Tools and policy for a sustainable preservation of historical buildings

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Main issues for sustainable preservation of historic buildings are:

- Identification and diagnosis of the construction materials and structures characteristics, function, architectural features and morphology
- Understanding of traditional construction materials and techniques sustainability/durability
- Estimation of materials susceptibility and risk assessment, under all environmental load and stresses
- Studying decay mechanisms regarding materials/construction/environment interfaces
- Studying construction pathology mechanisms and interrelating them to the deterioration processes of building materials
- Applying proper criteria and methodology to develop new advanced repair materials, compatible with and ameliorating traditional materials, promoting strategical conservation intervention and prevention planning (integrated environmental and urban management, as well as promoting the rehabilitation of cultural heritage and reuse of public spaces)
Innovative tools that serve the above aims are

- New techniques and methodologies to assess and evaluate in real scale compatibility, effectiveness and performance of materials/structures.
- New technologies for the mitigation of environmental pressures, for advanced diagnostics and for innovative planning strategies.
Validation by Lab Techniques

In Situ NDT & E
DIP, FOM,
IR-Thermo,
US, GPR

Advanced Spatial Data Management & Assessment Methods

ON MONUMENTS SCALE
- Materials Characterisation
- Evaluation of Materials Compatibility
- Environmental Impact Assessment
- Planning of Conservation Interventions

INTEGRATED PROJECTS
- Strategic Planning of Conservation Interventions, on Historic Buildings
- Strategic Planning of Environmental Management as a tool for a Sustainable Preservation of Historic Cities
- The Protection of Cultural Heritage & the Development of Cultural Tourism
Incompatible restoration materials, hard carbonate and biogenic crust, partial replacement by new incompatible building stones (a, a')

Alveolar disease varying from disintegration to pitting, cavities, interconnected cavities and full face caves (b, b')
Fibre Optics Microscopy
Evaluation of Cleaning & Consolidation Interventions

- black organic depositions, before cleaning, Pentelic Marble surface (x25), Athens Academy Historic Building

- Untreated Surface, (x50), Rhodes Porous Stone

- black organic depositions area, after cleaning, Pentelic Marble surface, (x25) Athens Academy Historic Building

- Surface treated with PH (pre-hydrolysed ethyl silicate with amorphous silica) (x50)

✓ study of the surface morphology before and after cleaning interventions, indicating the cleaning method’s abrasive levels or its selectivity

✓ After consolidation treatments, information regarding microstructural modifications of porous materials, can be gathered
IR Thermography
Evaluation of Restoration Materials, Monument Scale

Photo of the Investigated Surface, Historic Building in Nafplio

Thermal Image

(a1-b1) beige painted plaster,
(a2-b2) new light beige painted plaster,
(a3-b3) dark brown painted hammered textured plaster
Evaluation of Pilot Consolidation Interventions, Monuments Scale, Medieval Fortifications of Rhodes

**Untreated Stone**

**Stone Treated with Colloidal Silica Dispersion**
Ground Penetrating Radar

GPR reveal surfaces of plastered mosaics, wherein areas of detached tesserae, as well as areas with moisture problems and presence of salts are displayed. The boundaries of problematic areas are detectable, since differentiations to the EM waves transmission are arisen.

The under investigation surface of Vakif intervention at the dome of Hagia Sophia, between the 19th and the 20th rib.
Planning of Historic Buildings Conservation Interventions, using Integrated Information systems

Mela Palace in Historic Centre of Athens
Materials mapping using the Integrated Information system of AutoCAD Mapping

Mela Palace Historic Building in Athens polluted urban environment

Mela Palace North Façade, where:
- red corresponds to stuccos,
- beige to painted plaster surfaces,
- purple to imitations of edge cornered stones,
- green to white marble surfaces and
- black to grey marble surfaces

AutoCAD design of North Façade
Decay Mapping & Environmental Impact Assessment through Management of DIP Images & Infrared Thermographs

Painted plaster surfaces at west façade.
Green → dust fall & black depositions
Aqua → washed out surface
Purple → blackish depositions
Pink → firm painting

Infrared Thermograph at east façade
Planning of Conservation Interventions by the Management of AutoCAD Mapping Results

Removal of plaster surfaces paintings using a wet micro blasting method of 2.5bar maximum pressure

