O projeto Niker: os seus objetivos e resultados

PROF. FRANCESCA DA PORTO

francesca.daporto@unipd.it

DEPARTMENT ICEA
UNIVERSITY OF PADOVA

MAIN TARGET OF THE PROJECT

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DEPARTMENT ICEA
UNIVERSITY OF PADOVA

Development of integrated and knowledge based methodologies for the protection of Cultural Heritage assets from earthquakes on the basis of optimization and 'minimum intervention' approach.

MAIN PROJECT OBJECTIVES

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Based on post-earthquake survey of damages after seismic events, drawbacks and limitations of the state-of-the-art technologies and approaches have been understood. Hence, the objective is to overcome the current shortcomings mainly related to:

- **use of inadequate intervention techniques**
- **use of inadequate materials**
- **use of inadequate tools for analysis or dated design methods**
- **analysis carried out on the basis of limited information**

MAIN NIKER INNOVATIONS

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- Materials and techniques for intervention
- Studies and techniques for structural connections
- Optimization approach for CH buildings
- Testing and sub-structuring test methods
- Monitoring and early warning systems
- Integrated, multidisciplinary approach for CH
- Standardization

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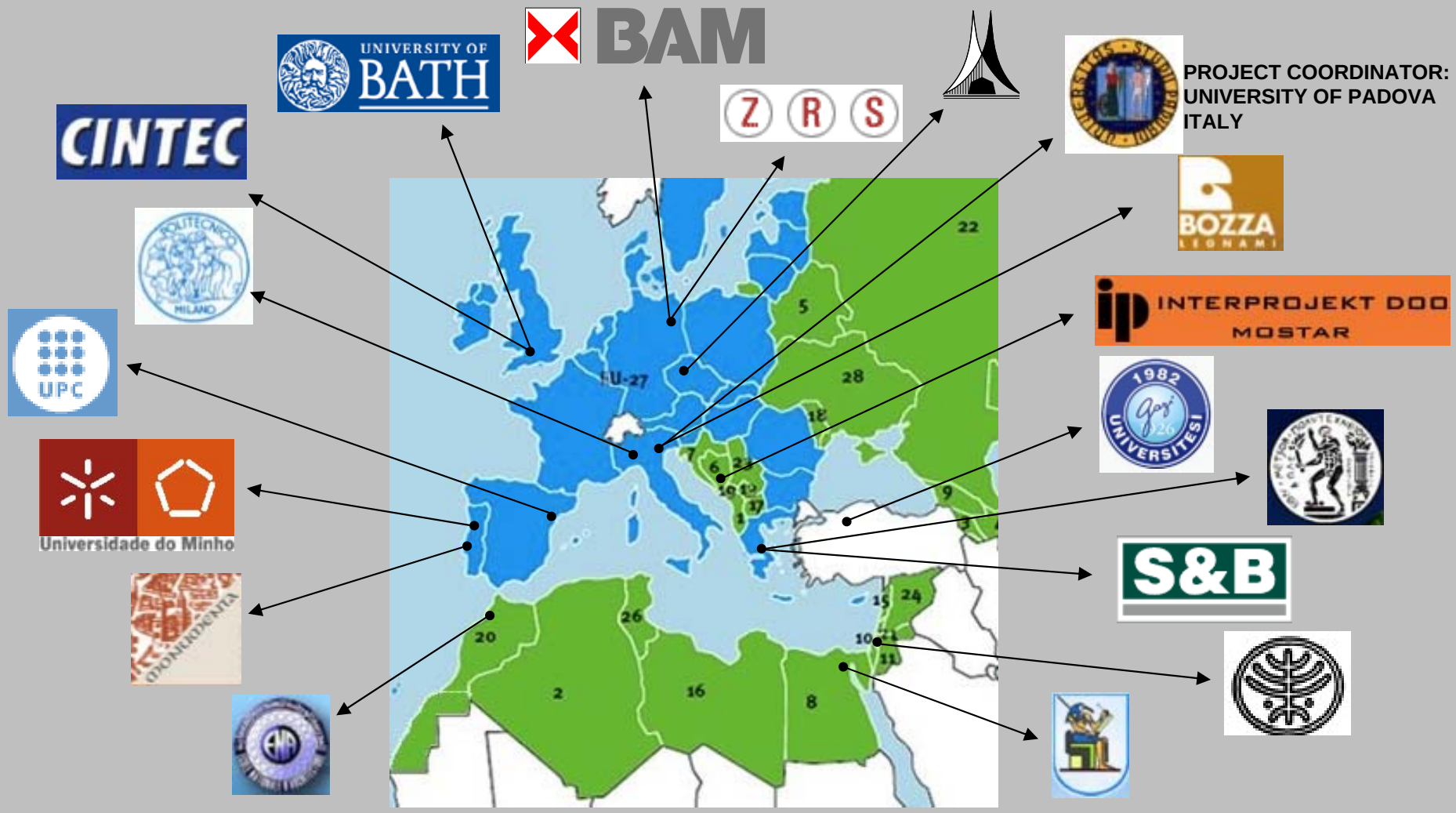

- 18 partners
- 12 countries
- 9 Universities
- 2 Research centres
- 6 Enterprises
- 1 Public body

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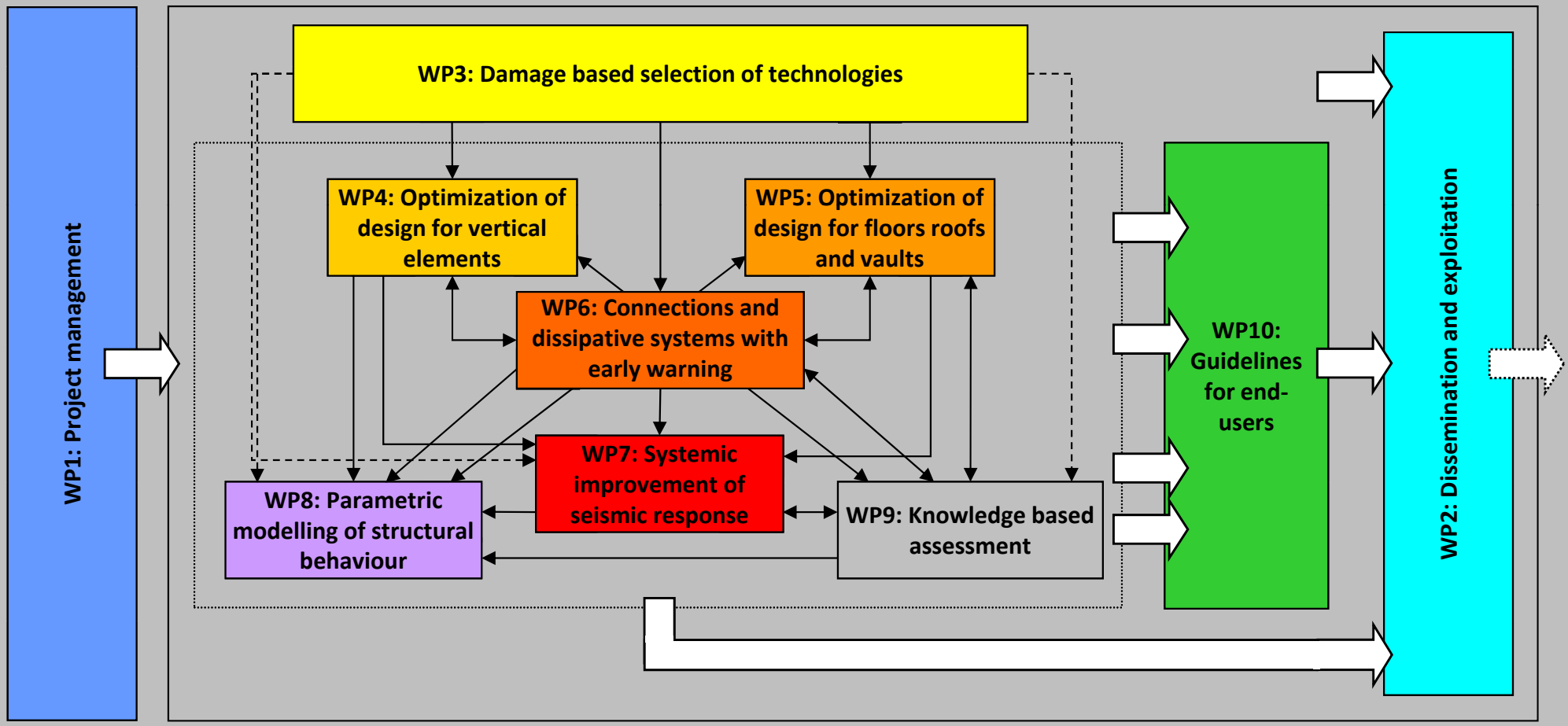
NEW INTEGRATED KNOWLEDGE BASED APPROACHES TO THE PROTECTION OF CULTURAL HERITAGE FROM EARTHQUAKE INDUCED RISK



