F R C M

F *iber*

R *einforced*

C *ementitious*

M *atrix*

FRCM-Durability

REINFORCING MATERIALS

POLIPARAFENILENBENZOBISOXAZOLO (PBO)

CARBON(C)

+ CEMENTITIOUS MORTAR = **FRCM**

+ EPOXY RESIN = **FRP**

RUREDIL

Direzione Tecnica

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Chemicals for building

FRCM carbon fiber mesh with cementitius matrix for masonry structures strengthening

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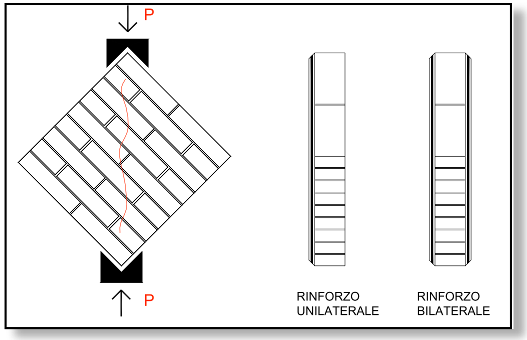
Ruredil X Mesh C10 M25

Experimental investigation on masonry walls

- specimen dimensions were 467,5x467,5x105 mm^3
- they were made of clay brick of 225x105x45 mm^3
- horizontal mortar joint had a mean thickness of 10 mm



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Ruredil X Mesh C10 M25

Experimental investigation on masonry walls

- control panels (PM1 and PM2)
- application of cementitious matrix on one panel side (PM3 and PM4)
- application of one FRCM layer on one panel side with carbon fibre net orientation 0°/90°, as mortar joints path (PM5 and PM6)
- application of two FRCM layers on one panel side with carbon fibre orientation 0°/90 and ±45° (PM7 and PM8)
- application of two FRCM layers on both panel sides with carbon fibre orientation 0°/90 and ±45° (PM9, PM10 and PM11).

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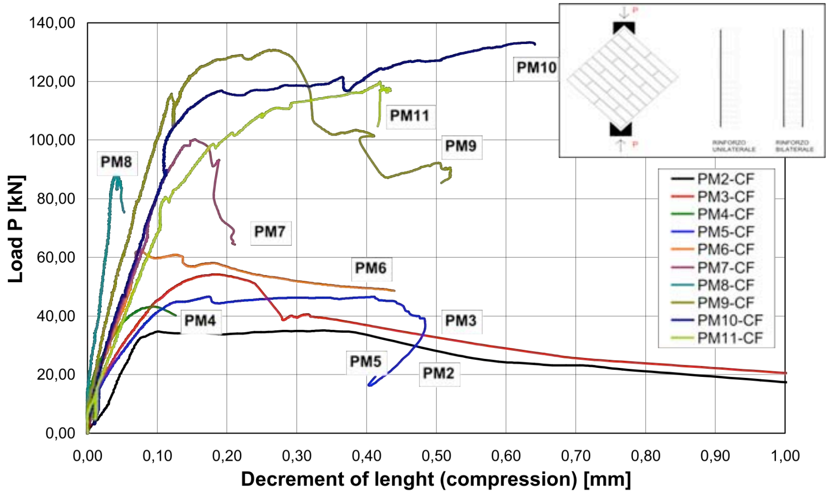
Experimental investigation on masonry walls



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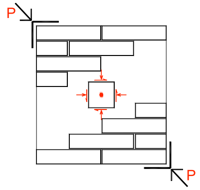
Definition of characteristic shear strength



U: one side B: both sides

M: only mortar S: one layer D: two layers

Specimen	P_{max} [N]	f_{tm} [N/mm²]	τ_k [N/mm²]	τ_{k0}/τ_{ki}
PM2	$35x10^3$	0.37	0.33	1
PM3-UM	$54.2x10^3$	0.57	0.52	1.55
PM4-UM	$43.2\ x10^3$	0.45	0.41	1.23
PM5-US	$46.4\ x10^3$	0.49	0.44	1.33
PM6-US	$61.9\ x10^3$	0.65	0.59	1.77
PM7-UD	$100.2\ x10^3$	1.05	0.96	2.86
PM8-UD	$88.2\ x10^3$	0.93	0.84	2.52
PM9-BD	$130.7\ x10^3$	1.37	1.25	3.79
PM10-BD	$133.3\ x10^3$	1.40	1.27	3.81
PM11-BD	$119.8\ x10^3$	1.26	1.15	3.42

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Ruredil X Mesh C10 M25

Conclusions

- The failure mechanism in strengthened panels was due to masonry cracking and FRCM ripping

- The strengthening system modifies the failure mechanism, increasing maximum applied force and panel stiffness. These aspects has to be considered in strengthening design.