Protection with siloxan paints
Total Quality Control of a Stock of Buildings

Ministry of Culture: Directorate General for Monuments Restoration, Museums and Construction Works
The implementation of a total quality control system, applying proper criteria and methodology permit to accomplish:

- Continuing monitoring and control
- Total quality control of materials and structures
- Definition of ranking indices of buildings
- Decision-making of priorities on actions (inspection-diagnosis-interventions), and the selection of the appropriate materials and intervention techniques, as well as the time / cost/specifications for every action needed
- Manual of instructions/glossary/terms for the people involved (experts/technicians/artisans)
Diagrammatic representation of the proposed methodology
Parametrical analysis

STEP 1: Documentation-Collection of all relevant data (historical, archives etc).

STEP 2: Identification of masonry units and materials

STEP 3: Recording of all the decoration and specific coatings

STEP 4: Recording of all the artistic elements.

STEP 5: Macroscopic observations.

STEP 6: Sampling of materials and deterioration products.

STEP 7: In situ non-destructive testing.

STEP 8: Determination of the state of conservation, by the use of analytical techniques for materials and deterioration products characterization.
The case of Municipality of Pyrgos

North Side

South facade

East facade

West facade
<table>
<thead>
<tr>
<th>BUILDING</th>
<th>Macroscopic observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipal Market of Pyrgos</td>
<td>Low cohesion mortar, beige colouring, incorporating big aggregates, and white small fragments, possibly lime that can be attributed in the insufficient mixing.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FACADE OR LOCATION OF SAMPLING ZONE</th>
<th>General remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>South side, inner</td>
<td>Mixed masonry with stones and bricks. Uneven filling of masonry with mortar. Spot of T10 drilled sample.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SAMPLE NAME</th>
<th>SAMPLING ZONE</th>
<th>SAMPLE MATERIAL</th>
<th>SAMPLE PHOTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrgos_1_1</td>
<td>Pyrgos_1</td>
<td>Mortar (filling)</td>
<td></td>
</tr>
</tbody>
</table>

Sample information, location and macroscopic observations
### FIBRE OPTICS MICROSCOPY

<table>
<thead>
<tr>
<th>Measurement number</th>
<th>General remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOM_Pyrgos_1_1</td>
<td>Inhomogeneous mortar with the presence of microcracks and voids, of variable sizes. Large aggregates are present throughout the mortar matrix, and are distributed inhomogeneously in the binder matrix. The colouring is attributed to clay soil.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample name</th>
<th>Pyrgos_1_1</th>
</tr>
</thead>
</table>

### Remarks on photo 1
- FOM, X50 Magnification, mortar. Lumps of lime are observed due to the inadequate mixing.
- Photo 1, X25 Magnification, or as stated in remarks above

### Remarks on photo 2
- FOM, X50 Magnification, aggregates.
- Round shaped aggregates.
- Photo 2, X50 Magnification, or as stated in remarks above

### Remarks on photo 3
- Photo 3, X100 Magnification, or as stated in remarks above
### Differential Thermal and Thermogravimetric Analysis

<table>
<thead>
<tr>
<th>Sample number</th>
<th>Sample name</th>
</tr>
</thead>
<tbody>
<tr>
<td>DTATG_Pyrgos_1_1</td>
<td>Pyrgos_1_1</td>
</tr>
</tbody>
</table>

**Percentage of absorbed water:** small, < 1% 

**Weight loss in temperature range 120-200 deg C:** small

**Crystalline water of hydrated salts**

**Weight loss in temperature range 200-600 deg C:**

- 2%, presence of silico-aluminate compounds

**Weight loss in temperature > 600 deg C:**

- 6%, small, calcite decomposition is approximately 13.6%

**Phase change at 573 deg C:**

- Presence of quartz is detected, with phase transition from type a to b and no weight loss.

