted and bonded GFRP structures*	***1.7%*** - -

Nuove costruzioni

2.1. Applications in architecture and conservation field





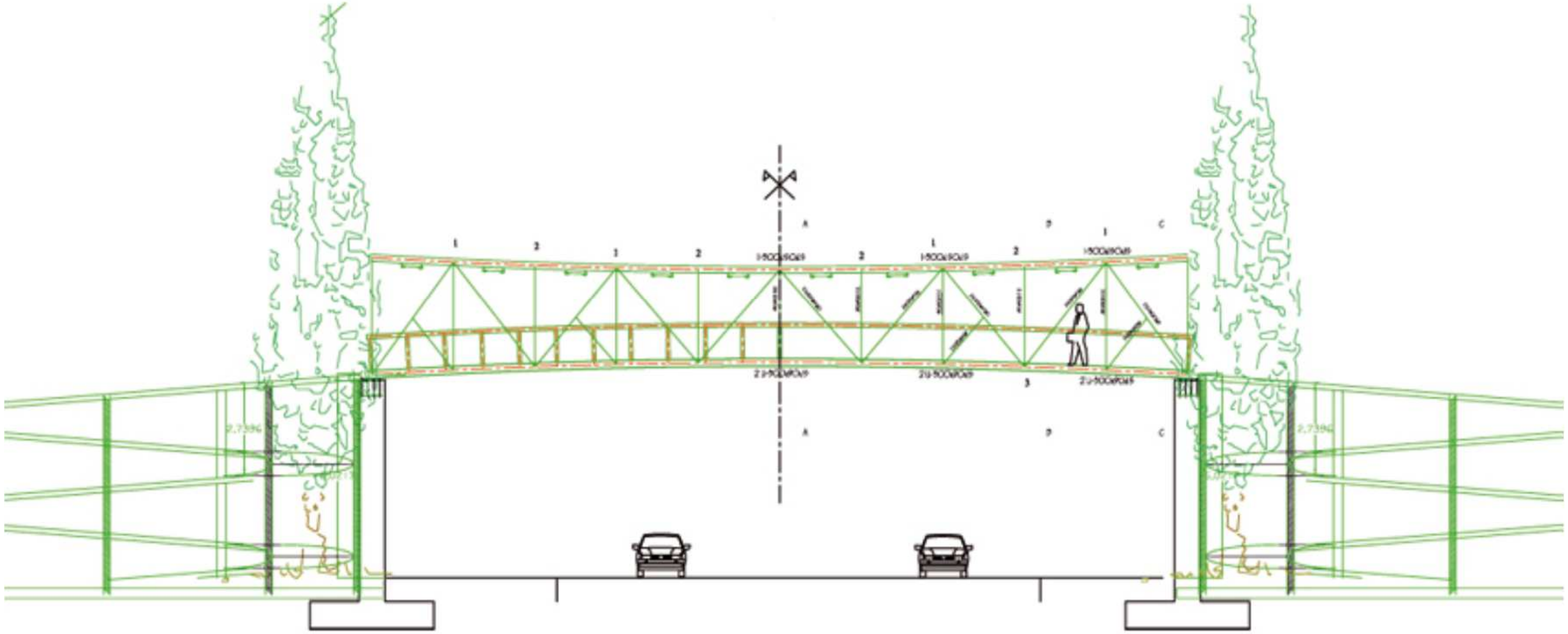
Eyecatcher, Basel, Switzerland, 1999

The Staten Island September 11 Memorial, New York, USA, 2003

Spacebox, Delft, The Netherlands, 2004

Conference Center, Badajoz, Spain, 2005

Metro Station, Copenhagen, Denmark, 2008

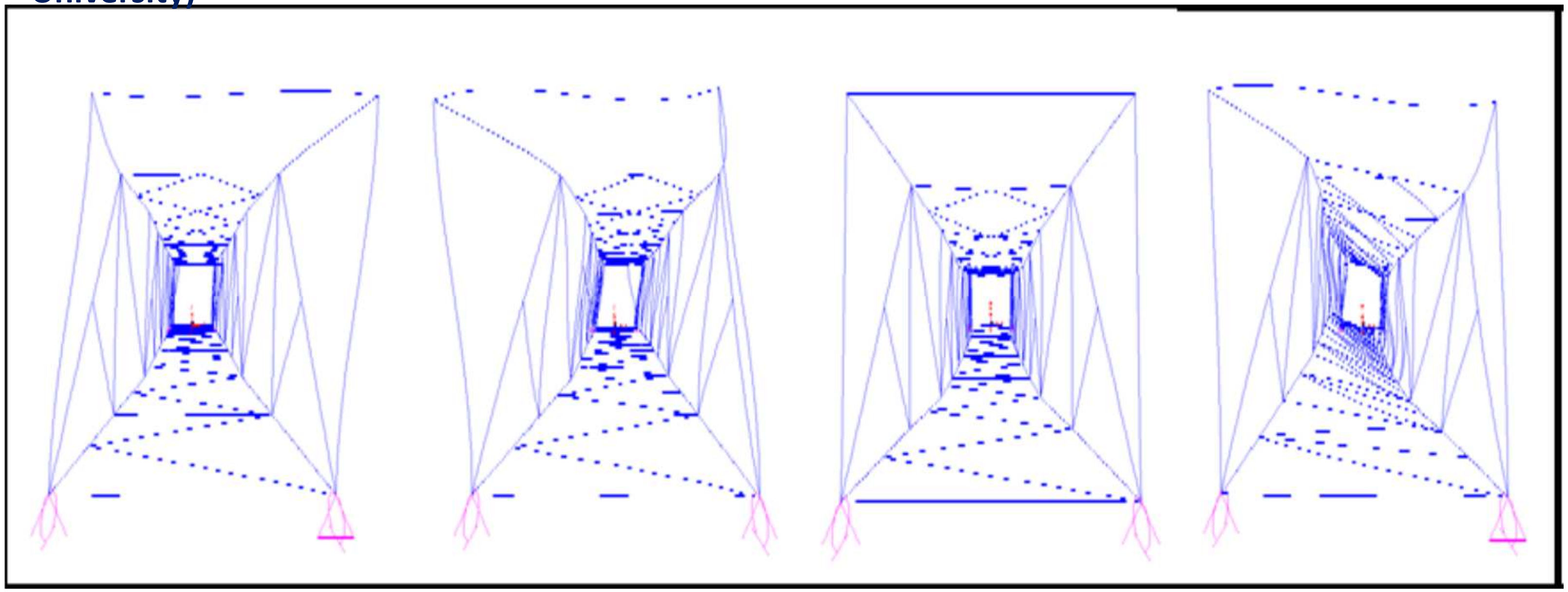


