



Paris, February 25<sup>th</sup> 2015.

Mr Director,

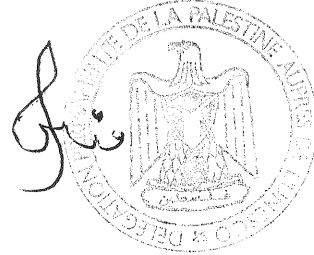
The Permanent Delegation of Palestine to UNESCO presents its complement to you and is pleased to submit herewith the State of Conservation report concerning the following sites:

- Birthplace of Jesus: Church of the Nativity and the Pilgrimage Route, Bethlehem (Palestine) and its annexes,
- Palestine: Land of Olives and Vines – Cultural Landscape of Southern Jerusalem, Battir, Palestine.

Furthermore, our Delegation has no objection to make these reports available online.

The Permanent Delegation of Palestine to UNESCO avails itself of this opportunity to renew to you the expression of its highest consideration.

Permanent Delegation of  
Palestine to UNESCO



M. Kishore Rao,  
Director, UNESCO World Heritage Centre  
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State of Palestine

## **State of Conservation Report**

**For**

**Birthplace of Jesus**

**Church of the Nativity and the Pilgrimage Route, Bethlehem**

Ref. 1433, Palestine

Bethlehem, Palestine

February 2015

The State of Conservation Report (SoC) for the World Heritage Site (WHS) of the **Birthplace of Jesus: Church of the Nativity and the Pilgrimage Route, Bethlehem (1433)** was prepared by the Centre for Cultural Heritage Preservation in close cooperation with the Ministry of Tourism and Antiquities and Bethlehem Municipality for the Pilgrimage Route and the Historic town of Bethlehem (buffer zone). Moreover, the Presidential Committee for the Restoration of the Church of the Nativity participated in the preparation of the part concerning the ongoing restoration works in the Church.

On site restoration works of Church of the Nativity commenced on September 2013 in the roof and windows based on a comprehensive on-site investigation completed in 2011 and conducted by a consortium led by CFR (Administrative project managing - Ferrara – Italy) and managed locally by Community Development Group (CDG).

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## **1 Executive Summary**

Birthplace of Jesus: Church of the Nativity and the Pilgrimage Route, Bethlehem (Ref. 1433) was inscribed of the World Heritage List on emergency on the basis of criteria (iv) and (vi); the inscription on the Danger List was due to the lack of repair of the roof structure of the Church of the Nativity and the consequent threat to the roof timbers, roof covering, and the interior wall surfaces from water ingress.

Moreover, the Statement of Outstanding Universal Value adopted by the World Heritage Committee (Decision 37 COM 8.B.56) has pointed out to negative impact of the sharp increase in the number of vehicles, inadequate parking, and small industries within the historic town, which have produced a polluted environment that is negatively affecting the façades of both the Church of the Nativity and the buildings along the Pilgrimage Route. It also acknowledged the urban pressure in the surrounding urban areas, to which largely unregulated tourism and traffic contribute.

This report shall present the key corrective measures carried out by stakeholders; the Ministry of Tourism and Antiquities, Bethlehem Municipality, the Presidential Committee for the Restoration of the Church of the Nativity and the Centre for Cultural Heritage Preservation in facing the threats that are negatively affecting the property.

Key corrective measures focused on the restoration works of the roof and windows of the Church of the Nativity (Phase I). The report also highlights the restoration works of the narthex and the related doors (Phase II) and the wall mosaics, which include the internal plaster and stone façades (Phase III) commenced in September 2013 and shall be concluded in December 2016.

Before the commencement of the restoration of the roof of the narthex, works were carried out to consolidate its aisles and corners so as to have the wall surfaces restored before the installation of the lead sheets, which can be easily deformed and worn out under concentrated loads. These works revealed that the vaults were partially detached from the wall; this detachment was foreseen by the experts as a threat to the stability of the roof of the narthex. Accordingly, works has started to further investigate the structure in order to come out with a comprehensive plan for the conservation of the narthex; the conservation plan for the narthex is expected to be completed in December 2015, upon which the implementation of the works shall start in 2016.

The report also summarizes other actions that tackle the various issues included in the Statement of Outstanding Universal Value to face the impact of the urban growth within the buffer zone and the surrounding corridors, and the management of tourism movement within the core zone. Actions also included the efforts to set a proper management plan that involves all stakeholders in the management of the property.



## **2 Response from the State Party to the World Heritage Committee's Decision**

### *2.1 Restoration of the Church of the Nativity*

The Team of Experts working on the restoration of the Church of the Nativity has prepared a report that responds to the inquiries of ICOMOS regarding the ongoing and future restoration works of the Church. The Presidential Committee for the Restoration of the Church of the Nativity submitted the report “Answers to the Request of the Specifications Addressed by ICOMOS to the State Party” to the Palestinian Mission to UNESCO on July 2014. The report was submitted to the World Heritage Centre.

The report summarizes the results of the survey and investigation that was carried out by the Team of Experts led by CFR (Ferrara – Italy) and managed by Community Development Group (CDG), and presents a conservation plan for the Church. It is worth noting here that the restoration works that are being currently implemented are based on the conservation plan that resulted from the comprehensive investigation that was carried on the Church between 2009 and 2010.

The report also refers to the conservation strategy that shall be implemented through the Presidential Committee for the Restoration of the Church of the Nativity in order to reach the desired state of conservation indicated in the investigation report of 2010. However, it is worth noting that during the restoration works, unexpected issues that require further investigation may appear, this affects the both the schedule for the implementation of the works, and sometimes may require some changes to the work plan.

### *2.2 Desired State of Conservation and Corrective Measures Developed for the Property*

The Desired State of Conservation prepared by the Advisory Bodies states “Completed conservation and repair of the roof structure of the Church of the Holy Nativity”, and the Corrective Measures indicate the following:

1. Complete a full investigative survey of the historic timbers and lead work of the roof, identifying the chronology and historical significance of the various component parts in relation with overall archaeological, historical and architectural analysis of the Church of the Holy Nativity.
2. Develop a Conservation Plan for the roof that synthesizes the conclusions of the detailed investigative survey into a clear statement of the significance of the various elements of the roof within a comprehensive conservation philosophy for the Church of the Holy Nativity.
3. Prepare a detailed project specification for the roof repairs that allow a full understanding of which elements of the roof will be maintained, which repaired and which replaced.

#### 4. Undertake the roof repair project and document its interventions.

The following brief report explains the actions took by the Presidential Committee for the Restoration of the Church of the Nativity through its consultant towards achieving the desired state of conservation of the Church. However, the previously mentioned detachment of the vaults of the Narthex remain to form a threat to the stability of the Church, and an obstacle to complete the restoration of the roof of the narthex. The necessary actions shall be indicated upon the completion of the investigation of the situation, which is expected to be completed by December 2015.

#### **Summary Report on the Restoration Works of the Church of the Nativity**

The intention of this summary report is to provide updated information on all progress made until January 2015 in the restoration of the Church of the Nativity. This document shall also respond to the concerns of the World Heritage Committee related to the preparation of a state of conservation report, knowing that the desired state of conservation stems only from a correct approach to the interventions of restoration based on the full respect of the past history of the artifact, its peculiarities and the main Principles of Restoration.

The report is divided into the following sections: Progress Report, Investigation Survey of the Historic Timbers and Lead Works on the Roof, Conservation Plan and Project specification for the Roof Restoration including the Documentation of the Interventions.

- **Progress report:**

The survey and repair works on all trusses, purlins, boards, big cantilevers and the seismic improvements to increase the in-plane stiffness of the roof and to strengthen its connection to the masonry walls have been all completed. Currently some works are still in progress only on the roof covering of the northern aisle, the last are not yet completed. The new roof layers shall guarantee effective internal ventilation and a durable waterproofing coverage. Moreover the new windows, installed almost everywhere, shall guarantee the necessary protection of trusses, mosaics and plasters against rainwater and UV.

It is worth noting that full shop drawings, showing the state of conservation of all components before the interventions and the improvements achievable after the intervention, were prepared by the Contractor, checked by an International team of experts appointed by the Committee and authorized by the Project Manager. Moreover, Archaeological surveys were carried out during all restoration works; a detailed documentation has been provided and it is kept updated in order to allow for an accurate graphic and descriptive recording of all data emerged.

Roof and window restoration works are expected to be completed by the end of February 2015. By that date the main cause of water infiltration into the church

shall be eliminated. The in the delay in implementation of the works is due to the additional works that become necessary after the discovery of unexpected damage conditions or new construction details, which impose changes, sometimes significant, to the original action plan. For this reason it was, and it is still impossible, as remarked often in previous reports, to provide a definitive, static projection of the state of conservation, which, on the contrary, evolves and changes from day to day in consequence of what emerges during the various work phases.

Moreover, in accordance with the list of work priorities provided by the Presidential Committee, additional works were awarded to the Contractor. They include the restoration of the Narthex, the Narthex eastern wooden door, the wall mosaics, the internal plasters and the external stone surfaces. The Contractor has already completed the restoration of the Narthex eastern wooden door and the cleaning/consolidation of the external stone surfaces. The latter works started in correspondence of aisles and corners in order to have the wall surfaces restored before the installation of the lead sheets, which can be easily deformed and worn out under concentrated loads.

The archaeological excavation above the three vaults of the Narthex is completed and a full documentation has been provided. Currently the consolidation solutions for the damaged vaults are being evaluated on the basis of a laser scanner survey, the analysis of the changes occurred over time in the bearing walls, the information obtainable from the historical documentation, checks on stone and mortar material properties and numerical 3D simulations of the structural behaviour. The cleaning for the internal plasters has already started and it is almost completed in the nave; additional works are expected to be completed in December 2016 if financial resources are available to allow such works.

For further details please refer to the documents (Annex-3: Project Specification for Roof Restoration including the Interventions Documentation) and (Annex-4: The Brief Construction Progress Report "September 15, 2013 – January 19, 2015").

- **Investigation survey of the historic timbers and lead work of the roof**

The general principles were laid down at first, according to which the overall investigative surveys on the Church had to be carried out. The survey of the roof structures and their components was carried out in close relationship with the overall archaeological, historical and architectural analyses carried out on the whole Church of the Nativity. At the same time, the plan of investigations on the roof was conceived to fully integrate the information provided by the global scale researches.

The general methodology adopted in such investigations was defined in such a way as to accomplish specific tasks: evaluation of the state of conservation of windows and drainage system, diagnosis of timber structures, dendrochronological dating of the timber structures. All the diagnostic works were performed by taking into account the requirements provided by the Italian standard UNI 11161:2005 “Cultural Heritage - Wooden Artefacts - Guidelines for Conservation, Restoration and Maintenance”.

For further details please refer to the document (Annex-1: Investigation survey of the historic timbers and lead work of the roof) that contains all historic information concerning the roof and the main conclusions of the archaeological analysis. It contains also the most significant and representative parts of the diagnosis carried out by the Consortium in 2010 on the timber trusses, purlins, boards, windows and drainage system and written out in full in the Final Report.

- **Conservation plan**

The basic principles of restoration and the general guidelines for the design of any intervention on timbers structures and for a correct approach to the preservation of ancient buildings, in addition to a program for an effective maintenance of the roof and of the other parts of the Church, are all reported in the document (Annex-2: Conservation plan).

These principles, guidelines and programmes together constitute the general conservation plan for the Church, expression of that conservation philosophy which has inspired and underlies all the interventions planned and carried out until the date of the preparation of this report. A more detailed conservation plan evolves dynamically day by day on the basis of new findings, unexpected damages and unforeseen needs, which appear during the processing stages. It results in updated shop drawings, new specifications, more appropriate technical approaches, all consistent with the Principles of Restoration, the general work methodology and plan of action described in the given recommendations and guidelines.

- **Project specifications for roof restoration including the interventions documentation**

The project specifications contain all instructions and recommendations to be followed to protect all decorated surfaces from possible damages caused by the works in progress in the Church, provide the most appropriate storage areas, carry out the interventions of restoration on all wooden components of the roof, install the new roof covering and the new windows. All these guidelines represent the project specifications, which the Contractor has to follow and respect during the work on interventions. The Contractor is required to comply strictly with these requirements, the observance of which is guaranteed by periodic on-site checks and the daily monitoring carried out by the team of

experts, appointed by the Committee, on the basis of the project documentation provided by the Project Manager.

The document (*Annex-1: Project Specifications for Roof Restoration including the Interventions Documentation*) presents the specific guidelines and the description of the actual interventions in order to highlight the consistency of the technical choices made or, in some cases, the discrepancies that respect the main features of the artefacts and the main Principles of Restoration. Such guidelines and the surveys carried out allow for a correct implementation of the criteria to be followed to select the wooden parts to be kept on site as they are, the ones to be repaired and the ones to be replaced. The document contains also the recommendations for a correct archaeological recording and a short description of all archaeological findings since the beginning of the works.

### *2.3 Management Plan for the World Heritage Site in Bethlehem*

The acting stakeholders in the property; Ministry of Tourism and Antiquities, Bethlehem Municipality, Presidential Committee for the Restoration of the Church of the Nativity and Centre for Cultural Heritage Preservation commenced with the preparation of a Management Plan for the World Heritage Site in December 2013. The work was conducted by the Centre for Cultural Heritage Preservation (a non-profit organization that works on the preservation of cultural heritage resources in Palestine) through an EU funded project, with the technical assistant of RehabiMed Association in Spain.

During the work on the project, which was concluded in July 2014, the stakeholders initiated a unit for the management of the site, based on the recommendations of the team working on the project. The main goal of the unit is to coordinate between the stakeholders in the different issues related to the site. However, the management plan was not concluded by the Centre for Cultural Heritage Preservation; instead, Guidelines for the Management Plan was presented to the project partners in order to proceed with the preparation of a plan.

The Guidelines set forward the administrative structure of the site management unit and its role in the management of the site including the preparation of a comprehensive management plan. The unit, as set in the Guidelines shall be managed through a steering Committee headed by the 'Mayor of Bethlehem' and including representatives of the Ministry of Tourism and antiquities, the Presidential Committee for the Restoration of the Church of the Nativity, the Centre for Cultural Heritage Preservation and the Head of the 'Unit' in addition to two representatives of local community organizations. It was agreed by all stakeholders that the first mission of the 'Unit' shall be the finalization of the 'Management Plan'.

It is worth noting that the finalization of the 'Management Plan' by Centre for Cultural Heritage Preservation encountered some obstacles, namely because the Site is the first to be inscribed by Palestine. This has caused some complications in setting

the administrative structure of the unit, and the roles and responsibilities of each party. In addition, the process of reviewing and ratifying the different decisions of the stakeholders according to the implemented laws and regulations in Palestine, and the insufficiency of the financial resources to follow up with the decisions of the stakeholders have contributed to the delay in the finalization of the Management Plan.

The first mission of the Management Unit of the World Heritage Site, which was officially formulated in December 2014, shall be the preparation of a management plan for the Site. The management plan shall focus on the various issues related to the 'Site' including traffic management, tourism, conservation of the built up heritage, and regulating other within the property. The work on the plan is expected to be finalized by the mid 2016.

### **3 Implemented and Future Actions to Secure the Conservation of the Property**

In addition to the restoration of the Church of the Nativity, the various stakeholders are implementing several other actions to ensure a proper conservation of the property, and to solve the various issues related to the urban growth within the buffer zone and the surrounding corridors, and the management of tourism movement within the core zone.

The implemented actions are divided to four major categories that include (1) managing the interventions within the historic town of Bethlehem (buffer zone) and the area surrounding it, (2) providing accessibility to the 'Site', (3) conservation of built up heritage and (4) providing services for the visitors.

#### *3.1 Managing Interventions*

The historic town of Bethlehem, which is designated as the buffer zone of the Site is an integral part of the town of Bethlehem. 5'000 inhabitants (of 35'000) reside within its borders. In order to ensure a proper conservation of the architectural heritage within the property, Bethlehem Municipality, the Ministry of Tourism and Antiquities and the Centre for Cultural Heritage Preservation has accomplished the following:

- Drafting and ratifying Regulatory Bylaws for the Conservation of the Historic Centre in Bethlehem and the Individual Traditional Buildings (156/2014): the Regulatory Bylaws became effective as of 15 September 2014. The Regulatory Bylaws aim at providing a framework for interventions in the specified areas, and contribute to the preservation of the architectural heritage within the historic centre (*Annex 5: Regulatory Bylaws for the Conservation of the Historic Centre in Bethlehem and the Individual Traditional Buildings (156/2014) – English translation*)



- Preparing a Manual for the Rehabilitation of the Historic Town in Bethlehem: the manual aims at presenting guidelines for architects and professionals as well working in the conservation of traditional buildings and for the local authorities that shall contribute to a better understanding of urban fabric, morphology and architecture of the town.

The 'Regulatory Bylaws' and the 'Manual' were prepared by the Centre for Cultural Heritage Preservation in Association with Bethlehem Municipality under the technical supervision of RehabiMed Association. The project was funded by the European Commission and co-funded by the Swedish International Development Agency (Sida) through UNESCO Office in Ramallah.

Future actions include setting Regulatory Bylaws for a 70-metre wide belt that surrounds the buffer zone in order to ensure proper visual corridors to the property. It is worth noting that during the preparation of the Physical Plan of Bethlehem (2014-2015), the 70-metre belt was designated by Bethlehem Municipality as a protection area for the World Heritage Site and its Regulatory Bylaws are considered as a priority. The work on the Regulatory Bylaws shall commence as soon as the funds are secured for the work.

Future actions shall also include the preparation of a Marketing Management Plan for the Pilgrimage Route; the project shall be funded by the Government of Russia, and is expected to be finalized by May, 2017.

### *3.2 Providing Accessibility to the Site*

In order to meet the accelerating needs of creating alternative routes that provide accessibility for the historic centre, Bethlehem Municipality and the Centre for Cultural Heritage Preservation has worked on three major components; which include:

- The Rehabilitation of the King David Road; a detour that provide a drop-of point at the entrance of the Pilgrimage Route and an exit to the vehicles to the main street: this project is considered the backbone that shall contribute to preventing traffic through the Pilgrimage Route.
- Rehabilitation of several stairways that connect the Pilgrimage Route with the rest of the town: stairways are a major component of the fabric of the historic town, and their rehabilitation shall contribute to providing accessibility for the inhabitants and the visitors of the historic centre.
- Creation of parking lots in the periphery of the site: these parking lots shall mainly serve the inhabitants of the Pilgrimage Route and its users. These parking lots together with the rehabilitation of the stairways shall directly contribute to preventing traffic through the Pilgrimage Route.

Until the preparation of this report, the following projects were implemented in this category:

No.	Project	Completion date	Brief Description
1	Rehabilitation of King David Street	January, 2015	<p>The works included the rehabilitation of an existing route that was not suitable for vehicles in order to create a connection between the entrance of the pilgrimage route and Manger Street; this project shall directly contribute to preventing traffic through the Pilgrimage Route.</p> <p><i>Funded by: United States Agency for International Development (USAID) through the West Bank Compete Project</i></p>
2	Rehabilitation of Bus Stairway and Parking	October, 2014	<p>The parking area shall provide 20 parking lots for the visitors of the Manger Square and the Church of the Nativity, and a connecting stairway that links the parking area with the Square; this project shall directly contribute to reducing traffic in the Manger Square.</p> <p><i>Funded by: United States Agency for International Development (USAID) through the West Bank</i></p>
3	Rehabilitation of Al-Batten Street	September, 2014	<p>The works include paving an existing road that connects the historic centre with Bethlehem University; the project shall create an exit to the vehicles approaching the Pilgrimage Route from the market area, and thus contribute to preventing traffic along the Pilgrimage Route.</p> <p><i>Project implemented by Bethlehem Municipality</i></p>
4	Rehabilitation of Kattan Stairway	July, 2014	<p>The stairway shall directly connect the Pilgrimage Route with Paul VI Street and the market area, and thus provide a pedestrian network of routes for the users and visitors</p>

			<p>of the Site.</p> <p><i>Funded by: United States Agency for International Development (USAID) through the West Bank</i></p>
5	Rehabilitation of Handal Square	July, 2014	<p>The project provided an alternative location for the sellers in the Marketplace during its rehabilitation. Upon the completion of the rehabilitation works of the Market, Handal Square shall be used as a temporary artisans market.</p> <p><i>Funded by: Swedish International Development Cooperation Agency (Sida), through UNESCO Office in Ramallah</i></p>
6	Rehabilitation of Al-Madbaseh Street (Paul VI Street)	July, 2014	<p>The project enhanced the physical structure of one of the major routes within the historic centre. The project is expected to provide proper infrastructure for the area and enhance the experience of its visitors.</p> <p><i>Funded by: Government of Italy through the Palestinian Municipalities Support Programme (PMSP)</i></p>

Future actions include the rehabilitation of other stairways, roads and parking lots in order meets the needs and requirements of the inhabitants of the historic centre and its visitors, in order to be able to prevent the traffic along the Pilgrimage route. These projects include:

No.	Project	Expected Completion date	Brief Description
1	Rehabilitation of Morcus Nassar Stairway	June, 2015 (Ongoing)	<p>The stairway shall directly connect the southern public transportation parking with the Manger Square through the historic centre.</p> <p><i>Funded by Swedish International Development Cooperation Agency (Sida), through UNESCO Office in</i></p>

			<i>Ramallah</i>
2	Rehabilitation of the Pilgrimage Route	May, 2017 (commencement date: May, 2015)	<p>Rehabilitation of the façades of the buildings along the route, rehabilitation of water cisterns within the area and of the pavement of the route; the project shall have minimum interventions that respect the authenticity and integrity of the site. The project shall directly contribute to preventing traffic along the route.</p> <p><i>Funded by: Government of Russia</i></p>
3	Nativity Square Tunnel	<i>Conceptual Project</i>	<p>The tunnel aims at providing alternative underground connection that links the northern and southern parts of the town, and that replaces the only connection that crosses directly in front of the Church of the Nativity. The tunnel is expected to serve at least 1'500 vehicles that cross the Manger Square daily; and is expected to contribute to preventing traffic along the Pilgrimage Route and the Nativity Square.</p> <p>Upon the completion of the conceptual design, proposed design, an impact assessment report shall be submitted to the World Heritage Centre in order to obtain their feedback on the project before the commencing with the work.</p> <p><b><i>Funding is not available for the project, and shall be secured upon its approval.</i></b></p>

**It is worth mentioning the projects in category 3.1 and 3.2 include minimum interventions and mainly target the rehabilitation of the infrastructure and pavements.**

### *3.3 Conservation of Built Up Heritage*

Several projects aimed at the rehabilitation of abundant and not-used buildings, and their adaptation for uses that form attractions were implemented throughout the property. These projects also include the rehabilitation of open spaces within the historic centre. Such projects are implemented with minimum interventions that respect the integrity and authenticity of the property, and contribute to its preservation. It is worth mentioning that several projects were implemented by Bethlehem 2000 Project Authority, which were followed by other projects by Bethlehem Municipality and the Centre for Cultural Heritage Preservation (for further information refer to the annex of the nomination document); after 15 years of the conclusion of Bethlehem 2000 Project, some of the implemented works are in desperate need for maintenance.

Until the preparation of this report, the following projects were implemented in this category:

<b>No.</b>	<b>Project</b>	<b>Completion date</b>	<b>Brief Description</b>
1	Rehabilitation of Al-Bedd Museum	October, 2014	A traditional olive press building adapted as museum in the historic centre, close to the Church of the Nativity. The museum is about the history of Bethlehem and its olives.  <i>Funded by: Government of France</i>
2	Rehabilitation of <i>Hosh Abu Jarour</i> Quarter)	October, 2014	The project included the rehabilitation of an abundant building along the Pilgrimage Route and adapting it for the use of Bethlehem Icon School (an artisan workshop that aims to revive the art of Arab <i>Melkite</i> icons; the rehabilitation works included minor interventions that respected the building and its settings. The project contributed to the enhancement of the physical structure of the Site, and shall directly contribute to the revitalization of the Pilgrimage Route.

			<i>Funded by: United States Agency for International Development (USAID) through the West Bank Compete Project</i>
3	Rehabilitation of the Syriac Quarter	July, 2014	<p>The project included the rehabilitation of an abundant quarter (complex) and adapting it as a hotel within the historic centre; the rehabilitation works included minor interventions that respected the building and its settings. The project contributed to enhancing the physical structure within the historic centre, and shall directly contribute to the revitalization of the Pilgrimage Route due to its closeness to the Site.</p> <p><i>Funded by: Government of Italy through the Palestinian Municipalities Support Programme (PMSP)</i></p>
4	Rehabilitation of Hazboun Residence	January, 2015	<p>The project included the rehabilitation of an abundant building in Al-Anatrah Quarter and adapting it as a locale for the Centre for Cultural Heritage Preservation; the rehabilitation works included minor interventions that respected the building and its settings. The project contributed to enhancing the physical structure within the historic centre.</p> <p><i>Funded by Swedish International Development Cooperation Agency (Sida), through UNESCO Office in Ramallah</i></p>

Future actions include the rehabilitation of other buildings in order to both preserve the built-up heritage within the property and provide services for its inhabitants and visitors.

No.	Project	Expected Completion date	Brief Description
1	Rehabilitation of Bethlehem Old Market	September, 2015	Rehabilitation of the market area inside the historic centre of providing infrastructure, and control the services provided by the municipality; the project has minimum surface interventions and shall no affect the authenticity and integrity of its surrounding.  <i>Funded by: ANERA (American Near East Refugee Aid)</i>
2	Rehabilitation of Kattan Square	July, 2015	Rehabilitation of 380 m2 neglected plot of land within the historic centre, in order to create a public garden for the area.  <i>Funded by: United States Agency for International Development (USAID) through the West Bank Compete Project</i>
3	Rehabilitation of Dar Ghazzawi	May, 2017	The project aims at the rehabilitation of a building that is not being used along the Pilgrimage Route and adapting it as a cultural centre that shall be operated by the municipality; the rehabilitation works shall included minor interventions that respected the building and its settings. The project contributed to enhancing the services and the physical structure within along the Pilgrimage Route.  <i>Funded by: Government of Russia</i>

### 3.4 Providing Services for the Visitors

In order to enhance the experience within the site and provide various services to its visitors, the various stakeholders and the private sectors worked together on various projects that contribute to this goal.

Until the preparation of this report, the following projects were implemented in this category:

No.	Project	Completion date	Brief Description
1	Installation of Public Toilets (at the basement of Bethlehem Municipality)	July, 2014	<p>The project included the installation of public toilets within the basement floor of Bethlehem, the toilets are accessible from the Manger Square, and shall serve the visitors of the area; the facility is also monitored by a janitor all the time; the facility is totally inside Bethlehem Municipality building.</p> <p><i>Funded by: United States Agency for International Development (USAID) through the West Bank Compete Project</i></p>
2	Installation of QR Codes through the Property	August, 2014	<p>An experimental project that aimed at providing directions using QR Codes throughout the property; the project also provided free Wi-Fi connection for the visitors for a period of two months.</p> <p><i>Funded by: European Commission in cooperation with Sina Institute/Bir Zeit University)</i></p>
3	Opening of Visit Palestine (Visitors Information Centre)	December, 2014	<p>A visitors-information centre located along the stairway that connects the Central Bus Station with the Pilgrimage Route.</p> <p><i>Private Initiative.</i></p>
4	Improvement of Street Lighting Network along the Pilgrimage Route	August, 2014	<p>The project included maintenance of the lighting fixtures along the route. The project shall enhance the experience of the visitors to the site.</p> <p><i>Funded by: United States Agency for International Development (USAID) through the West Bank Compete Project</i></p>

Future actions that aim to provide services and promote the site shall be also be implemented by the future.



No.	Project	Expected Completion date	Brief Description
1	Rehabilitation of the Manger Square Bethlehem Municipality Buildings in Manger square	September, 2015	<p>The project aims at the rehabilitation of the Manger Square and the Adjacent two municipality buildings (constructed in 1968 &amp; 1976), and providing services and a media centre; the project shall have minimum physical and visual impact and shall aim at cleaning the façades and the interior of the two buildings.</p> <p><i>Funded: by Consolidated Contractors Company (CCC) through Bethlehem Development Foundation</i></p>
2	Installation of Interpretation Panels throughout the Property	September, 2015	<p>The project aims at providing interpretation panels throughout the property; the design and material used in the panels and their size shall respect the site and its settings.</p> <p><i>Funded by: United States Agency for International Development (USAID) through the West Bank Compete Project</i></p>
3	Numbering and Naming the Streets throughout the Property	December, 2015	<p>The project shall contribute to an easier orientation throughout the property.</p> <p><i>Funded by: United States Agency for International Development (USAID) through the West Bank Compete Project</i></p>
4	Rehabilitation of the public toilets inside Bethlehem Peace Centre	December, 2015	<p>The project shall enhance the services in the building, which houses the official tourists information centre and a cultural centre.</p> <p><i>Funded by: Government of Russia</i></p>

#### General Note:

It is worth mentioning here that the majority of the projects are selected based on community participation campaigns that include the local community and the various stakeholders. In addition, the implementation of the projects is always accompanied with awareness campaigns that aim to encourage the commitment of the local community in the preservation of cultural heritage resources.

#### **4 Progress towards the Removal of the Property from the Danger List**

As indicated in section 2 of this report, the Desired State of Conservation prepared by the Advisory Bodies states “Completed conservation and repair of the roof structure of the Church of the Holy Nativity”, and the Corrective Measures indicate the following:

1. Complete a full investigative survey of the historic timbers and lead work of the roof, identifying the chronology and historical significance of the various component parts in relation with overall archaeological, historical and architectural analysis of the Church of the Holy Nativity.
2. Develop a Conservation Plan for the roof that synthesizes the conclusions of the detailed investigative survey into a clear statement of the significance of the various elements of the roof within a comprehensive conservation philosophy for the Church of the Holy Nativity.
3. Prepare a detailed project specification for the roof repairs that allow a full understanding of which elements of the roof will be maintained, which repaired and which replaced.
4. Undertake the roof repair project and document its interventions.

However, the previously mentioned detachment of the vaults of the Narthex was foreseen by the experts as a threat to the stability of the roof of the narthex, and works has started to further investigate the structure in order to come out with a comprehensive plan for the conservation of the narthex; the conservation plan for the narthex is expected to be completed in December 2015, upon which the implementation of the works shall start in 2016.

#### **5. Conclusion**

Since the last report, various activities were conducted by the stakeholders and the private sector to ensure the preservation of the property and enhance the experience of its inhabitants and visitors. However, the restoration works of the Church of the Nativity remain the most important action that shall contribute to the removal of the property from the World Heritage List.