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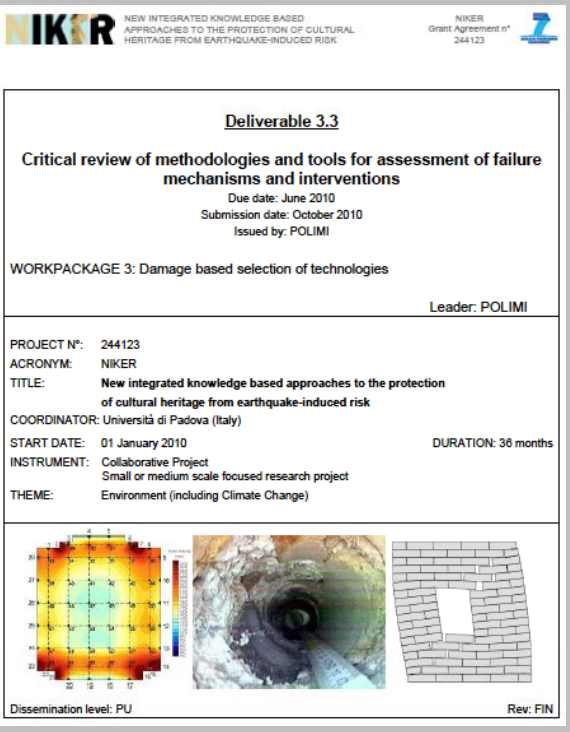


NEW INTEGRATED KNOWLEDGE BASED APPROACHES TO THE PROTECTION OF CULTURAL HERITAGE FROM EARTHQUAKE-INDUCED RISK

NIKER Grant Agreement n° 244123

Deliverable 3.3

Critical review of methodologies and tools for assessment of failure mechanisms and interventions

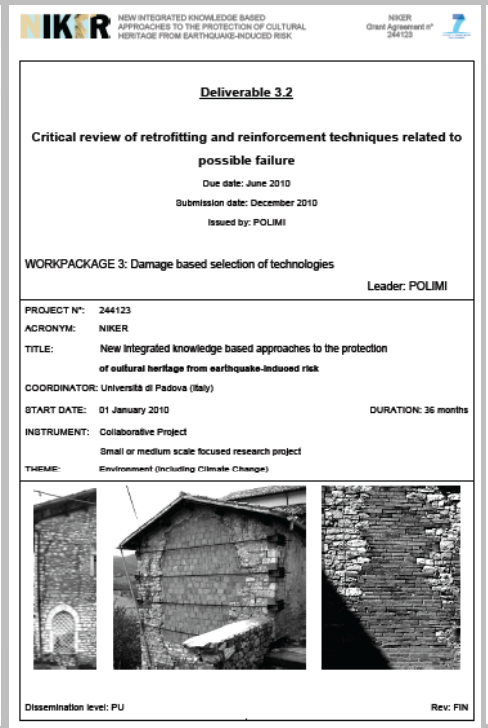
Due date: June 2010
Submission date: October 2010
Issued by: POLIMI

WORKPACKAGE 3: Damage based selection of technologies

Leader: POLIMI

PROJECT N°: 244123
ACRONYM: NIKER
TITLE: New integrated knowledge based approaches to the protection of cultural heritage from earthquake-induced risk
COORDINATOR: Università di Padova (Italy)
START DATE: 01 January 2010 DURATION: 36 months
INSTRUMENT: Collaborative Project
Small or medium scale focused research project
THEME: Environment (including Climate Change)

Dissemination level: PU Rev: FIN



NEW INTEGRATED KNOWLEDGE BASED APPROACHES TO THE PROTECTION OF CULTURAL HERITAGE FROM EARTHQUAKE-INDUCED RISK

NIKER Grant Agreement n° 244123

Deliverable 3.2

Critical review of retrofitting and reinforcement techniques related to possible failure

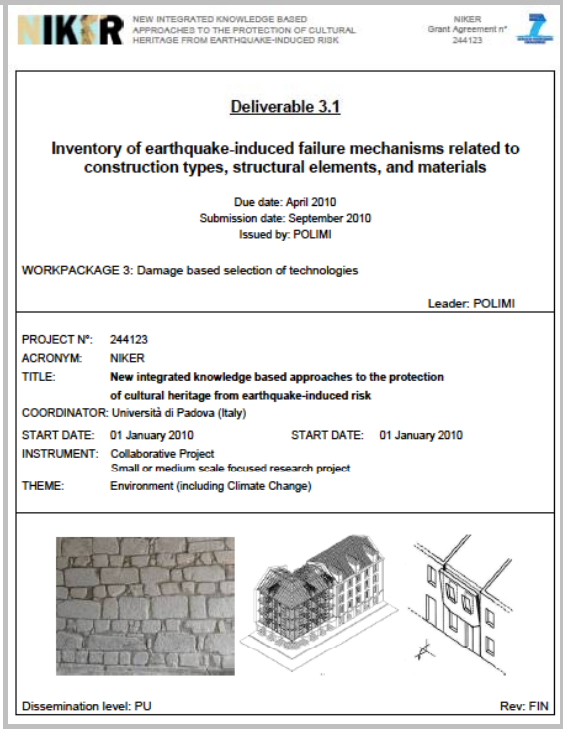
Due date: June 2010
Submission date: December 2010
Issued by: POLIMI

WORKPACKAGE 3: Damage based selection of technologies

Leader: POLIMI

PROJECT N°: 244123
ACRONYM: NIKER
TITLE: New integrated knowledge based approaches to the protection of cultural heritage from earthquake-induced risk
COORDINATOR: Università di Padova (Italy)
START DATE: 01 January 2010 DURATION: 36 months
INSTRUMENT: Collaborative Project
Small or medium scale focused research project
THEME: Environment (including Climate Change)

Dissemination level: PU Rev: FIN



NEW INTEGRATED KNOWLEDGE BASED APPROACHES TO THE PROTECTION OF CULTURAL HERITAGE FROM EARTHQUAKE-INDUCED RISK

NIKER Grant Agreement n° 244123

Deliverable 3.1

Inventory of earthquake-induced failure mechanisms related to construction types, structural elements, and materials

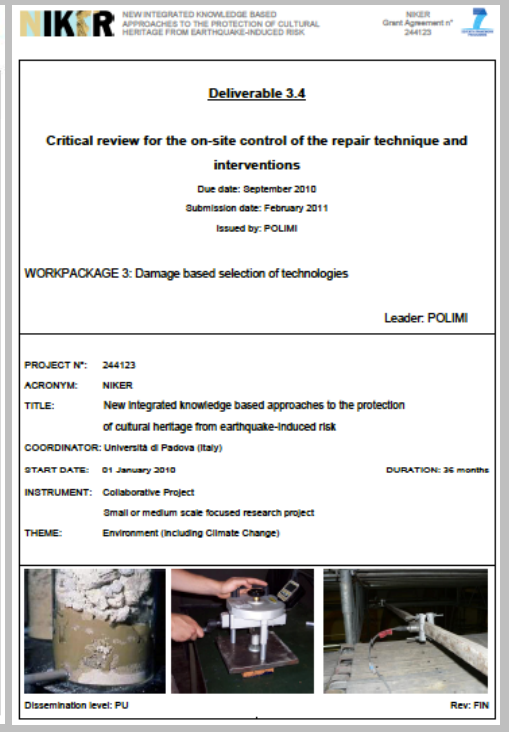
Due date: April 2010
Submission date: September 2010
Issued by: POLIMI

WORKPACKAGE 3: Damage based selection of technologies

Leader: POLIMI

PROJECT N°: 244123
ACRONYM: NIKER
TITLE: New integrated knowledge based approaches to the protection of cultural heritage from earthquake-induced risk
COORDINATOR: Università di Padova (Italy)
START DATE: 01 January 2010 START DATE: 01 January 2010
INSTRUMENT: Collaborative Project
Small or medium scale focused research project
THEME: Environment (including Climate Change)

Dissemination level: PU Rev: FIN



NEW INTEGRATED KNOWLEDGE BASED APPROACHES TO THE PROTECTION OF CULTURAL HERITAGE FROM EARTHQUAKE-INDUCED RISK

NIKER Grant Agreement n° 244123

Deliverable 3.4

Critical review for the on-site control of the repair technique and interventions

Due date: September 2010
Submission date: February 2011
Issued by: POLIMI

WORKPACKAGE 3: Damage based selection of technologies

Leader: POLIMI

PROJECT N°: 244123
ACRONYM: NIKER
TITLE: New integrated knowledge based approaches to the protection of cultural heritage from earthquake-induced risk
COORDINATOR: Università di Padova (Italy)
START DATE: 01 January 2010 DURATION: 36 months
INSTRUMENT: Collaborative Project
Small or medium scale focused research project
THEME: Environment (including Climate Change)

Dissemination level: PU Rev: FIN

D3.1 Inventory of earthquake-induced failure mechanisms related to construction types, structural elements, and materials

D3.2 Critical review of retrofitting and reinforcement techniques related to possible failure mechanisms and requirements

D3.3 Critical review of methodologies and tools for assessment of failure mechanisms and interventions

D3.4 Critical review for the onsite control of the repair technique and interventions

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D3.5 Development of materials and techniques for interventions