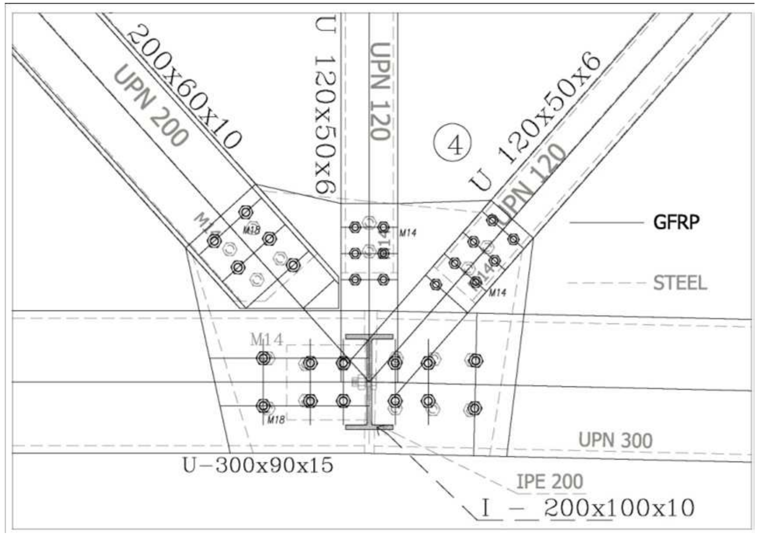
8
tons total weight

25
meter span length

5,0
kN/m² bearing capacity

<u>Designer</u>: ing A. Adilardi (Municipality of Prato); <u>Static/dynamic assessment and check</u>: Prof. S.Russo (Iuav University)





- Only **one truck** needed to transport the entire structure in situ already assembled

- And only **two days** to connect the bridge to the RC edges