In the light of the above, a proper time schedule for the removal of the property can be prepared upon the completion of the investigation regarding the vaults of the narthex and the completion of a proper conservation plan to consolidate its structure. Accordingly, and despite the progress in the restoration of the Church of the Nativity, Palestine wishes to retain the property “Birthplace of Jesus: Church of the Nativity and the Pilgrimage Route, Bethlehem” from the List of World Heritage in Danger.



STATE OF PALESTINE

PALESTINIAN PRESIDENTIAL NATIONAL COMMITTEE FOR

RESTORATION OF THE NATIVITY CHURCH BETHLEHEM

# ANNEXES (1,2,3 &4) TO THE BRIEF REPORT DATED JANUARY 2015



JANUARY 2015



community development group  
المجموعة الاستشارية للتنمية والاعمار

ARCHITECTS, ENGINEERS & PROJECT MANAGERS



University of Ferrara  
SADILAB Structural Analysis & Design Laboratory

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## 1 ANNEX 1: INVESTIGATION TO THE HISTORIC TIMBERS AND LEAD WORK AT THE ROOF

The present Section 1 represents the answer to the following request of specifications addressed by ICOMOS to the Consortium:

**“Complete a full investigative survey of the historic timbers and lead work of the roof, identifying the age and historical significance of the various component parts in relation with overall archaeological, historical and architectural analysis of the Church of the Holy Nativity.”**

### 1.1 FULL INVESTIGATIVE SURVEY OF THE HISTORIC TIMBERS AND LEAD WORK

It is worth noting that the reciprocal interaction between global and local scales of analysis of an historical monumental building can provide helpful evidence related to the historical, architectural and technical interaction among different elements composing the building.

In particular, the results of specialized and local analyses on the existing components and materials of the roof, when compared with historical and archaeological surveys on the global scale of the building, allow a deeper insight on the construction history of the whole Church and, on the other side, illuminate better on the historical and architectural significance of the single elements.

Therefore, the investigative survey on the roof structures and their components was carried out in close relationship with the overall archaeological, historical and architectural analyses carried out on the whole Church of the Nativity. The general principles were laid down at first, according to which the overall investigative surveys on the Church were carried out. At the same time, the plan of investigations on the roof was conceived to fully integrate the information provided by the global scale researches.

#### 1.1.1 Historical analysis

##### 1.1.1.1 Bethlehem as historical problem

In the context of the international team for the survey, assessment study, and conservation plan for the Basilica of the Nativity, the unit being responsible for historical and archaeological analysis has been focused on the historical aspects and the gathering of written sources. The research work, coordinated by Prof. Michele Bacci (University of Siena), was developed on two different, yet strictly intertwined, grounds: 1) it aimed at providing the other units with historical information being useful for the current works of investigation of the roofs and other material parts of the buildings; 2) it provided some grounds for a thorough reassessment of the historical problems underlying the site and its architectural-artistic peculiarities, starting from an analysis of the different methodological approaches applied by past scholars to the interpretation of the Nativity church.

In first instance, it must be remarked that, despite the large number of publications concerning the site, many aspects of its history still prove to be disregarded or not investigated. More specifically, the contributions of experts in many different disciplinary fields have mostly not been merged into a general history of the Basilica. The scholarly debate started already in the 16th and 17th centuries with the publications by both Greek and Franciscan authors who basically dealt with the origins of the site, its holy mementoes in their devotional and commemorative significance, and the properties and rights granted to each Christian community. From the 19<sup>th</sup> century onwards, the basilica has been investigated from the viewpoint of historical-religious topography (Tobler

1849; Vincent and Abel 1914), architectural history (de Vogüé 1860, Enlart 1925-1928, Pringle 1993), structural analysis (Harvey 1935; Wenzel 2005) and archaeology (Harvey et alii 1910, Hamilton 1947, Bagatti 1952), and art history and iconography (Stern 1936, 1948 and 1957; Kühnel 1987 and 1988, Folda 1995). Whereas the early history of the building has been much discussed since the very beginnings, its developments in the Byzantine and Crusader periods have been more specifically investigated only in much more recent works. Notwithstanding the large amount of written sources bearing witness to the history of the monument in the later centuries, the latter have not so much retained the attention of scholars.

In this chapter only the historical data concerning the roof and the roof covering are reported. A more exhaustive and comprehensive historical analysis can be found in the Final Report delivered by the Consortium in 2010.

### **1.1.1.2 State-of-the-Art**

To some extent, the abundance and variety of sources constitute a limitation to the development of historical research. Chronicles and archival documents occasionally shed some lights on specific aspects of the site history. Yet, pilgrims' accounts constitute by and large the most important category of written sources: those worked out from the 4<sup>th</sup> through the late 13<sup>th</sup> century are easily accessible in a published collections of texts in both their original language (Greek, Latin, Armenian, and Arabic) and Latin, Greek, English or French translations (including Wright 1848; Tobler 1874; Tobler-Molinier 1880-1885; Koikilides-Fokydis 1911; Baldi 1945; Geyer et alii 1965; Wilkinson 1977). On the other hand, from the 14<sup>th</sup> century onwards pilgrimage reports and descriptions of the holy sites were disseminated almost everywhere and were written in almost all the European and Mediterranean languages (including Italian, Spanish, Portuguese, French, English, German, Danish, Czech, Polish, Hungarian, Croatian, Serbian, Bulgarian, Russian, Greek, Armenian, Georgian, Arabic, Persian, and Ethiopic); a thorough examination of all such sources (partially listed by Röhrich 1890) proves to be extremely difficult, as many of them have been published by scholars interested only in their historical-linguistic aspects and, even if some of them can be accessed through some anthologies of texts (including Röhrich-Meisner 1880; Conrady 1882; De Khitrow 1889; Koikilides-Fokydis 1911; Baldi 1945; Schmid 1957; De Sandoli 1979-1984; Kadas 1986; Wilkinson-Hill-Ryan 1988; Huygens 1994; Herz-Huschenbett-Sczesny 1998) have never been gathered within systematic databases, a preliminary attempt being that recently established by the project *Digiberichte* of Kiel University ([www.digiberichte.de](http://www.digiberichte.de)).

On the whole, the contributions given by many different scholars have managed to shed light on specific aspects of the history of the Basilica, yet a wider and fuller interpretation of the site is still lacking and many questions remain unanswered. A comprehensive description of the history of the Church and a State-of-the-Art of the historical analyses carried out until now are reported in the Final Report delivered by the Consortium to the Palestinian Presidential National Committee and the reader is referred to it for more detailed information.

### **1.1.1.3 New Evidence on Past Restorations**

The history of the basilica after the Crusaders is still scarcely investigated, the main study being still that by Vincent and Abel (1914). The first references to the conditions of the roof date back to the 14<sup>th</sup> century. It can be said, in general terms, that in the 13<sup>th</sup> through the 19<sup>th</sup> century the building did not undergo significant alterations: according to both Ayyubid, Mamluk and Ottoman customary law, Christians were allowed to preserve their churches but they were prevented from both erecting new buildings and embellishing old ones; in order to make repairs, it was necessary to receive a special permission from the Sultan himself. Because of lack of maintenance the church started falling into a state of decay, as was frequently remarked, from the 14<sup>th</sup> century onwards, by those same pilgrims who never stopped manifesting their astonishment for the beauty of the church, its paintings, marble incrustations, monumental columns, and magnificent roof.



The most serious problems concerned the church roof. The medieval one, which was always described as made with several qualities of wood (cedar of Lebanon and cypress) and covered with lead, was by the late 15<sup>th</sup> century in such a bad state of preservation, that rain fell down from its many holes and the pavement was covered with birds' dung, even if, according to some sources, a first restoration had been accomplished in 1435 under the auspices of the Greek Emperor of Trebizond Alexios Komnenos Doukas (Ioannides 1867: 45). Yet, the portion of roof overhanging the choir was going to collapse when the Italian pilgrim visited the church in 1474 and saw that the Franciscan friars had been obliged to erect a wooden structure to hold it up (Calamai 1993: 142). As we are informed by Friar Francesco Suriano (Golubovich 1900: 190), the Franciscan Guardian Giovanni Tomacelli obtained the Sultan's permission for the thorough restoration of the roof; this fact is also witnessed by the original firman (Castellani 1922: 61) and Felix Fabri's account (Hassler 1843-1849, I: 475-477). Tomacelli was an Observant friar and his efforts to restore the basilica's ancient decorum manifested a radical change of attitude, implicitly contrasting that of the previous Conventual administration (as is implied by Suriano's words). He was able enough to obtain sponsorships from the Duke of Bourgogne and the King of England; whereas the latter's money was used for the lead covering, the former's was invested for the making of the new wooden structure. Venetian carpenters and wood-carvers came to Bethlehem to take measurements and they subsequently made beams out of pine-woods from the Alps. The materials were then transported by ship to Jaffa and thence transferred to Bethlehem by means of camels and oxen; special machines were constructed in order to transport the hugest and longest beams.

Sources are silent about the roof in the 16<sup>th</sup> century, but as early as 1607 and later on in 1617 its condition had become precarious, and the Greek community was allowed to operate some substitutions of rotten beams. Yet, a much more efficacious intervention took place on the initiative of the Greek Patriarch Dositheos in 1672: thanks to the sponsorship of a rich Greek devotee, Manolakis of Kastoria, it was possible not only to renovate the roof with new beams from Mytilene and a new lead covering, but also to make new ornaments in the church. The windows, which had been previously closed with hard stones, were substituted with iron casings and glass; some of the nave walls were plastered, and the entrances to the Nativity grotto were embellished with new marble slabs (Patriarch Dositheos 1715: 1214; Ioannides 1867: 45-46).

Only interventions for the building's ordinary maintenance took place in the 18<sup>th</sup> century, except for the restoration, in 1775, of a wall, located close to the west entrance that was going to collapse (Ioannides 1867: 47). In 1834 the basilica was damaged by an earthquake and already by 1837 the Greek community had received lots of offerings from the devotees to make new embellishments in the narthex (Chrysanthos 1837: 93). Finally, in 1842 the Sultan Abdul Mecit, answering to the official request of the Greek Patriarch Athanasius III, gave permission to work out a thorough renovation of the wooden roof and its lead coverings; on the same occasion, a new pavement was made in the choir with marble slabs from the Propontis and in the nave with local stones (Ioannides 1867: 47). At the same time, with the exception of the extant remnants of the 12<sup>th</sup> century mosaic decoration, the upper portions of the nave and transept walls were almost completely covered with a thick plastering; according to some authors (Vincent and Abel 1914: 203-204), significant portions of mosaic may have been hidden under this plastering and it would prove extremely important to bring them back to visibility, with the help of a thermographic analysis and a thorough restoration of the walls.

That of 1842 was the last significant intervention made in the basilica. The historical data here mentioned are the only information till now available on the past history of the roof and their components.

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- Wright, Th. 1848. *Early Travels in Palestine*. London.

### 1.1.2 Archaeological and stratigraphic analysis

The methodology followed to carry out the archaeological and stratigraphic analysis of the whole masonry structure of the Church and the results obtained are in the Final Report delivered by the Consortium in 2010. Here only the main conclusions are reported, as useful information about the masonry support of the roof.

### **1.1.2.1 Building Construction Technique 1 (Justinian phase)**

Building Technique 1 is characterised by the use of large and perfectly squared ashlar blocks up to 1m long and up to 0.4 m in height, set in parallel horizontal courses of fairly consistent but not invariably identical height, the variation being determined by the height of the stones. The bedding planes and vertical joints, when visible, are extremely narrow, thanks to the perfectly cut contact faces of the stone blocks. The crudely-spread cement mortar covering the original bedding joints has made it impossible to identify secure examples of the original pointing, save that it is represented by a hard whitish mortar containing plentiful fragments of crushed tile that has at some unidentified time been applied in such a way as to cover the edges of the stones. In places the courses have then been marked on the surface with a sharp instrument (see Figure 1).

The traces of working on the stones indicate the use of a bolster with a flat blade 2-3 cm wide for making the contact surfaces of the stones and of two different types of toothed bolster for finishing the exposed faces (Figure 2).

Building Technique 1, using a local 'malachite' stone varying in hardness and ranging in colour from light yellow to grey, is a tribute to the high skill of the imperial masons, who adopted it as the sole technique of construction for the whole of the basilica.

The contemporaneity of the Technique 1 walling is demonstrated by clear stratigraphic relationships showing that all of the walls of the basilica were built as part of a single strictly planned process, within which there are easily recognisable structural 'signatures' such as the use of L-shaped stones to tie some of the walls together at their junctions.

### **1.1.2.2 Stage of construction**

The two clear structural joints, symmetrically placed at the junction of the transepts and the rest of the basilica, have given rise to the suggestion of a particular sequence of construction, essentially unitary and contemporaneous but with a difference between two main blocks of walling. The first comprises the three apses and their linking walls, to a total of about 93 m in length. The second comprises the external walls of the two aisles and the two walls of the western façade, to a total length of 124 m, along with the walls above the nave arcade.

The construction would therefore have commenced at the west front, afterwards moving progressively within the same basic constructional phase to the building of the apses, the latter joining the main body of the church at the construction joints noted above, where the stones of the transepts butt against those of the nave.

Judging from the consistent level of the window sills and the linking semi-pilasters (which however do not in all cases start at the same level) the construction of the upper parts of the walls would then have proceeded simultaneously around the whole perimeter of the church, including the 34 arches necessary for the construction of the window openings (Figure 3).

### **1.1.2.3 Building Construction Technique 2**

Building Technique 2 is characterised by the use of roughly squared blocks of fairly modest dimensions set in horizontal and parallel courses. The bedding joints vary up to about 3 cm in thickness. The crudely spread cement mortar/plaster covering the original bedding joints makes it impossible to identify secure examples of the original pointing.

The traces of tooling on the contact surfaces of the stones suggest the use of a wide flat-faced bolster, consistently seen to be of notable width, up to 10 cm and in some cases even up to 20 cm. The exposed faces show the consistent use of a diagonally angles bolster to apply the surface finish to the ashlar blocks (Figure 4).



Building Technique 2, again using the local 'malachite' stone, is attributable to the specialised workmanship identified from the beginning of the 12th century onwards with the Crusader conquest and with the construction of the citadel inside the Justinian basilica.

In the walling of the basilica this technique is seen principally in the heightening in the external walls of the aisles (Elevations 100 and 2300), in the façade above the narthex roof-terrace (Elevation 2700) and in most but not all of the internal walls of the narthex.



Figure 1: traces of mortar and finishing that characterize the eastern and northern walls of the apse



Figure 2: Building technique 1. Sample technique above. Traces of working tools at the bottom

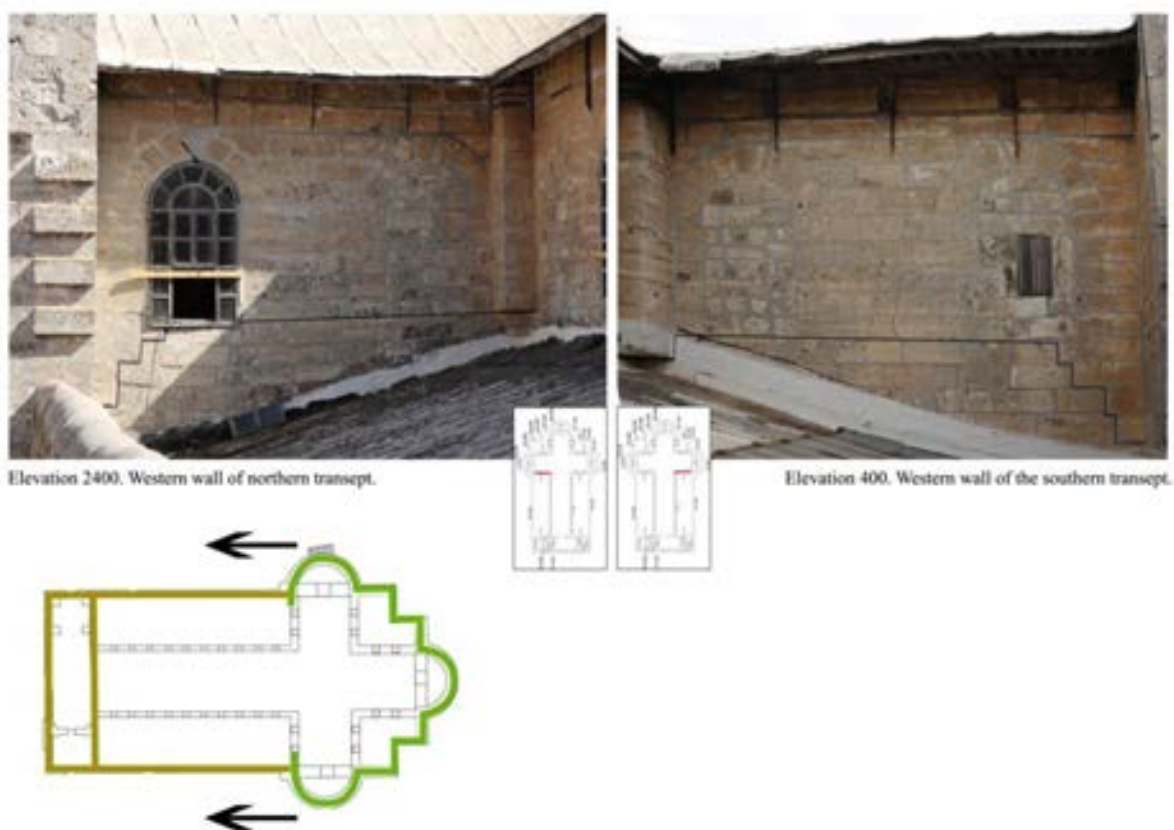


Figure 3: Cesure construction index of precise construction methods

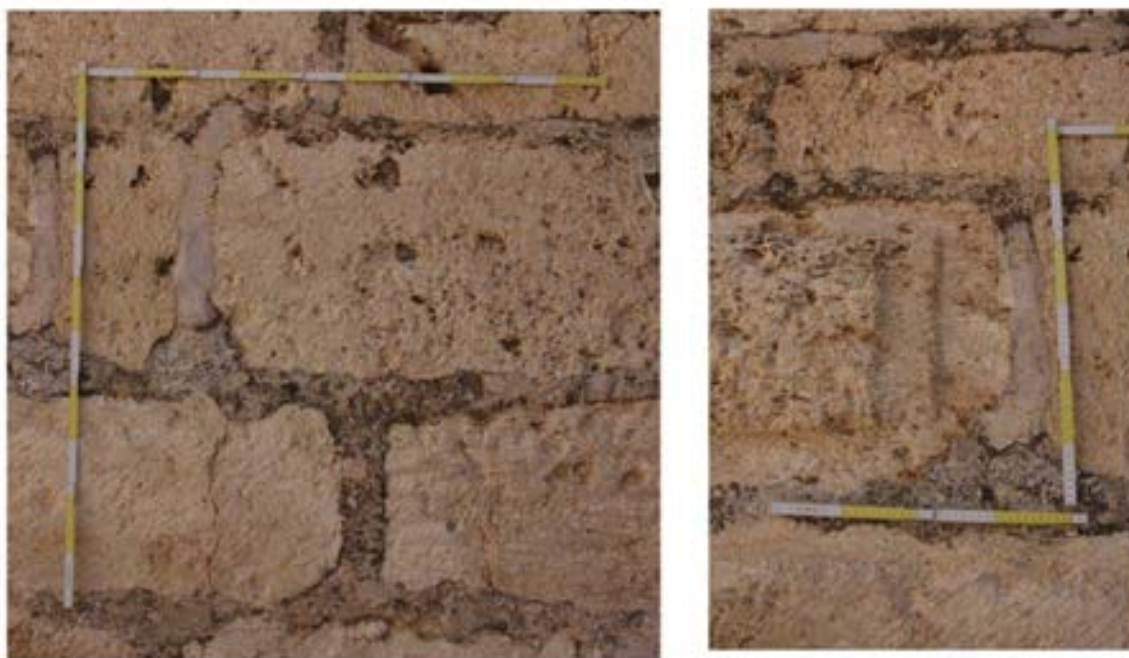


Figure 4: Building technique 2. Sample technique above. Traces of working tools at the bottom.



### **1.1.3 Roof and windows**

Doors and architraves above the colonnades were also analysed and the results are in the Consortium Final Report. Here only the analyses concerning roof and windows are reported because they are the parts of the Church presently subject to restoration.

#### **1.1.3.1 General methodology**

The following tasks had to be accomplished:

1. Evaluation of the state of preservation of windows.
2. Diagnosis of timber structures.
3. Dendrochronological dating of the timber structures.

All the diagnostic works were performed by taking into account the requirements considered by the Italian standard UNI 11161:2005 "Cultural heritage - Wooden artefacts - Guidelines for conservation, restoration and maintenance". They are:

1. Retrieval of possible historical documentation, including chronological interventions and transformations endured.
2. Description of the artefact and a photographic documentation.
3. A survey of the artefact and a graphic representation.
4. Dating the artefact, specifying the methodology executed.
5. Identification of the wooden species which constitutes the artefact.
6. Description of the environmental thermo-hygrometric conditions in typical conditions of conservation of the artefact and the consequent moisture content of wood.
7. Description of the environmental thermo-hygrometric conditions that the artefact will undergo after intervention.
8. Diagnosis of the state of the artefact and all of its wood components through identification, classification and quantification of the abiotic and biotic decay.
9. Description of the modality of conservation and/or maintenance and/or restoration carried out on the artefact.
10. Description of the modality of control of the efficaciousness of the intervention, with the passing of time

#### **1.1.3.2 Evaluation of the state of preservation of windows**

A more detailed analysis is in the Consortium Final Report. Here only the most significant damage pathologies are reported.

The state of preservation was evaluated in situ with respect to the biotic decay (wood fungi and insects) and the abiotic decay, principally in the semi-circular windows that are exposed to the atmospheric agents. The decay due to the atmospheric agents, principally UV radiation, is called "weathering".

Insects decay can occur on indoor timber on sapwood or also on heartwood in species without a clear distinction between the two areas.



Fungal decay occurs when the moisture content of wood is higher than 20% (exterior structures or damp areas). Fungi degrade the cell wall components (cellulose, hemicelluloses and lignin) and cause a modification of mechanical, physical and chemical wood properties. The attack is on sapwood and heartwood and is generally localized in a damp area of timber element; it determines a decreasing of total resistance only in the attacked area.

During the inspection some samples were collected for anatomical identification of wood species.

Anatomical identification analyses were performed in the CNR-IVALSA laboratories. The wood samples were boiled and cut in thin sections in the transverse, radial longitudinal and tangential longitudinal planes. Thin sections were observed under light microscope. The knowledge of wood species is important to define the natural durability of wood in the service condition and to give recommendation about the remedial treatment and maintenance.

The semi-circular windows are placed in:

- Roof level: north and south transepts, apse
- High level: North and south walls of the central nave, above the mosaics
- Ground level: North and south transepts, apse.

Drawings of high level windows are represented in the following figures (Figure 5, Figure 6), the windows placed in the east part, apse, are showed in (Figure 7).

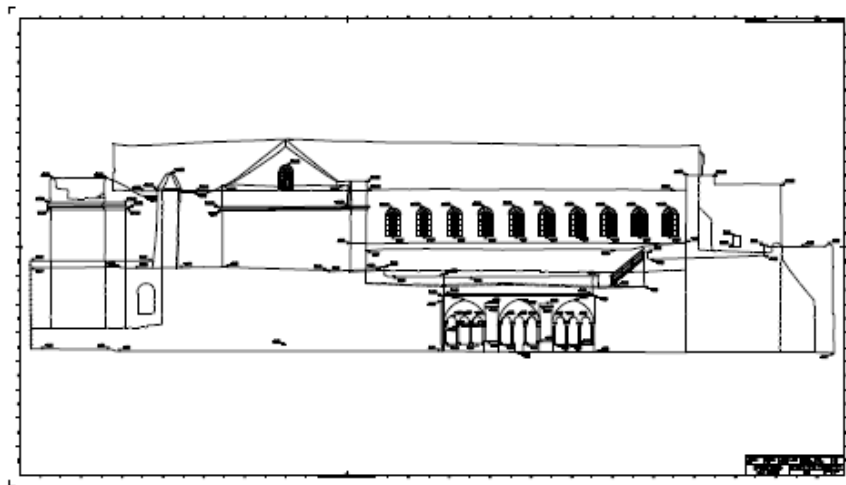


Figure 5: windows in the north walls

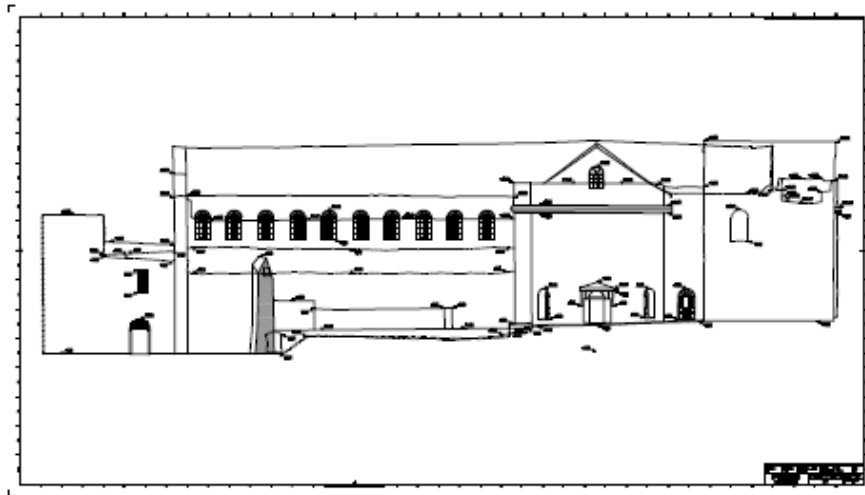


Figure 6: windows in the south walls.

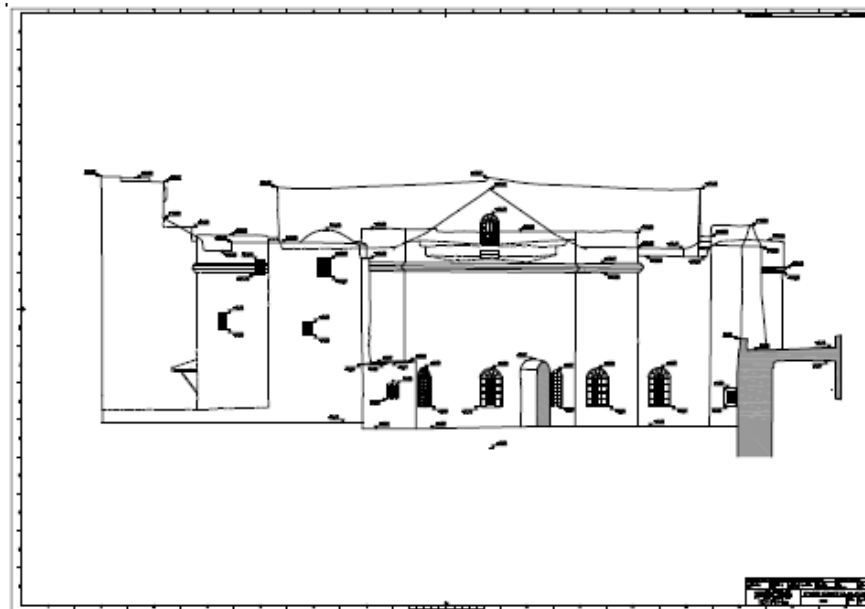


Figure 7: windows in the east side walls.

The inspection started from the windows of the high level. In each longitudinal wall there are ten windows, numbered in this report from west to east. The overhang of the wooden roof protects the semi-circular windows in the walls of the central nave and the transepts. The wooden elements of the overhang showed attacks by insects and fungi (Figure 8).



Figure 8: overhang of north transept

The identification of wood species on samples collected from different windows, of north wall gave as results *Pinus sylvestris* and *Picea abies*, species non-durable with respect to biotic decay.

The grey paint is often detached from the wood due to shrinkage and swelling of wood during the daily and seasonal hygrometric variations. This weathering effect is more pronounced in the southern part due to the more severe exposition to sunlight with the consequence that some wooden part are warped (Figure 9).



Figure 9: deformation of wood frame due to the weathering

In many cases the wooden frame of the windows is not well anchored to the wall due to the mortar detachment. From the openings between the wood and the wall the rain can enter the church, creating dangerous conditions for the internal mosaics.

Many windows have decay mainly due to the weathering and fungi (Figure 10). One of them has a bullet hole whereas some others have some glass pieces missing.



Figure 10: window 9 south wall, fungal decay in the bottom

The conservation status of the windows on the ground floor is a little better than that at the higher level because such windows are sheltered from weathering (Figure 11). Nevertheless some fungal decay was also observed in the windows placed at the high level of north transept. In the majority of them a detachment of paint from the wooden support was observed.



Figure 11: ground level window in the Franciscan garden, apse

As all these windows were installed during the XIX century and have no significant artistic value, the diffused presence everywhere of a serious physical decay suggests their replacement rather than a restoration which might not guarantee long lasting beneficial effects. However, this does not exempt from defining a scheduled maintenance plan even after the replacement.

### **1.1.3.3 Roof covering and rainwater drainage system**

#### **1.1.3.3.1 General description**

In the present chapter questions concerning the paths of the rain water from the roof to the outside of the Church are faced. The rainfall both on the central nave and on the lateral naves runs up to the perimeter of the lateral naves by using only the slopes of the roof. Then it is canalized outside the Church by a few discrete points which, as was expectable, represent complex critical points that urgently require restoration as well as special and ordinary maintenance.

In

Figure 12 the complete and clear distribution of the roof's slopes in the central and lateral naves, and of all the drainpipes (especially in the wall thickness) and downpipes is depicted along with the photographs which shoot them. The figure is extremely useful to fully understand the path of the rain and to locate the critical points which may provoke damage inside the church.

All the photographs will be furnished with the deliverables at the end of the third phase.

On the basis of the above survey some critical situations have been located.

First of all it must be underlined that the roof is covered by a lead sheet with a layer of bitumen (see Figure 13) which is not suitable any more to guarantee the waterproofing of the roof. In fact, in occasion of the rain the water leaks from the roof through the areas not covered any more by the bitumen and along many intersection lines between roof and wall. The recommendations will take into account such an element and they will propose one or more solutions in the respect of the historical and architectural aspects. It must be pointed out that at the moment there are no horizontal drainpipes collecting the rain along the perimeter of the roof and, for this reason, all the rain collected by the central nave roof flow on the lateral naves and finally to the ground by few connecting points.