- This technology is applicable easily by every bricklayer.

Mortar

The system

Net

Cutting

Application

1

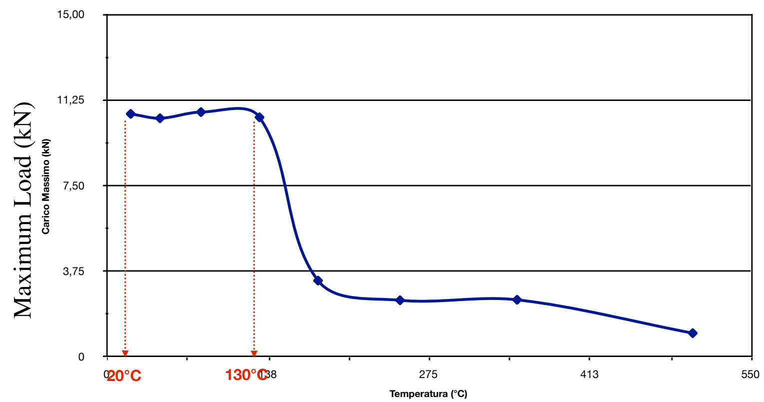
2

3

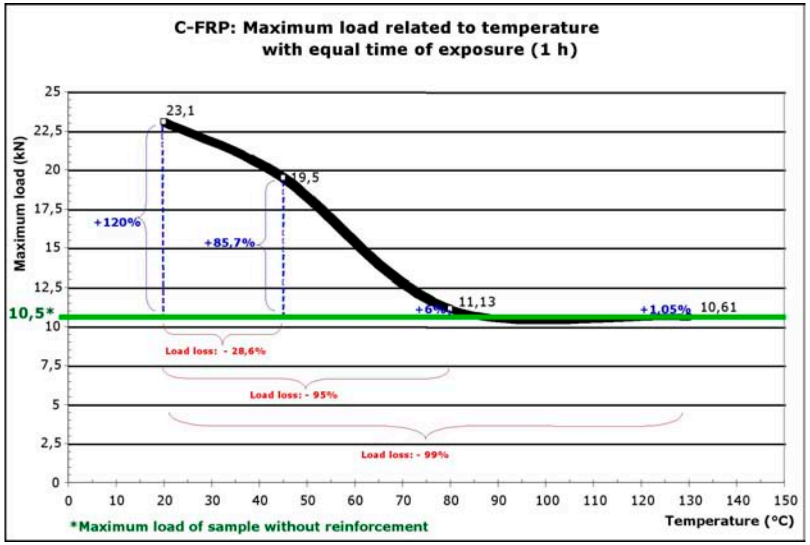
4

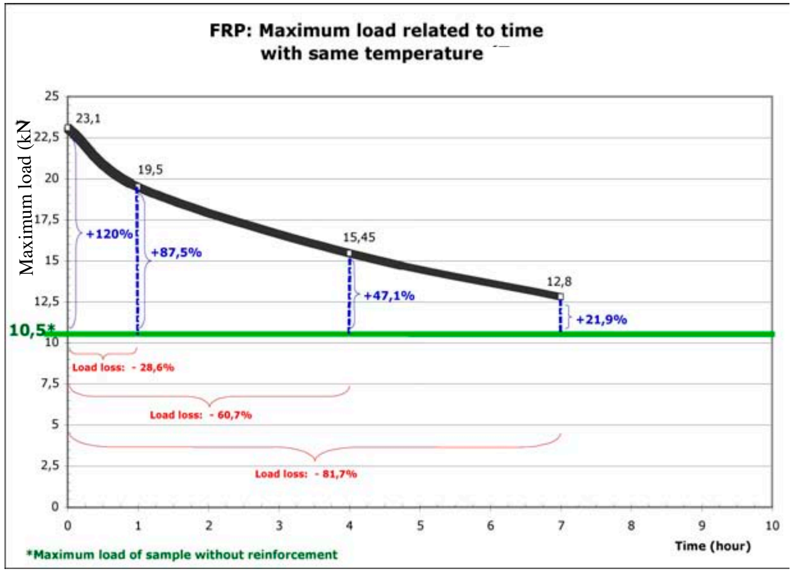
FRP Vs FRCM - Temperature behaviour

RESISTENZA A FLESSIONE DEL CALCESTRUZZO NON RINFORZATO IN FUNZIONE DELLA TEMPERATURA



*20°C-130°C : intervallo di temperatura entro il quale la resistenza a flessione del calcestruzzo non rinforzato rimane invariata all'aumentare della temperatura