NIKER — NEW INTEGRATED KNOWLEDGE BASED APPROACHES TO THE PROTECTION OF CULTURAL HERITAGE FROM EARTHQUAKE-INDUCED RISK

NIKER Grant Agreement n° 244123

Deliverable 3.5

Development of materials and techniques for interventions

Due date: December 2010

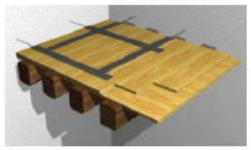
Submission date: March 2011

Issued by: POLIMI

WORKPACKAGE 3: Damage based selection of technologies

Leader: POLIMI

PROJECT N°:	244123
ACRONYM:	NIKER
TITLE:	**New integrated knowledge based approaches to the protection of cultural heritage from earthquake-induced risk**
COORDINATOR:	Università di Padova (Italy)
START DATE:	01 January 2010 — DURATION: 36 months
INSTRUMENT:	Collaborative Project Small or medium scale focused research project
THEME:	Environment (including Climate Change)


Dissemination level: PP

TECHNIQUE:						
Local intervention ☐			Global intervention ☐			
Structural element	wall ☐	pillar ☐	floor ☐	roof ☐	arch/vault ☐	sub-assembly ☐
Material	masonry (from catalogue) ☐		stone masonry ☐	brick masonry ☐	adobe ☐	
	wood ☐		other ☐	Description		
Aim of the application / Advantages						
Seismic mechanism (from damage catalogue)						

Parameters to estimate

Property		Range of values	Improvement
Section monolithism	…	…	… %
Tensile strength	f_t [N/mm²]	…	… %
Compressive strength	f_c [N/mm²]	…	… %
Initial shear strength	f_{v0} [N/mm²]	…	… %
Displacement capacity	ψ [%]	…	… %
Ductility	μ [-]	…	… %
Energy diss. capacity	E_{dis}/E_{inp} [%]	…	… %
….	…	…	… %

Limits / Applicability / Restrictions

Documented seismic performances

Application procedures and remarks

Improved by the simultaneous use of:

Possible mistakes in the application

Maintenance suggestions and periodic controls/monitoring

Long term performance / durability

Standards and/or Recommendations

References

CONTROLS

Preliminary laboratory tests (on the material, on the assemblage, etc.)

Parameters to estimate

Property		Range of values	Improv
Section monolithism	…	…	… %
Tensile strength	f_t [N/mm²]	…	… %
Compressive strength	f_c [N/mm²]	…	… %
Initial shear strength	f_{v0} [N/mm²]	…	… %
Displacement capacity	ψ [%]	…	… %
Ductility	μ [-]	…	… %
Energy diss. capacity	E_{dis}/E_{inp} [%]	…	… %
….	…	…	… %

Standards and/or Recommendations

In absence of addressed standards:

procedure description	
tools and equipments	
sample dimensions and characteristics	
number of samples	

References

ON SITE CONTROLS

Parameters to estimate

Before the application	
After the application	

Property		Range of values	Improvement
Section monolithism	…	…	… %
Tensile strength	f_t [N/mm²]	…	… %
Compressive strength	f_c [N/mm²]	…	… %
Initial shear strength	f_{v0} [N/mm²]	…	… %
Displacement capacity	ψ [%]	…	… %
Ductility	μ [-]	…	… %
Energy diss. capacity	E_{dis}/E_{inp} [%]	…	… %
….	…	…	… %

Standards and/or Recommendations

In absence of addressed standards:

Procedures description and/or complementary tests	
Tools and equipments	
investigation area	
number of tests	

References

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NIKER CATALOGUE

http://www.niker.eu

WP3 - DAMAGE BASED SELECTION OF TECHNOLOGIES

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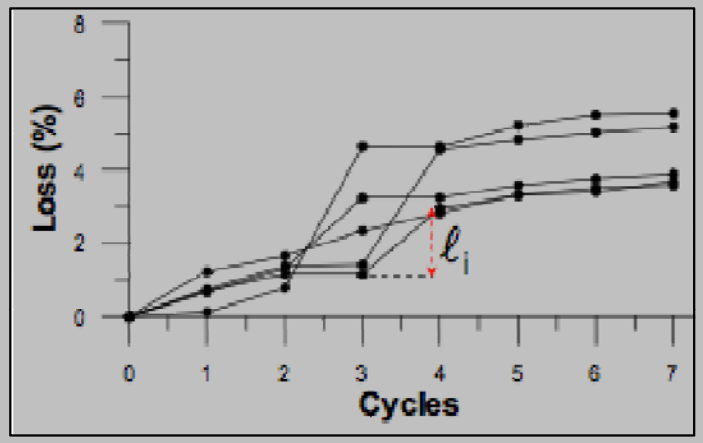
D3.7 – Critical evaluation of the effectiveness and compatibility of the new materials