In Figure 14 different critical positions are located and named with different capital letter. Three situations are identified. Number 1 refers to the way the rainwater is carried from the apses' terraces to outside the church; number 2 copes with the rain water which is collected on the entire orthodox quarter of the Church; finally, number 3 locates the ways, mainly through the boundary walls, through which the rain falling on the central nave is conducted towards the Franciscan terrace and the Orthodox and Armenian gardens.

The system which conducts the rain water from the apses' terraces outside does not seem to have created damages so far even though there are some aspects which may overload other drainpipes. The apse's terrace of the transept at the Franciscan side has no connection through the battlement and the rain water is led by the slope directly to the lateral nave on the Armenian corner (see Figure 15 left). In 1A and in 1B two horizontal drainpipes through the wall (see Figure 15 centre, right) take the water pouring to the garden (with or without tiles) below; such pipes seem not leaking inside the wall but the substitution (and the successive continuous ordinary maintenance) will be warmly recommended.

The path covered by the rainwater falling on the Armenian and Orthodox corners (see Figure 16 left) have both a critical point in the drainpipe located through the masonry wall corner (see Figure 16 right). The pipe in 2A continues into an external pipe in the Franciscan garden (see Figure 17 left) and then in a horizontal pipe underneath; such an element is very probably leaking as damage due to humidity has occurred inside the Church (Armenian corner – see Figure 18). As a matter of fact it must be pointed out that the external surface of the wall under discussion is directly faced to the soil and thus directly hit by the water filtering from above. The question is even more critical in the Orthodox corner 2B; here the pipe is hidden in the masonry (see Figure 19) and then taken horizontally in a pipe running parallel (and very close) to the masonry wall (see Figure 19 right). The lack of waterproof in the system is evidenced by the damage depicted in Figure 20.

Finally let's take into examination the perimeter line of the lateral naves' roof. Both lines are not open thus they do not let the rain water to leak outside the Church along the perimeter. The external side of each lateral nave is closed by a battlement, and such a short masonry wall is crossed by inclined drainpipe which conduct the rainwater on the other side. On one side (3A) the rain water spills on the Franciscan side 3A (see Figure 21) whereas on the other side (see Figure 22) the water is conducted to a lead channel that, very probably, has been added successively to mitigate the fall effect. In both cases the lack of waterproof of the intersection between roof and battlement is evident from the leakage signs visible in the lateral naves as depicted in Figure 23. The recommendations will surely have to take into account the need to design a robust and waterproof system to protect such lines.

Finally special attention must be paid to the roof area nearby the tympanum close the main entrance. The problem is similar to what occurs to the areas 3A and 3B and the leakage is evident from inside as depicted in Figure 24.



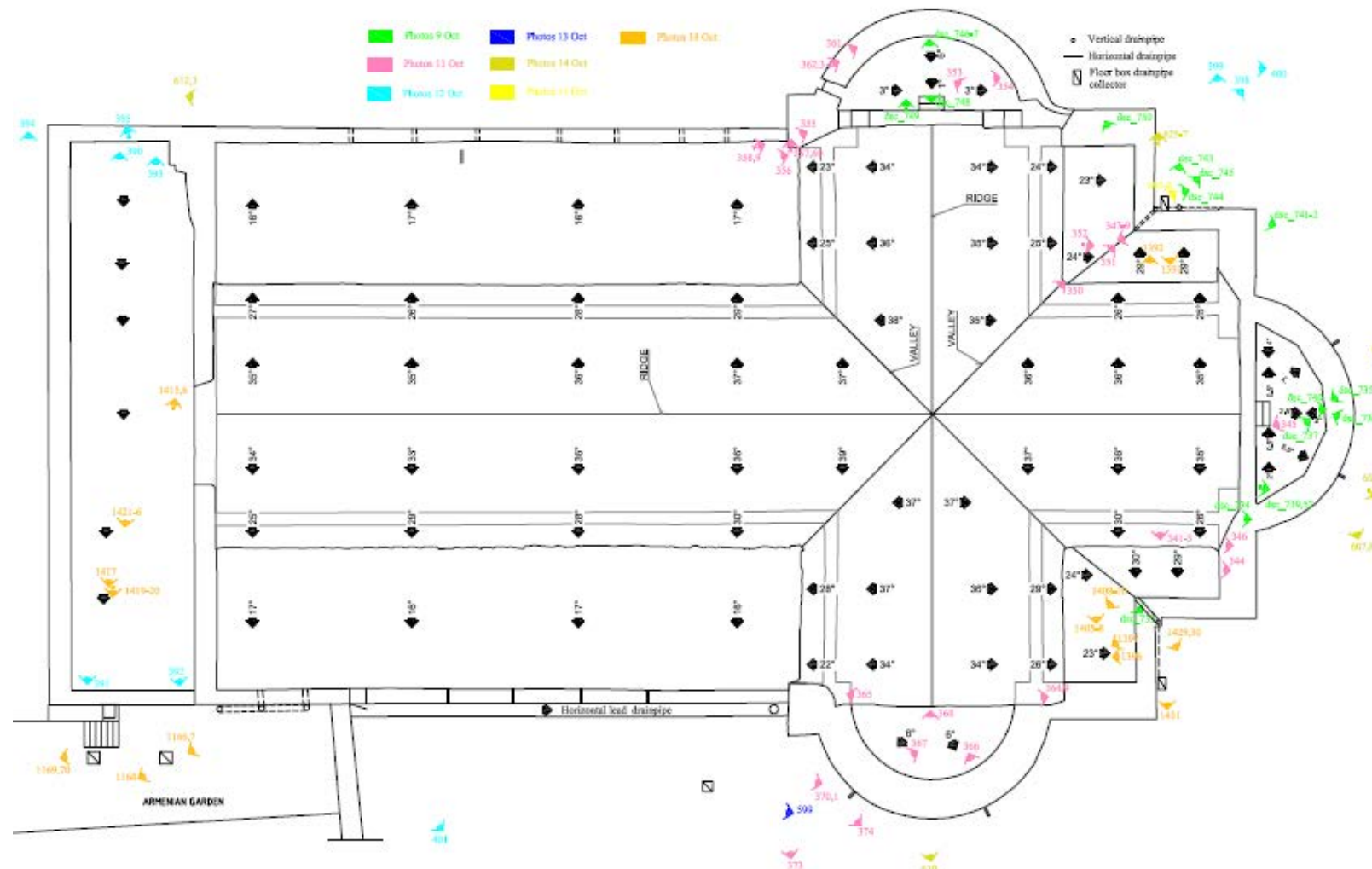


Figure 12: Roof slopes and drainpipes to represent the rain path



Figure 13: Lead and bitumen covering the roof

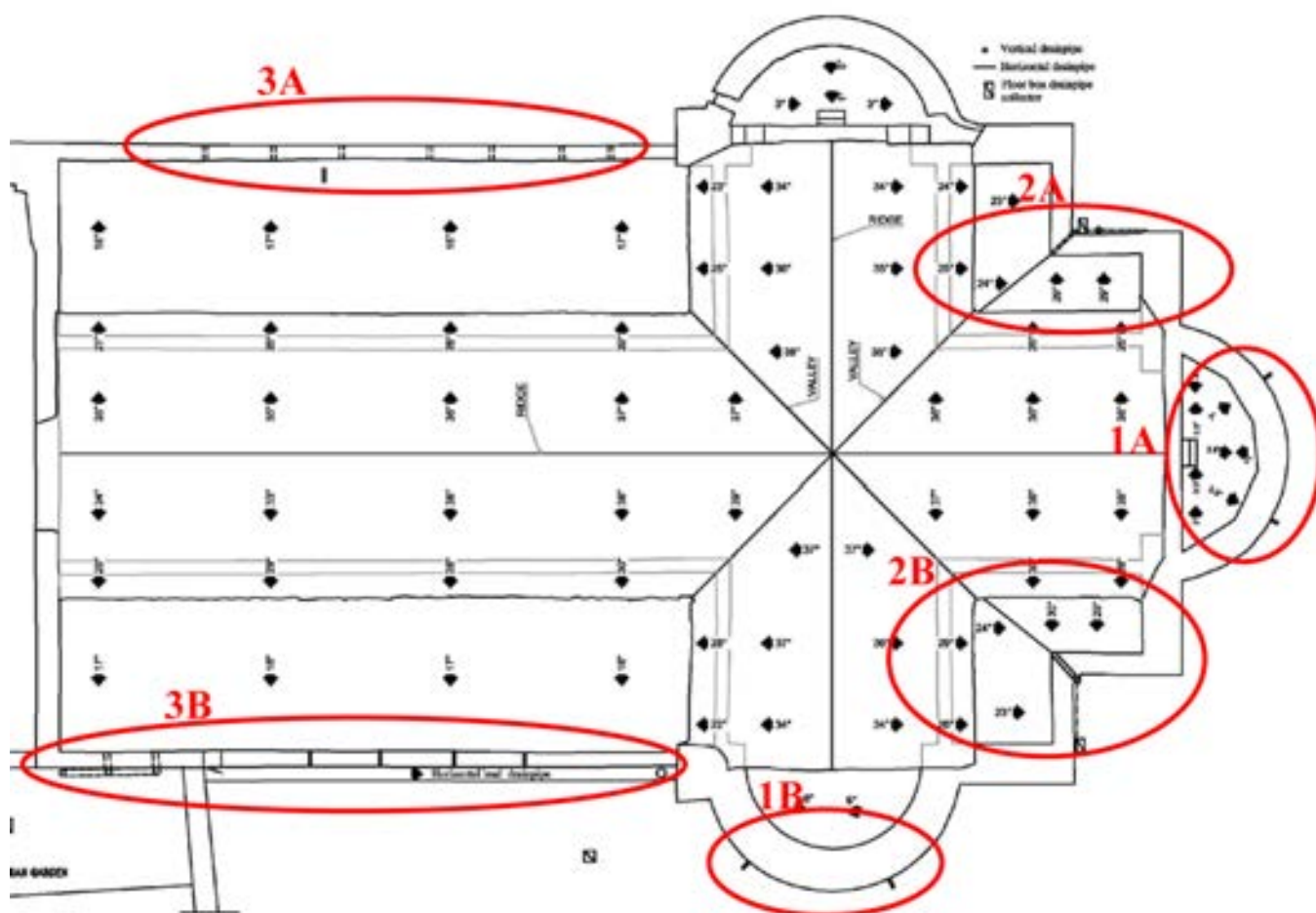


Figure 14: Location of the critical points with reference to the transportation of the rain water





Figure 15: (Left) Apse on the Franciscan side; (right) drainpipes in A1; (bottom) drainpipes in B1



Figure 16: (Left) Armenian (2A) and Orthodox (2B) corners. (Right) Drainpipe through the corner wall



Figure 17: Pipe collecting the rainwater in 2A



Figure 18: Damages on the wall due to the humidity on the other side (2A)



Figure 19: Drainpipe hidden in the masonry in the Orthodox corner (2B)



Figure 20: Damage due to the rain leakage in the Orthodox corner (2B)

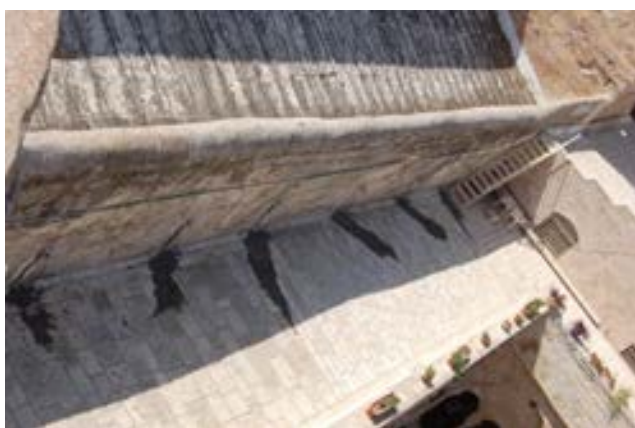


Figure 21: Franciscan side 3A



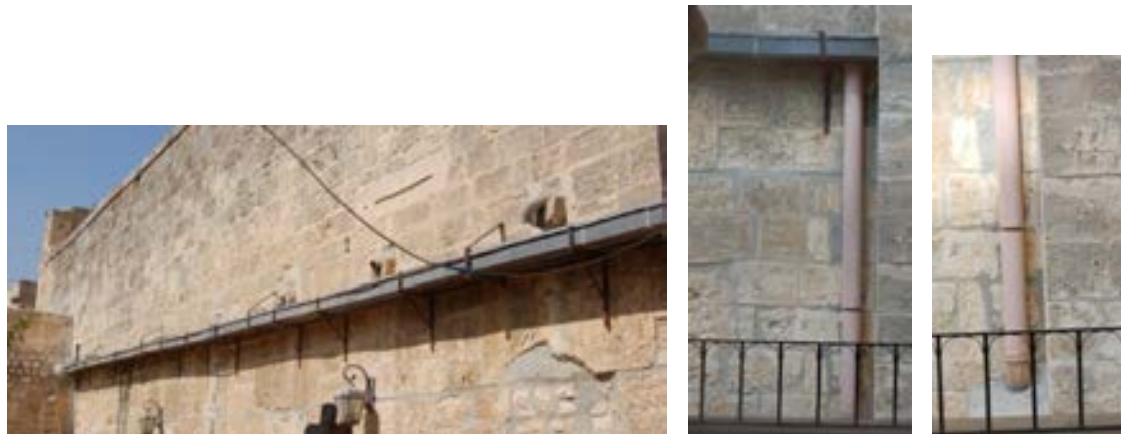


Figure 22: Orthodox side 3B.



Figure 23: Rainwater leakage signs in the lateral nave close to the Orthodox side 3B



Figure 24: Rainwater leakage signs inside the central nave on the tympanum nearby the main entrance

## **1.1.4 Diagnosis of timber structures**

The general methodology suggested by the Italian norm UNI 11161:2005 “Cultural heritage - Wooden artefacts - Guidelines for conservation, restoration and maintenance” was developed through the following steps:

1. Data base;
2. Biological damage;
3. Dendrochronological dating;
4. Conclusions;

### **1.1.4.1 Data base**

According to a general methodology based mainly on the Italian Codes UNI 11161:2005 “Cultural heritage - Wooden artefacts - Guidelines for conservation, restoration and maintenance” a complete data base was set up after an accurate geometrical survey of all roof timber elements. Data sheets were created, illustrating the features of each examined truss (geometrical data of the transverse sections, structural grading, wooden species). When measurements are given for two sections it means that the two sections are at the opposite sides of the timber element; when the measurements of one section only is reported it means that the section is in the middle of the element (it occurs in shorter elements, such as struts, or regular elements, such as king posts). The defects to determine the structural grading were measured on the truss principal elements: tie beams and rafters. A short description of the most important features of the trusses follows the tables with measurements. Photos, when available, are also pasted to the document.

The numbering of the trusses follows the scheme:

Principal nave: CN01 to CN12 from the façade to the crossing area.

North transept: T13 to T 17 from the North wall to the crossing area.

South transept: T 36 to T 40 from the South wall to the crossing area.

Apse: A31 to A35 from the East wall to the crossing area.



Figure 25: the timber structure at the crossing nave – transepts., from below

Crossing area: four big cantilevers (Figure 25) are placed along the diagonals of the square and called from A to D. starting clockwise from the NE corner. Four corresponding pillars go clockwise from NE corner, from E to H. One set of four small trusses are numbered from CA18 to CA21 (Figure 26) going clockwise from the north side. Two diagonal trusses are numbered from CA22 to CA25 going clockwise from the NW corner. Another set of smaller trusses is numbered from CA26 to CA29 going clockwise from the north side. The element 30 is the big central king post. Finally, the eight short elements connecting the cantilevers with the trusses (B in Figure 25) are called with the letter of the cantilever and the number of the connected truss: A17, A35, B35, B40, C40, C12, D12, D17. Those elements are not described in the sheets because they are completely covered by boards.

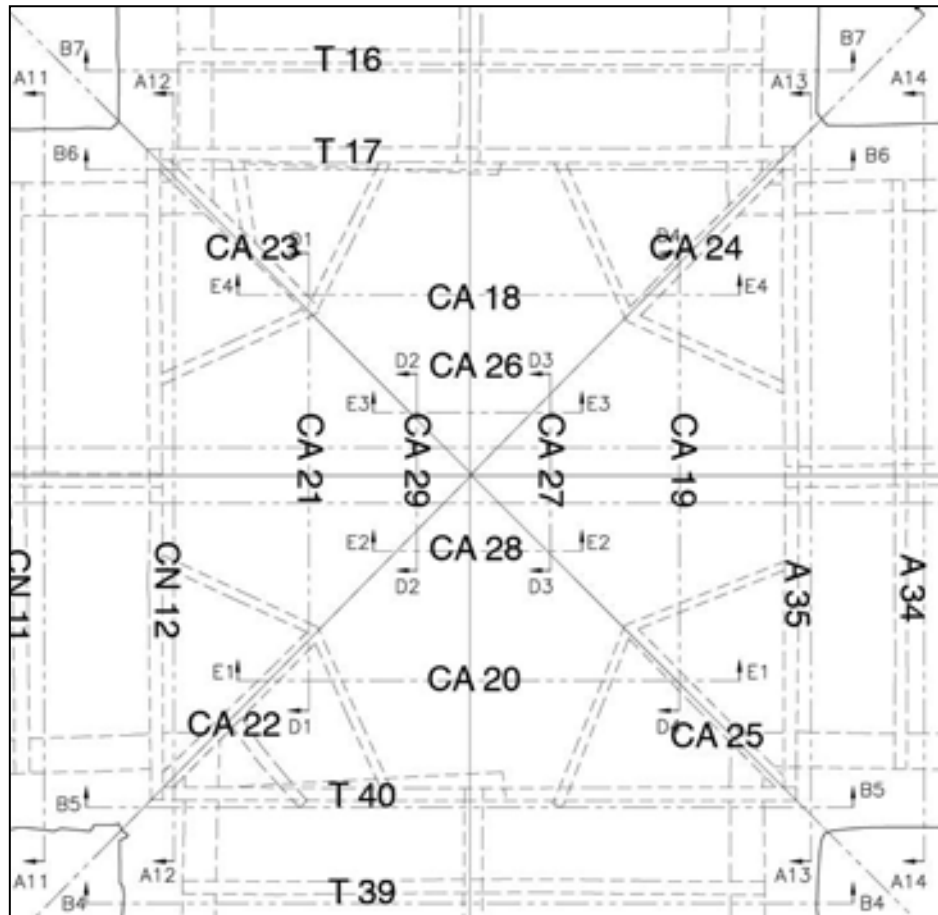


Figure 26: plan of the central "crossing area" giving the numbering of the timber elements

Lateral naves: the numbering of the trusses follows the same scheme as for the principal nave. So they are divided into LNN (Lateral Nave North) and LNS (Lateral Nave South) and numbered from 1 to 12. Different numbering for the two "corners" between transepts and apse. For those frames it was decided to utilise the numbers of the sections of the SCDS relief, preceded by CN (Corner North) and CS (Corner South).

As a general dimensional reference, the length of some tie beams (wall to wall) is reported:

- T 12: 951 cm
- T 17: 944 cm
- T 35: 950 cm
- T 40: 950 cm
- Distance from T 21 to façade wall: 31,61 m

The database was set up on the basis of the information collected during the survey campaign. In particular, a CAD file was created, reporting the grading classes and the presence and extension of decay.

The timber grading is performed according to the Italian standard UNI 11119:2004 that identifies three classes (here expressed as I, II, III grades). The timber elements having a lower structural quality are marked as N.S. (not

suitable for mechanical purposes); at the end of the standard, the Tables suggest the maximum stresses allowed in the application of admissible stresses method and the average bending MOE of on-site grades of principle timber species, applicable for wood moisture content = 12%. For N.S. elements there are no mechanical profiles to suggest.

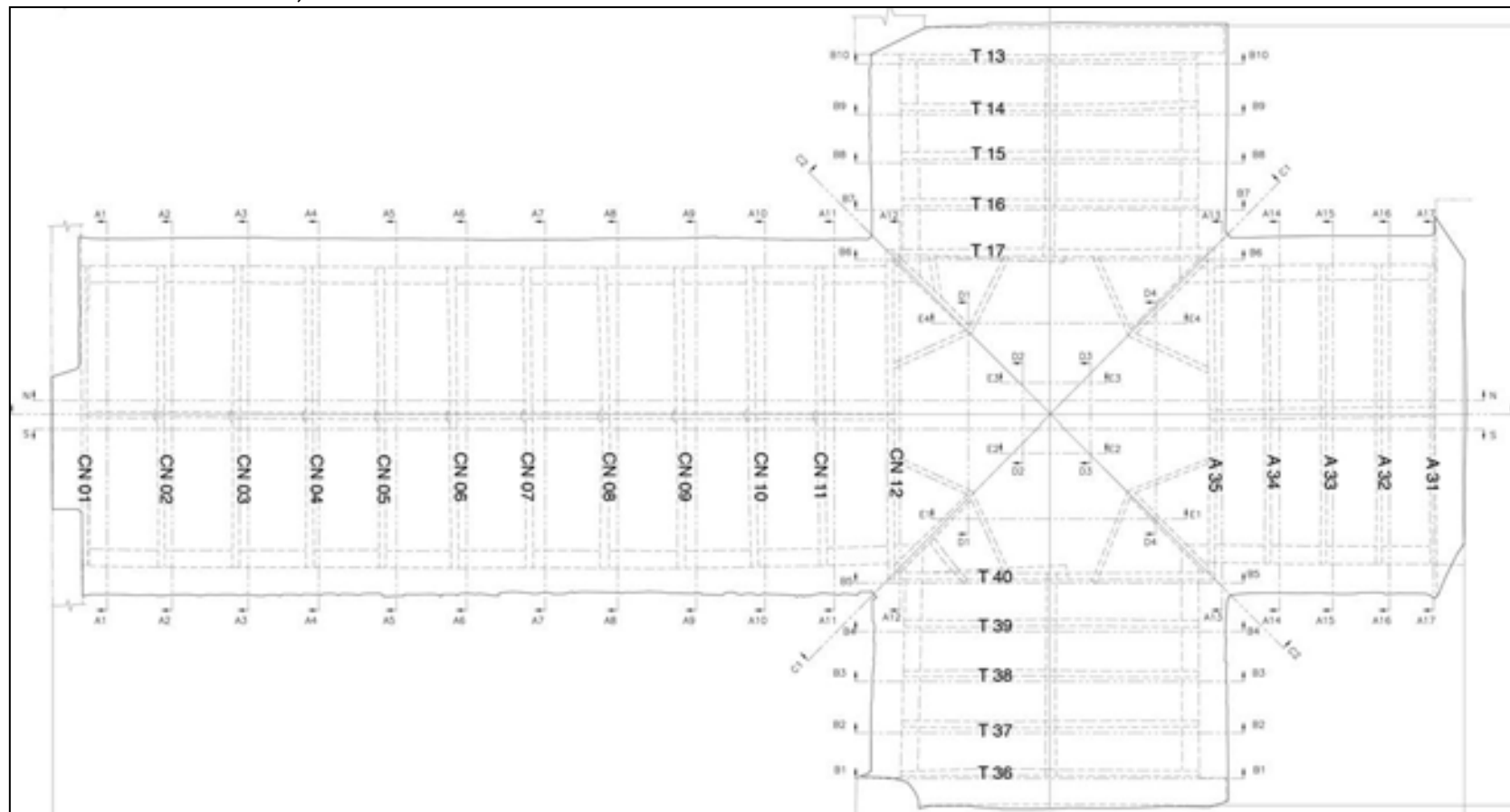
Elements marked as N.G. are not gradable due to contingent situations, such as covered elements or composed elements (such as for the west rafter of T 14 in the North transept).

The extension of the decay, measured by means of resistographic drillings, is given per classes: 0 – 25%, 25 – 50%, 50 – 75% and 75 – 100%.

The species, determined per each element, has been identified both through macroscopic evaluation and through microscopic analysis. The microscopic identification was made through the drawing of samples and the identification in Lab. Dendrochronological dating



# CENTRAL NAVE, TRANSEPT AND APSE



The following is an example, referred to truss CN07, of how the main features are described:

Truss	Tie beam		Rafter N		Rafter S		Strut Upper		Strut Lower		Sleeper		King post
	N	S	Beam	Apex	Beam	Apex	N	S	N	S	N	S	
7 CN	20 x 19	18 x 19	22 x 30	22 x 23	24 x 24	23 x 25	20 x 19	18 x 16	19 x 20	18 x 18	18	17	18 x 21

On-site structural grading:

Tie beam	North Rafter	South Rafter	King post	Strut Upper		Strut Lower	
III	II	II	I	N	S	N	S
				I	I	I	I

The tie beam is entirely covered by boards, dimensions and defects are not easily measurable.

Tie beam, Rafters, and struts made of Oak. Length of cantilevers: N 148cm, S 157cm

Sleepers and cantilevers made of Lebanon cedar.

The cantilever north shows an inner decay of 6cm in the portion within the wall

There is a reduction of the section of the tie beam at the connection with the south rafter (a wane 9,5 x 7 cm).

The northern rafter has an inner decay 25 – 50% along the whole length. Probably the defect was already on the standing tree.

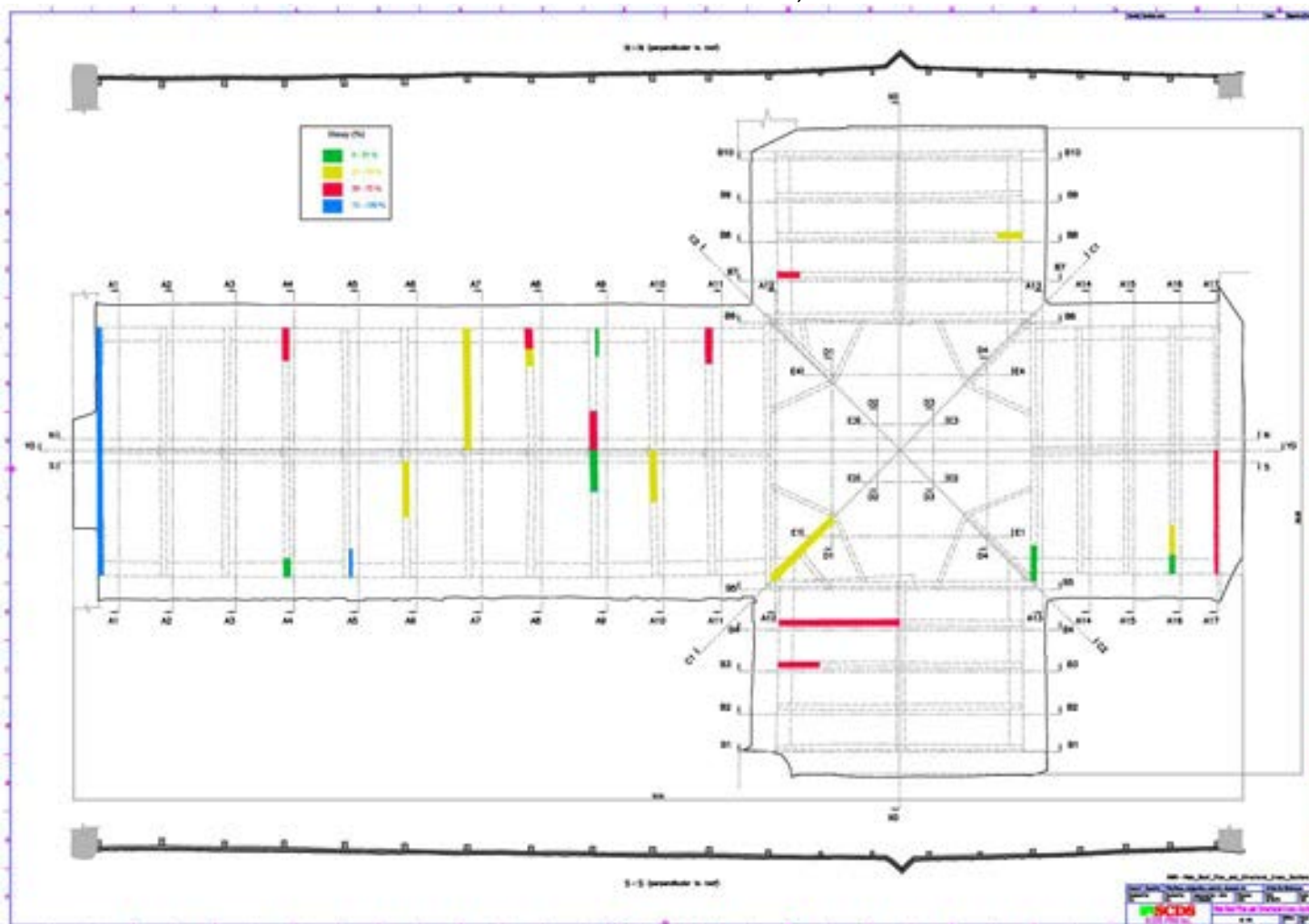
Resistographic drillings didn't reveal any decay on the southern side of the truss.