C-FRP: Maximum load related to temperature
with equal time of exposure (1 h)
Maximum load (kN)
25
22,5
20
17,5
15
12,5
10,5*
10
7,5
5
2,5
0
23,1
19,5
11,13
10,61
+120%
+85,7%
+6%
+1,05%
Load loss: - 28,6%
Load loss: - 95%
Load loss: - 99%
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Temperature (°C)
*Maximum load of sample without reinforcement


FRP: Maximum load related to time
with same temperature
Maximum load (kN)
25
22,5
20
17,5
15
12,5
10
7,5
5
2,5
0
23,1
19,5
15,45
12,8
+120%
+87,5%
+47,1%
+21,9%
10,5*
Load loss: - 28,6%
Load loss: - 60,7%
Load loss: - 81,7%
0
1
2
3
4
5
6
7
8
9
10
Time (hour)
*Maximum load of sample without reinforcement

Temperature and moisture test

Il trattamento termico **a 80°C e 100% UR** (umidita relativa) è stato eseguito mediante camera di stagionatura a vapore, corredata di resistenze riscaldanti alettate, sensore d'umidità e temperatura e vaporizzatore con capacità di nebulizzazione pari a 0,5 litri/h.

Il test è stato eseguito **su 120 provini** in calcestruzzo delle dimensioni di 400x100x100 mm ,suddivisi in 12 serie da 10 provini cadauna:

- PBO-FRCM
- (EB) C-FRP con resina Tg= 100 °C

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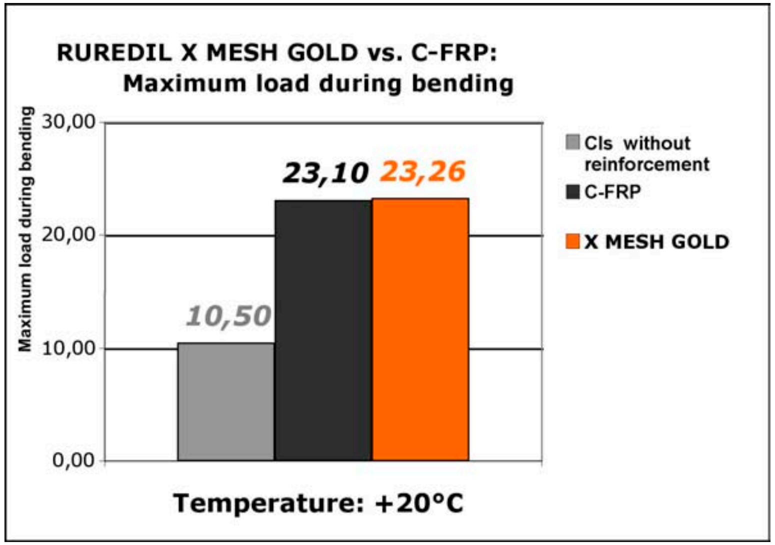
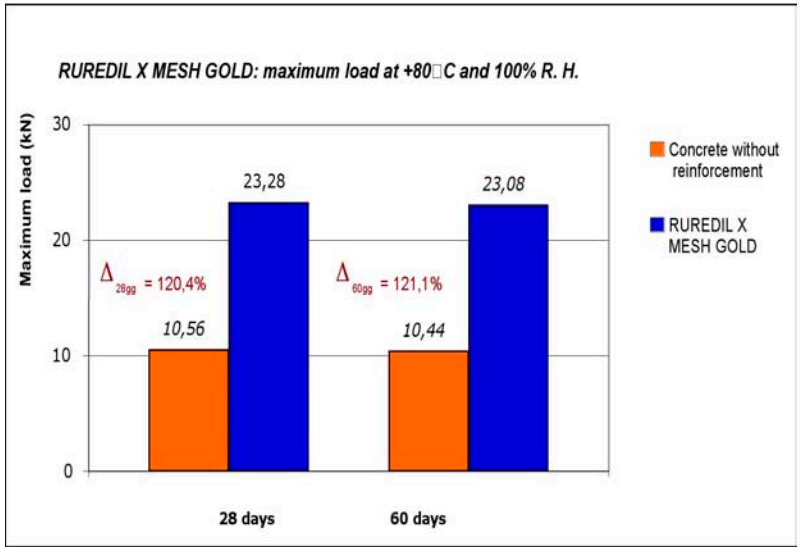
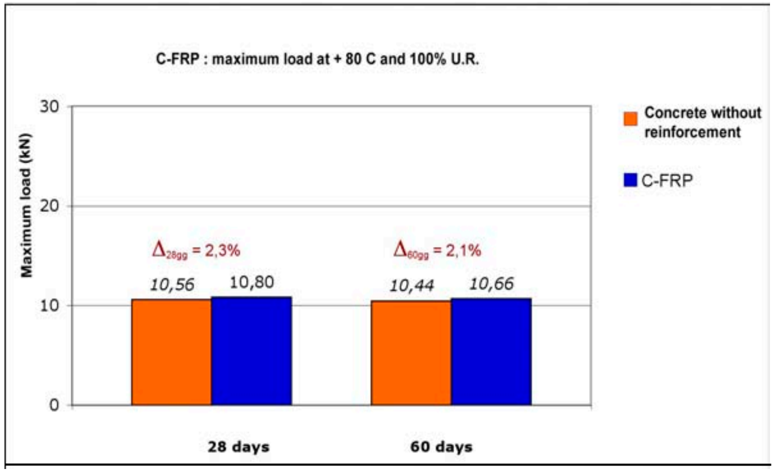
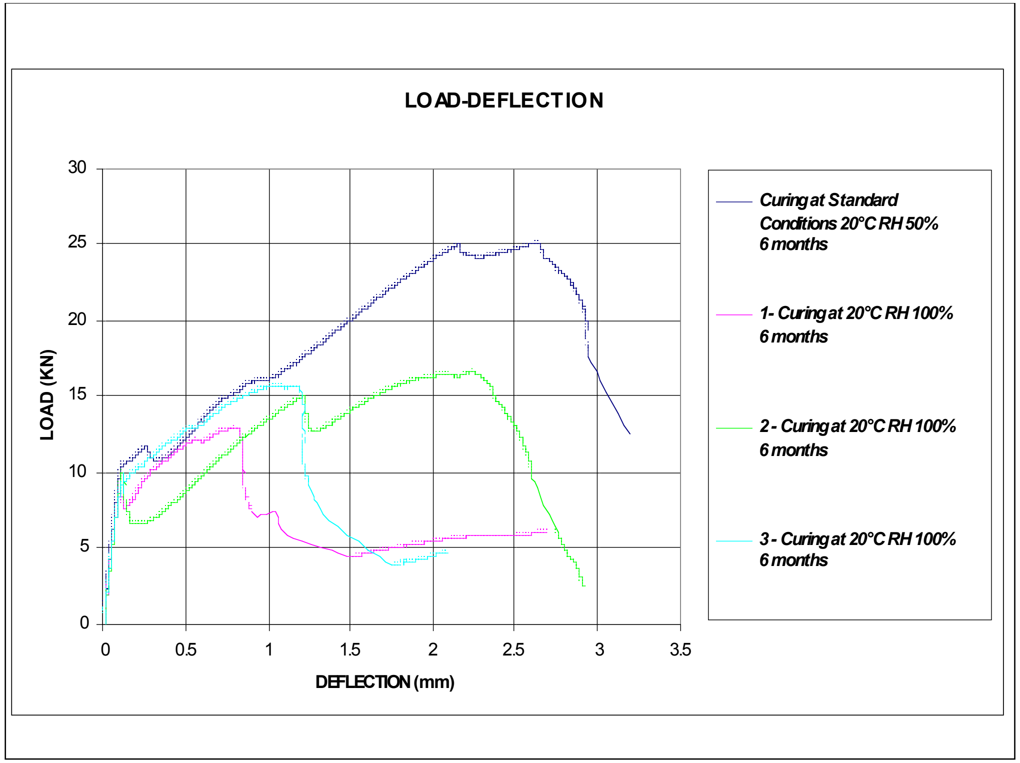

RUREDIL X MESH GOLD vs. C-FRP:
Maximum load during bending
Maximum load during bending
30,00
20,00
10,00
0,00
10,50
23,10
23,26
Cls without reinforcement
C-FRP
X MESH GOLD
Temperature: +20°C