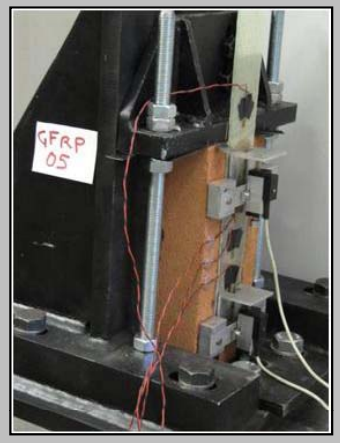
DURABILITY OF COMMERCIAL NATURAL HYDRAULIC LIME MORTARS



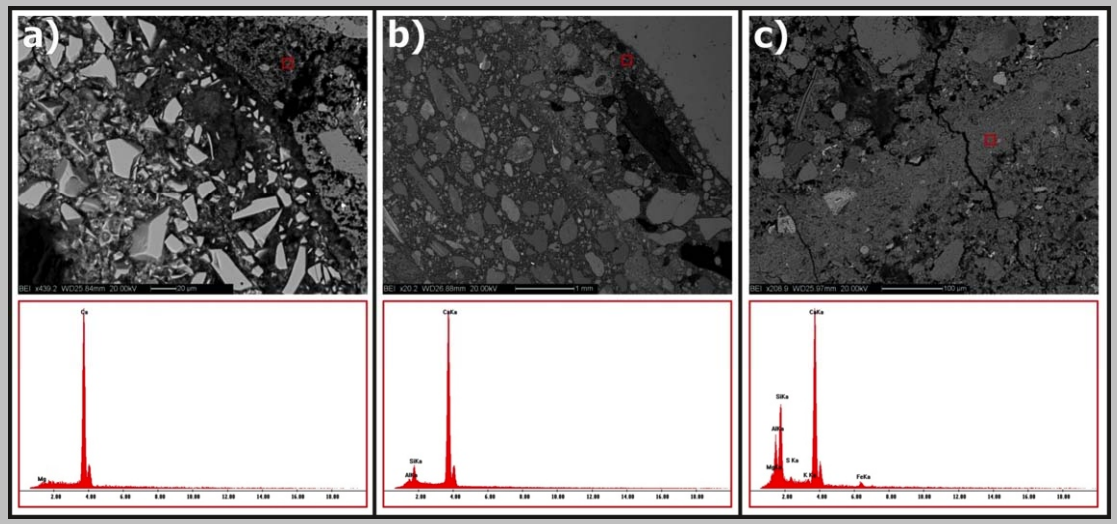
INJECTABILITY OF GROUT ADMIXTURES ON STONE MASONRY WALLS

DURABILITY OF FRP APPLICATIONS ON BRICK MASONRY

BOND BEHAVIOUR OF FRP APPLIED ON BRICK MASONRY



MICROSTRUCTURAL CHARACTERIZATION OF GROUT TO STONE MASONRY ORIGINAL MORTAR INTERFACE



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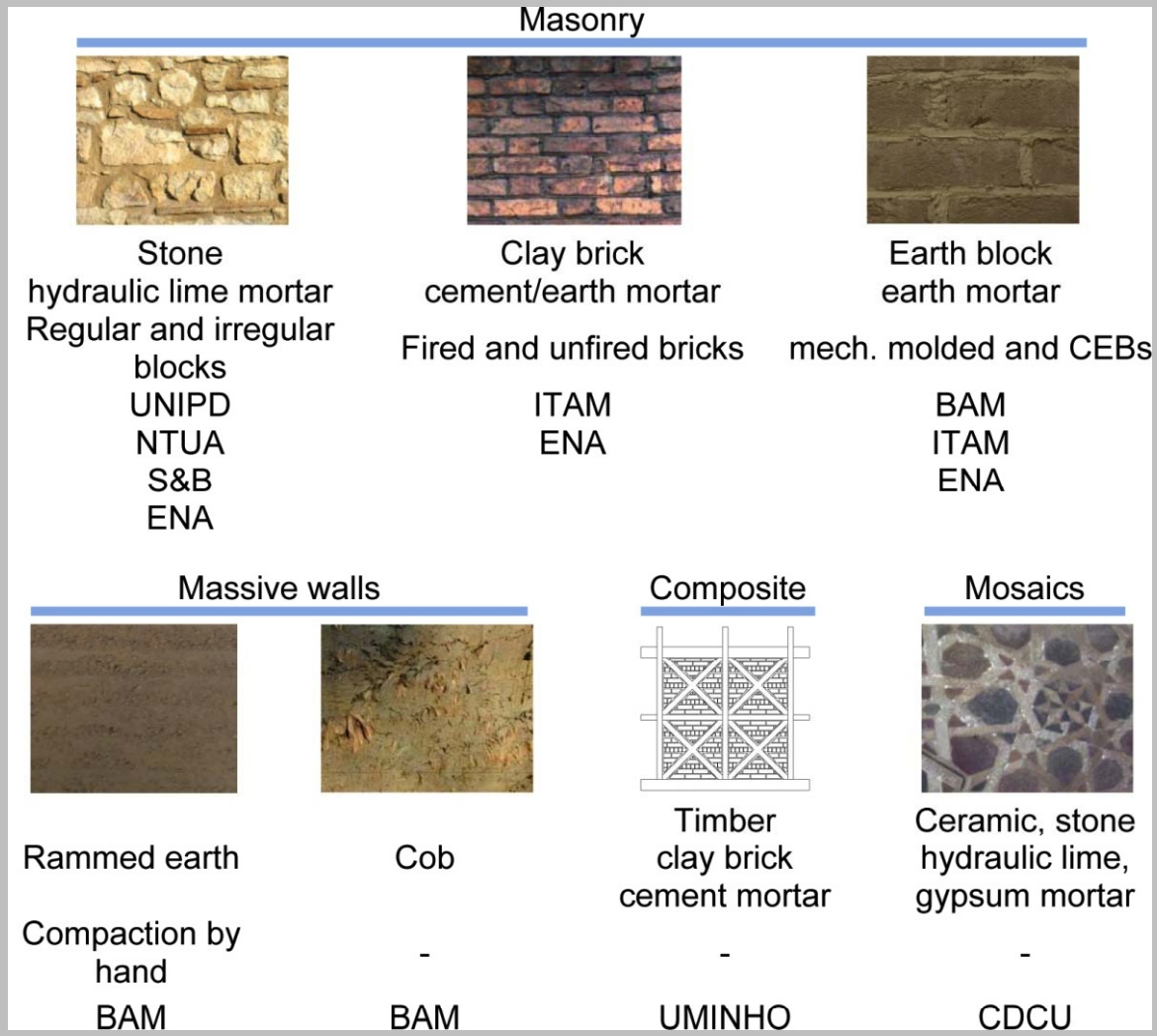
WP4 RATIONALE

Experimental campaigns carried out

Definition of:

- Adequate and feasible intervention methods for vertical structural elements

- Improvement of laboratory procedures for evaluating the intervention methods and specifications for laboratory specimens.



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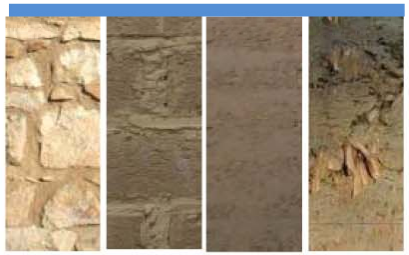
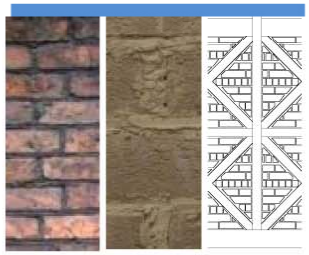
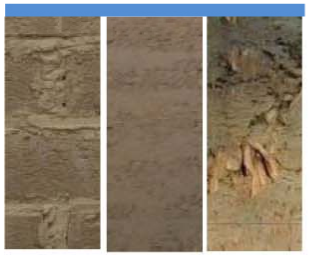
WP4 RATIONALE

Experimental campaigns carried out

- Characterize the experimental behaviour of original and strengthened walls, in order to obtain information on the system performance and the main constitutive laws relevant for modelling.

- Numerical simulation of the experimental behaviour and perform parametric assessment to define critical mechanical parameters or define optimized design procedures.

Grouting	FRP strips/Nets	Textile belts	Others
			
Lime based, earthen materials	GFRP, PP, PET	PE, 3 cm, 5 cm with hydraulic mortar	Steel wire ropes

WP4 - OPTIMIZATION OF DESIGN FOR VERTICAL ELEMENTS

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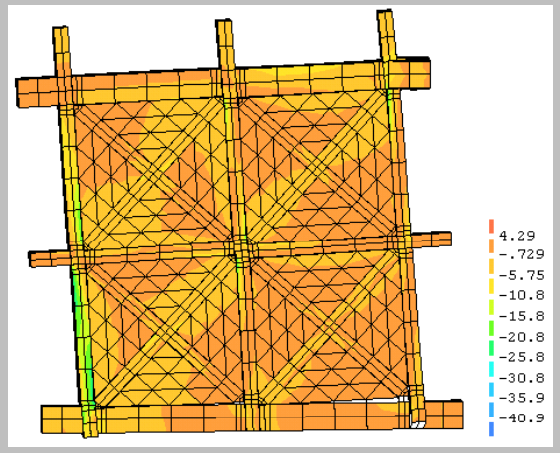
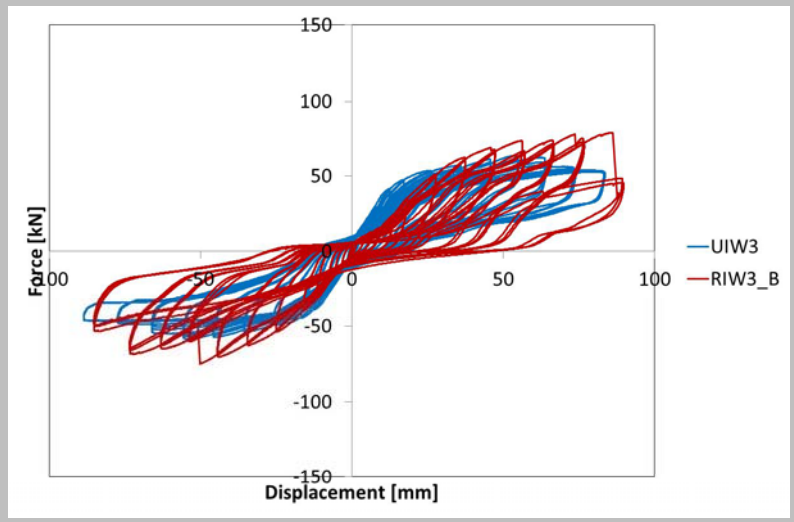
Intervention techniques, testing, modelling, analyses and derivation of design charts/equations.





$$\begin{cases} f_{wc,0} = (V_{ex}/V)\cdot f_{ex,c} \\ f_{wc,s} = f_{wc,0} + (V_{\inf}/V)\cdot f_{\inf,s} \end{cases}$$

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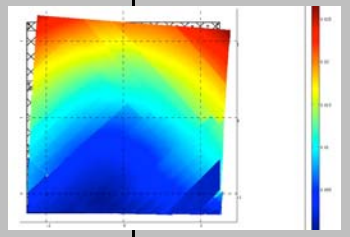
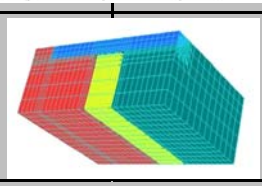
WP5 RATIONALE: WOODEN FLOORS

FLOORS								
Level of investigation	Partner	Testing	Modeling			Parametric analysis		
		Experimental tests	Analytical modeling	FEM Linear	FEM Non Linear	Analytical modeling	FEM Linear	FEM Non Linear
Element	UNIPD BOZZA	Monotonic and cyclic tests on strengthened timber floors	Identification of in-plane stiffness and energy dissipation parameters	Calibration of global behaviour (in-plane strength and deformability)				
	ITAM	Experimental in-plane cyclic tests on authentic floor segments	Identification of in-plane stiffness and energy dissipation parameters	Calibration of global behaviour (in-plane strength and deformability)			Influence of planking orientation on the floor stiffness	
Local	UNIPD BOZZA			Characterization and calibration of behaviour of connections			Influence of connections on the global behaviour of floors	

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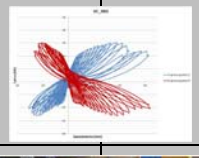
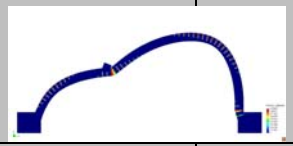
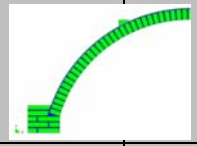
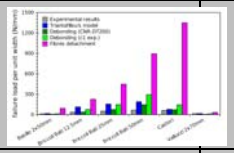
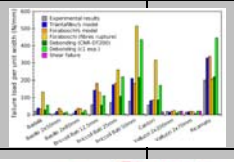
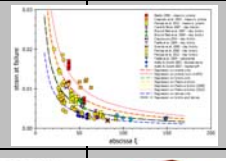
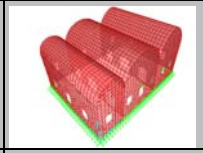
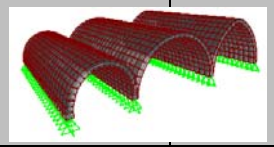
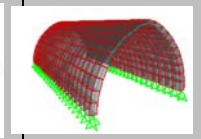
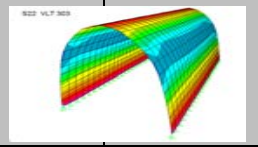
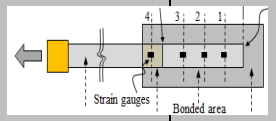
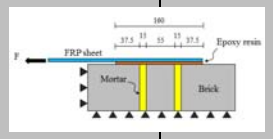
WP5 RATIONALE: VAULTS