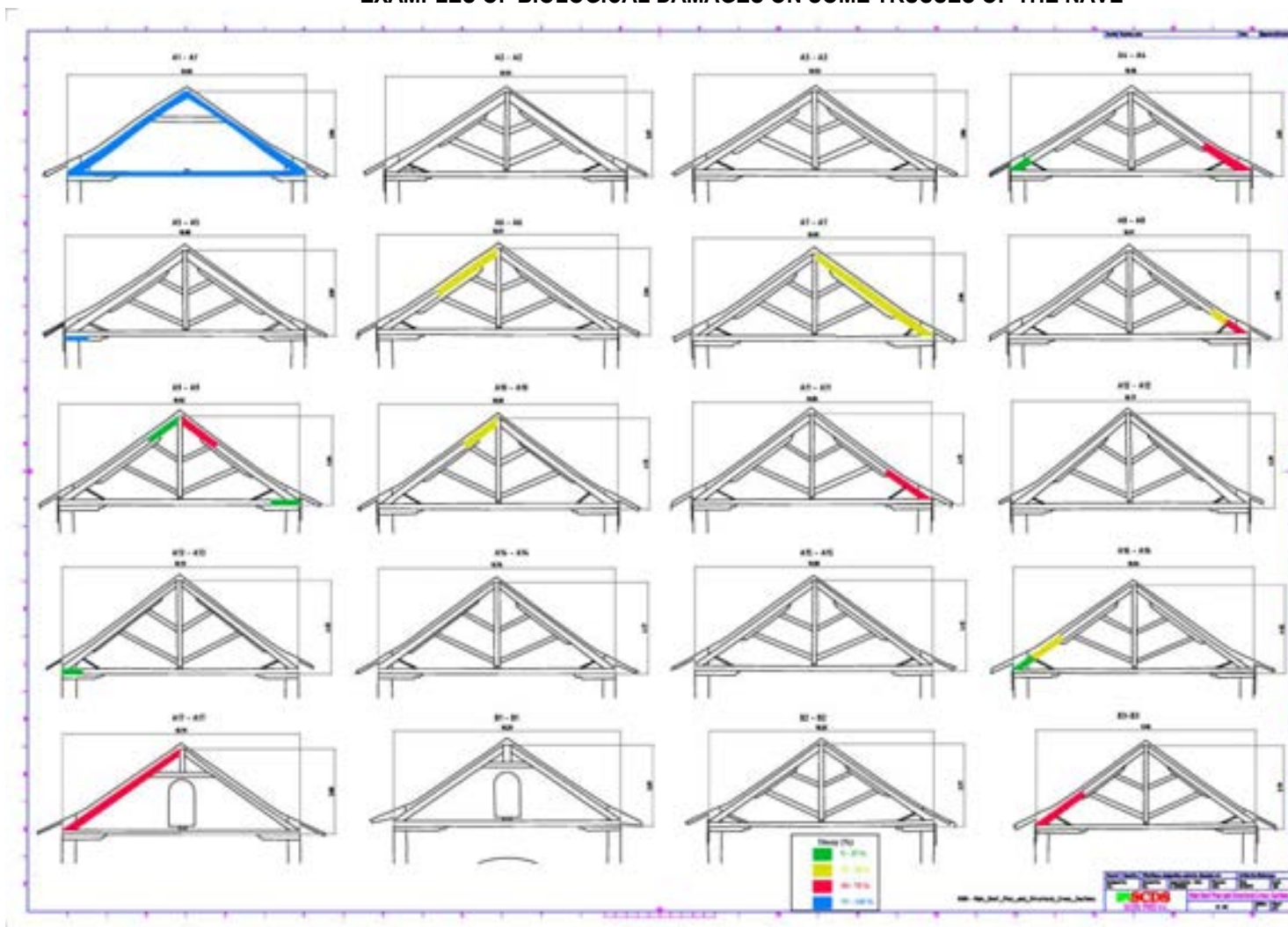
## BIOLOGICAL DAMAGE

The extension of the decay, measured by means of resistographic drillings, is given per classes: 0 – 25%, 25 – 50%, 50 – 75% and 75 – 100%.

# BIOLOGICAL DAMAGE ON NAVE, TRANSEPT AND APSE

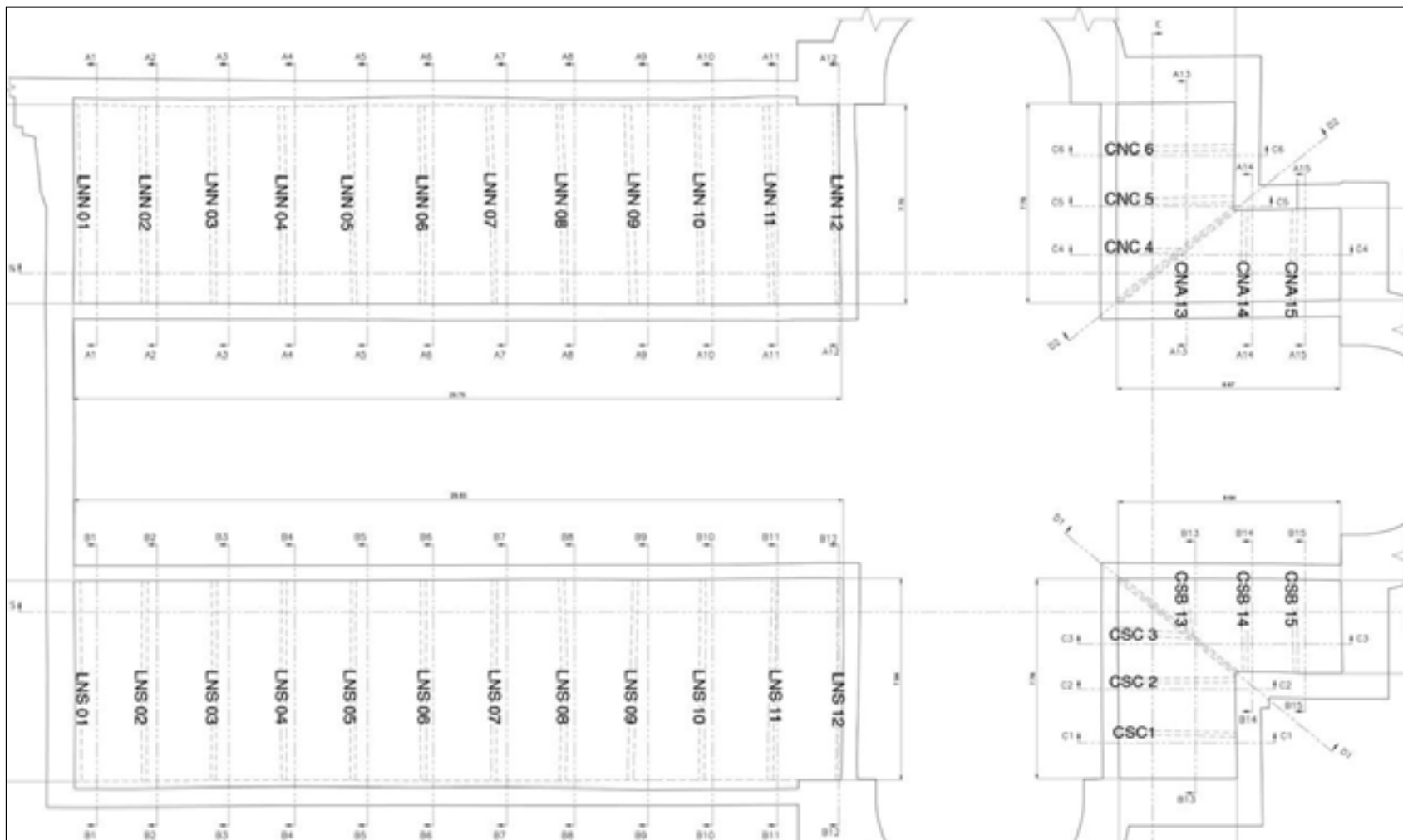


### EXAMPLES OF BIOLOGICAL DAMAGES ON SOME TRUSSES OF THE NAVE





## AISLES AND CORNERS



The following is an example, referred to truss LNN05, of how the main features are described:

Truss	Tie beam		Rafter		Strut S		Central strut S		Central strut N	
LNN 5	N	S	N	S	Up	Down	Up	Down	Up	Down
	24 x 23	23 x 25	23 x 24	23 x 19	18 x 20	/	15 x 21	/	21 x 13	/

On site grading

Tie beam	Rafter	Strut S	Central strut S	Central Strut N
II	I	II	II	II

Rafter made of oak.

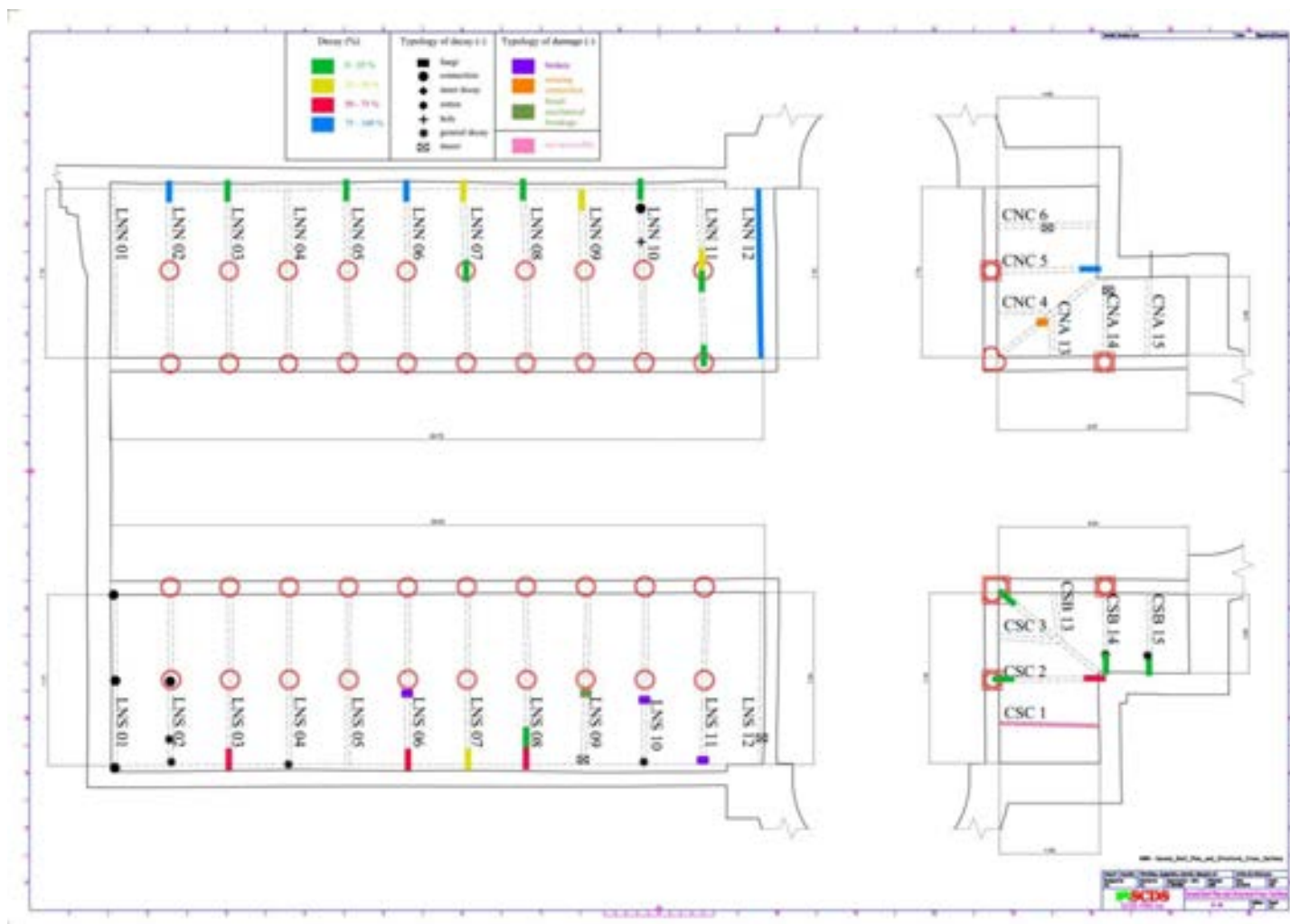
Tie beam, sleepers, central struts and strut S made of Lebanon cedar.

The rafter is made of two pieces.

Two sleepers present, one between rafter and strut S (23 x 13) and the other between central struts and rafter (23 x 15).

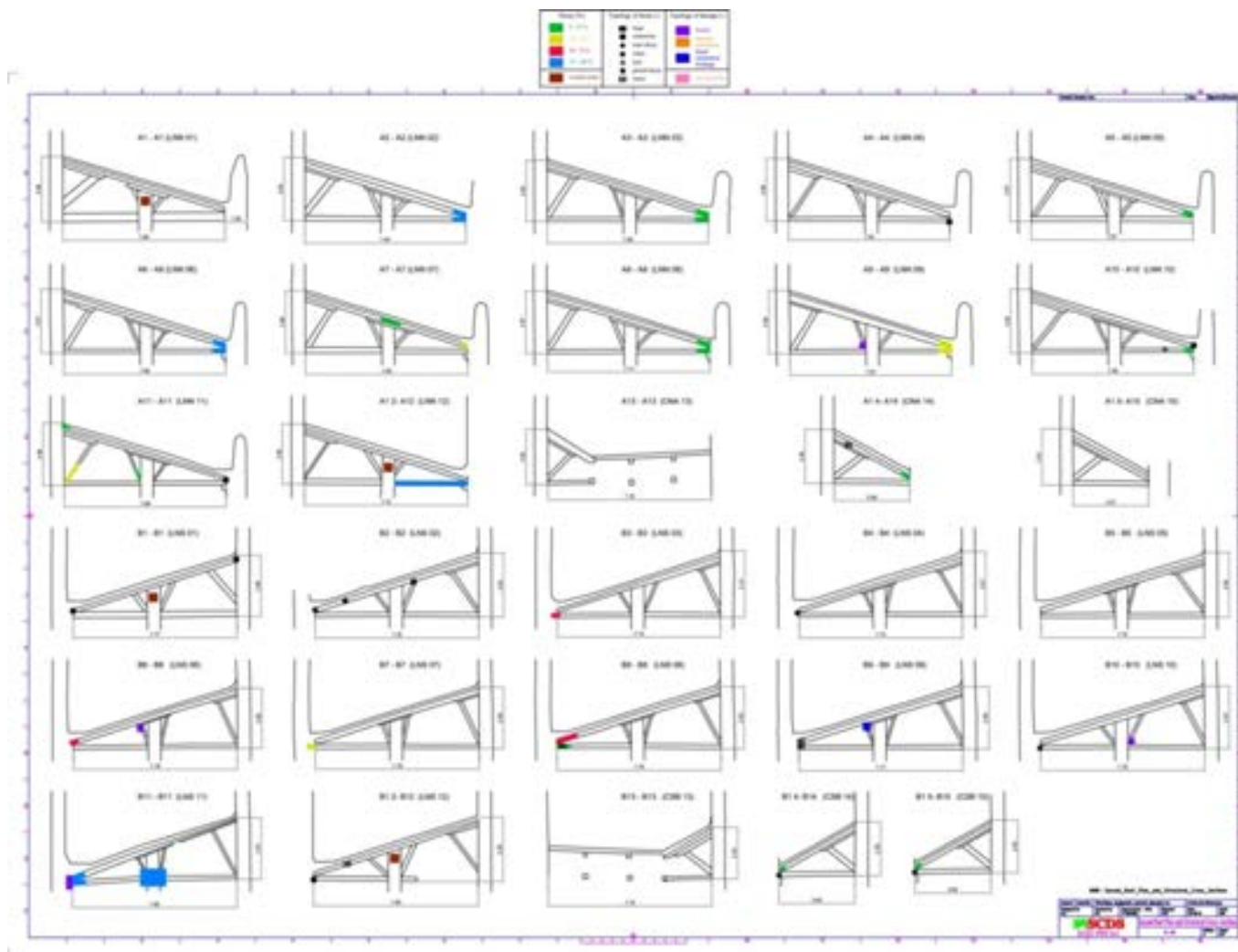
Resistographic drillings reveal the presence of a decay on the north support of the rafter involving 0 – 25% of the section.

### BIOLOGICAL DAMAGE ON AISLES AND CORNERS





### EXAMPLES OF BIOLOGICAL DAMAGE ON SOME TRUSSES OF THE AISLES



## 1.1.5 Dendrochronological dating

### 1.1.5.1 Introduction

Dendrochronology is a scientific dating method based on the analysis of tree-ring growth patterns. Dendrochronology, at the present time, is considered the most important dating technique for wooden artefacts. The tree-ring pattern from a timber of unknown date can be compared to the tree-ring pattern of a well dated reference chronology to match the most similar portion known. When a satisfying matching has been found, the date of each tree-ring on the test sample can be inferred from the reference graph.

The method can be considered not invasive. If the tree-ring series are clearly visible, sampling can be done through mobile instruments, such as video camera or high definition pictures. If tree-ring series are invisible, it is possible to use x-ray images. When all these sampling methods are unreliable, an incremental borer could be used, causing just a small hole of less than 5 mm of diameter.

This method advantage is its independency from every other dating techniques and it can be used to detect fake or misattributed works of art.

The aims of the dendrochronological analysis on the Nativity Basilica roof are:

- to date the wooden elements of the structure;
- to identify possible re-used or substituted wooden elements and, eventually, the different phases of the construction.

### 1.1.5.2 Material and Methods

The tree-ring series were collected by different methods: manual marks on paper tape, photographic records and wood core sampled with an increment borer. As a whole, 151 wooden structural elements were sampled: 103 wood cores, 81 digital images, 30 manual records, besides 41 small wood fragments.

Together with roof structures, 12 samples from the structural wooden elements of the architrave above the colonnades were collected. All the material consists of 255 samples.



Figure 27: a digital image of tree-rings in the truss 3.

As a first step, wood species of each sample (cores and fragments) was identified by analysis of microscopic features (UNI 11118/2004). Wood cores were then fixed on holders and annual rings were picked out on cross section surface using a scalpel or razor blades; often, chalk powder and water turn out helpful for growth rings spotlight. Annual rings width of each sample were measured with LINTAB (LINear TABle, Rinn Tech, Germany) a device that allows a resolution of 1/100 of millimeter, and then recorded with TSAP.

Win software (Rinn Tech, Germany) as elementary chronology. Tree-ring widths were always measured perpendicularly to its boundary. Each elementary chronology has always been matched with each other in order to ensure the accuracy of measurements and to detect the presence of xylological anomalies as false rings, double rings or missing rings. Such verification, as well as every cross-matching, teleconnection and heteroconnection, was done by statistical and visual comparison. Visual comparison consists of curves overlapping (elementary, individual and mean chronology) for maximum and minimum peaks coincidence and general growth trend evaluation. In case of two or more samples for a single structural element, a representative sample chronology is obtained by averaging elementary chronologies. Finally, a mean chronology of structural elements groups is achieved by averaging chronologies (sample chronologies and elementary chronologies) that had shown good values of cross-matching.

### **1.1.5.3 The interpretation of the statistical tests**

Generally, statistical tests represent a great help for chronology cross-matching; however, in case of uncritical applications, mistakes could arise. In particular, they could lead analysis on these kind of wrong conclusions (Sander e Levanic, 1997):

- erroneous results reached by fortuitous high statistical values (mistake type I);
- right matching missed because of occasional low statistical tests (mistake type II);

In order to repair to these kind of troubles, each chronology was analyzed through statistical and visual matching using more than one reference chronology. Statistical tests considered were:

- TBP: a Student's t test suited for time series analysis by Baillie e Pilcher (1973). As general rule, a cross matching could be considered reliable when TBP, confirmed also by statistical parameters as Glk and its significance, reaches values greater than 4. Just to have an idea, for a more than 100 years time series reaching TBP value of 3,5, the probability of an accidental (wrong) dating is one above thousand (Baillie e Pilcher, 1973).
- Glk (Gleichläufigkeit): this value, varying from 0 to 100, represents the slope equivalence of a given sample with its reference chronology within the overlapping parts of these two records (Kaennel and Schweingruber, 1995).
- Significance of the Glk: it returns the statistical significance level of the Glk. It's synthetically expressed by \*, \*\* and \*\*\* when Glk values are respectively greater than 95,0%, 99,0% and 99,9%.

### **1.1.5.4 Results**

#### **1.1.5.4.1 The wood species identification**

The microscopical analysis on sampled structural elements had shown the following results: 31 elements made of Larch (*Larix decidua* Mill.), 38 of Oak (*Quercus* sp.), 79 of Cedar (*Cedrus* sp.), 2 of Cypress (*Cupressus sempervirens* L.) and 2 of Pine (*Pinus* sp.). Oak samples belong to the sub-genus *Quercus* (Schweingruber, 1990) that groups together the deciduous species (*Quercus robur* L., *Q. petraea* Lebl., *Q. pubescens* Willid, etc.).



Cedar samples should be considered as genus since the anatomical features do not allow the distinction of the species. The Pine samples, because of a common anatomical structure, could be made both by Scots pine (*P. sylvestris* L.) and Black pine (*Pinus nigra* Arn.) although, regarding geographical origins, the second hypothesis appears more plausible. Sampled elements composition and map are showed in the table enclosed.

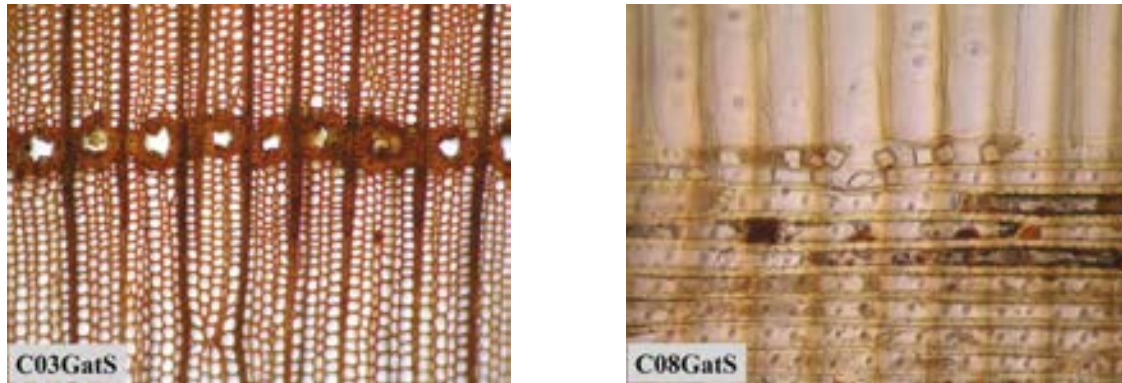


Figure 28: *Cedrus* sp. Cross section with a characteristic tangential row of traumatic resin ducts (C03GatS) and radial section (C08GatS) with a ray showing parenchyma, marginal tracheids and prismatic crystals

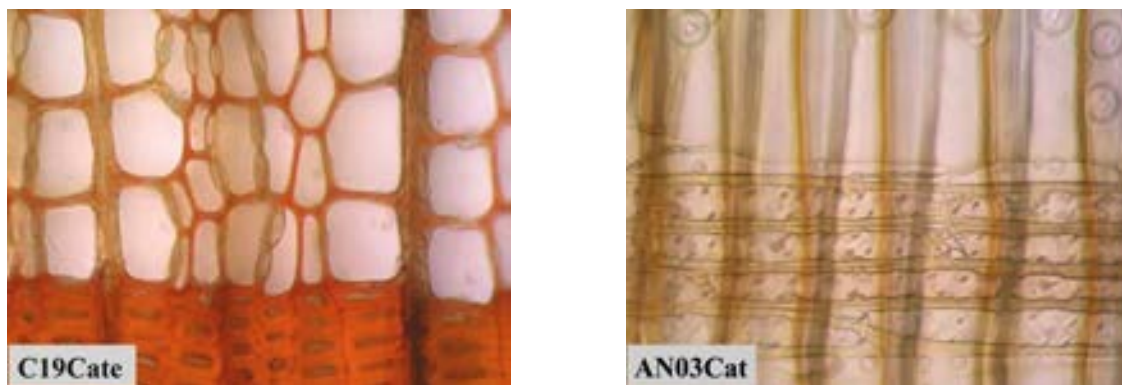


Figure 29: *Larix decidua* Mill. Cross section showing typical couples of bordered pits (C19Cate) and radial section with ray and characteristic pit sections in marginal tracheids (AN03Cat).

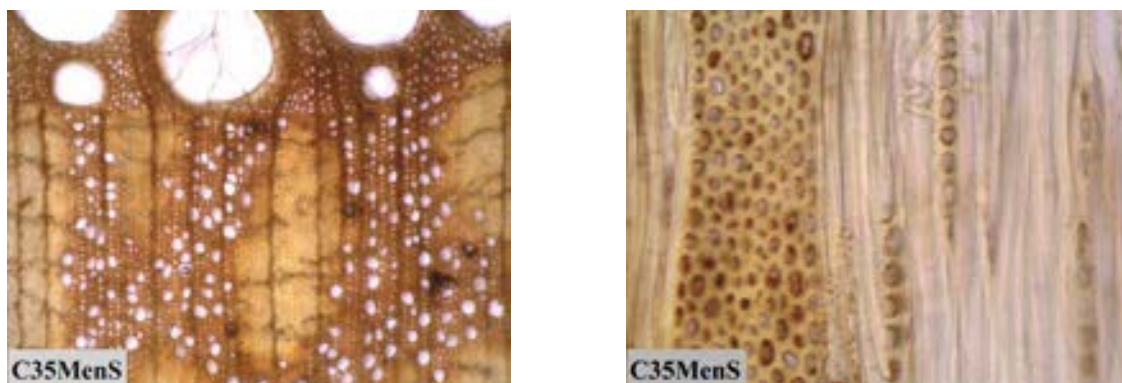


Figure 30: *Quercus* sp. Wood pores in cross section the smaller of which in latewood show polygonal shape typical of deciduous species, sub-genus *Quercus* (Schweingruber, 1990); tangential section with uniseriate and wide multi-seriate parenchyma rays.





Figure 33: the sapwood limit on the sample AN07SaeS.

Thanks to that, it was possible to calculate the most probably trees felling year adding to mean chronology (AN07SaeS lies at the end of mean chronology) the number of years corresponding to the sapwood. Sapwood in fact, after a certain age, is constituted by a quite fixed number of tree-rings that, in larch, could be around 30 or more. In case of very old plants, showing narrow or very narrow tree-rings, often a sapwood about 50 tree-rings could be found (pers. comm. Christa Beckmeroff). Since sampled materials showed great age (two samples exceed 400 years) and very narrow growth rings, an amount of 50 years can be added to larch mean chronology.

So a felling date around 1460 could be considered to which, the time of seasoning, transportation end processing should be added to reach the roof realization date.

Author	Region	T <sub>BP</sub>	Gik	Overlap
Bebber	Eastern Alps (Italy)	<b>18.2</b>	69.80***	598
Beckmeroff	Val di sole (TN, Italy)	<b>18.7</b>	73.80***	444
Serre-Bachet	Les Merveilles (France)	<b>10.4</b>	65.50***	425

Table 1: Statistical tests of larch mean chronology (NBL01) and reference chronologies match

## Oak

Because of the hardness of the wood, that often made difficult the use of increment borer causing crumbling in wood cores, the biggest part of the sampling was done by photographic records. Nevertheless small samples of wood were collected for anatomical analysis, for dendrochronological purposes and with a view to radiocarbon dating eventuality.

21 elements samples, that had shown good correlation values, had permitted the construction of a well replicated mean chronology that measures 315 years (NBQ01) and well-represents the oak roof structural elements of the Nativity Church. Other two samples had shown good cross-dating values among them, but they did not match the NBQ01 chronology. The remaining 15 samples had given no reliable results of correlation both each to other chronology and with any other reference chronology.

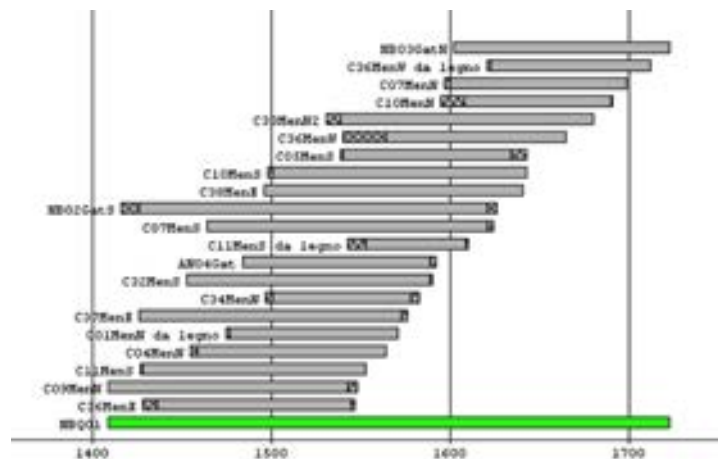


Figure 34: bar graph of the oak samples dating (grey) with the oak mean chronology (green); C36MenW, C11MenS and C01MenN chronologies are obtained from wood samples analysis the others from photographic records.

Since appeared hard to make any guess about the provenance of oak wood, that could come from very different regions under the rule of very different administrators (such as Arabian, British, French, Mameluk and Venetian), it seemed useful to involve the international forum of dendrochronologists. In this way the oak mean chronology of the Nativity Church was matched with a lot of reference chronologies from all over the world and by some of the most important laboratories, obtaining considerable results. The most accurate dating was suggested by the working group of the Cornell University, New York, USA. Brita Lorentzen in particular had found great correlations with Turkish provenance and she dated the Nativity Church oak mean chronology at 1723, last year. This suggested result is also confirmed by great concordances with the most part of Anatolia reference chronologies and also by a very interesting good correlation that arose with the oak mean chronology of the Santa Sophia Cathedral roof in Istanbul (Table 2). Similarities appeared so strong that Tomas Wazny, associate researcher at Cornell University, had considered that the timbers of both roofs could be made with the wood of trees grown in the same forest.

Also in this case, to detected date of 1723 an amount of years concerning the rings of sapwood token away during timber squaring, should be added. But poor information are available about heartwood sapwood ratio for eastern Mediterranean oaks whilst no sapwood were detected on sampled material.

Probably, at least 40 years should be added to our oak mean chronology but, cautiously the date of 1723 as a terminus ante quem non is here proposed.



```
*****
*** TSAP CROSS-DATING *** DATE: 2011.02.07 TIME: 16.40. ***
-> Find match of sample and references:
-> MinLeftOverlap=30 / MinRightOverlap=30
-> Chrono signature conditions: Density=4 / Internal G1k=75
-> Results listed for each sample-reference pair.
-> List 5 best matches.
-> Match acceptance: logical OR - connection of threshold values,
    one of the following threshold values has to be exceeded.
    Threshold conditions:
    G1k>60 SGIk>70 SSG1k>70 TV>3.0 CrC>0.6 CDI>10
*****

Sample (=Chrono): Bethlehem Bethlehem, Church of the Nativity (Mauro Bernabei) QUSP 0 315 1 315
Reference (=Chrono): TrNorthM North Turkey Middle 1&2 Clean Masters Quercus sp. 0 520 1356 1875

Sample Ref. PosL PosR OVL G1k G1L _SG S G SSG SSI RSI %CC TV TVBP TVH CDI DateL DateR
Bethlehem TrNorthM 54 368 315 57 ** 62 28 37 85 308 34 6.4 5.2 4.7 23 1409 1723
Bethlehem TrNorthM 176 490 315 56 * 60 25 30 77 303 -2 0.3 3.3 3.1 14 1531 1845
Bethlehem TrNorthM -49 265 266 61 *** 57 26 19 67 257 9 1.4 2.9 3.4 12 1307 1621
Bethlehem TrNorthM 61 375 315 57 ** 52 20 23 62 307 12 2.2 3.0 3.1 12 1416 1730
Bethlehem TrNorthM 56 370 315 46 47 19 19 58 308 11 2.0 4.5 2.6 12 1411 1725

Sample (=Chrono): Bethlehem Bethlehem, Church of the Nativity (Mauro Bernabei) QUSP 0 315 1 315
Reference (=Single): TrSOFTUR Hg. Sophia, Turke Quercus sp. 0 260 1356 1615

Sample Ref. PosL PosR OVL G1k G1L _SG S G SSG SSI RSI %CC TV TVBP TVH CDI DateL DateR
Bethlehem TrSOFTUR 54 368 207 45 *** 0 32 0 65 204 53 8.9 7.5 7.1 31 1409 1723
Bethlehem TrSOFTUR -49 265 260 57 * 0 24 0 61 255 6 0.9 3.4 3.6 14 1307 1621
Bethlehem TrSOFTUR -16 298 260 57 * 0 29 0 73 255 14 2.3 3.3 2.6 13 1340 1654
Bethlehem TrSOFTUR 43 357 218 47 0 17 0 37 215 7 1.1 3.2 2.9 9 1398 1712
Bethlehem TrSOFTUR 56 370 205 45 0 16 0 32 202 28 4.2 4.8 2.3 9 1411 1725

*** DATE: 2011.02.07 TIME: 16.40. End of cross-date job. ***
*****
```

Table 2: Cross-dating statistical report of the TSAP programme, related to the comparison of the Nativity oak mean chronology with Turkey master chronologies.