RUREDIL X MESH GOLD: maximum load at +80□C and 100% R. H.
Maximum load (kN)
30
20
10
0
23,28
23,08
10,56
10,44
Δ 28gg = 120,4%
Δ 60gg = 121,1%
Concrete without reinforcement
RUREDIL X MESH GOLD
28 days
60 days


C-FRP : maximum load at + 80 C and 100% U.R.
Maximum load (kN)
30
20
10
0
Δ_{28gg} = 2,3%
Δ_{60gg} = 2,1%
10,56
10,80
10,44
10,66
28 days
60 days
Concrete without reinforcement
C-FRP

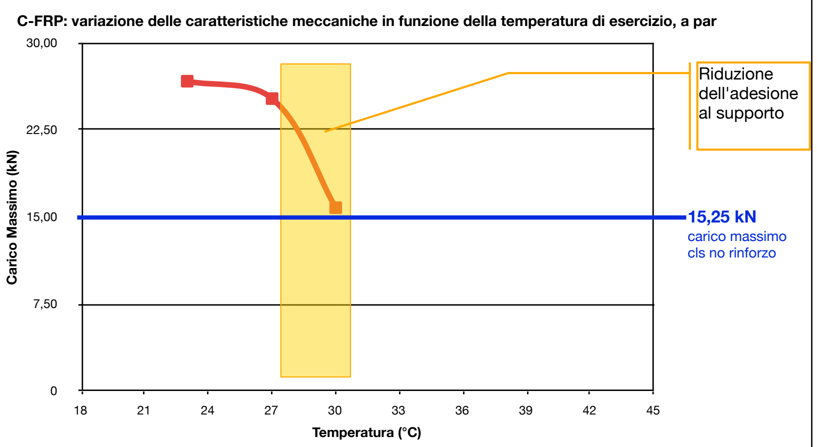


LOAD-DEFLECTION
LOAD (KN)
DEFLECTION (mm)
0
5
10
15
20
25
30
0
0.5
1
1.5
2
2.5
3
3.5
Curing at Standard Conditions 20°C RH 50% 6 months
1- Curing at 20°C RH 100% 6 months
2 - Curing at 20°C RH 100% 6 months
3 - Curing at 20°C RH 100% 6 months

New development

C- FRP - Flexural test at costant temperature of 30°C $\underline{+}$ 1

Il test riguarda 15 provini ed è stato eseguito termostatando la macchina di prova attraverso una



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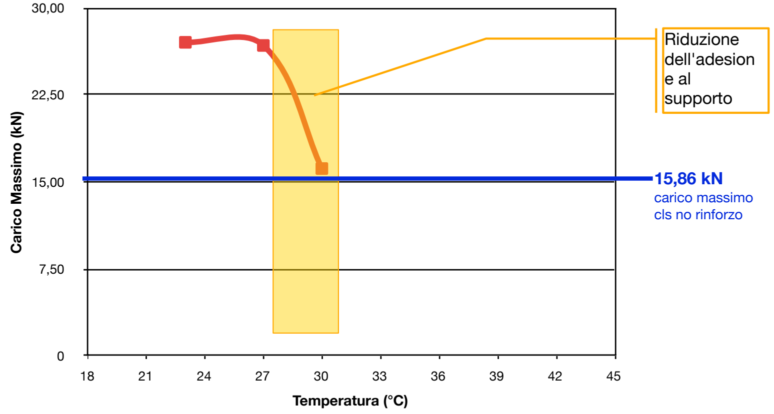
C-FRP: variazione delle caratteristiche meccaniche in funzione della temperatura di esercizio, a par



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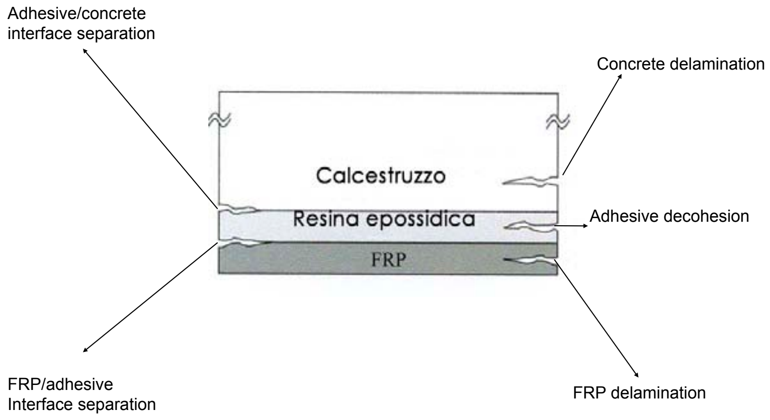
FRCM-Durabilità