VAULTS								
Level of investigation	Partner	Testing	Modeling			Parametric analysis		
		Experimental tests	Analytical modeling	FEM Linear	FEM Non Linear	Analytical modeling	FEM Linear	FEM Non Linear
Element	UNIPD	Monotonic and cyclic tests on barrel vaults						
	UBATH	Pseudo-dynamic and cyclic tests on arches						
	UPC			Modelling of strengthened vaults				Simulation of strengthening and failure modes
	UNIPD					Calibration of design parameters for shear bond		
	GUNI					Interaction of parallel vaults with boundary conditions		
Local	UMINHO	Shear bond of composites to brick units			Shear bond behaviour between bricks and composites			3D modelling of bond behaviour on prisms
	UNIPD	Bond of composites (pull-off, shear loads, dowel effect) to bricks	Analytical formulation of local mechanisms in strengthened conditions			Influence of local effects on load capacity. Calibration of pull-off bond		

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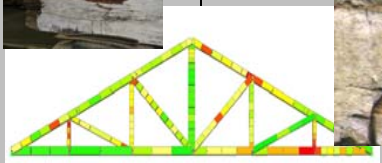
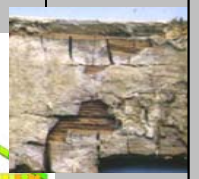
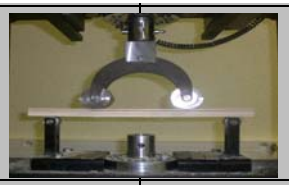
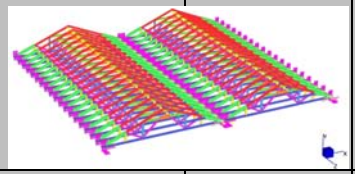
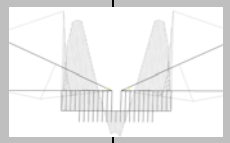
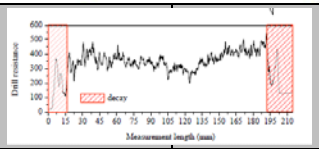
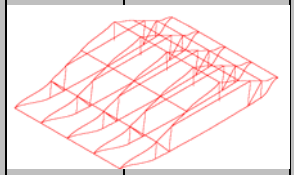
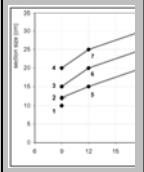
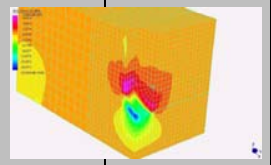
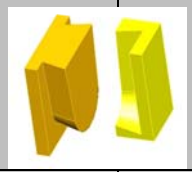
WP5 RATIONALE: WOODEN ROOFS

ROOFS								
Level of investigation	Partner	Testing	Modeling			Parametric analysis		
		Experimental tests	Analytical modeling	FEM Linear	FEM Non Linear	Analytical modeling	FEM Linear	FEM Non Linear
Element	UMINHO	Vertical loading on wooden trusses rescued from existing building and deterioration investigation on connections				  		
	ENA	Physical and mechanical characterization of wooden materials in timber elements	Verification of wooden floors and joists based on design criteria					
	UNIPD			Modelling of series of trusses				Influence of corbel length on behaviour of serial trusses
	UMINHO			Modelling the load-carrying tests performed in full-scale timber trusses		Reliability assessment of timber trusses from NDT data		
	POLIMI			Dynamic response of roof structures			Influence of geometric parameters in seismic vulnerability of timber trusses	
Local	UNIPD BOZZA			Calibration of mortise-tenon joint behaviour				

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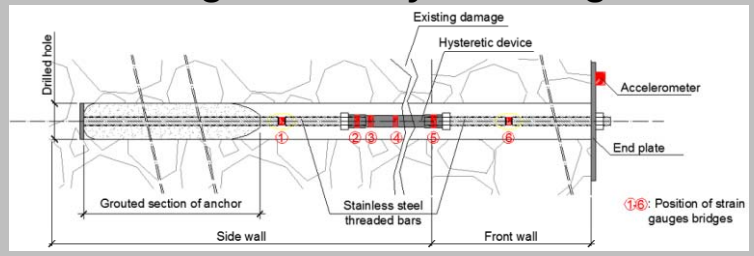
WP6 RATIONALE: TECHNIQUES FOR CONNECTIONS

- Testing procedures for the experimental validation of unreinforced and strengthened connections;
- Innovative techniques relying on ductility and energy dissipation;
- Indications on how to design connection strengthening and where to source parameters required in the process;
- Tackle the lack of information regarding:

Less studied historic materials, such as earthen materials

Traditional reinforcement systems, such as timber lacing

Possible use of innovative systems for connection strengthening, monitoring and early warning



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WP6 RATIONALE: TECHNIQUES FOR CONNECTIONS

Type of specimen	Specimen	Materials – Description of the structure	Partner	Testing	
				Type of tests	Strengthening
Connection interface = 1 structural element + strengthening		English-bond brickwork masonry	UBATH/ CINTEC	Monotonic pull-out	Metallic grouted anchors w/o *dissipative anchoring devices*
		Earth block masonry/ rammed earth/ cob wall panels	BAM	Monotonic pull-out	GFRP/metallic grouted anchors
		Rubble stone masonry panels	UMINHO/ MONUMENTA	Monotonic pull-out	Grouted metallic anchors
Whole connection = 2 structural elements + strengthening		T-shaped double-bond brickwork masonry	UBATH/ CINTEC	Pseudo-static cyclic	Metallic grouted anchors w/o *dissipative anchoring devices*
		Timber carpentry joint	ITAM	Dynamic cyclic	Various (e.g. carbon plates, nails, *high-friction plates*, oak plates, pin)
		Rubble stone masonry panels and timber beams	UMINHO/ MONUMENTA	Monotonic pull-out	Metallic L profile bolted to beam and anchored to wall + *ductile anchor*
Whole structure		Three-leaf stone masonry walls with horizontal timber structures	NTUA	Recorded signals on shaking table	Timber-lacing

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PERFORMANCE PARAMETERS - E.G. ANCHORS

How should one dimension an anchor? What parameters does one need for the design? How are these parameters identified by tests? How do test compare with design codes and other references? How can be dissipative devices integrated in the design?

ULS:

$$F_{1U} = a_U M \le \frac{\pi d^2}{4} f_y n = F_{2U}$$

$$F_{2U} = \le \pi d_2 l f_b = F_3$$

$$F_{2U} \le \sqrt{2} l \left(l + d_2 \right) \tau_k = F_3$$

DLS:

$$F_{1D} = a_D M \le F_{2D}$$

F_{2D}: device activation load (yielding of hysteretic element/sliding of friction element

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Characterization of the seismic behaviour of original substructures and/or model buildings and the same strengthened with integrated interventions, coming from previous tests, by shaking table tests.

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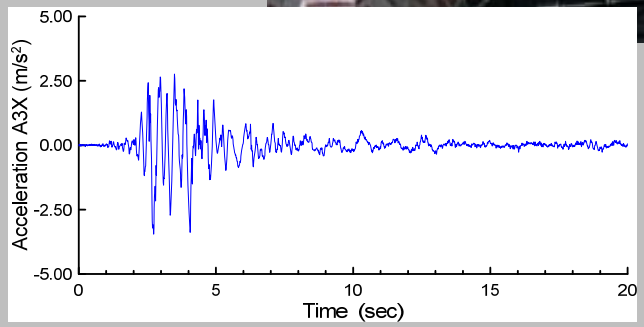
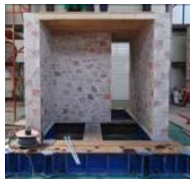
SHAKING TABLE TESTS OF SUB-STRUCTURES



1	Element		Three-leaf stone masonry
2	Element		Adobe
3	Subassembly		Adobe + light timber floor
4	Subassembly		Adobe + heavy timber floor
5	Subassembly		Adobe + light roof with stiff diaphragm
6	Subassembly		Three-leaf stone masonry piers + timber floor
7	Subassembly		Three-leaf stone masonry piers + brick arches and cross vault