Tomasz Wazny also suggested a dating for the two samples excluded from the mean series. Dates are AD 1578 for sample NB03GatS and AD 1590 (by visual matching) for sample NB04GatS and good statistic results were equally found (TBP > 4 with many oak chronologies from Turkey). As the others structural elements, also these two samples had shown no sapwood so, it was hard to reach precise conclusions. In fact, it's not possible to say if these two samples were made in a previous historic period (1590 against 1723) or simply are made removing more wood from the outer parts of the trunk during squaring.

## Cedar

Not all the 79 cedar sampled elements had given good chronologies: an amount of them resulted worthless because of their shortness or due to the particular growing trend that was affected, as the case of cypress, by a specific very high sensitivity.

Anyway 41 samples gave useful chronologies with good correlations values that had divided samples in three different groups. Groups did not show correlation among themselves and this could be the result of different geographic provenances and/or different ages.

- Cedar group 1: constituted by a 144 years chronology made with 7 elementary chronologies obtained from the samples of the trabeation.
- Cedar group 2: this chronology, that is the longest with its 247 years, is constituted by the highest number of elementary chronology, 20, obtained from various structural elements of the roof.
- Cedar group 3: made of 14 elementary series, from different structural elements of the roof, this chronology has an extent of 152 years.



Currently, no dendrochronological results arose from cedar samples analysis; very important will be the findings of radiocarbon dating.

### **Pine**

Only 2 structural elements turned out to be made with this wood: respective elementary chronologies (92 and 219 years) had shown reciprocal good concordance of the growth pattern. Pine series were compared with the NOAA website ([http://hurricane.ncdc.noaa.gov/pls/paleo/fm\\_createpages.treering](http://hurricane.ncdc.noaa.gov/pls/paleo/fm_createpages.treering)) reference chronologies valid for the Black and Scots Pine of the near East but no correlation was found.

Further attempts, with various reference chronologies, were made also by the group at the Cornell University, but no significant results came out. The dating of this material remain still unknown.

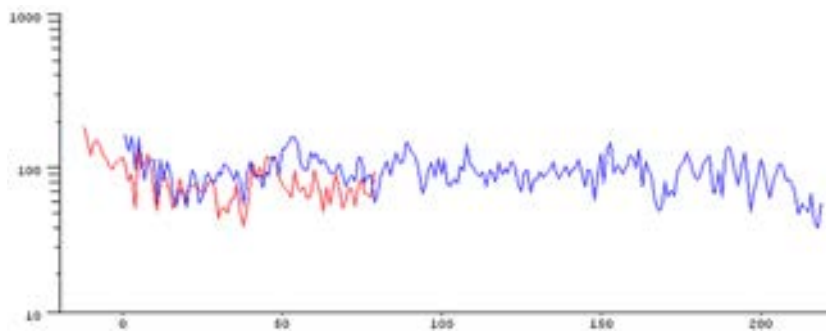


Figure 35: Pine samples elementary chronologies matching. Logarithmic scale

### **Cypress**

As common for Cypress, the only one sample with an adequate number of growth rings had shown extreme sensitivity and growth rings anomalies that make it ineffective for dendrochronological dating. No date is therefore suggested for this sample.

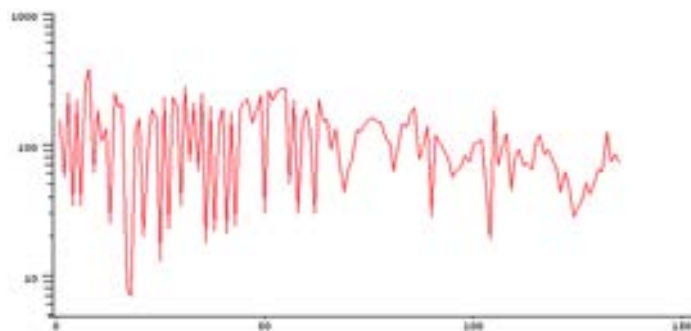


Figure 36: Cypress C17GatW sample chronology measuring 135 years. Logarithmic scale.

#### **1.1.5.4.3 Radiocarbon**

Dating technique used for Nativity Church wood is the one called “wiggle-matching” that, for each sample, requires a double sampling at a well-known tree-rings distance.

In practice, collecting two tiny samples from two different growth rings of a well-known distance in the sample we should impose the following conditions:

- the sample drawn from the tree-ring closer to the pith must be older than the sample drawn from the tree-ring closer to the bark (in trees the growth is achieved by centrifugal superimposition so, external tree-rings are most recent);
- the time lag that separates the samples is known and corresponds to the number of tree-rings counted between the samples.

By the imposition of these two conditions during the calibration of radiocarbon results, the achievement of a great resolution is usually possible.

Nativity samples submitted to radiocarbon dating are constituted by the following elements:

Sample Code	Species	Structural element
C34Cate	Oak	Apse - truss 34 - tie beam
TC01	Cedar (group 1)	Architrave 1 central tie beam
C02SaBS	Cedar (group 2)	Nave - truss 2 - lower strut
NB09Punt	Cedar (group 3)	Nave B - truss 9 - rafter

Table 3: Pivotal samples destined to radiocarbon dating

The material for radiocarbon dating was selected in the light of dendrochronological results: only in this way <sup>14</sup>C analysis could be date pivotal samples to which many other are linked. So, samples for radiocarbon dating could not be chosen before the ending of dendrochronological studies and, since <sup>14</sup>C analysis need a couple of months, the results will be updated soon as possible.

In conclusion, dendrochronological dating had provided the following results:

Larch: 1412

Oak1: 1723

Oak2: 1590

Cedar: 3 different groups.

The three groups of cedar chronologies (chrono 1, chrono 2, chrono 3, fig. 6) showing good internal correlation, but no relationship with each other and this could be the results of different geographic provenances and/or different age.

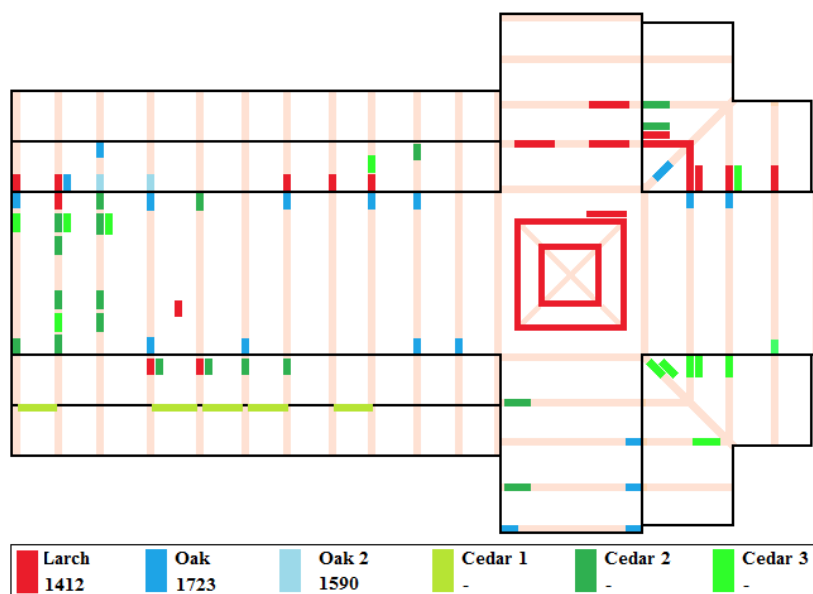


Figure 37: position and wood species of dendrochronological dated elements.

The samples analysis had shown that only the architrave could be considered homogeneous both by species (cedar) and age: in fact, although an exact date is not still picked out, architrave samples clearly had shown the origin from a precise and common age. On the contrary, various ages and various woods, such as larch, oak, cedar, pine, etc., arose by the analysis of the sampled elements scattered around the current roof structure. In the light of such results, it could be assumed that Nativity Church roof was at times disassembled and reconstructed, using also prior elements still considered useful and appropriate.

## 1.1.6 Conclusions

The principal results obtained from the analysis of the timber structures of Nativity church can be summarised as follows.

### 1.1.6.1 Wood species

The most important wood species identified in the principal structures of the two levels roof are the oak (*Quercus* sp.), the Lebanon cedar (*Cedrus libani* L.) and European larch (*Larix decidua* Mill.). Are also present some sparse elements of cypress (*Cupressus sempervirens* L.) and pine (*Pinus sylvestris* L. or *Pinus nigra* Arn.). Among the listed species only the cedar and the cypress can be considered as native, while more probably larch and pine have an alpine origin and oak is probably European or Turkish.

Their distribution into the timber structures is the final output of the different phases of construction, dismantling, reconstruction and maintenance of the roof of the church during the centuries. Looking more thoroughly the principal elements of the wooden frames are made of oak or of larch and only smaller and secondary elements are made of cedar.

### **1.1.6.2 Wood quality**

Generally speaking the quality of the larch elements is quite good and the surface aspect as well. Sapwood was always removed and the selection of the elements, in terms of defect frequency, dimension and distribution, reflects the fine work performed by the Venetian carpenters at the end of the XV century.

We cannot confirm the same selective action on oak timber, where defects are more visible and the presence of decay already developed on the standing tree was not avoided (e.g. rot, bark inclusions, insect attacks); at the same time sapwood attacked by insects was frequently found (attacks no more active).

We must honestly say that hardwood timber elements are more defective than softwood ones, due to the natural shape and branching of broadleaves compared to conifers. Moreover on Mediterranean hardwoods is practically impossible to find a low defectiveness on oak elements longer than 4 – 5 meters.

Thus the presence of flaws and defects is quite high on the structural elements of the timber frames of the Nativity church. It must be also underlined that the available length forced the carpenters to vary the connections typologies in the rafter-tie beam structural joints or to reduce the surfaces of the rafter-king post joints.

A good witness of this situation can be considered the fact that almost all the tie beams of the principal nave were covered with softwood boards in order to hide their smaller sections, defectiveness and shape.

### **1.1.6.3 Wood characteristics**

The three principal wood species found in the structure are all characterised by a high natural durability, that is a natural attitude to resist to the biotic (in this case insect and fungi) destroying attacks. This means that the heartwood of oak, larch and cedar naturally offers a good capacity to stand against the attacks by insect and fungi.

Nevertheless the timber structure of the roof needed to be reconstructed or refurbished several times during the centuries; at least two times (probably more) during the last five centuries due to the presence of dangerous fungal attacks.

It can be useful a comparison with the timber structures of many monumental buildings of the city of Florence. One can find many examples of timber structures more ancient than the Venetian reconstruction of the roof of the Nativity church, most of them still have the original structure even if this one is made with a timber having a very low natural durability, silver fir (*Abies alba* Mill). The durability of a timber structure is made more of the technical design conservative solution and of a continuous control and maintenance, than of the natural durability of the constituting material. The latter can help, but the design helps more.

The high moisture content of wood causes the attacks of fungi, so through avoiding moisture traps and damp accumulation, by means of specific design devices, it will prevent from the dangerous rot attacks. It will be then an important task of the maintenance activity to control the efficacy of the design devices during time.

The moisture content of the timber elements, measured during the inspections was always very low, generally lower than 10%, with only one value of 15% along the lateral naves. Fungal attacks are possible only when the wood moisture content is between 20 and 35%. But the walls of the church testify the presence of high humidity by the traces of the rain straining. During the inspection we encountered a good weather, but during rains, water falls down into the church and for sure it reaches wood surfaces where, in most cases, it can dry quickly, but when water enters wood-wood joints or shrinkage cracks the drying becomes difficult and the moisture can be absorbed by wood, reaching the threshold limits for fungal attacks.

### **1.1.7 Legislative references**

- Legg.vo n. 42 22/01/2004 Heritage cultural and landscape code, according to article 10 of the law July 6, 2002, n 137 (Suppl.Ord. alla GU. 24.2.2004, n. 45)
- 156 AA.GG./STC 04/07/1996, Instructions for the application of "Technical standards relative to the general criteria for the design of constructions, and for loads and live loads" of which D.M. LL. PP. 16/01/1996
- D.P.R. n. 554, 21/12/1999, Regulations in carrying out laws dealing with public works February 11, 1994, n. 109, and successive modifications
- D.M. LL. PP: 16/01/1996 Technical standards relative to "The general criteria for the design of constructions, and for loads and live loads" (G.U. 05/02/1996, n. 29 Suppl. Ord. n. 19)

UNI 11119:2004

UNI 11138:2004

UNI 8662-1:1984 Treatment of wood - General terminology

UNI 11035-1:2003 Structural Wood - Visual classification of Italian timber according to mechanical resistance: terminology and measurements of its characteristics

UNI 11035-2:2003 Structural Wood - Rules for visual classification according to resistance and characteristic values for types of structural Italian timber

UNI ENV 1998-1-2 Eurocode 8 - Project/design indications for seismic resistance of structures - General rules for buildings

## **1.2 STRUCTURAL ANALYSIS**

On the basis of the diagnostic investigations carried out, the following analyses were also carried out with the aim of improving the knowledge of the building:

- interpretation of the structural behaviour of the bearing elements of the roof;
- analysis of the construction techniques adopted, with particular interest for the shapes of the joints, the presence and quality of nails and of mutual connection among the elements;
- understanding of the construction phases of the roof, with special reference for the historical sequence of the interventions;
- possibility of identifying the sources of supply of the different materials used in the construction.

This amount of information were crossed with the evidences drawn by the historical and archaeological investigations, leading to the formulation of work hypotheses about the construction history of the building, and to a conscious assessment of the importance and value of its constructive elements within a historical, technical and structural perspective.

In particular, a comprehensive structural analysis of the bearing elements of the roof was carried out, in order to survey the actual bearing capacity of each structural elements individuated in the information system, and of its safety level. Drawing the framework of the residual structural capacity of the existing timbers is a fundamental aspect of the overall investigation process, aiming at completing the scenario of the intervention demand required by the building.

Safeguard of historical buildings from the structural risk is a difficult task regarding first the prevention, then the whole process from building assessment through design and execution of interventions. The adoption, for historical masonry buildings, of the same type of predictive models and, especially, of checking procedures, developed for new constructions can mislead about the real safety level of the structures and can bring to the choice of useless or even harmful structural interventions. In a few words, interventions on historical buildings cannot be assessed through “standard” procedures. Such interventions cannot be so invasive to modify permanently the cultural value and the structural behaviour of the buildings.

Historical buildings deserve a special attention in dealing with the structural safety mainly due to two issues. First, historical buildings usually date back to many centuries ago and, therefore, were built according to ancient structural safety standards. Second, the structural approach of intervention must fully respect the particularity of the building under analysis, and any proposal of structural restoration must be consistent with the historical-artistic characteristics of the building and the general Principles of Conservation and Restoration. On the other hand, it must provide the highest structural protection permitted by the National and International Codes, and by the imposed conditions.



All timber elements of structural interest have been investigated and suitably represented. The damage on trusses, purlins and boards of the roof, as well as the damage/cracking in the masonry walls, has been depicted with respect to a multi-level scale. For instance, the damage on the principal and secondary wood elements has been mainly represented in four-level scale (0-25%, 25-50%, 50-75% and 75-100%) whereas the cracking on masonry walls has been differentiated between main cracks and diffused micro-cracks.

On the basis of such a representation it was possible to define the critical zones where a structural intervention might be proposed. The choice of the specific intervention is, of course, influenced by the safety level of the damaged structural element. The structural checks were carried out with reference to three different procedures. Such procedures, detailed in the following sections, are all respectful of the European (EuroCode 8) and the Italian (2008 Italian Code) and they are implemented in the framework of both the “Admissible Stress” and of the “Ultimate Limit State”. Such checks made it possible to define, with reasonable approximation, the zones/parts of the roof structure characterized by significant damage rates and for which structural interventions are strongly recommended.

The procedure has been fully applied to the wood elements of the roof, aiming at the design of the interventions proposed in the conservation plan.

It must be pointed out that the adopted solution for the roof entails an acceptable increase of the dead loads (0.1 kN/m<sup>2</sup>).

The structural analyses, performed and collected in the Consortium Intermediate Report, have shown that the sound wood elements undergo acceptable stress levels under the prescribed loads and therefore fulfil the safety requirements. On the other hand, it is known that some wood elements are damaged and need to be checked thoroughly in order to choose the minimal structural intervention.

The approach to the damaged wood elements has been drawn with the following steps. First of all, each damage has been included (as reduction of section) into the Finite Element beam model in order to determine a more correct distribution of the internal actions (axial force, shear and bending moment). It must be pointed out that each element has been modelled by keeping into account its actual wood species and structural grading. The analysis has been performed by considering the design loads (and not the current loads). Afterward, the stress level of each damaged element has been investigated with respect to three different acceptable thresholds:

1. The “acceptable stress level (ASL)” is determined in the framework of the “admissible stress (AS)” context as detailed in the UNI 11119 ; the mechanical characteristics of each wood species are obtained from the UNI 11119 for what concerns the oak and from the UNI11035-2 for Lebanon Cedar and Larch (see Table I).
2. The ASL is determined as “Ultimate Limit State (ULS)” as suggested by the Eurocode; due to the lack of Codes expressing the Characteristic Strength (CS) in terms of the wood species and of the Structural Grading (I, II or III as detailed in the UNI 11119, see Table II), the adopted Design Strength (DS) has been obtained by amplifying the CS by a factor of either 2.5 (for tension/compression states) or 3.5 (for bending states); such values have then been affected by some safety coefficients (all less than the unit) as suggested by the Eurocode.
3. The ASL is determined as in 2., but the safety coefficients are set equal to one, i.e. the CS coincides with the DS. Such an approach is useful to have information about the reserve of strength in the element.

All the results refer to the loading conditions adopted in the AS context. As a matter of fact, the amplifying coefficient applied to the design loads change passing from the AS to the ULS framework.

The detailed analysis of some meaningful trusses are in the Consortium Reports.



### **1.2.1 Structural checks**

The structural checks are all summarized in Table III. Here, only part of this Table (the one referred to the nave) is represented for the sake of brevity and as a mere example of the criterion and procedure followed. The complete Table III is in the Consortium Final Report and in the T.O.R. The first and the second columns collate information about the position of the involved truss and the elements, inside the truss, which are damaged. The remaining columns, but the last one collecting information about the proposed structural intervention, indicate the structural checks performed on the basis of the above three procedures; the indicated percentage represent the ratio between the current stress and the design stress DS.

Table I – Admissible stress for different wood species (Procedure 1.)

Species	Structural Grading	Compression parallel to the fibers	Compression perpendicular to the fibers	Bending	Tension parallel to the fibers	Shear (parallel to the fibers)	Young Modulus E	Shear Modulus G
	[dimensionless]	[N/mm <sup>2</sup> ]	[N/mm <sup>2</sup> ]	[N/mm <sup>2</sup> ]	[N/mm <sup>2</sup> ]	[N/mm <sup>2</sup> ]	[N/mm <sup>2</sup> ]	[N/mm <sup>2</sup> ]
OAK	I	12	3.0	13	12	1.2	13500	845
	II	10	2.5	11	10	1.0	12500	780
	III	7.5	2.2	8.5	7	0.9	11500	720
LEBANON CEDAR	I	9.6	1.6	9.4	8	0.94	12300	770
	II	8.8	1.6	7.4	6.4	0.77	11400	710
	III	8	1.6	6.3	5.2	0.69	10500	660
LARCH	I	12	2.5	13	12	1.1	15500	810
	II	10	2.2	11	9.5	1.0	14500	750
	III	7.5	2.0	8.5	7	0.9	13500	720

Table II – Characteristic stress for different wood species (Procedure 2. and 3.)

Species	Structural Grading	Compression parallel to the fibers	Compression perpendicular to the fibers	Bending	Tension parallel to the fibers	Shear (parallel to the fibers)	Young Modulus E	Shear Modulus G
	[dimensionless]	[N/mm <sup>2</sup> ]	[N/mm <sup>2</sup> ]	[N/mm <sup>2</sup> ]	[N/mm <sup>2</sup> ]	[N/mm <sup>2</sup> ]	[N/mm <sup>2</sup> ]	[N/mm <sup>2</sup> ]
OAK	I	30	7.5	45.5	30	3.0	13500	845
	II	25	6.25	38.5	25	2.5	12500	780
	III	18.75	5.5	29.75	17.5	2.25	11500	720
LEBANON CEDAR	I	24	4.0	33	20	3.3	12300	770
	II	22	4.0	26	16	2.7	11400	710
	III	20	4.0	22	13	2.4	10500	660
LARCH	I	30	6.25	45.5	30	2.75	15500	810
	II	25	5.5	38.5	25	2.5	14500	750
	III	18.75	5.0	29.75	17.5	2.25	13500	720

Table III: Characteristic stress for different wood species (Procedure 2. and 3.) and intervention proposals

Truss	Wood elements involved by the damage	Percentage of decay	A.S. Test (1) Sound elements	A.S. Test(1) Damaged elements	D.S. Test (2) Sound elements	D.S. Test (2) Damaged elements	D.S. Test (3) Sound elements	D.S. Test (3) Damaged elements	intervention
	[-]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[-]
CN01	rafters , tie beam	75-100	-	-	-	-	-	-	total replacement of the truss
CN02	-	-	-	-	-	-	-	-	nothing
CN03	-	-	-	-	-	-	-	-	nothing
CN04	rafter	50	42,01	>1000	21,81	>1000	12,4	>1000	prosthesis -rafter
	rafter	75		>1000		>1000		>1000	
	rafter	25		139,59		97,45		58,48	
CN05	-	-	-	-	-	-	-	-	Replacement of lower part of the tie beam in correspondence of the support
CN06	rafter	25	27,38	110,55	12,6	60,33	8,42	38,9	prosthesis rafter
	rafter	50		193,72		108,06		69,38	
CN07	rafter	25	27,38	110,55	12,6	60,33	8,42	38,9	replacement rafter
	rafter	50		193,72		108,06		69,38	
CN08	rafter	50	42,01	>1000	21,81	>1000	12,4	>1000	prosthesis -rafter
	rafter	75		>1000		>1000		>1000	
CN09	rafter	50	38,23	200,62	21,35	130,48	12,82	70,07	prosthesis -rafter

Truss	Wood elements involved by the damage	Percentage of decay	A.S. Test (1) Sound elements	A.S. Test(1) Damaged elements	D.S. Test (2) Sound elements	D.S. Test (2) Damaged elements	D.S. Test (3) Sound elements	D.S. Test (3) Damaged elements	intervention
	[-]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[-]
	rafter	75		281,81		185,05		98,69	
	rafter	25	27,38	84,96	14,82	49,02	8,89	29,41	nothing
	tie beam	25	8,3	<26,37	5,3	<26,37	4	<26,37	nothing
CN10	rafter	25	27,38	110,55	12,6	60,33	8,42	38,9	prosthesis rafter
	rafter	50		193,72		108,06		69,38	
CN11	rafter	50	42,01	>1000	21,81	>1000	12,4	>1000	prosthesis rafter
	rafter	75		>1000		>1000		>1000	
CN12	catena	broken	-	-	-	-	-	-	replacement tie beam

## 1.2.2 Seismic protection

Nowadays it is still rather difficult to adequate cultural heritage buildings to the modern anti-seismic safety standards and to preserve, at the same time, all their historical, architectural and artistic characteristics. On the other hand, the concept of “seismic improvement” has been spreading more and more in the structural engineering community: rather than increasing the seismic performances to the level required by new buildings, it is advisable and more reasonable to simply improve them as much as possible but without making any significant change to the main characteristics of the building . And this is the main criterion that has been followed in the interventions suggested in the enclosed Technical Forms. Such interventions mainly aim at improving the connections between roof and masonry walls in order to:

1. avoid any out-of-plane mechanism of any masonry wall, with special reference to the tympanum of the Church;
2. improve the in-plane stiffness of the roof (in both central nave and aisles) ;
3. guarantee a sufficient number of connections between the roof structure and the masonry walls which might bear the horizontal seismic action.

The structural analyses presented in the second report, integrated by the nonlinear analysis concerning the walls of the central nave, have demonstrated that the out-of-plane mechanism occurring with the highest probability is the one in the tympanum wall. Such a wall, in fact, does not bear appreciable vertical loads and faces on the main entrance of the Church.

Furthermore, Figure 38 shows the seismic bearing walls which absorb the seismic actions (or horizontal shear loads) in the y or N-S direction (in yellow) and in the x or W-E direction (in green) transferred by the roof of the aisles (Figure 38 - left) and by the roof of the nave (Figure 38 - right) respectively. In both cases the roof is represented by dotted surfaces.

It must be pointed out that such walls must be continuous from the top to the bottom in order to be considered structurally efficient.

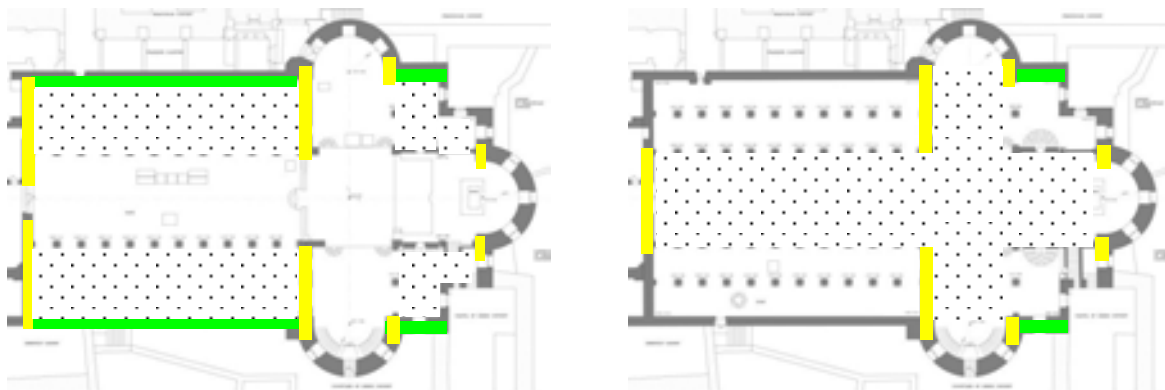


Figure 38 – Seismic bearing walls in the principal directions: below (left) and above (right) the aisle's roof.

As a matter of fact, such a consideration is valid in general only if the connections between the roofs and the walls are reliable and capable to transfer horizontal loads. Moreover, in Figure 38 - right it is sufficiently clear that the total area of the horizontal sections of the seismic bearing walls in the W-E direction (green walls) is a small percentage (around 3%)

of the area of the dotted surface representing the roof of the aisles. Furthermore, the total area of the seismic bearing walls at the ground level in the x or W-E direction is nearly 6% of the total area occupied by the Church whereas the total area of the seismic bearing walls in the y or N-S direction is nearly 5% of the same area.

On the basis of the above considerations and of the results obtained in the second report, the following recommendations can be given in relation to the structural interventions proposed:

- a. Reliable connections must be guaranteed in various positions (details are given in the enclosed Technical Forms) both to limit the out-of-plane movement and to guarantee a suitable transferring of the seismic actions to the bearing walls.
- b. The in-plane stiffness of the roof must be increased in order to better transfer the seismic actions to the foundations.

### 1.2.3 Notes

On the basis of the above considerations, the following interventions are designed to increase the structural strength of the overall Church under vertical and horizontal actions.

Prosthesis are designed to replace all those parts of the trusses which, after a careful survey, have been considered too damaged for bearing the prescribed loads. It is worth noting that for some specific interventions, such as prosthesis, only a qualitative description is given, without any reference to quantitative estimations which would require more detailed and accurate analyses. For this reason the stress state arising in consequence of a supposed prosthesis, for instance, has not been evaluated and therefore some quotes, like the diameters of holes and steel bars or the length of the overlapping steel bars, have not been reported in the corresponding Technical Forms. However, this does not affect significantly the overall quantitative and cost estimation of the proposed interventions.

The roof's in-plane stiffness of both the central nave and the aisles has been increased by adding diagonal steel strips nailed to the underneath layer of boards. This intervention, with a negligible increase of the weight, is extremely useful to improve the overall seismic resistance of the Church. It must be pointed out that the various layers of the roof must be strongly connected to one another by nails or screws as follows: secondary wood girders to the boards, steel strips to the boards, boards to the purlins and purlins to the rafters of the trusses. The type of nails/screws are not presented in detail as they will be designed on the basis of the local stakeholders indications.

Connections between the header (intersection point between rafter and tie-beam) and the masonry wall underneath are added where no damage has occurred and no prosthesis has been suggested. Such connections are fundamental to transfer the horizontal seismic loads to the bearing masonry walls. They have not been designed in detail (quotes are missing in the related Technical Forms) they will be better determined once all the truss' headers will be opened by removing the surrounding masonry.



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## 2 ANNEX 2: CONSERVATION PLAN

This Section 2 wants to be the answer to the following request of specification addressed by ICOMOS to the Consortium:

**“Develop a Conservation Plan for the roof that synthesizes the conclusions of the detailed investigative survey into a clear statement of the significance of the various elements of the roof within a comprehensive conservation philosophy for the Church of the Holy Nativity.”**

In the first part, the general conservation philosophy adopted for the restoration of the roof Church of the Nativity will be presented with reference to the main principles and Charts of Conservation and Restoration and the most significant International Technical Codes to be followed when dealing with monuments and historical sites. These general principles reflect the interdisciplinary nature of the restoration process where different but complementary professionals are required to obtain the desired results. The Consortium team, composed of Historians and Archaeologists (University of Siena), Restorers (University of Rome “La Sapienza”), Architects and Engineers (University of Ferrara), Specialists in timber and timber structures (CNR Ivalsa – Florence), Surveyors (Canada) and experts in nondestructive tests on masonry has worked since the beginning in conditions of mutual interaction which allowed a continuous confrontation on the main problems and the continuous research of sharable solutions.

In the second part, the results of the detailed investigative survey carried out on the roof of the Church will be synthesized by means of some examples into a model of interpretation which will support the formulation of a clear assessment of the significance of the various elements of the roof; the same approach will drive the development of the conservation plan of the roof to the desired level of interaction with the other planned interventions on the building, leading to a comprehensive and integrated restoration approach, thanks to which the required future performances of the building will be reached.