DEBONDING MODES



FRCM-Durabily

COHESION FRP/CONCRETE

PEELING -maximum bending moment section

design strain is the minimum value:

- characteristic rupture strain of FRP reinforcement (ε_{fu})
- maximum strain of FRP reinforcemant before debonding- $\varepsilon_{f,max}$(without enviromental conditions)

Peeling (maximum strain debonding-minimum value)

$$\varepsilon_{fd} = \min\left\{\eta_a \frac{\varepsilon_{fu}}{\gamma_f},\ \eta_b\ \ \varepsilon_{f,\max}\right\}$$

Material rupture

$\gamma_f = 1.2 \div 1.3$ partial factor

$\eta_a = 0.5 \div 0.95$ enviromental conversion factor.

$\varepsilon_{fd} =$ maximum strain of FRP reinforcemant before debonding

Compliance to UNI EN 13501-1-2007

Fire classification of FRCM and FRP :

	A1–A2	No contribution to fire / flameproofing	No i flash-over
FRCM	B-s1,d_0	No contribution to fire/ non-combustible	No i flash-over
	C	Contributionn to fire- very low	No i flash-over
	D	Contributionn to fire- low	flash-over risk
FRP	E	Reaction to fire-very low	flash-over risk
	F	No performance to reaction fire	flash-over risk

I sistemi FRP, contribuendo alla generazione e/o alla propagazione del fuoco, necessitano di una adeguata protezione con prodotti intumescenti; mentre i sistemi FRCM non sono combustibili e non contribuiscono all'incendio.

Edimburg University *Prof. Bisby*

Flexural beam test at temperature of 30- 200 °C/U.R. 50%

Near surface mounted (NSM) FRP
Externally-Bonded (EB) FRP
FRCM

CNR

1-Flexural test at 20 - 35 °C / U.R. 50%
2-Flexural test at U.R 60-100% / T. 23 °C

FRP
FRCM

Ruredil X Mesh C10

Work in progress
2008 - 2009

Referenze - Estero

Hilandar Monastery - *XII secolo*

Monte Athos - Grecia

Rinforzo strutturale di circa 4000 m2





Direzione Tecnica

Ruredil

Il complesso

Ruredil X Mesh C10

Direzione Tecnica

Ruredil

I dipinti

Ruredil X Mesh C10

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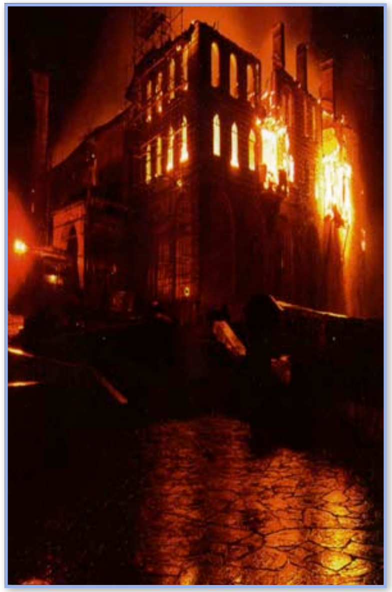
L' incendio del 2004



Ruredil X Mesh C10

Direzione Tecnica

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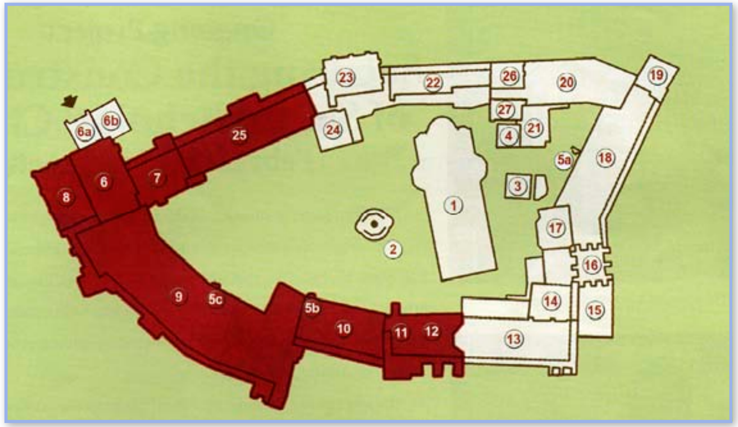
Ruredil X Mesh C10