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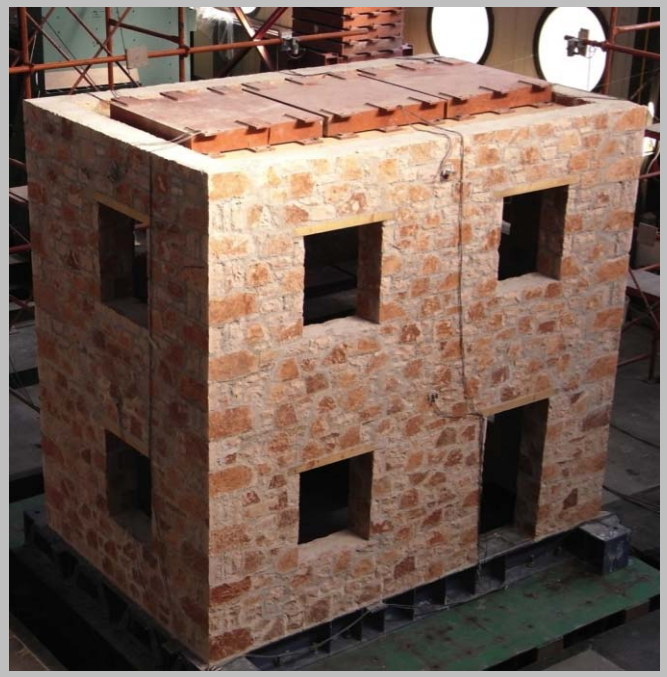
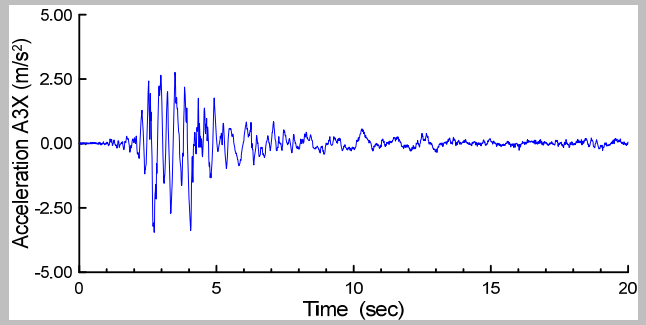


SHAKING TABLE TESTS OF MODEL BUILDINGS

	Type of specimen	Specimen	Materials – Description of the structure	Partner	Testing: Type of tests	Testing: Strengthening
1	Model building		Three-leaf stone masonry + timber floors (double planking and steel ties)	UNIPD	Shaking table tests. Motion along two axes	(a) As-built (b) Grouting
2	Model building		Three-leaf stone masonry + timber floors (double planking and steel ties)	UNIPD	Shaking table tests. Motion along two axes	(a) Grouting
3	Model building		Three-leaf stone masonry + timber floors	NTUA	Shaking table tests. Motion along two axes	(a) As built (b) Grouting of masonry and enhancement of diaphragm action of floors
4	Model building		Three-leaf stone masonry + timber floors + timber laces	NTUA	Shaking table tests. Motion along two axes	(a) As built (b) Grouting (c) Enhancement of diaphragm action of top floor



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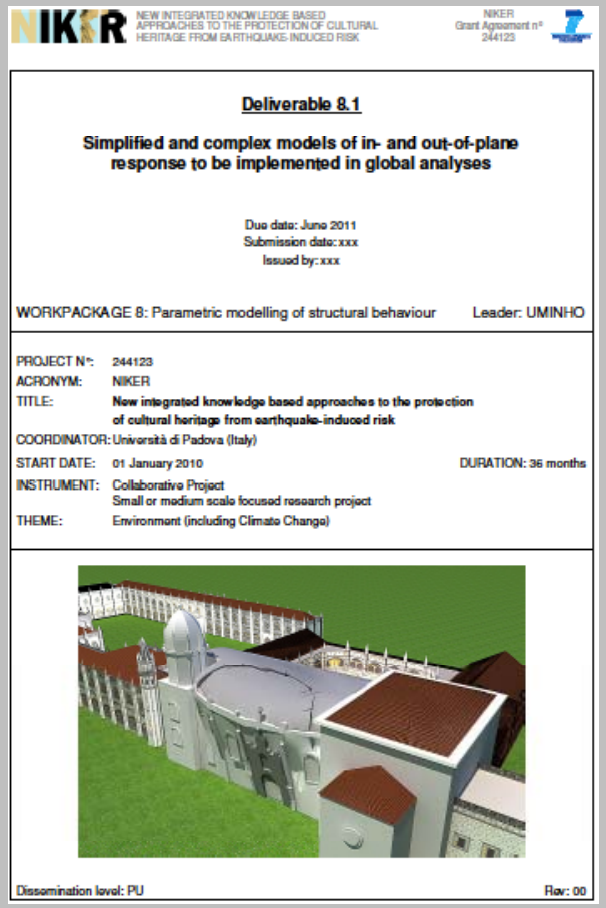

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NIKER Grant Agreement n° 244123

Deliverable 8.1

Simplified and complex models of in- and out-of-plane response to be implemented in global analyses

Due date: June 2011
Submission date: xxx
Issued by: xxx

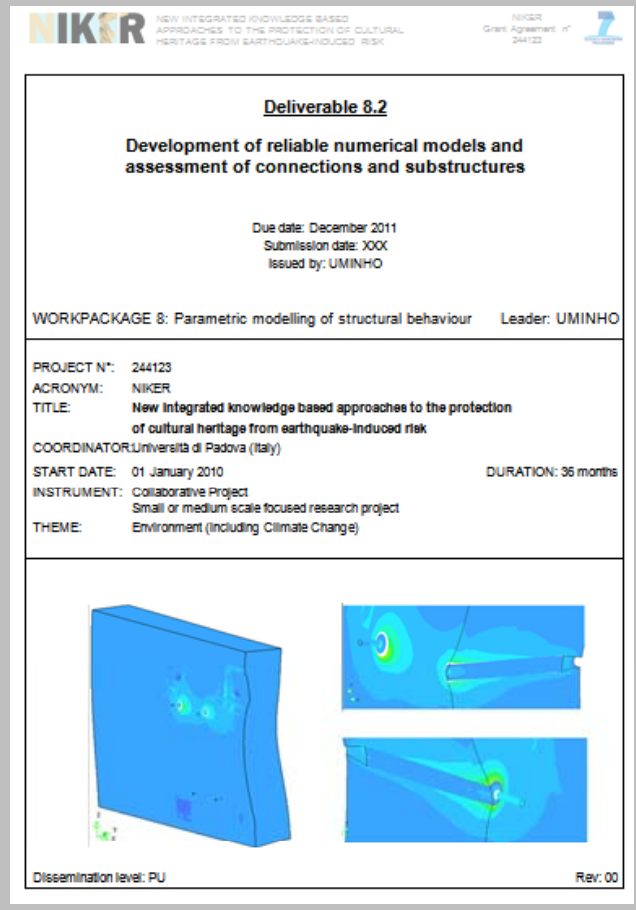
WORKPACKAGE 8: Parametric modelling of structural behaviour — Leader: UMINHO

PROJECT N°: 244123
ACRONYM: NIKER
TITLE: New integrated knowledge based approaches to the protection of cultural heritage from earthquake-induced risk
COORDINATOR: Università di Padova (Italy)
START DATE: 01 January 2010 — DURATION: 36 months
INSTRUMENT: Collaborative Project, Small or medium scale focused research project
THEME: Environment (including Climate Change)

Dissemination level: PU — Rev: 00

D8.1 – Simplified and complex models of in- and out-of-plane response to be implemented in global analyses

D8.2 - Development of reliable numerical models and assessment of connections and substructures



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NIKER Grant Agreement n° 244123

Deliverable 8.2

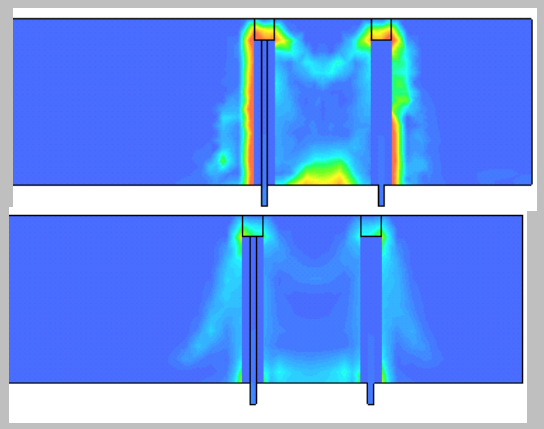
Development of reliable numerical models and assessment of connections and substructures

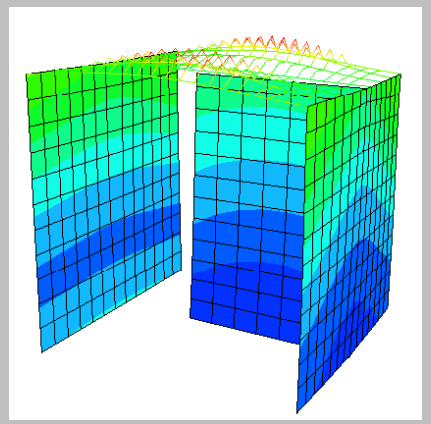
Due date: December 2011
Submission date: XXX
Issued by: UMINHO

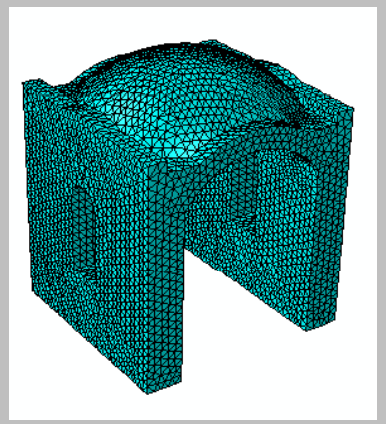
WORKPACKAGE 8: Parametric modelling of structural behaviour — Leader: UMINHO