**Observations and Remarks:**

From the shape and characteristics of the DTA-TG Plot, and from investigation of the sample DTATG_Pyrgos_1_1_binder, the mortar is characterized as lime-clay mortar, with ratio binder(lime)/aggregates, 1/4.
### Mercury Intrusion Porosimetry of a Sample

<table>
<thead>
<tr>
<th>Sample number</th>
<th>Sample name</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIP_Pyrgos_1_1</td>
<td>Pyrgos_1_1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Remarks on value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total specific volume</td>
<td>192 mm³/g</td>
<td>high</td>
</tr>
<tr>
<td>Bulk density</td>
<td>g/mm³</td>
<td></td>
</tr>
<tr>
<td>Pore radius average</td>
<td>21 μm</td>
<td>high</td>
</tr>
<tr>
<td>Porosity</td>
<td>37 %</td>
<td>high</td>
</tr>
<tr>
<td>Specific surface area</td>
<td>3.36 m²/g</td>
<td>relatively high</td>
</tr>
</tbody>
</table>

**Remarks on pore size distribution**
The pore size distribution of specific volume presents a wide dispersion of values with tendency to large radius.

**Conclusions**
The average pore radius is high (21 μm) which probably can be attributed to the presence of porous aggregates that have high pore radius.
Material mapping at the facade of the Municipal Market of Pyrgos.
Mapping of the state of conservation of materials on the facade of the Municipal Market of Pyrgos

- Detachment of outer layer of plasters
- White Paint
- Graffiti
- Loss of Masonry Unit Elements
- Vegetation
- Soot and Blackening Crusts
- Stains in Façade Marbles
Preservation Planning as a Tool for a Sustainable Historic City

The Medieval City Intra Muros of Rhodes
Infra Red Thermographs managed by GIS for the Environmental Impact Assessment and Related Management regarding i.e. the Planning of Underground Networks in the Medieval City of Rhodes
Environmental Impact Assessment & Environmental Management & Valuation of Uses by GIS for the Medieval City of Rhodes

Cultural Uses
Pollution sources
Planting
Dark grey line shows part of the sewer system
Salt spray sources
Preservation Planning as a Tool for a Sustainable Historic City

The Historic City Centre of Heraklion within the Venetian Fortifications
Environmental Impact Assessment for the Venetian Fortifications of Heraklion by GIS

Raster Map showing the principal pollutants concentration
(CO, O₃, NO, NO₂, SO₂)
for the years: 1997, 1998, 1999

Base Map showing
the Soluble Anions Concentration
(Cl⁻, NO₃⁻, SO₄²⁻)
Environmental Impact Assessment & Environmental Management & Valuation of Uses by GIS for the Venetian Fortifications of Heraklion

Cultural Uses
Pollution sources
Planting
Salt spray sources
Athletics
The Protection of Cultural Heritage & the Development of Cultural Tourism

The Historic City Centre of Patras
Presentation of the Distribution of Historic Buildings, Monuments & Archaeological Sites in Patra by GIS
monuments of historic centre integrated with monuments out of historic centre within city plan
City development as a whole through:
- the protection of cultural heritage,
- the planning of special tourist and cultural routes
- and finally the progress of Cultural Tourism,
  (the paradigm of historic centre of Patras, a city
  challenged by the institution of the European Cultural
  Capital in 2006)

The use of innovative technologies like NDT & E techniques
validated in lab
have a major contribution to
the preservation and management of a historic city
and
when integrated into tools like AutoCAD Map on building
scale and GIS on complexes scale
reassign the urban and suburban planning
enhancing the cultural identity of a modern city
leading gradually to its sustainable development
The strategic planning methodology for the assessing and decision-making regarding the preservation and management of the historic cities and/or historic centers, according to their needs & future perspectives, can be accomplished by:

- Strategic planning of the conservation interventions on historic buildings, using data management in integrated information systems for their rehabilitation and protection. Therefore, the historic physiognomy of the historic centre is revealed and people's accessibility to cultural heritage is promoted, (Athens historic centre paradigm, on the threshold of the Olympic Games 2004)

- Strategic planning of integrated environmental management, as a tool for the sustainable development of historic cities using GIS for their preservation within urban and land use planning of the city. (the paradigms of medieval city of Rhodes -World Cultural Heritage Monument- and historic centre of Heraklion within the Venetian Fortifications)
Sustainable Construction—State of the art in Europe*

*Working Group, SCMT Interim report 270703, Sustainable Construction methods & Techniques, July 2003
State of the Art:

- Cultural Heritage has been acknowledged as a determining factor (already in FP6) in enhancing the quality of life of people

- A trend towards integrated solutions seem to be in motion

- The dissemination efforts of sustainable construction have resulted in relevant applications

- There is a considerable amount of quality literature available on the subject of sustainable construction

- The relevance of the construction sector in Sustainable Development has been understood

- There is a popular support for the idea of sustainability
Focus on:

- Holistic, environmental, common EU indicators and targets adapted by each MS together with the common EU assessment methods, using a common language to all stakeholders of the construction industry.