Il complesso



Danneggiata dall'incendio

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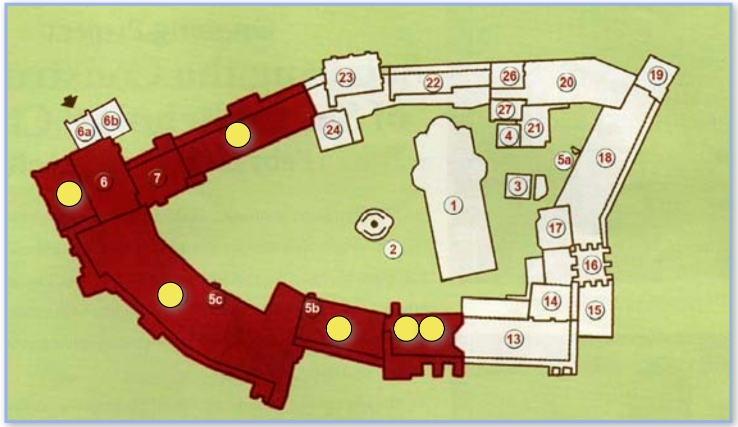
Ruredil

Il complesso

Ruredil X Mesh C10



Ricostruzione e rinforzi strutturali in corso

La ricostruzione

Ruredil X Mesh C10

Direzione Tecnica

Ruredil

La ricostruzione

Ruredil X Mesh C10

Direzione Tecnica

Ruredil

La ricostruzione

Ruredil X Mesh C10

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La ricostruzione - *Rinzaffatura*

Ruredil X Mesh C10

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Ruredil

Il rinforzo strutturale -Ruredil X Mesh M25

Ruredil X Mesh C10

Il rinforzo strutturale - *Ruredil X Mesh C10*

Ruredil X Mesh C10

Direzione Tecnica

Ruredil

Il rinforzo strutturale - *Finitura*

Ruredil X Mesh C10

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Prime verifiche dei rinforzi strutturali eseguiti con FRCM