PROJECT N°: 244123
ACRONYM: NIKER
TITLE: New integrated knowledge based approaches to the protection of cultural heritage from earthquake-induced risk
COORDINATOR: Università di Padova (Italy)
START DATE: 01 January 2010 — DURATION: 36 months
INSTRUMENT: Collaborative Project, Small or medium scale focused research project
THEME: Environment (including Climate Change)

Dissemination level: PU — Rev: 00







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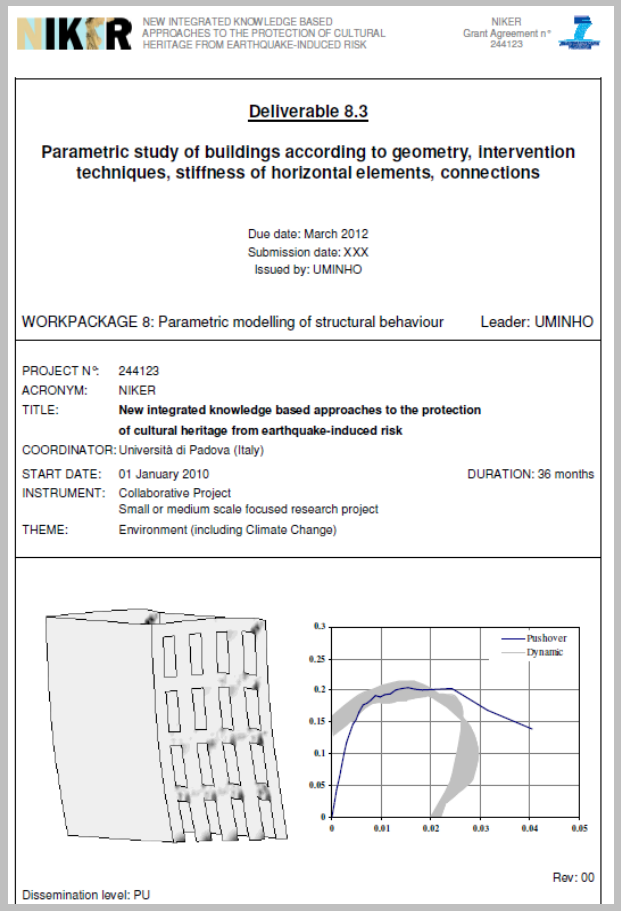

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NIKER Grant Agreement n° 244123

Deliverable 8.3

Parametric study of buildings according to geometry, intervention techniques, stiffness of horizontal elements, connections

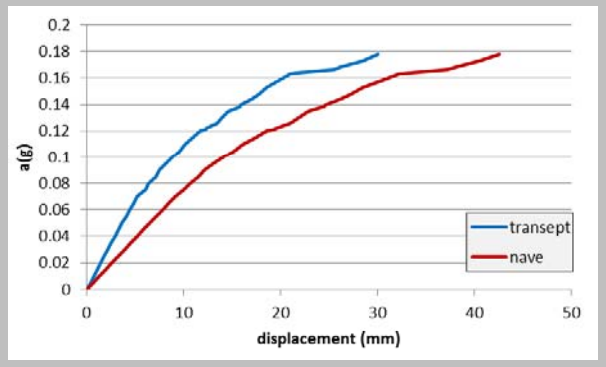
Due date: March 2012
Submission date: XXX
Issued by: UMINHO

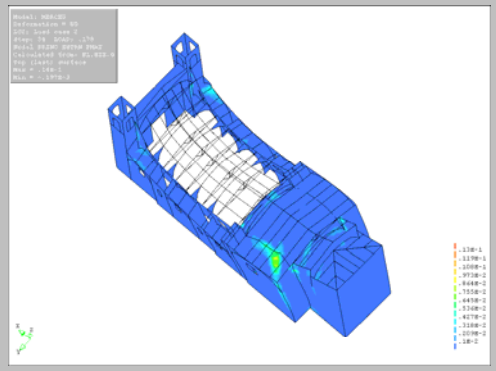
WORKPACKAGE 8: Parametric modelling of structural behaviour — Leader: UMINHO

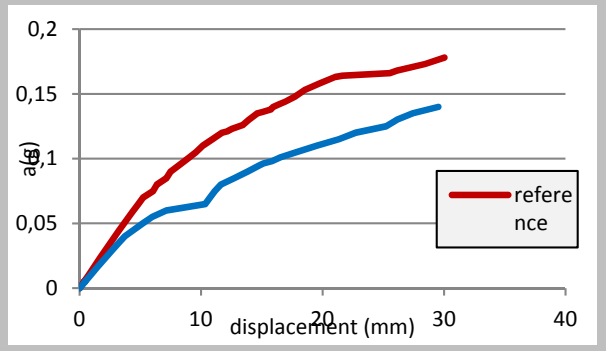
PROJECT N°: 244123
ACRONYM: NIKER
TITLE: **New integrated knowledge based approaches to the protection of cultural heritage from earthquake-induced risk**
COORDINATOR: Università di Padova (Italy)
START DATE: 01 January 2010 — DURATION: 36 months
INSTRUMENT: Collaborative Project
Small or medium scale focused research project
THEME: Environment (including Climate Change)

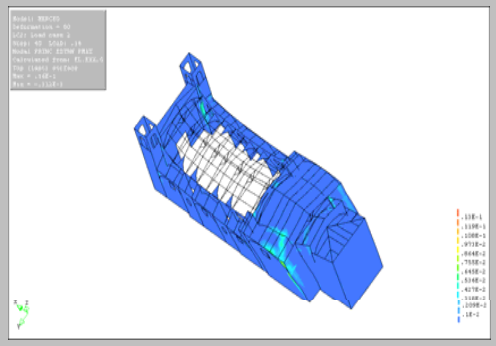
Dissemination level: PU — Rev: 00

D8.3 – Parametric study of buildings according to intervention techniques, stiffness of horizontal elements, connections

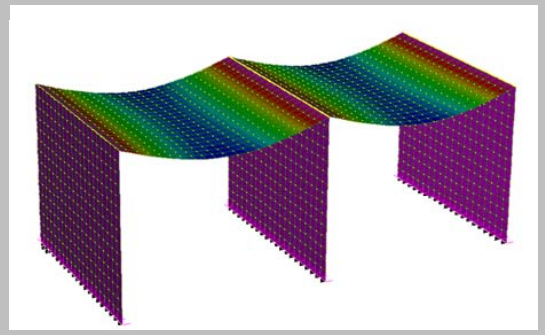


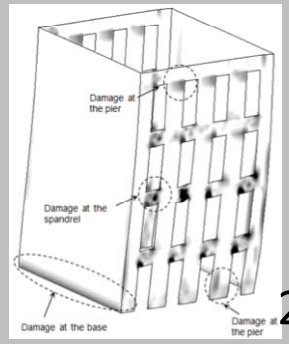






- Influence of floor stiffness on the distribution of horizontal loads among walls;
- Different types of constructions;
- Various geometric features;
- Various mechanical parameters;
- Various tyoes of analyses.





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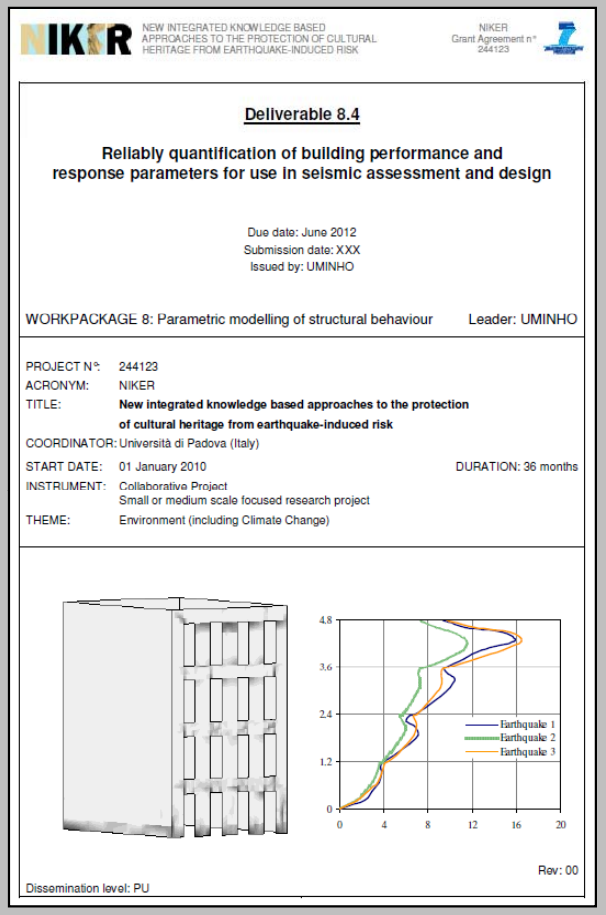

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Deliverable 8.4

Reliably quantification of building performance and response parameters for use in seismic assessment and design