### 2.1 THE CONSERVATION PLAN OF THE CHURCH

#### 2.1.1 General methodology

The conservation of ancient constructions poses important challenges because of the complexity of their geometry, the variability of the mechanical and physical properties of the constitutive materials, the construction techniques used, the scarce knowledge of the various actions which affected the constructions throughout their life and the lack, sometimes, of applicable codes. In addition, restrictions in the inspection and the removal of specimens in buildings of historical value, as well as the high costs involved in inspection and diagnosis, often result in limited information about the internal constructive system or the properties of the existing materials.

These aspects call for qualified analysts that combine advanced knowledge in different but all interacting areas, as well as a careful, humble and time-consuming approach. In particular, it is noted that significant advances occurred in the last decade in the field of the numerical modelling and simulation of the structural behaviour of historical buildings. That helped to describe and understand not only the behaviour of the building before and after the interventions of consolidation but also to give a scientific justification, together with the historic documents, to some hypotheses concerning the origin of some damages. This is an important achievement

because it allows to plan appropriate interventions, suitably designed not only to remedy the damaged caused but also to eliminate the cause of the damage.

Structures of architectural heritage, by their very nature and history (material and assembly), present a number of challenges in diagnosis and restoration that limit the application of modern technical codes and modern building standards. Recommendations are desirable and necessary to both ensure rational methods of analysis and repair methods appropriate to the cultural context.

Such Recommendations are intended to be useful to all those involved in conservation and restoration problems, but cannot in anyway replace specific knowledge acquired from scientific and technical texts.

The Recommendations presented in the document are in two sets: Principles, where the basic concepts of conservation and restoration are presented; Guidelines, where the rules and methodology that a designer should follow are discussed. Such Guidelines were presented in detail within the specific report of each Consortium Unit directly involved in restoration of the monument and only the main body with some significant examples will be presented in this Section.

Principles for the preservation of the historic timber structures are reported here and are reconsidered later in the section dedicated to timber structures to stress the importance of such structures in the project and the need for a controlled and guided intervention.

Principles and Guidelines are provided in agreement and adherence with the main Charters and Documents of Restoration, i.e.

- International Conference in Athens. Athens Charter (1931)
- Italian Restoration Charter (1932)
- Convention for the protection of Cultural Heritage in case of armed conflict (L'Aja, 1954)
- Venice Charter (1964)
- European Convention for the protection of the Archaeological (Londra, 1969)
- Italian Restoration Charter (1972)
- Convention concerning the protection of the world cultural and natural heritage (World Heritage Convention, Paris 1972)
- European Charter of Architectural Heritage (Amsterdam, 1975)
- Amsterdam Declaration (1975)
- Convention for the protection of the European Architectural Heritage (Granada, 1985)
- Charter for the conservation of historic towns and urban areas (Washington Charter 1987)
- ICOMOS Charter for the protection and management of the Archaeological Heritage (1990)
- Principles for the Recording of Monuments, Groups of Buildings and Sites (1996)
- International Cultural Tourism Charter (1999)
- Principles for the Preservation of Historic Timber Structures (1999)
- Cracovia Charter (2000)
- Recommendations for the Analysis and Restoration of Historical Structures. ICOMOS/ISCARSAH (2001, adopted in 2003)
- ICOMOS Charter - Principles for the analysis, conservation and structural restoration of architectural heritage (2003)
- ICOMOS - Principles for the analysis, conservation and structural restoration of architectural heritage (2003)
- Vienna Memorandum on the "World heritage and contemporary architecture - managing the historic urban landscape" (2005)
- ICOMOS Charter for the interpretation and presentation of cultural heritage sites (2008).

## **2.1.2 Principles**

### **2.1.2.1 General criteria**

- 1.1 Conservation, reinforcement and restoration of architectural heritage requires a multi-disciplinary approach.
- 1.2 Value and authenticity of architectural heritage cannot be based on fixed criteria because the respect due to all cultures also requires that its physical heritage be considered within the cultural context to which it belongs.
- 1.3 The value of architectural heritage is not only in its appearance, but also in the integrity of all its components as a unique product of the specific building technology of its time.
- 1.4 When any change of use or function is proposed, all the conservation requirements and safety conditions have to be carefully taken into account.
- 1.5 Restoration of the structure in Architectural Heritage is not an end in itself but a means to an end, which is the building as a whole.
- 1.6 The peculiarity of heritage structures, with their complex history, requires the organisation of studies and proposals in precise steps that are similar to those used in medicine. Anamnesis, diagnosis, therapy and controls, individuation of the causes of damage and decay, choice of the remedial measures and control of the efficiency of the interventions are all necessary steps to achieve cost effectiveness and minimal impact on architectural heritage.
- 1.7 No action should be undertaken without ascertaining the achievable benefit and harm to the architectural heritage, except in cases where urgent safeguard measures are necessary to avoid the imminent collapse of the structures (e.g. after seismic damages); those urgent measures, however, should, whenever possible, avoid modifying the building in an irreversible way.

### **2.1.2.2 Remedial measures and controls**

- 2.1 Therapy should address root causes rather than symptoms.
- 2.2 The best therapy is preventive maintenance
- 2.3 Safety evaluation and an understanding of the significance of the structure should be the basis for conservation and reinforcement measures.
- 2.4 No actions should be undertaken without demonstrating that they are indispensable.
- 2.5 Each intervention should be in proportion to the safety objectives set, thus keeping intervention to the minimum to guarantee safety and durability with the least harm to heritage values.

- 2.6 The design of any intervention should be based on a full understanding of the kinds of action that have caused the damage or decay and of those that will act in the future
- 2.7 The choice between traditional and innovative techniques should be weighed up on a case-by-case basis and preference given to those that are least invasive and most compatible with heritage values, bearing in mind safety and durability requirements.
- 2.8 At times the difficulty of evaluating the real safety levels and the possible benefits of interventions may suggest an observational method, i.e. an incremental approach, starting from a minimum level of intervention, with the possible subsequent adoption of a series of supplementary or corrective measures.
- 2.9 Where possible, any measures adopted should be reversible so that they can be removed and replaced with more suitable measures when new knowledge is acquired. Where they are not completely reversible, interventions should not limit further interventions.
- 2.10 The characteristics of materials used in restoration work (in particular new materials) and their compatibility with existing materials should be fully established. This must include long-term impacts, so that undesirable side-effects are avoided.
- 2.11 The distinguishing qualities of the structure and its environment, in their original or earlier states, should not be destroyed.
- 2.12 Each intervention should, as far as possible, respect the concept, techniques and historical value of the original or earlier states of the structure and leaves evidence that can be recognised in the future.
- 2.13 Intervention should be the result of an overall integrated plan that gives due weight to the different aspects of architecture, structure, installations and functionality.
- 2.14 The removal or alteration of any historic material or distinctive architectural features should be avoided whenever possible.
- 2.15 Deteriorated structures whenever possible should be repaired rather than replaced.
- 2.16 Imperfections and alterations, when they have become part of the history of the structure, should be maintained as far as they do not compromise the safety requirements.
- 2.17 Dismantling and reassembly should only be undertaken as an optional measure required by the very nature of the materials and structure when conservation by other means is impossible or harmful.
- 2.18 Provisional safeguard systems used during the intervention should show their purpose and function without creating any harm to heritage values.
- 2.19 Any proposal for intervention must be accompanied by a programme of control to be carried out, as far as possible, while the work is in progress.

- 2.20 Measures that are impossible to control during execution should not be allowed.
- 2.21 Checks and monitoring during and after the intervention should be carried out to ascertain the efficacy of the results.
- 2.22 All the activities of checking and monitoring should be documented and kept as part of the history of the structure.
- 2.23 An adequate maintenance can limit or postpone the need for subsequent intervention.

### **2.1.3 Guidelines**

Specific guidelines for conservation, restoration and maintenance, containing the rules and methodology that a designer should follow in each field of intervention, are provided by each Unit of the Consortium team, according to its own scientific and technical competence, i.e. roof wooden structures and other wooden elements (architraves, windows, doors), masonry structures, structural stability, mosaics, plasters, paintings, rainwater drainage system. Such guidelines will refer to Italian, European and International Codes in general. Here only the specific guidelines concerning timbers structures, with particular reference to the roof structures, and related safety problems will be reported.

#### **2.1.3.1 Preservation of historic timber structures – General criteria**

For the purpose of the preservation of such structures, the following Principles have to be taken into account:

- 1.1 Recognise the importance of timber structures from all periods as part of the cultural heritage of the world;
- 1.2 Take into account the great diversity of historic timber structures;
- 1.3 Take into account the various species and qualities of wood used to build them;
- 1.4 Recognise the vulnerability of structures wholly or partially in timber due to material decay and degradation in varying environmental and climatic conditions, caused by humidity fluctuations, light, fungal and insect attacks, wear and tear, fire and other disasters;
- 1.5 Recognise the increasing scarcity of historic timber structures due to vulnerability, misuse and the loss of skills and knowledge of traditional design and construction technology;
- 1.6 Take into account the great variety of actions and treatments required for the preservation and conservation of these heritage resources;
- 1.7 Note the main Charters of Conservation and Restoration, as well as UNESCO and ICOMOS doctrine, and seek to apply these general principles to the protection and preservation of historic timber structures;



### **2.1.3.2 Remedial measure and control for the preservation of historic timber structures**

(Adopted by ICOMOS at the 12th General Assembly in Mexico, October 1999)

A coherent strategy of regular monitoring and maintenance is crucial for the protection of historic timber structures and their cultural significance.

Any proposed intervention should for preference:

- 1.8 follow traditional means;
- 1.9 be reversible, if technically possible; or
- 1.10 at least not prejudice or impede future preservation work whenever this may become necessary; and
- 1.11 not hinder the possibility of later access to evidence incorporated in the structure.
- 1.12 In the case of interventions, the historic structure should be considered as a whole; all material, including structural members, in-fill panels, weather-boarding, roofs, floors, doors and windows, etc., should be given equal attention. In principle, as much as possible of the existing material should be retained.
- 1.13 The aim of restoration is to conserve the historic structure and its loadbearing function and to reveal its cultural values by improving the legibility of its historical integrity, its earlier state and design within the limits of existing historic material evidence, as indicated in articles 9 - 13 of the Venice Charter. Removed members and other components of the historic structure should be catalogued, and characteristic samples kept in permanent storage as part of the documentation.
- 1.14 In the repair of a historic structure, replacement timber can be used with due respect to relevant historical and aesthetical values, and where it is an appropriate response to the need to replace decayed or damaged members or their parts, or to the requirements of restoration.
- 1.15 New members or parts of members should be made of the same species of wood with the same, or, if appropriate, with better, grading as in the members being replaced. Where possible, this should also include similar natural characteristics. The moisture content and other physical characteristics of the replacement timber should be compatible with the existing structure.
- 1.16 Craftsmanship and construction technology, including the use of dressing tools or machinery, should, where possible, correspond with those used originally. Nails and other secondary materials should, where appropriate, duplicate the originals.
- 1.17 If a part of a member is replaced, traditional woodwork joints should, if appropriate and compatible with structural requirements, be used to splice the new and the existing part.



- 1.18 It should be accepted that new members or parts of members will be distinguishable from the existing ones. To copy the natural decay or deformation of the replaced members or parts is not desirable. Appropriate traditional or well-tested modern methods may be used to match the colouring of the old and the new with due regard that this will not harm or degrade the surface of the wooden member.
- 1.19 New members or parts of members should be discretely marked, by carving, by marks burnt into the wood or by other methods, so that they can be identified later.
- 1.20 Contemporary materials, such as epoxy resins, and techniques, such as structural steel reinforcement, should be chosen and used with the greatest caution, and only in cases where the durability and structural behaviour of the materials and construction techniques have been satisfactorily proven over a sufficiently long period of time. Utilities, such as heating, and fire detection and prevention systems, should be installed with due recognition of the historic and aesthetic significance of the structure or site.
- 1.21 The use of chemical preservatives should be carefully controlled and monitored, and should be used only where there is an assured benefit, where public and environmental safety will not be affected and where the likelihood of success over the long term is significant.
- 1.22 Where either reinforcing or consolidating materials are introduced, their compatibility with the timber structure must be verified. For example steel fasteners may be susceptible to corrosion in association with some species and so stainless steels should be used. Interventions should not restrict the evaporation of moisture from the timber.

### **2.1.3.3 Italian standard UNI 11119:2004**

This standard establishes objectives, procedures and requirements for the diagnosis of the state of conservation and the evaluation of the strength and durability of timber members in load-bearing structures in the area of cultural heritage, through the execution of onsite inspections and the use of non-destructive techniques and methods.

The present standard has been elaborated by the “Cultural Heritage Commission –NORMAL” of the UNI, within the workgroup “Wood and wood based materials”.

It is applicable to all wooden species which are part of structures pertaining to the 3 service classes defined by UNI ENV 1995-1-1.

The present standard precisely defines the admissible exceptions to the procedures established in UNI EN 518, in order to apply strength grading methods on structural timber members, even when operative conditions significantly differ from the standard grading of sawn wood.

Readers should also note that the UNI standards correspond to EN and ISO standards which are cited as standard references, i.e. :

UNI 1118 Cultural Heritage - Wooden Artefacts - Criteria for the identification of wooden species

UNI EN 335-1 Durability of wood and wood-based products. Definition of hazard classes of biological attack. General.

UNI EN 335-2 Durability of wood and wood-based products. Definition on hazard classes of biological attack. Application to solid wood.

UNI EN 518 Structural timber. Grading. Requirements for visual strength grading standards.

UNI ENV 1995-1-1 Eurocode 5 - Design of timber structures - Part 1-1: General - Common rules and rules for buildings

UNI 11035-1 Structural timber - Visual strength grading for Italian structural timbers: terminology and measurement of features

UNI 11035-2 Structural timber - Visual strength grading rules and characteristics values for Italian structural timber population

#### **2.1.3.4 Italian standard UNI 11138:2004**

##### **Scope and field of application**

This standard provides information on the criteria that should be followed in the preliminary evaluation, planning and eventual execution of conservation, maintenance and restoration of wooden artefacts which serve as load bearing structures in buildings of cultural interest.

This standard deals with problems regarding load bearing timber structures in buildings of cultural, historical and artistic interest. The conservation of these timber artefacts constitute the principle aim of this standard.

In this regard and in this context, one shall always consider it obligatory to carry out the following verifications and evaluations, as a preliminary requirement:

- preliminary verification of the compatibility of use and destination, in particular between the function of the building or parts of it and the structural performance;
- preliminary evaluation of the state of conservation and the service condition of each single timber element which constitutes the timber structure as a whole and which will undergo eventual intervention;
- preliminary evaluation of the building's or monument's condition that may influence the type and entity of an eventual conservative intervention on single timber elements.

These verifications and preliminary evaluations can also aid in avoiding adjustments that may reveal themselves to be incompatible with the purpose of conservation.

The preliminary evaluation may not necessarily have, as an outcome, the definition of an intervention (maintenance, conservation or restoration)

The definition of restoration (according to the legislation in force [1] on the subject pertaining to cultural and environmental heritage) means direct intervention on artefacts with the purpose of maintaining the integrity of the material and assuring the conservation and protection of its cultural value. In this context, "cultural value" includes construction techniques, work technology including the structural configuration of the single wooden members and/or the structure as a whole.

The conservation of wooden members of cultural, historic and artistic interest constitutes multidisciplinary activities, which depend on close collaboration between operative specialists of varying disciplinary fields. Cooperation is imperative between professionals and technical restorers who have the delicate task of working directly on the artefact. Keeping in mind this constant collaboration, this standard deals with aspects which are strictly scientific and technical, and that are related to the evaluation, the design and the execution of an intervention, without supplying all the operative details.

Note: Appendix A lists the legislation referred to in squared parenthesis in the text.

The present standard defers to prescriptions contained in other publications by means of dated and non-dated references. These standard references are quoted within the text and are listed hereafter. Regarding dated references, future modifications or revisions introduced in the mentioned publications are valid only if introduced in the present standard as being updated or reviewed. Regarding non-dated references, the last edition of the publication to which it is being referred is valid (including updates).

UNI 8662-2  
UNI 11063  
UNI 11118  
UNI 11119  
UNI 13306  
UNI EN 335-1  
UNI EN 335-2  
UNI ENV 1991-1  
UNI ENV 1991-2-1  
UNI ENV 1991-2-2  
UNI ENV 1991-2-3  
UNI ENV 1991-2-4  
UNI ENV 1995-1-1  
UNI ENV 1995-1-2  
UNI ENV 1995-2  
UNI ENV 1998-1-1  
UNI ENV 1998-1-3  
UNI ENV 1998-1-4

Note: Appendix A lists the legislation referred to in squared parenthesis in the text.

In particular the standard deals with:

- A. preliminary evaluation of the state of conservation
- B. planning of the intervention
- C. criteria for controlling the efficiency of an intervention
- D. methodology and techniques in the execution of an intervention periodic inspections

#### **A. Preliminary evaluation of the state of conservation**

### **A.1. General introduction**

Preliminary evaluation comes before any eventual decision relative to the artefact. This includes both the operational and preliminary investigations and does not necessarily produce results in the definition, design and/or intervention of conservation or restoration.

This preliminary evaluation can therefore be requested for the sole purpose of knowledge or for the evaluation of static suitability, or in cases where conditions have been verified to produce decay or progressive decay or sudden trauma to a structural timber member. It has also the scope of understanding the global behaviour of the building and the role of timber structures, also with respect of its overall stability.

Preliminary evaluation shall be based on a series of preliminary operations described in the following paragraphs. Each of the operations described may be more or less thoroughly examined or even completely absent, according to the higher or lower complexity of the problem and to the level of detail requested. The level of accuracy shall be established by expert scientists with specific experience in the field of conservation of load bearing timber elements.

### **A.2. Historical analysis**

It is an analysis of the historical events of a building, its structural typologies and their evolution and their construction characteristics and traumatic events. Besides the research of archival documentation, this information can also provide, when available, documentation on the design, contract specifications and contracts for material supplies and labor.

In this context, the dating of material is important in order to obtain knowledge of the construction techniques presumably utilized during a certain period and in a certain territory. This information can help in the choice of eventual interventions.

### **A.3. Characterization of materials**

In order to identify wooden species refer entirely to UNI 11118, and for the evaluation of the state of conservation and the strength grading of structural wooden members refer to UNI 11119.

Given the uncertainty of the actual state of knowledge, when indirect testing methods are used, it is always necessary to confront the measurements obtained with different methods. In using values supplied by such investigations, one shall consider that the fields of variability of each single parameter are nevertheless quite broad.

### **A.4. Geometric characterization**

It is always necessary to have a geometric survey of each timber member, of the timber structure as a whole and, in particular, of the joints (carpentry or mechanical ones).

Particular care shall be executed when surveying existing deformations on single timber members and on structures. One shall always distinguish whenever possible, the state of deformation deriving from the actions applied to the structure and from the material (for example, caused by anatomic defects, improper cutting, etc..) This survey can give indispensable information in comprehending phenomena that may have caused damage to timber members under investigation and, therefore, it is fundamental during this phase of preliminary evaluation. Even when considering an elementary model of verification such as a wooden member with a constant cross section, one shall include, among the defects, the variability of dimension and shape of the transversal section

that cannot be usually ignored. This variation can take place especially in non-squared timber members and almost always in ancient wood.

#### **A.5. Characterizations of decay**

One shall recognize, specify and characterize biotic decay.

Possible interaction between decay and environmental conditions shall be analyzed. Therefore, particular attention shall be given at the analysis of micro-climates that has established around the wooden member or a part of it (for example, the ends of beams and trusses inserted in walls).

Damage of a timber member or a part of it, or of the joint between timber members or connections between a timber member and other parts of an artefact can also be caused by stresses not compatible with the element and / or connection, or by accidental actions (or events), or by static conditions which have changed (even if not directly attributed to the wood). The evaluation of damage, as well as its relative cause and consequence shall absolutely undergo static analysis.

#### **A.6. Structural Analysis**

The evaluation of the actual static condition of an artefact and the actual stresses shall always be considered, in this context, mandatory. Proposed interventions can be performed in detail at different levels, depending on the complexity of the problem that must be analyzed, as well as the economic aspects of the interventions which are consequently proposed.

The definition of the structural scheme (or different static schemes to be considered as limit cases) shall, in general terms, also include all non-timber elements whose behaviour may interfere with the performance of the structural element as a whole. Other timber elements that contribute in the completion of the structure (decorative or accessory) shall also be carefully evaluated.

In the definition of structural schematization one must refer to:

- general static scheme, in order to clearly identify the contribution of the timber structure to the static performance of the analyzed building as a whole;
- detailed static scheme of single structural units (trusses, floor);
- detailed models of single timber members;
- detailed models of connections (internal) or restraints.

A particular attention shall be given to the verification of the details of the connections of single timber members pertaining to the ends of beams and, generally, near to whatever variation is found in the cross section of a wooden member.

In particularly simple cases, one can only refer to models of detail relative to a single timber element, neglecting overall static analysis. As an example, such are cases where a decision has been made already during the preliminary analysis stage such as the carrying out of a localized restoration of internal joints in a timber structure or the substitution of a timber element (or a part of it) that is considered unrecoverable.

With respect to the definition of the actions (direct and indirect) relevant for a timber member or structure (also see UNI ENV 1991-1, UNI ENV 1991-2-1, UNI ENV 1991-2-2, UNI ENV 1991-2-3, UNI ENV 1991-2-4, and the

legislation in force [2]), particular attention shall be given in determining the entity of the action and its temporal variations which can directly influence the relative partial safety factor.

Although one could propose different levels of close examination, where structural analysis is concerned, it is always necessary to assume, in the analytical and numerical models used for analyses, an adequate level of variability in the values of parameters that characterize the model itself.

In this context, the phase of detailed verification of single timber elements, and if pertinent, wooden structures should be considered mandatory. In the verification phase which takes place during the preliminary evaluation, the so-called “minimum evaluations”, as well as the undertaking “on the safety side” can be present only to demonstrate that the timber member or structure can guarantee, in the current condition, an acceptable level of safety, but it does not mean that it justifies any intervention.

## **A.7. Presentation of the results**

### **A.7.1. Essential requirements**

At the very least, the following must be indicated:

- the building subject to investigation;
- general description (location, typology, destination, fundamental dimensions);
- the customer of the investigation;
- executors of the different investigations (historical analysis, material analysis, surveys, structural analysis);
- dates in which the various investigations were carried out;
- investigations carried out, reasons (if relevant) for the exclusion or the simplification of some of the investigations;
- normative references;
- criteria used for the safety analysis and schemes adopted for structural analysis;
- safety of the timber member or structure, with reference to the applied criteria.

### **A.7.2. Additional requirements**

The following documents shall be elaborated upon completion of the preliminary analysis in cases which present particularly complex structures, and in all cases in which this analysis does not lead immediately to the definition of an intervention:

- detailed charts fully describing the work under investigation;
- detailed geometric descriptions of the single timber members;
- maps of decay and damage;
- criteria employed in analysis, in particular:



- theoretical schemes adopted for the structure and for the constraints;
- models used for the structure and for the constraints;
- theoretical schemes employed for actions;
- values adopted for the definition of single mechanical parameters that characterize the wooden members;
- type (or types) of analysis performed;
- an estimation on the actual performance of the single timber member and/or structure.

## **B. PLANNING OF THE INTERVENTION**

### **B.1. General Introduction**

The choice in the type of intervention, materials and methodology to be employed in both extraordinary intervention and in ordinary maintenance depends on the characteristics and the state of conservation of the artefact.

The constant presence of multidisciplinary competence is necessary even in the initial stages of a project.

The project of intervention must respect the indications and the results which arose during the preliminary evaluation phase, considering also the outcome of the compatibility verification.

One shall however ascertain that the choices made for the project is based on preliminary evaluations on the effectiveness of a proposed intervention and of the tolerability of the different materials (including those that are not timber-based) which constitute the artefact or building.

The following list shall be brought to immediate attention during the design stage:

- A. the specific aim of every operation and its necessity;
- B. the location of the intervention;
- C. the materials that one intends to use;
- D. the methodology of application, with a description of the eventual machinery to be used;
- E. the preliminary evaluation of the effectiveness of an intervention;
- F. the controls to be performed during the execution phase and at the end of the intervention, as well as those that should take place periodically.

With regards to the preceding A clause, the planning stage shall above all show evidence that the timber member and/or structure in its present state cannot guarantee the predetermined safety levels.

With regards to the preceding E clause, the evaluation of the effectiveness shall always be foreseen, but it can be completed either in the planning stage with the traditional methods of verification; or by experimental simulation

performed on typologies similar to the one that will be adopted; or also through an appropriate extension of known results to the present case.

The verifications to be performed during the execution of an intervention and the possible range of acceptability of the relative results shall always be foreseen and clearly indicated in the project. This shall be done in order to avoid continuation and/or completion of operations when it has been demonstrated that works cannot be made according to the project, and/or the execution is impracticable for reasons which could not be evaluated preliminarily during the design stage.

The project shall clearly indicate the type and the time intervals of periodic ordinary maintenance carried out on the artefact that has undergone intervention. This shall be carried out according to clause F. In addition, there shall be indications on the conditions of usage which directly influence the concept of safety found in the document “maintenance plan”, which consists of the following documents: user manual, maintenance manual and maintenance program.

## **B.2. Informative criteria for design choices**

In general terms, all interventions that have been designed and realized should leave a “trace” that should not be hidden but rather, harmonized with the present structural context. In the scope of the present standard the “reversibility” shall be considered as a tendency which should be pursued. Operations involving the removal of past interventions (treatments, repairs, reinforcements) are to be generally avoided, especially if they have become stratified through time.

From a structural point of view, the project shall try (whenever possible) to respect the overall performance of the static model; a localized reinforcement applied to the single timber member is in agreement with this requirement. However, this requirement cannot be imposed when it has been clearly and exhaustively demonstrated that the actual configuration is not compatible with the levels of safety previously indicated, even after eventual reinforcements specifically designed for this aspect.

Connections, nodes and restraints shall be restored maintaining their original stiffness, unless it has been clearly demonstrated that the actual stiffness values are responsible (in whole or in part) for the actual structural crisis.

When a timber member does not present works of artistic interest on its surface, partial substitution with timber prosthesis (possibly of the same species) is allowed in order to remove decayed parts which can no longer be recovered. The substitution or lateral support of a single timber member is possible only when it has been proven that it has a complete static inefficiency.

Maximum care shall be taken in the design of an intervention in order to guarantee the possibility of a variation of a timber member’s dimension which can be caused by variation of moisture content, without the introduction of appreciable self-stresses. Therefore, as an example, interventions where the longitudinal shrinkage fissures are tampered or interventions which prevent in any way the transversal swelling and shrinkage of wood are not allowable.

## **B.3. Definition of actions**

For the definition of static safety of timber artefacts and for the undertaking of relevant safety factors for ultimate limit states and serviceability limit states, one can refer to the relevant standards (UNI ENV 1991-1, UNI ENV 1995-1-1).

On this premise, in dealing with existing timber members of cultural interest, it is also opportune to evaluate the safety of the actual artefact itself, adjusting the values of the safety factors for the limit state being considered, the

importance of the framework and the consequently acceptable risk level. For the general definition of “safety level” and “risk level” one shall refer to the prescriptions of the existing national laws.

With regards to safety factors to apply on actions (direct or indirect), the definition can be carried out accurately, in particular with permanent actions. In this context it is admissible to adapt the relative partial safety factors to the modality and accuracy of the evaluation of the action taken into consideration: this assumption shall be justified in detail. Even with regards to particular variable actions, one can reach a precise definition making references to the values of the load and its spatial disposition, in order to adapt its partial safety factors. In all the above cases, the user and maintenance manuals shall report and clearly point out the criteria and modality of use of the structure, which have been assumed as design criteria.

These notes are essential even for future assessments that will take place during periodic inspections (see 8). The eventual limitations to be imposed on variable loads or other particular dispositions shall however be clearly displayed on proper plates, which shall be fixed and made visible in the interested area.

#### **B.4. Interventions of restoration**

##### **B.4.1. General Introduction**

Interventions of restoration in a compromised static situation are allowed, even when using non-wooden materials, as long as the criteria of reversibility and physical-mechanical compatibility are fulfilled. The interventions that reintegrate the continuity of a single timber element can be considered as comprised in this category.

##### **B.4.2. Reintegration of material**

In interventions involving the reintegration of missing wooden materials, one shall distinguish interventions which use wooden material from interventions that use material other than wood.

The integration of the same identical species of wood as that of the structural element under intervention is allowed. Particular attention shall be made so that the average value of moisture content of the new portion being introduced is close ( $\pm 4\%$  variation) to that of the piece in service. The integration of material other than wood on a structural element shall be evaluated carefully, and is not recommended according to the actual state of scientific knowledge.

##### **B.4.3. Recovery of the structural continuity of a wooden member**

The recovery of structural continuity between different parts of the same element can be made by traditional dry connections such as metallic elements or, when possible, by wood or other materials considered suitable.

It can also be made by a system that uses structural adhesives and metallic or timber elements. The use of structural adhesives to transmit normal stresses orthogonal to the glue layer is not possible (also see UNI ENV 1995).

Adhesives used for structures must be specifically formulated for use with wood and eventually for the single intervention. Considering the complexity of the problem and, in particular, the elastic behavior of glued joints up to failure, detailed structural verifications shall be reported, together with the types of control that must be executed before, during and after the intervention.

#### **B.4.4. Reintegration of the functionality of joints between elements**

As previously noted, joints between different timber members shall be repaired to their static function maintaining their original stiffness values. An example of incorrect intervention is the mechanical locking of elements which were previously connected by an “hinge”. When the actual stiffness values clearly demonstrate that they are responsible (as a whole or in part) for the actual structural crisis this requirement is not imposed.

#### **B.4.5. Recovery of the functionality of the timber structure within the building**

The definition of the structural scheme (or different static schemes which will be considered as limit cases), shall in general include all the non-wooden elements that can interfere with the overall performance of the timber structure.

One shall also observe that in general, the timber structure constitutes an essential part of the static behaviour of the building as a whole. Consequently, modifications to the timber structure which are statically important shall undergo overall static analysis in order to point out the interaction between timber and non-timber elements as well as the effective contribution of timber members to the overall structural performance, even during the intermediate phases of intervention.

The above said analysis would additionally allow a sufficient and correct evaluation of the original overall static contribution that the timber structure supplied: this contribution shall be recovered whenever possible and respecting the general informative principles.