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Chemicals for building

CAPORCIANO - Santa Maria di Centurelli

Consolidamento delle volte

FRCM

Ruredil

Chemicals for building

S. Maria dei Cinturelli

Ottobre 2003

Ruredil
Chemicals for building

S. Maria dei Cinturelli

Ruredil
Chemicals for building

S. Maria dei Cinturelli

Ruredil

Chemicals for building

S. Maria dei Cinturelli

Ruredil

Chemicals for building

S. Maria dei Cinturelli

Ruredil
Chemicals for building

S. Maria dei Cinturelli

CAPORCIANO - Santa Maria di Centurelli

Dopo il sisma del 6 Aprile 2009

Ruredil

Chemicals for building

S. Maria dei Cinturelli

2009

Ruredil

Chemicals for building

S. Maria dei Cinturelli

2009

Ruredil

Chemicals for building

2009

S. Maria dei Cinturelli

Ruredil

Chemicals for building

S. Maria dei Cinturelli

Ruredil
Chemicals for building

FRCM

L'Aquila

L'Aquila - *Basilica di San Bernardino*

Ruredil
Chemicals for building

Basilica San Bernardino

Consolidamento delle volte del refettorio (mq 350) - Nessuna lesione -

Ruredil

Chemicals for building

FRCM

CHIETI- Palazzo de Mayo

Ruredil
Chemicals for building

Chieti - Palazzo De Mayo

Consolidamento delle volte (mq 3000) - Nessuna lesione

CHIETI- Palazzo de Mayo

Ruredil
Chemicals for building

Palazzo De Mayo

Ruredil

Chemicals for building

Palazzo De Mayo

Ruredil

Chemicals for building

Palazzo De Mayo

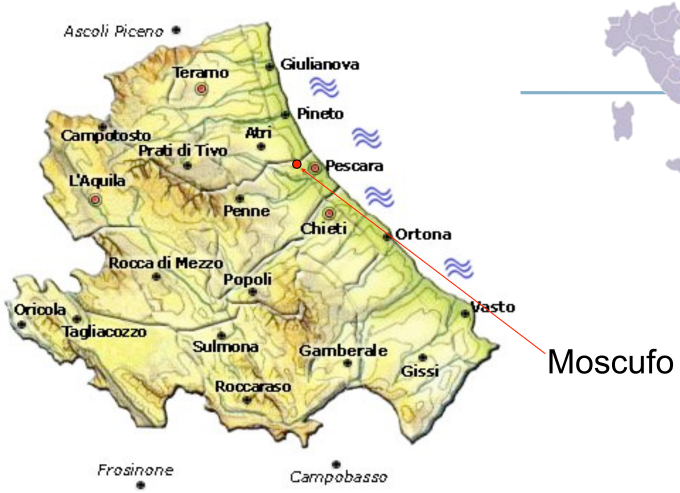
Ruredil

Chemicals for building

Palazzo De Mayo

Ruredil

Chemicals for building



FRCM

Moscufo - *Chiesa*

Ruredil
Chemicals for building

Consolidamento delle volte (mq 250) - Nessuna lesione -

Chiesa di Moscufo

Ruredil
Chemicals for building

FRCM

Collecorvino - *Convento*

Ruredil
Chemicals for building

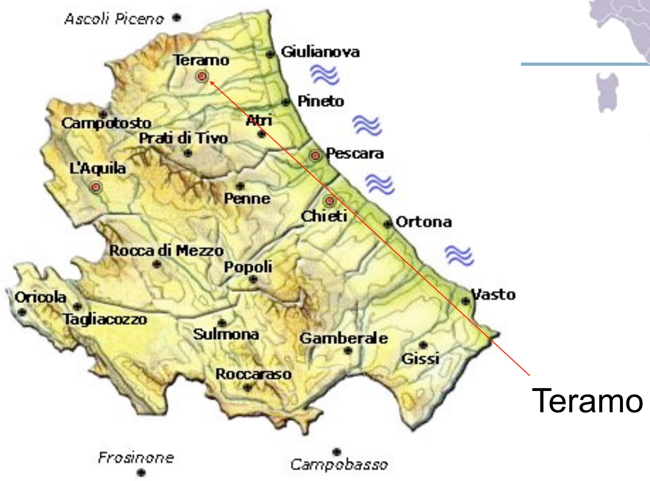
Convento di Collecorvino

Consolidamento delle volte (mq 600) - Nessuna lesione -

Ruredil

Chemicals for building

FRCM

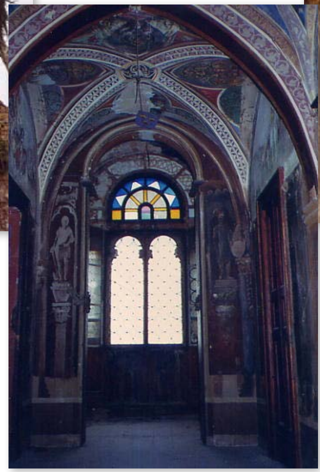


Teramo - *Castello della Monica*

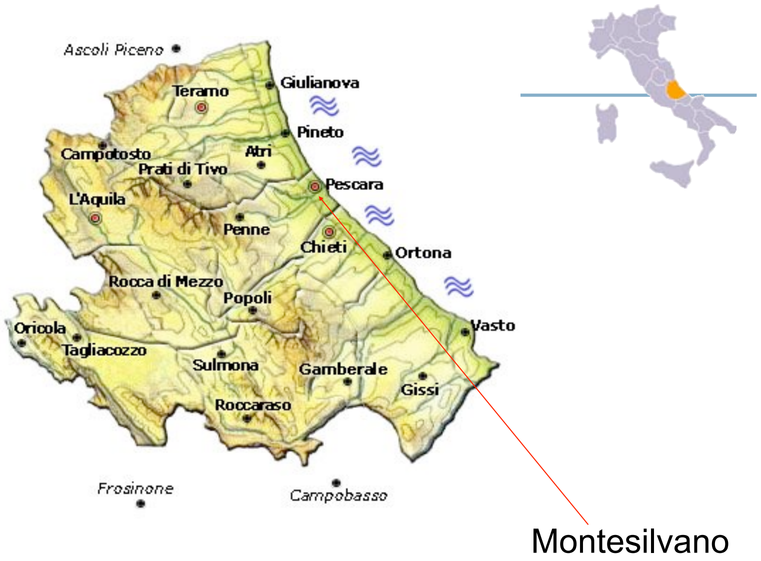
Ruredil
Chemicals for building

Teramo - Castello della Monica

Consolidamento delle volte (mq 600) - Nessuna lesione -



Ruredil
Chemicals for building



FRCM

Montesilvano *-Ex Colonia Stella Maris*

Ruredil

Chemicals for building

Montesilvano - Ex Colonia Stella Maris

Rinforzo Travi (mq 600) - Nessuna lesione -