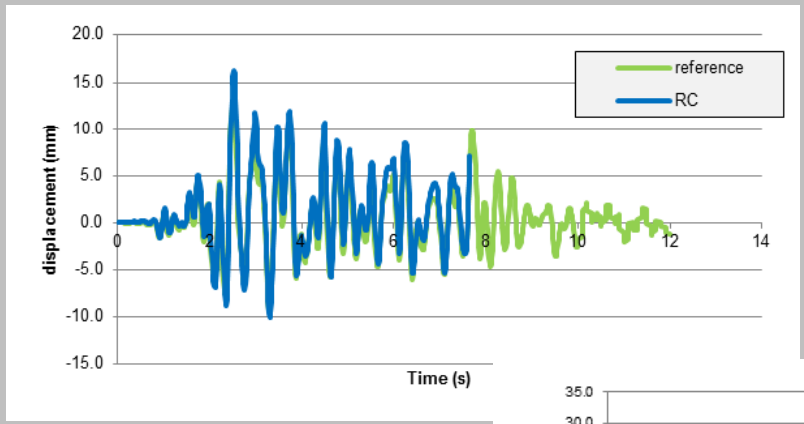
Due date: June 2012
Submission date: XXX
Issued by: UMINHO

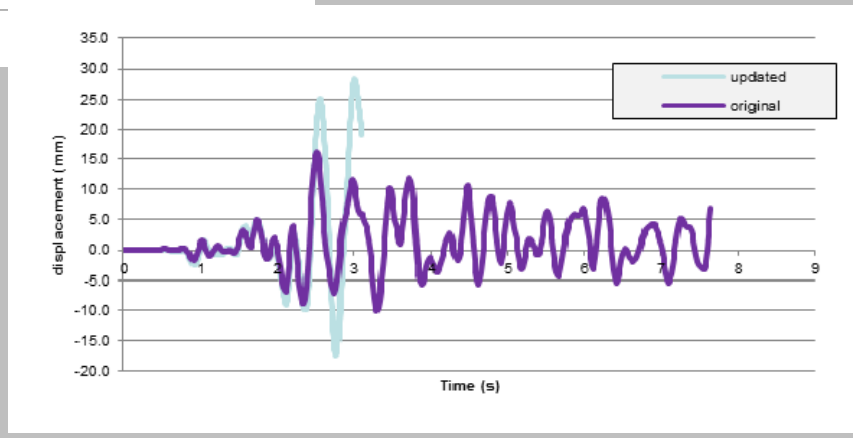
WORKPACKAGE 8: Parametric modelling of structural behaviour — Leader: UMINHO

PROJECT N°: 244123
ACRONYM: NIKER
TITLE: **New integrated knowledge based approaches to the protection of cultural heritage from earthquake-induced risk**
COORDINATOR: Università di Padova (Italy)
START DATE: 01 January 2010 — DURATION: 36 months
INSTRUMENT: Collaborative Project
Small or medium scale focused research project
THEME: Environment (including Climate Change)

Rev: 00
Dissemination level: PU

D8.4 – Reliable quantification of building performance and response parameters for use in seismic assessment and design





- **Displacement based design applied to a masonry structure;**
- **Seismic performance of strengthened two-story buildings;**
- **Seismic performance of strengthened historical single nave churches;**
- **Analytical approach for the seismic risk assessment of traditional earthen buildings.**

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WP9 RATIONALE

Evaluate and validate proposed methods for knowledge based assessment

SELECTION (20 cases)

The collection of building has been chosen to cover different cases regarding:

- ❑Significance of the building as CH
- ❑Structural features and typology. Towers, fortresses, churches, palaces, other.
- ❑Availability of information history (construction technologies, historical events…)
- ❑Local seismicity. Low, moderate and high seismic locations
- ❑Present and foreseen future uses and number of people at risk.
- ❑In some cases, presence of valuable artistic contents.
- ❑Present condition and damage. Almost intact to severely damaged/partially collapsed.
- ❑Possibility of carrying out interventions.





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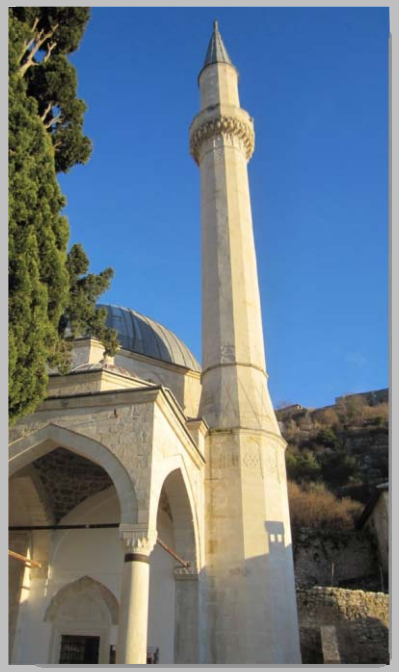

From left to right, top to bottom: Hagia Sophia Museum (Trabzon), Ras Cherratine Medersa (Fez), minaret of the Hadži-Alija's mosque (Počitelj, Bosnia-Herzegovina), Former Casa da Bragança, Foundation Head Office in Lisbon, Preceptory in Ambel, Spain, Os Jerónimos Monastery (Lisbon), Cansignorio Stone Tomb (Verona)

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Case studies affected by the 2009 earthquake in l'Aquila:
S. Biagio and S. Giuseppe churches, Spanish Fortress, S. Agostino church,
S. Silvestro Church, Civic Tower, S. Marco church.

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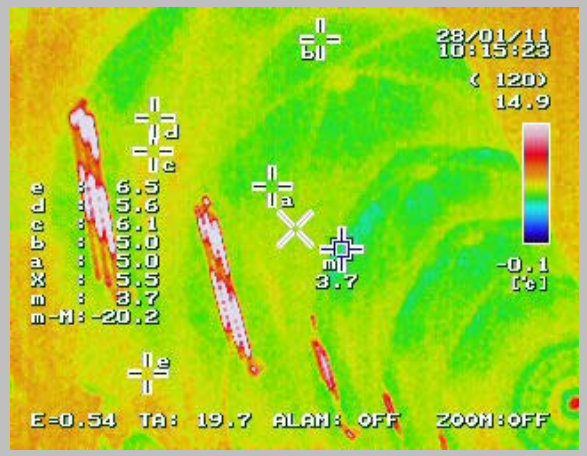
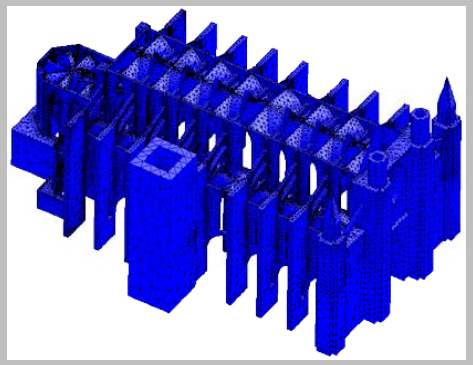
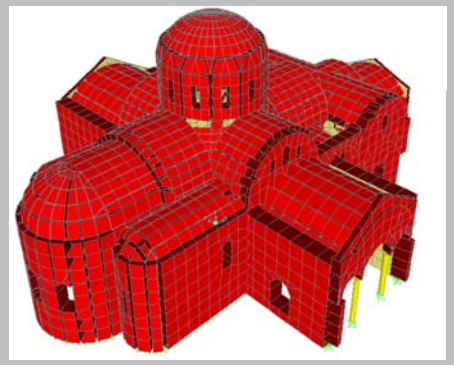
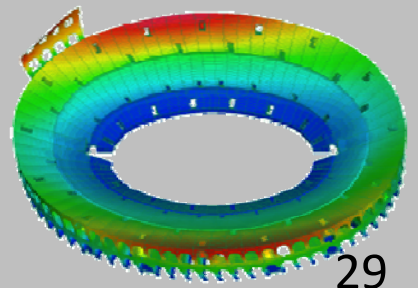
- Calibration of techniques to be applied on site
- Preparatory work
- Inspection
- Monitoring
- Numerical modelling
- Model updating
- Seismic assessment
- Intervention proposal
- Definition of post-intervention programme
- Conclusions









WP10 – GUIDELINES FOR END-USERS

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Public bodies, authorities

Stakeholder, owners

Architects/Engineers

Service providers

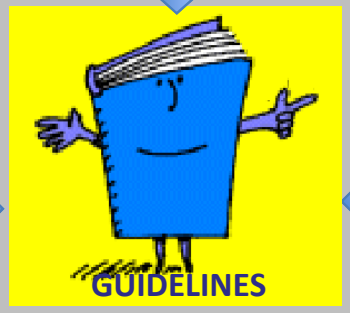
Designers

Industry

Standardization & research

Construction companies

EUROPE



WORLD

- D10.1: GUIDELINES FOR DESIGN & EXECUTION OF INTERVENTIONS
- D10.2: GUIDELINES FOR ASSESS. & IMPR. OF CONNECTIONS & BUILDINGS
- D10.3: GUIDELINES FOR STICK-SLIP & HYSTERETIC DISSIPATIVE ANCHORS
- D10.4: GUIDELINES FOR SEISMIC ANALYSIS & KNOWLEDGE BASED ASSESS
- D10.5: INTEGRATED METHODOLOGY FOR PROTECTION & IMPROVEMENT OF CH

TECH

METH

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DEPARTMENT OF CIVIL, ENVIRONMENTAL &
ARCHITECTURAL ENGINEERING
UNIVERSITY OF PADOVA, ITALY