In cases where this said recovery is considered insufficient, this shall first of all be justified on the basis of adequately refined numerical models. In such cases, during the design stage, one shall evaluate and propose minimal intervention and guarantee the overall static safety. This evaluation can also include economic considerations in relation to the cultural importance of the artefact.

Interventions which cause modifications of the original overall static performance, which do not necessarily correspond with the actual structural situation, shall be adequately justified.

#### **B.4.6. Interventions by means of self-stresses**

Interventions for the consolidation, improvement and restoration performed on a structure or single timber member that is in a permanent self-stress state shall be evaluated with particular attention.

Considering the field of application, this kind of intervention calls for a close examination of the reological behaviour of the material, especially when applied pre-stresses lead to stresses orthogonal to the grain.

Whenever a state of permanent pre-stress shall be applied, the performance of the timber structure shall be evaluated for long-term load duration and eventually one shall take into consideration the device used in maintaining the structure in this state. Maintenance manuals shall clearly report the methods of inspection and the restoration of the state of pre-stress being considered. The efficiency of the pre-stress state used on the artefact shall be closely examined during the periodic inspections.

#### **B.4.7. Indirect interventions**

Particular interventions which neither involve the wooden member directly, but positively modify its safety and/or conditions of durability shall be taken into consideration. Micro climatic variations shall be evaluated in relation to the compatibility and the conservation of the wooden material.

Among these kinds of interventions, can be particularly cited those which improve the moisture conditions at the beam and truss heads inserted into the walls and, generally, all interventions that allow favorable modifications to the micro climatic conditions surrounding any timber element.

#### **B.4.8. Performance improvements with respect to accidental actions**

For the definition of static behavior in timber artefacts in case of accidental actions (for example seismic, fire) refer to the relevant standards (for example the appropriate sections of UNI ENV 1991-2-2, UNI ENV 1995-1-2, UNI ENV 1998-1-1, UNI ENV 1998-1-3, UNI ENV 1998-1-4).

Based on these premises, it may be impossible to perform any kind of intervention for the improvement or adjustment of a timber element because of its cultural importance, which prevents or advises against any form of alteration.

In any case, for a generic consolidating intervention deemed admissible, one shall at least verify that any kind of modification will not worsen its static behavior to accidental actions, even when referring to the whole structure. In other words, one is requested at the very least, that the planned intervention does not lower the standard of safety with respect to such actions.

#### **B.4.9. Treatments**

It is necessary to attentively define the interventions that positively influence the durability of a timber structure, for example those aimed at improving the micro climatic conditions. Nevertheless, one can hypothesize a preliminary and curative preservation treatment<sup>1</sup> in the presence of high biological risk conditions (UNI EN335-1, UNI EN335-2) and, if it is impossible, to obtain a lower class of biological hazard through “passive” methods.

Preservative treatments have the aim of preventing, slowing down or weakening the process of biotic attack and deterioration in general.

Treatment may also include a reestablishment of the hygienic conditions of the wood: therefore, this should be preliminary to any intervention of conservation or maintenance. This phase which is called “cleaning”, shall be conducted with non-aggressive methods which take special care of the coat and the eventual finishing. Consequently, any kind of surface intervention shall be accurately planned.

#### **B.5. Definition of maintenance and inspection program**

In general, the definitive project shall contain clear indications on the ordinary maintenance program to be performed on the timber structure. The types of inspection and the time intervals shall be indicated. These indications shall be reported in detail in the operative document called “maintenance manual”, which is part of the maintenance plan to which one should refer during periodic inspections.

##### **B.5.1. Essential requirements of a project**

Often, consolidating interventions, improvements and restoration present some uncertainties that can be resolved during the phase of execution. Consequently, one shall introduce the necessary integration to the original works in progress. Such cases should nevertheless be limited and depend exclusively upon a preliminary evaluation that, for various reasons, may have incomplete results. The following is a list of some specific requirements that

<sup>1</sup> In compliance with UNI 8662-2, “biological risk” means the probability that decay has taken place in wood due to xylophagous attacks, in relation to the wood species and environmental service conditions. “High biological risk” means that the wood species, which are less durable or not durable, and the service conditions are favorable to its biodegradation.

shall be applied to the context, and above all, those which are in any case requested by the laws in force, but assume a particular meaning in this context.

### **B.5.2. Essential requirements for the preliminary plan**

The following is data that shall be indicated and documentation that must be provided:

- the structure or artefact needing intervention;
- general description (location, typology, destination, fundamental dimensions);
- property of the artefact and commissioner of the intervention;
- references to executed preliminary surveys and a concise judgment on the actual performance of the timber members or structure on the basis of these surveys;
- planning of eventual supplementary surveys;
- justifiable declarations on the inadequacy of the present state of the structure;
- informative criteria on the planned intervention;
- qualitative and functional characteristics of the operations to be executed;
- assessment of the technical feasibility of the intervention;
- cost and benefit of the planned intervention;
- Graphic schemes identifying the dimensional, volumetric, typological, functional and technological characteristics of the operations to be carried out.

### **B.5.3. Essential requirements for the definitive project**

In addition to the documentation previously pointed out, the following detailed reports shall be presented, which are in part results from preliminary surveys:

- detailed charts thoroughly describing the work under investigation and a complete critical survey;
- geometric drawings describing the single elements
- a map of decay and damage;
- detailed project charts and drawings thoroughly describing all the foreseeable interventions and materials to be used;
- an accurate description of the phases of work for every intervention;
- descriptive reports;
- special static reports, where necessary (geological, geo technical, seismic etc..);



- specific technical reports for interventions on timber structures, including the static calculations carried out for each type of intervention;
- documents that describe technical elements and their performance;
- estimated metric calculation and economic summary.

#### **B.5.4. Essential requirements for the executive project**

The detailed reports cited in 5.6.2 must eventually be corrected, completed and integrated with the following:

- detailed graphic drawings of each intervention to be executed on the timber structure;
- a static detailed technical report;
- a list of unit cost and eventual analysis of prices;
- estimated definitive metric calculation and economic summary;
- inspections that shall be carried out during the various phases of work;
- ordinary maintenance program and periodic inspection carried out on the structure;
- chronological program;
- safety plan and coordination.

### **C. CRITERIA FOR CONTROLLING THE EFFICIENCY OF AN INTERVENTION**

Controlling the efficiency of an intervention can be executed not only in view of the conservation of a certain artefact, but also with the aim of qualifying eventual new products and/or methods of intervention.

The evaluation of the efficiency of an intervention shall always be carried out before the execution of an intervention itself: this evaluation is in fact, an integral part of an intervention project.

Control of the efficiency of an intervention can be carried out, generally, or through direct physical experimentation or through numeric simulation, based on trusted and proven mathematical models and, therefore, can be performed during the preliminary stage of the project, using customary methods of assessment. Inspection through experimental simulation shall be carried out on interventions that are typologically similar to that which will be effectively used, with particular reference also to the volume of the timber material involved ("scale effect"): the extension to full-scale of the experimental results executed on the so-called "scaled-up samples" shall therefore be suitably evaluated. In this case, the possibility of extending for the long term loading the results obtained on models with a short term loading shall also be pointed out. In both cases, the evaluation of the efficiency of an intervention shall also be executed with references to time parameters.

Control can also be carried out by an opportune extension of known results to the present case.

#### **D. METHODOLOGIES AND TECHNIQUES IN EXECUTING AN INTERVENTION**

Interventions are to be executed only by specialized technical personnel, restorers, and technical operators who are specialized in this field. The ability of the personnel who works on an artefact shall be demonstrated (by means of proven documentation) and based on an adequate curriculum of works with similar characteristics, performed by the operator him/herself.

#### **E. PERIODIC INSPECTIONS**

Periodic inspections shall be chosen, clearly indicating both the typology and time intervals. In addition, one shall clearly indicate the type and periodic ordinary maintenance which shall be carried out on the artefact which has undergone intervention as already indicated. These indications shall be reported in detail in the use and maintenance manuals found in the Maintenance Plan.

Periodic inspection shall, above all, ascertain that the element or structure which has undergone intervention is in agreement to the specifics of the plan and that the environmental conditions respect the planned hypothesis. This assessment shall, in particular, verify that the permanent actions and when possible, those variable, respect what was foreseeable during the elaboration of the plan as reported, if relevant, in the user manual and displayed on proper panel in each single area.

Periodic inspection generally includes a thorough and careful visual examination in order to ascertain if single members show possible new or accentuated damage, as compared to what was determined during the preliminary investigation or following intervention. During this examination, particular attention shall be given to the presence of possible biotic attack (or the beginning stages of biotic attack).

The results of the periodic inspections shall be annotated, in detail, in the so-called “maintenance intervention paragraph” found in the document “maintenance plan”.

## APPENDIX A - LEGISLATIVE REFERENCES

At the date of publication of this standard the following laws are in force.

- Legg.vo n. 42 22/01/2004 Heritage cultural and landscape code, according to article 10 of the law July 6, 2002, n 137 (Suppl.Ord. alla GU. 24.2.2004, n. 45)
- 156 AA.GG./STC 04/07/1996, Instructions for the application of "Technical standards relative to the general criteria for the design of constructions, and for loads and live loads" of which D.M. LL. PP. 16/01/1996
- D.P.R. n. 554, 21/12/1999, Regulations in carrying out laws dealing with public works February 11, 1994, n. 109, and successive modifications
- D.M. LL. PP: 16/01/1996 Technical standards relative to "The general criteria for the design of constructions, and for loads and live loads" (G.U. 05/02/1996, n. 29 Suppl. Ord. n. 19)

UNI 8662-1:1984	Treatment of wood - General terminology
UNI 11035-1:2003	Structural Wood - Visual classification of Italian timber according to mechanical resistance: terminology and measurements of its characteristics
UNI 11035-2:2003	Structural Wood - Rules for visual classification according to resistance and characteristic values for types of structural Italian timber
UNI ENV 1998-1-2	Eurocode 8 - Project/design indications for seismic resistance of structures - General rules for buildings

## 2.2 THE STRUCTURAL APPROACH

The approach to the intervention can be divided into two major tasks:

4. Providing an adequate conservation of the building; this task refers especially to the material preservation of the single elements of the building, such as timber, mosaics, paintings, walls, etc..
5. Providing an adequate safety level of the building, with both respect to its static capacity and to the seismic protection; this task refers especially to the preservation of the mechanical properties demanded by each structural elements, and to the necessity of providing the overall seismic behaviour of the building with an adequate resistance.

With regard to these two points, it must be remarked that nowadays it is still rather difficult to adequate cultural heritage buildings to the modern anti-seismic safety standards and to preserve, at the same time, all their historical, architectural and artistic characteristics. On the other hand, the concept of “seismic improvement” has been spreading more and more in the structural engineering community: rather than increasing the seismic performances to the level required by new buildings, it is advisable and more reasonable to simply improve them as much as possible, but without making any significant change to the main characteristics of the building.

This is the main criterion that has been followed in the development of the conservation plan; in particular, the approach which has been adopted with regard to the seismic protection is mainly addressed to the improvement of the connections between roof and masonry walls, in order to:

- a. avoid any out-of-plane mechanism of any masonry wall, with special reference to the tympanum of the Church;
- b. improve the in-plane stiffness of the roof (in both central nave and aisles) ;
- c. guarantee the transfer of the seismic shear forces from the roof to the masonry walls able to bear the horizontal seismic actions.
- d. guarantee a rigid-box like behaviour of the whole building so as to prevent relative horizontal displacements, reduce the values of displacements and deformations and, as a consequence, the values of the internal stresses

For this reason, the static analyses regarding the roof structure, which were already performed in the investigation phase, have been integrated by nonlinear analyses concerning the main bearing walls of the building, in order to investigate the different levels of safety which was possible to achieve on the basis of different types of improvements .

Moreover, the structural role of each timber element is defined by cross checking the following aspects:

- its artistic and historic quality (age, rarity of the element within the building, presence of decoration, or other peculiarities worth of interest, etc.);
- its capacity of combining the need of preserving its material survival, as part of a document bequeathed to us by history, with the need of improving the overall static and seismic resistance of the structure it belongs to or of the building as a whole.

In facts, different design scenarios can be expected, depending on the type and amount of the interventions on the existing elements required to reach an acceptable level of safety. In an optimal situation, few interventions of reinforcement or consolidation may satisfy the needs of a high level of seismic improvement, while in worst situations, the choice has to be taken whether to find a right but difficult balance between preservation and safety or to accept heavier interventions which might compromise the preservation of both original materials and functions .

At this regard the approach followed in the conservation plan of the Church of the Holy Nativity is based on the assumption of respecting as much as possible the original materials and the structural functionality of the existing bearing elements, although admitting in some cases the possibility of replacing or integrating parts of them in order to guarantee their structural performance.

At the end of the restoration work a plan for periodic maintenance will be set up on the basis of appropriate manuals and training a team of restorers.

## **2.3 MAINTENANCE**

### **2.3.1. Introduction**

At the end of the restoration work a plan for periodic maintenance must be activated by trained workers and professionals on the basis of appropriate manuals and instructions.

A Maintenance Plan, organised in different sections, has already been prepared by the Consortium team and included in the Final Report to which the reader is referred for more details. Each section gives all the necessary procedures to be satisfied in order to guarantee the correct maintenance of the Church. Here some basic guidelines are reported, in particular the ones referring to works presently in progress in the Church.

Monuments, as any other construction, are subject to a permanent process of physical deterioration through use and under the action of external environment action. In spite of their solid appearance and sturdy components, they are actually quite sensitive to climatic aggression (sun, rain, cold or heat) and to all other natural actions. Normal use by people is also one of the causes for a progressive deterioration of the various elements of the building.

#### **2.3.1.1 Need for maintenance**

When we speak of maintenance, we speak about the most significant actions for the preservation of historical architectures. These actions, whether periodical or frequent, ensure the protection of the building over time and adapt it to the activities developed or planned inside. Two types of maintenance must be distinguished: common maintenance, whose goal is the preservation of a minimal functional capacity, and exceptional maintenance which makes the building respond to some extraordinary events or fulfil some special requirements.

Since the moment the restoration is completed the monument calls for maintenance.

#### **2.3.1.2 The role of the owners or users**

The owners or users are the ones who can detect, before any other, problems or pathologies in the construction. In the case of significant works, the owners must call upon some experts to solve specific problems or to evaluate the preservation state of the building.

Besides, managing a historical building requires knowledge and specific maintenance methods. Indeed, what is at stake is not only solving momentary problems but managing the whole estate, getting the best out of the building in its various aspects: use, preservation, historical and cultural value.

#### **2.3.1.3 A guidebook for maintenance**

For an effective diagnosis, all the data and information contributing to a better knowledge of the building must be gathered in order to create a technical guidebook, a data base useful to set up and manage a maintenance

program. This guidebook, will both keep a record of the risks and construction defects, and plan preventive or corrective maintenance works. It will be consulted before any action upon the building.

The objective of this guidebook is to:

- ensure the maintenance of the building to prevent further deterioration,
- facilitate future diagnosis operations,
- improve the knowledge of the construction materials and their lifespan, structural systems and traditional techniques,
- facilitate the follow-up of one or more daily maintenance actions.

Therefore, the maintenance guidebook will be the tool and reference book containing all the technical and historical information, the visually detected deterioration, the damages and repairs carried out on the building, and an identification of the actor (owner, expert, workman, etc.). This guidebook will keep a record of the state of the structure, it will help organize an agenda for periodical maintenance and set up preventive preservation works.

#### **2.3.1.4 Preventive maintenance**

Knowing the nature and the lifespan of the construction materials helps reduce deterioration and maintain architectural heritage in good condition. Periodical inspections detect pathologies or structural deterioration before they worsen, allows the cleaning of the materials and the control of the structures, guides the users in taking precautions for particular situations and in looking after fragile structures which could be damaged in the event of misuse. Thus, preventive maintenance limits damages and great spending in heavy restoration or maintenance operations and acts upon the building solely in the respect of its historical and architectural value.

##### **2.3.1.4.1 Specific maintenance programs**

In the following some of the specific maintenance programs are reported, mainly the ones related directly or indirectly to the roof. The reader is referred to the Consortium Final Report for more details at this regards.

##### **2.3.1.4.2 Roof of Central Nave and Aisles**

As a general comment it must be pointed out that, in some points, the present collection system of the rainwater falling on the roof is underestimated. For instance, the two vertical pipes in the Orthodox and Armenian corners collect the rainwater of about 170 m<sup>2</sup> of roof, although it is a common rule to provide at least one collection pipe for max 100 m<sup>2</sup>. Furthermore, there are no horizontal gutters collecting the rainwater from the roof of the Central Nave; this rainwater, therefore, falls down on the roof of the Aisles from a height of a few meters.

Hence, it is clear that special attention must be paid to the maintenance of all the paths of the rainwater, particularly in the areas where the roof intersects the collecting pipes.

The elements to be continuously monitored are:

- The holes taking the rainwater from the roof of the Aisles to the external gardens (Franciscan and Orthodox-Armenian sides)
- The two holes collecting the rainwater in the Armenian and Orthodox corners
- The vertical pipes taking the rainwater from the above corners to outside.
- The holes in the walls on the apses' terraces at the floor level.



Such elements need to be monitored every month. They must be cleaned from any obstruction at least at the beginning and at the end of the rain season. The protection webs must be kept undamaged and strongly connected to the hole frame to prevent animals entering the pipes and obstructing or damaging them.

Furthermore, two more elements deserve special attention:

- the vertical pipe inside the wall located in the Orthodox corner
- the horizontal pipe below the ground outside the Church in the Armenian corner (in the Franciscan garden).

The vertical pipe in the Orthodox corner is hidden inside the masonry wall but some inspection points have been planned in the intervention project. Every month the pipe must be monitored to check the occurrence of leakages; the inspection will consist of a visual investigation from the above mentioned inspection points and a check of possible damp patches in the surrounding masonry.

The vertical pipe in the Armenian corner ends up with a trunk in the Franciscan garden. This trunk must be inspected continuously (at least twice per year) to avoid any obstruction and to detect any possible leakage.

In the end, the waterproof layers of the roof must be kept under observation. At least twice per year, a visual survey (from inside the Church) of the wooden boards must be accomplished. Such an investigation must be pursued to detect any incipient leakage due to a possible local damage on the waterproof layers. In this way the most appropriate remedies (local replacement of the lead sheet, laying of a new waterproof patch, etc.) can be immediately taken before the rainwater leakage provokes new damages to the wood structure and to the artistic elements (mosaics, frescos, etc.).

#### **2.3.1.4.3 Narthex**

The surfaces of the Narthex show excessive moisture and a number of plants growing in the interstices between one stone and the other.

A proper maintenance should guarantee in the first place a smooth flow of the rainwater. That means that periodically, at least twice a year, at the beginning of the rainy season (about half of October), and at the end of it (late March, early April) it is necessary to inspect and, if necessary, clean and restore:

- The elements for collecting the rainwater, including descendants and lower wells, which should be cleaned from any residual earth and plants.
- The interstices between floor stones which should be properly sealed and with no element which may give rise to a decay process.
- The horizontal and vertical masonry surfaces where any kind of plant grown should be extirpated.
- The interstices between the stones of the walls which should be repaired if subject to physical decay or any kind of damage.

#### **2.3.1.5 Mosaics and paintings**

After the restoration, a continuous monitoring of humidity and temperature will be necessary inside the church in order to find and implement the better strategy (opening the windows, restricting the flow of visitors, etc.) to maintain a stable microclimate inside the Basilica.

#### **2.3.1.5.1 Wall mosaics**

A restoration specialist will check the wall mosaics every year. A mobile scaffolding will be installed, the mosaic surfaces will be inspected closely and the dust removed with brushes with natural bristles. The adhesion of the tiles to the support will be checked by touching the surface and having care of wearing cotton gloves. The adhesion of the various layers of plaster will be checked after "*nocchettatura*" on the surface without wearing white cotton gloves. Detailed charts will show the state of conservation, all documented photographically. The whole area will be monitored at close range to control the presence of deposits which may or may not be relevant, such as drips or efflorescence that are indicators of water infiltration problems in the building structure or microclimate inside the Basilica. In these cases you must first remove the factor of degradation and then repair the damage to surfaces. If necessary diagnostic tests will be performed.

#### **2.3.1.5.2 Floor mosaics**

Once a year the covers are removed and the floor mosaics are to be checked closely. The checks must be performed by a specialist restorer who will monitor the adhesion of the various layers of plaster, after "*nocchettatura*" of white cotton gloves on the surface. Tesserae will be checked for adhesion to the layer of bedding. The presence of biological deposits must be checked and, if necessary, quantitative and qualitative surveys must be carried out on samples taken with swabs. Graphic and photographic material will provide a detailed documentation of the actual conditions.

#### **2.3.1.5.3 Paintings on the columns**

A restoration specialist will check the paintings every year. A mobile scaffolding will be installed, the paintings will be inspected closely and the dust removed with brushes with natural bristles. Detailed charts will show the state of conservation, all documented photographically. The whole area will be monitored at close range to control the presence of deposits which may or may not be relevant, such as drips or efflorescence that are indicators of water infiltration problems in the building structure or microclimate inside the Basilica. In these cases you must first remove the cause of degradation and then repair the damage to surfaces. If necessary diagnostic tests will be performed.

#### **2.3.1.6 The wood elements**

##### **2.3.1.6.1 Windows and doors**

On new installed windows a control must be carried out once a year to check the preservation state of the sealing between the window frames and the masonry supports. Such controls might be carried out simultaneously with the glass cleaning. A control every five years on the varnishing must be scheduled, followed if necessary by maintenance works. Check the varnish used by the window makers and use for maintenance a varnish having the same characteristics.

The surfaces of the wooden parts of the grotto's doors and of the restored Armenian door must be cleaned once every three years by removing the dust and applying beeswax and turpentine treatments.

The periodic inspection of the windows, which will be opened from the outside, will be possible thanks to a light, not invasive and impacting external walkway, still to be designed.

Manual opening systems have been preferred to automatic opening systems for their robustness and for the greater simplicity in being repaired in the case of damage.

#### **2.3.1.6.2 Specific suggestions for restoration and maintenance of the timber structure**

The first leading suggestion is to apply the guidelines of the Italian Standard UNI 11138:2004 "Cultural Heritage - Wooden artefacts - Load bearing structures of buildings - Criteria for the preliminary evaluation, design and execution of works", at present the only one existing in Europe and concerning issues of conservation and maintenance.

All the new wooden elements that will be inserted during the restoration (roof boards and structural elements) must show no evident or hidden (insect at the stage of larvae or eggs) insect attacks. A certificate of pest control guarantee must be claimed. Moreover all the new elements must be treated in order to avoid new insect attacks after the restoration works. The eventual insects attacking the new elements could cause new attacks even on the ancient on site elements, thus the prevention activity is crucial to protect the ancient elements.

Specific maintenance programs and controls on the effectiveness of the interventions must be provided according to the interventions of conservation/ restoration carried out.

The maintenance inspection must provide the control of the moisture content of the timber members, according to their position in the structure and to the possible presence of moisture trap, with a particular attention to be paid at the connection with the walls. The depth of the measurement will be at least 5 cm. The tool to be used must be an electric wood hygrometer with electrodes. The electrodes must be sealed up to the needles, in order to measure only on the maximum depth of penetration of the electrodes. A moisture content above 18 – 20% will mean the presence of a moisture trap that could cause a fungal attack on wood.

The moisture trap means that close to the anomalous wood moisture content there could be a problem of water drainage or of water leaking from the roof. The problem must be solved.

It will be also important to control, from time to time, the possible evolution of the fungal decay wherever it involves less than the 50% of the resisting sections.

The inspection of the timber trusses will be possible through the existing access points (windows in correspondence of the tympanum of apse and transept) and by improving the existing walkway now connecting the trusses in the N-S direction and in the E-W direction.

#### **2.3.1.7 Fire alarm**

The fire alarm will mainly encompass both the sensors to detect the fire and the fire hydrants to extinguish it. Every week the sensors must be cleaned by removing any obstacle (mainly dust) with a delicate brush. The maintenance instructions given by the producers of the fire hydrants must be followed accurately.

#### **2.3.1.8 Indoor ventilation and thermal conditions**

It is important to check periodically the thermal equilibrium inside the church in order to improve the internal thermal comfort especially during the visiting hours. A recent study carried out by a N. Santopuoli (SSBAP), a member of the team, (CFD modelling of indoor ventilation and thermal comfort in monumental buildings, by R. Rossi, G. Iaccarino, N. Santopuoli, L. Seccia, 2011) shows that the thermal gradient between the inside and the outside of the Church increases considerably when all the upper windows of the Church are open in addition to the doors for the usual public access. For instance, according to such analyses, in the presence of an external temperature of nearly 40° C the internal temperature shows an average 25% reduction everywhere with a minimum temperature of nearly 30° C in the apse and the transept. Therefore, in order to guarantee or increase

the comfort of the visitors it is recommended to keep the upper windows open, or partially open, in the presence of great numbers of visitors inside, provided of course there is no rain. For this reason it is also recommended to connect the automatic opening system of the upper windows with a technical device measuring the internal temperature and humidity rate and operating the mechanism for opening windows as soon as the external/internal temperature ratio gets lower than a limit value.

Moreover, as for the indoor environmental monitoring, there are a number of firms (see for instance [www.lsi-lastem.it](http://www.lsi-lastem.it)) offering instruments for the measurement of all the various parameters defining the quality of an environment from the thermal, luminosity and chemical standpoints. The range includes a large variety of sensors and PC software for data acquisition and elaboration, particularly for the calculation of the thermal comfort indices (moderate environments) and thermal stress indices (hot and cold environments) from the incoming data. With a single portable instrument and a modular kit of probes it is possible to measure:

- Air, surface and fluid temperatures
- Mean radiant temperature
- Relative humidity, dew point
- Environmental air speed, airflow in ducts and at vent Outlets and the amount of air changes
- Differential air pressure (filters, exchangers and fans), Atmospheric pressure
- Thermal insulation walls (K factor)
- Air quality (CO<sub>2</sub>, CO concentrations, VOCS, etc.)
- Thermal comfort indices (TO, PMV-PPD)
- Thermal stress indices hot environments (WBGT, HSI, TTS, PHS, etc.) cold environments (ITR, WCI, TCH)
- Illumination
- Meteorological parameters (temperature, humidity, Wind speed and direction, solar radiation).

The complete system is easily transportable and can be set up on a tripod. Rechargeable batteries assure autonomy of approximately 24-32 hours, depending on the operating conditions and the sensors in use. All information can be easily viewed on the display: instantaneous values, average, minimum, maximum, standard deviation and trends.

In more detail, depending on the type of probe connected, the system can calculate certain derived quantities, the main ones for environment classification being:

**Airflow and air changes** - using anemometric probes and after having specified the geometry and dimensions of the outlets and ducts and the room volumes, it calculates the volumetric airflow (m<sup>3</sup> /sec), its mass (kg/sec) and the amount of air changes.

**Hygrothermometric quantities** (ISO 7726) - using the psychrometer, it calculates:

- relative humidity using the psychrometric method;
- dew point (also available with capacitive hygrometric probes);
- partial vapor pressure, absolute humidity, specific humidity, mixing ratio, damp air enthalpy, radiant temperature (programmable by LSI).

**Mean radiant temperature** - using the globe thermometer and the air temperature and speed probes, it calculates the average radiant temperature.

**WBGT** - using the globe thermometer and the natural ventilated temperature probe, it calculates the WBGT thermal stress index; an additional air temperature probe allows it to calculate WBGT for outdoor environments (ISO 7243 standards).

**Indices of localized discomfort (ISO7730)**

- % of dissatisfied by temperature vertical differences (BST130 probe)
- % of dissatisfied by floor temperature (BST130 probe)
- % of dissatisfied by radiant asymmetry (BSR231 probe).
- Heat stress index
- UV index

### 3 ANNEX 3: PROJECT SPECIFICATIONS FOR ROOF RESTORATION INCLUDING THE INTERVENTION DOCUMENTATION

This Section 3 intends to be the answer to the following requests of specification addressed by ICOMOS to the State Party:

1. "Prepare a detailed project specification for the roof repairs that allow a full understanding of which elements of the roof will be maintained, which repaired and which replaced."
2. "Undertake the roof repair project and document its interventions."

*In "Italics" the methodologies and the guidelines for the restoration of the roof, as provided in the Consortium Final Report and in the Term of Reference (T.O.R.) will be presented along with the required level of skill and accuracy which is necessary to guarantee the proper execution of the interventions of restoration. All recommendations provided will help Contractor and Project Manager to make the proper decision regarding the elements which have to be maintained, removed or repaired during the interventions on the roof of the Church (answer to point 1.). The most relevant and significant parts are highlighted in **bold**.*

**In normal typefaces** the actual interventions carried out between September 15, 2013 and June 30, 2014 are described. For each issue, or at least for the most meaningful issues, they are presented in such a way as to establish a direct correspondence with the related recommendations and guidelines (answer to point 2).

#### 3.1 PRECONSTRUCTION PHOTOGRAPHIC SURVEY

A Dilapidation Survey was required for submittal prior to the start of the works (Figure 39). This survey was carried out so as to provide a historical documentation of the existing site conditions prior to the start of construction. This is for the benefit of the Owner, the CMC, the Engineer and the Contractor.

The Contractor had to submit one electronic copy of the videos and photos listed below and two hard copies of the photos.

The Contractor had to perform the following, per the Engineer's satisfaction, as a minimum for satisfactory completion of this item:

- a. The Contractor shall detail existing structures pre construction, so that the existing site conditions can be easily and accurately defined and determined. This type of survey shall be drawn to a scale of 1:50 and a larger scale, 1:20 or full size, to capture the timber details or decorative plaster. Where walls and partitions are not vertical, measurements can vary according to the height at which they are taken. In such cases it is advisable to work at a uniform height preferably just about 300 mm above the level of the window board.
- b. The Contractor shall also take electronic photos of the site to capture all the architectural, historical, and structural elements (wooden trusses, purlins, planking, lead covering, lead plates, wooden boards...etc) from different angles more often to show specific existing site conditions. For interior work a wide angle lens is likely to be needed, complete with flash-gun with adjustable head to match the lens. For large, complex elevations the Contractor shall provide a whole plate print 16.5 x21.6 cm or 20.5 x 25.4cm to convey more details. Where needed, views should be taken obliquely to show two elevations.



- c. The Contractor shall provide a video version of the dilapidation survey of all of the work, with verbal captioning the video by detail or element naming.
- d. The Contractor shall adequately caption the pictures by photo number, so that the viewer can determine, date, time, location along with a general statement of the structure or detail being recorded.