- Need of integration principles of sustainability into the practice of design, construction, maintenance and management of buildings.

- Certification of construction must be performance based rather than prescriptive.

- Sustainable construction should be implemented through integrated approaches and optimised solutions.
**Key issues**

- Across EU, new building activity is between 0.5-2% of the total building stock.
- More than 50% of the construction activity is refurbishment and this segment continues to grow.
- Many of the parameters for assessing sustainability are quantifiable (e.g. indoor air quality), but others like quality of life of people are not so easy to quantify.
Research

- Extensive research on sustainable construction methods and techniques for **NEW** buildings

- Considerably less research on sustainable construction methods and techniques for retrofitting, refurbishment, and renovation of **OLD** buildings
Sustainable preservation with enhancement of cultural identity becomes a great challenge for World Heritage Cities having to assure:

- The valorization, reveal and preservation of the values of World Heritage Cities
- The revitalization, rehabilitation and integration of cultural heritage within the development of the city as a whole, meeting modern needs for quality of life
- The preservation of world heritage cities against threatening natural hazards as well as anthropogenic factors and environmental stresses
- The management of World Heritage Cities has to interconnect conservation with sustainable development (quality of urban life, economic competitiveness and job creation)
- Appropriate decision-making with communities’ participation
- The reconciliation of tourism development with the needs of preservation of cultural heritage
- Sustainable transport systems achieving accessibility to cultural heritage without damaging it
Know-how developed in the field of Sustainable Protection of Cultural Heritage should be used

- Produced, expressed and classified on all levels of strategic planning, decision-making, application, monitoring, assessment and control in a multi-disciplinary way integrating various scientific disciplines

- Reproduced and transferred by:
  - Education and training for the protection of cultural heritage
  - Historic cities as open labs of research and postgraduate education
Knowledge based decision-making is urged of

- A multidisciplinary knowledge based decision-making system
- Innovative preservation and conservation techniques have to be employed to assure:
  - structural restoration and earthquake protection
  - compatible and conservation interventions for sustainable preservation
  - information society and cultural heritage
  - integrated planning for the protection of the city
Tools and methodologies for the management of cultural heritage

Coordinated implementation plan

- Project management tools

- Time planning

- Funding scheme

- Mobilisation and allocation of funds (public sector)

- Motivation and incentives to mobilise private sector’s investments and entrepreneurship

- Job creation

- New institutional framework (program agreements) to merge on the level of local government the various responsibilities of state authorities (decentralisation of power and fund)

- Awareness, involvement and coordination of social partners in the venture - Citizens’ participation
Main policy issues to support sustainable preservation are:

Which building standards & specifications, codes, rules and requirements for the integrated construction process (planning, design, engineering, construction, management, quality control, maintenance, recycling) will promote sustainability?

• What are the dynamics of the role of the various partners in the process?

• How can society be aware of the cost benefit in the absence (as in current practice) and on the opposite implementation (as proposed) of a sustainable construction process?

• How can policy measures perform and establish support to decision-making in the field?
Conclusions:

High measuring technologies render & visualize properties and performances at the interfaces of construction materials/environment are now developed and standardized.

Even though further Research & Development support is needed to provide new, innovative, powerful and friendly to the users tools for:

-advanced sustainability impact assessment
-real time/real scale monitoring & control of construction systems performing at the interface (construction/materials/environment), documenting and mapping stresses incompatibilities and diversified driving forces responsible for deterioration and devaluation of materials and structures

-evaluation effectiveness and compatibility of repair materials and techniques
-provide data, critical thresholds of environmental stresses and background for strategical planning of integrated environmental management and protection (building, building stock, city center scale).

-Hence SSTs can optimize SBC
Research needs
- to identify sustainability indexes
- to evaluate and compare best practices
- to apply and promote benchmarking