Figure 39: dilapidation survey

### **3.2 PROTECTION MEASURES FOR MOSAICS, FLOOR, PAINTED COLUMNS, WOODEN ARCHITRAVES**

Before starting the construction of the scaffolding and all works on the roof structures it was mandatory to protect all decorative surfaces inside the Church against damages which might be caused by material handling, fall of work tools etc. The most common and reliable protection measures for mosaics, floor, painted columns and wooden architraves were adopted on the basis of guidelines and recommendations reported in the T.O.R. In the present Section, as well as in the following Sections, the technical proposals suggested in the guidelines will be presented, wherever possible, together with the actual solutions adopted by the Contractor and approved by the Supervisors.

#### **3.2.1 Wall mosaics**

*Concerning the safeguard of the wall mosaics, that may be strongly damaged by the vibrations due to the works on the roof covering, the following steps are recommended (Figure 40):*

- i) verify the perimeters of the damaged areas in order to go ahead firstly with punctual pre-consolidation operations, where necessary,*
- ii) adhesion of a protective layer (tissue paper) on the whole surface;*
- iii) collocation of Velcro strips along the whole perimeter of the fragments enlarging the protective layer on the plaster for a length of 50 centimetres minimum, in view of the possible presence of mosaic's sections underneath the layers of plaster;*
- iv) collocation of Velcro strips upon the whole surface, figuring a reticule of longitudinal parallel strips at a distance of about one meter;*
- v) application of non-woven fabric upon the whole surface;*
- vi) application of a wooden wainscot upon the whole surface;*

*vii) the protective system will be anchored to a supporting structure which will be developed along the whole surface and anchored, in its turn, either to uprights rising from the floor or to walls, in particular in correspondence of the window openings, without causing any damage to walls and surfaces.*

*viii) during the interventions on the roof, particular attention has to be paid to those internal surfaces on the top which might hide wall decorations or mosaics under the layers of plaster. In particular, in those areas where some timber elements will be removed, expert restorers and archaeologists should be present to verify the presence of possible hidden wall decorations.*

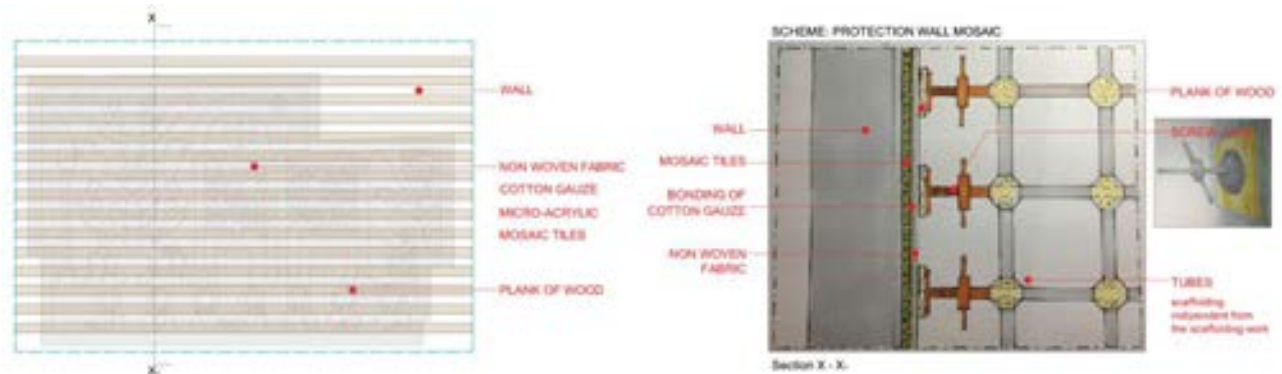


Figure 40: guidelines for wall mosaics protection

After completing the first scaffolding platform, at the window level, the Contractor started installing the temporary protection system of the wall mosaics by following as much as possible the guidelines (Figure 41, Figure 42). Because of the necessity of building the scaffolding nearly in adherence with the walls and because of the consequent reduction of the free space between scaffolding and walls, in agreement with the Supervisors, it was chosen to anchor the protective boards not to an independent structure, as in the guidelines, but directly to the walls, mainly in correspondence of the window openings, by paying great attention in not damaging the plasters.



Figure 41: protection of the wall mosaics with cotton gauzes, non-woven fabric and boards

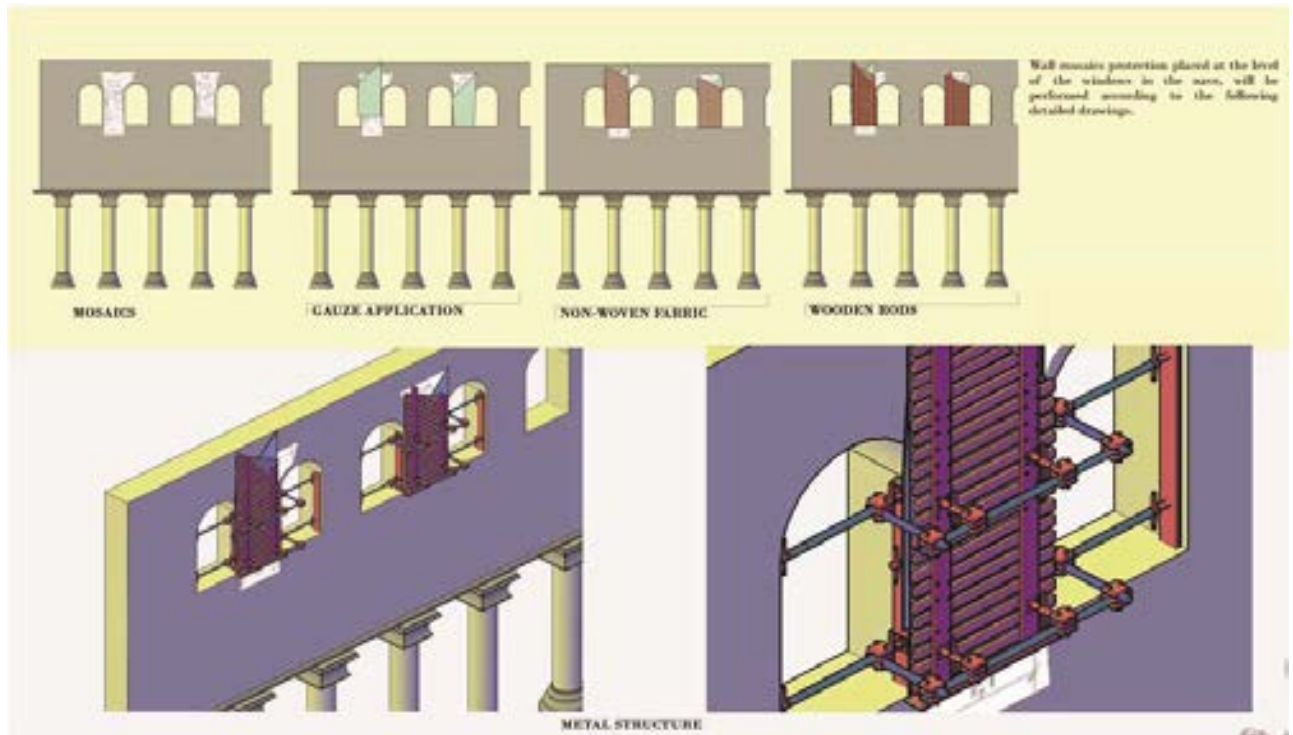


Figure 42: anchorage to the walls in correspondence of the window openings

### 3.2.2 Flooring and floor mosaics

The whole internal floor, made of different sized stone slabs, was properly protected by designing paths reserved to pilgrims. The floor itself was protected by using proper materials such as a layer of non-woven fabric and slabs of pressed cardboard (Figure 43)



Figure 43: materials for the floor protection

Before proceeding with the protection of the floor all the wooden trapdoors above the Constantinian floor mosaics must be checked and consolidated wherever it is necessary (Figure 44).



CHECKING OF WOODEN HATCHES, CHANGING OR STRENGTHENING THE WOODEN PLANKS COMPROMISED.

Figure 44: checking of the trapdoors

### 3.2.3 Paintings on the columns

*All painted columns must be properly protected by applying a non-woven fabric layer directly upon the painted surface (Figure 45) and a stiff protective structure, made with wooden boards, upon the whole lateral surface of the columns (Figure 46).*



Figure 45: materials recommended for column protection



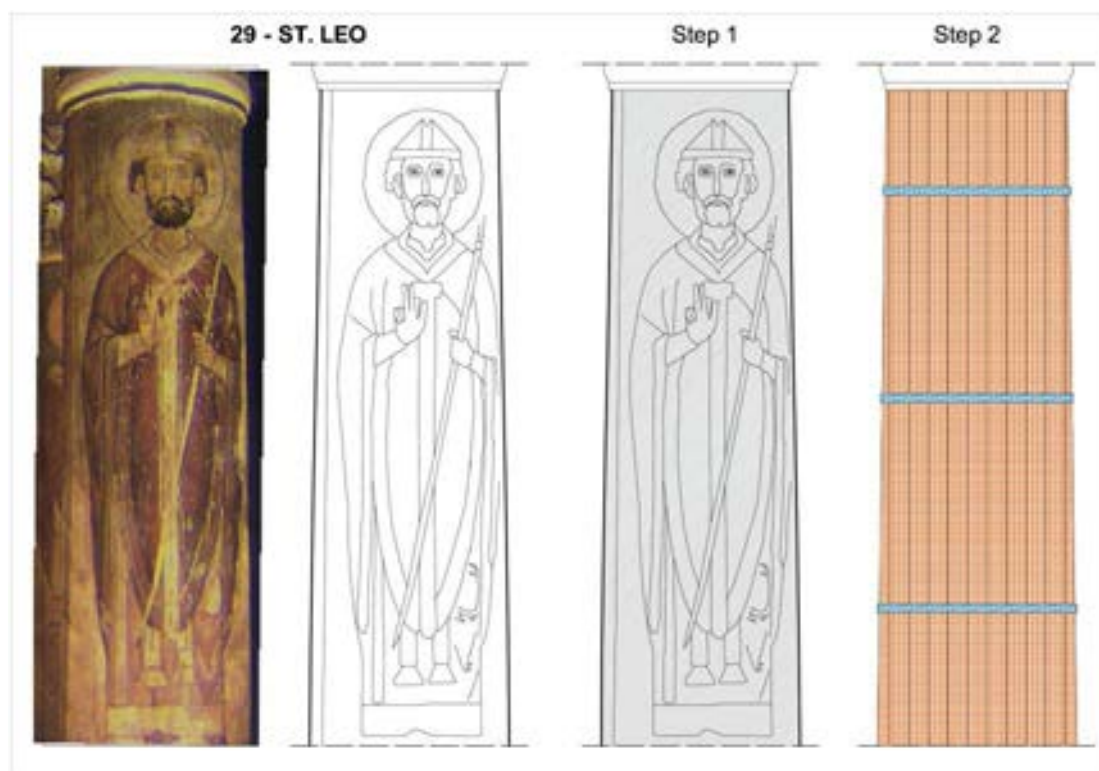


Figure 46: external protection suggested in the guidelines

Before starting the assembling of the scaffolding inside the church the Contractor, according with the guidelines and the Supervisors, protected the columns of the church by using a special layer of geotextile and vertical wooden boards in order to achieve the maximum protection level (Figure 47, Figure 48).

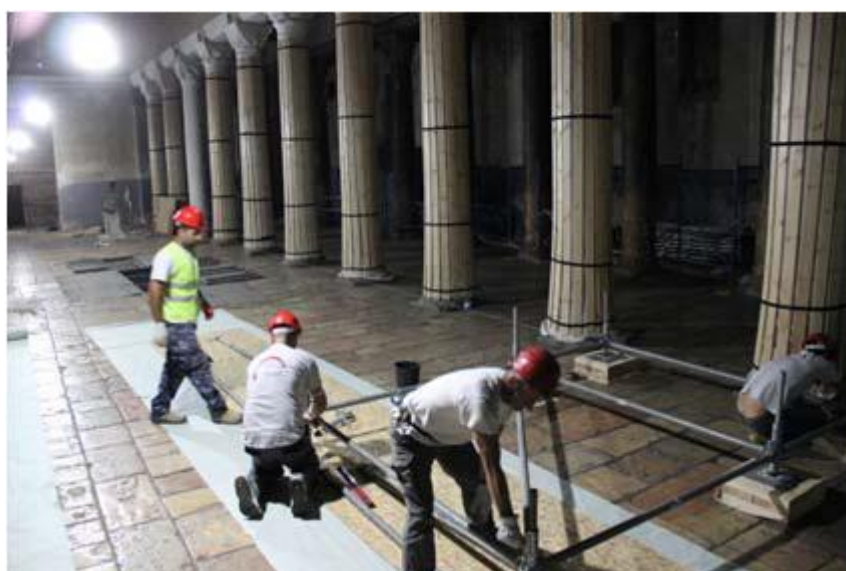


Figure 47: protection of the painted columns



Figure 48: a detail of the protective system for the painted columns

### 3.2.4 Wooden architrave

The wooden architrave and the stone capitals must be protected with non-woven fabric. In particular the wooden architrave, after being covered with non-woven fabric, must be protected by means of wooden boards properly blocked by scaffolding pipes and screw-jacks (Figure 49). The scaffolding pipes must be anchored to a simple scaffolding, set up along the wall in its whole height, completely independent from the one used to work at the truss level.

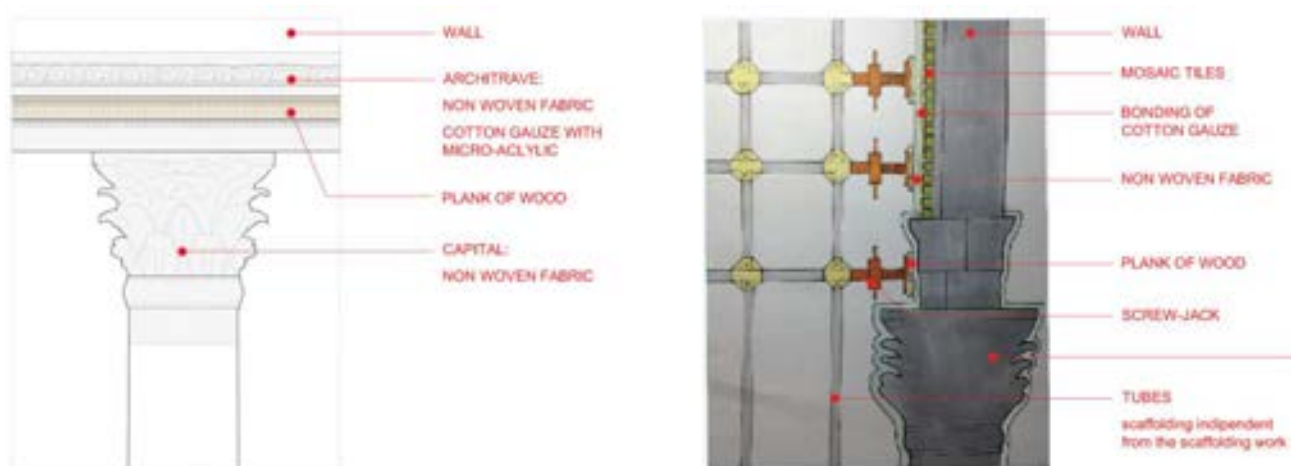


Figure 49: protective system for the wooden architrave according to the guidelines



As mentioned above, because of the necessity of building the scaffolding nearly in adherence with the walls and the consequent reduction of the free space between scaffolding and walls, in agreement with the Supervisors, it was chosen to simplify the whole protective system by using only cotton gauzes and non-woven fabric applied directly to the surfaces by using the greatest care in not causing any damage to wall mosaics and plasters (Figure 50, Figure 51).



Figure 50: protection for capitals and architrave

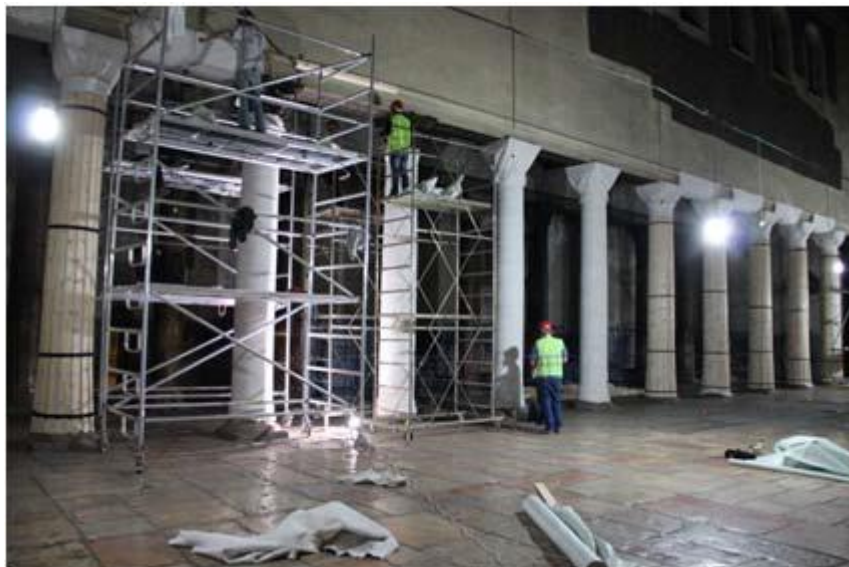


Figure 51: protection for capitals and architrave

### **3.3 EXTERNAL AREAS FOR STORAGE AND CRANES**

As already planned, according to the T.O.R. and after a coordination with the Churches, two areas in the square in front of the church were furnished as temporary storage areas for the materials and equipment to be used for the restoration works. In this area the following items are provided: a storage area for materials, an office equipped with chemical toilet, a staircase for workers' access to the roof of the Narthex. The same site is fitted with the necessary safety signboards and a fencing not less than two meters high to prevent pilgrims from entering the area of the site (Figure 52).



Figure 52: Site area and the main entrance area to the Narthex

During the processing and during the arrangement of the work site particular care was paid to avoid any damage to the stones of the square. Near this area a mobile crane was positioned with the aim of allowing the construction of a bigger and fixed crane in the Orthodox garden, South of the Church (Figure 53). Such a crane will speed up the restoration process and lift / transport the materials safely from one place to another. The Orthodox garden beside the bell tower was considered the best location where the bigger crane (Figure 54) could be erected and serve the widest area of the roof. Before choosing the definite position for both mobile and fixed crane, an investigation was carried out in the subsoil by means of Electric-Resistivity Techniques and direct inspections to check the presence and the dimensions of some reservoirs, documented in old maps and photos, or the presence of unknown underground cavities. The data surveyed were not such as to obstacle the planned activities and the installation of the cranes.

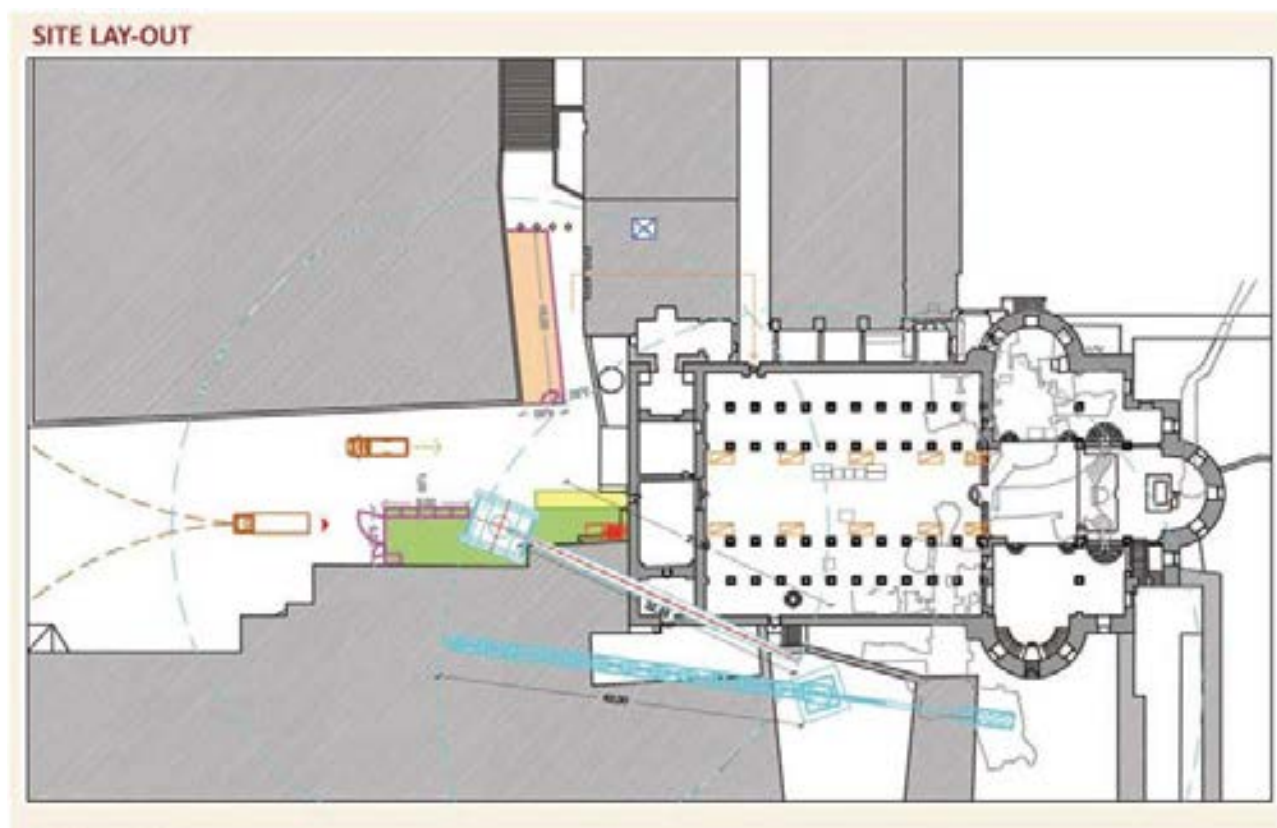


Figure 53: Storage area (green), mobile crane and fixed crane





Figure 54: the bigger crane

### **3.4 CONSTRUCTION SEQUENCE AND MAIN TYPES OF INTERVENTION**

*Presented in this section are the four main interventions to be carried out on the roof and the construction sequence to be considered in such interventions:*

- 1. intervention on the roof cover;*
- 2. mechanical survey of the end sections of the trusses and of the four big cantilevers at the intersections between nave and transept;*
- 3. repair of the decayed members of trusses with prostheses;*
- 4. replacement of totally decayed or broken members of trusses with new members.*

*The aforementioned interventions are not independent from each other. A consistent sequence of them should be engineered in order to optimize the duration of the works and avoid any possible impasse. The scaffolding needed for the interventions must be conceived in such a way as to change its configuration according to the position in elevation of the roof portion being considered. A suitable temporary roof is required. The waterproofing capability of the temporary roof must be checked accurately prior to start any other operation on the church roof. Before undertaking interventions No. 3 and 4, a suitable propping system must be implemented. In this respect, a truss repaired with a glued prosthesis must be kept unloaded for at least 7-10 days. The four interventions are described below.*

- 1. Intervention on the roof cover. This intervention includes: removal of bitumen and lead sheets; check of the boards; replacement of the decayed boards with new boards and drying of possible moist boards to be retained; check of the purlins supporting decayed boards; replacement of the decayed purlins with new purlins and drying of possible moist purlins to be retained; realization of connections between the purlins and the masonry walls at the western side of nave and aisles, at the eastern side of apse and aisles and at the northern and southern sides of transept and aisles (see the Final Report); fastening of pre-drilled stiffening steel tapes to the boards (see the Final Report); laying of the first waterproof vapour barrier, wood laths, phenolic plywood, second waterproof vapour barrier, gutter pipes and flashings, surface lead sheets and protection system (see the Final Report). If the upper layers of the existing roof cover (bitumen and lead sheets) are removed by portions, special attention must be paid to the overlapping zones between new roof and existing roof.*
- 2. Mechanical survey. The survey should be carried out from above after the removal of a roof portion of suitable dimensions and, if necessary, of stones. Not decayed boards and purlins to be removed for enabling the mechanical survey must be catalogued and stored. In fact, the pieces to be retained need to be put back in the same place they were originally. Since the survey can reveal the need for a truss repair using prostheses, the time required for geometrical survey and prosthesis design should be suitably accounted for. Therefore, for example, when the roof above the transept is considered, it is suggested that the wood portions of the four big cantilevers included into the supporting walls, for which a mechanical survey is required, are made available before any other operation. Similarly, when the trusses above the central nave are considered, it is suggested that the two end sections of at least two consecutive trusses are made available before any other operation. In particular, two rectangular roof portions of suitable dimensions should be removed in this case. If the mechanical survey reveals the need for one or more prostheses, the necessary geometrical survey should immediately be carried out in order to enable the prosthesis design. If the repair is not needed, the connections between trusses and masonry walls, where required (see the Final Report), should be made before the complete re-assembling of the roof.*
- 3. Repair of the decayed members. Glued prostheses should be used for repairing the decayed portions of the structural timber members. In particular, on the basis of the available in-situ survey campaign (see the Final Report), prostheses should be provided for: rafters, joints between rafter and tie beam members and king posts. The roof portions above rafters needing repair should be removed. The time required for the geometrical survey and the prosthesis design should suitably be accounted for. At the end of the repairs, the*

*connections between trusses and masonry walls, where required (see the Final Report), should be made before the complete re-assembling of the roof.*

4. *Replacement of totally decayed or broken members with new members. In particular, on the basis of the available in-situ survey campaign (see the Final Report), this intervention concerns entire rafters, tie beams and struts. In one single case, the substitution of the cantilever at one end section of a truss is required. Moreover, in another case, the replacement of the king post is required. Finally, the whole substitution of a truss of the nave is required. The roof portions above rafters needing substitution should be removed. The time required for the geometrical survey and the design of a new member should suitably be accounted for. At the end of the interventions of substitution, the connections between trusses and masonry walls, where required (see the Final Report), should be made before the complete re-assembling of the roof. The trusses located at the west side of the nave and at the eastern side of the apse, which are in contact with the end tympanum walls, need complete and partial (rafter) substitution, respectively. During the survey campaign (see the Final Report) it was not possible to clarify whether the purlins of the western and eastern roof spans bear on these two end trusses or, conversely, on the two tympanum walls. In the former case, the relevant roof portions should necessarily be disassembled. In the latter case, the substitution interventions can be carried out with no roof removal. However, in order to facilitate the operation, the roof removal from these zones could be decided, especially if some of the purlins are decayed and need substitution. In view of the purlin removal, the tympanum walls should be suitably connected to the scaffolding to prevent any rigid out-of-plane rotation. Hence, the scaffolding design should take account of possible lateral loads resulting from the tympanum walls.*

***It must be noted that , according to the particular situations that can be encountered during the works or to particular technical needs, the above interventions might be carried out also in parallel or in a different sequence.***

### **3.4.1 Internal scaffolding**

*The scaffolding is a fundamental and necessary step to create a safe and comfortable plane work for the replacement of the roof. The internal scaffolding must consists of two parts, the scaffolding in the nave and the one in the aisles (Figure 55, Figure 56).*



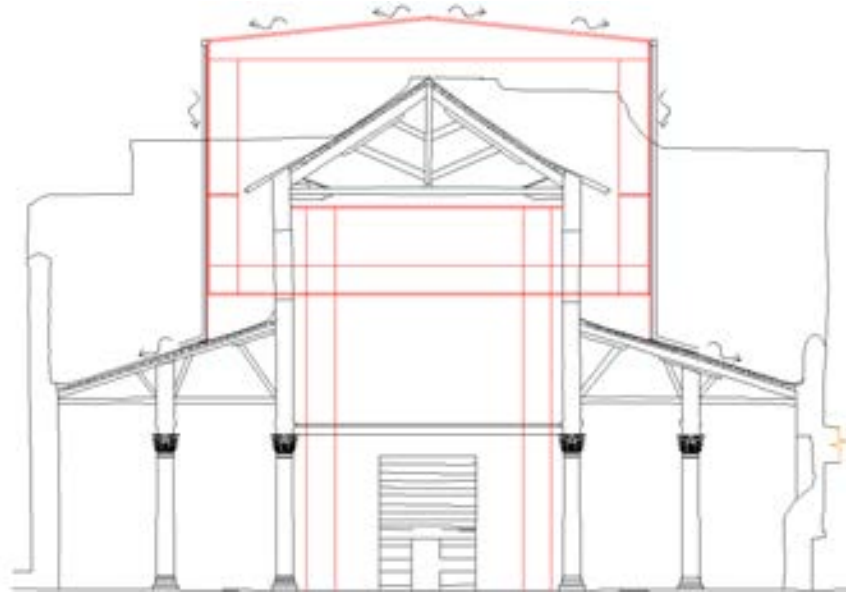


Figure 55: scaffolding in the nave (plus temporary roof)



Figure 56: scaffolding in the aisles

The scaffolding may be provided both on-site and imported from abroad; the use of steel elements is recommended.

Relatively to the support points of the columns, appropriate elements of distribution of the loads (wooden boards with a thickness of 4-5 cm, metal plates, etc..) must be provided. Before the works start the stability of the scaffolding, the flatness of the work plans and the horizontality of the frames must be verified. The bases of the supports should be adjustable to allow the necessary compensations.

*The internal scaffolding may be built in two phases: phase 1 (nave and aisles), phase 2 (apse, transept and corners) (Figure 57) and must be positioned with a gap from the work areas not exceeding 20 cm (alternatively equipped with railings at least 1.00m high).*

*Particular attention must be paid to the danger of material falling from above; for the work plans at the window level, adequate protection systems must be foreseen.*

*In assembling, dismantling and transforming the scaffolding collective protection measures must be taken. In any case workers must be provided with individual fall protection equipment.*

*In the case of bad weather conditions such as strong wind and / or rain, the external scaffolding must be evacuated. Scaffolding shall however be grounded by cables every 25 m. The manual handling of loads should be minimized.*

*It is absolutely forbidden to go up or down along the elements of scaffolding, appropriate access systems must be used. The access to the scaffolding platforms must be made possible exclusively by the appropriate ladders. It is important and necessary not to overload the scaffolding with deposits and equipment in excess; it is recommended to arrange small temporary storages only for the materials and tools strictly necessary to work; the space occupied by the material must allow the movements and the maneuvers necessary for the progress of the work.*

*It must be pointed out that this scaffolding has to be designed in such a way as to take into account the props that are necessary to repair the trusses and to replace the existing roof cover, i.e.:*

- 1. Props necessary to allow the workers to replace the existing roof cover (bitumen, lead, and, where envisaged to be substituted, boards);*
- 2. Props necessary to allow the interventions on the main trusses (prosthesis and/or replacement of wood elements).*

*A third type may be necessary in the case some columns of the scaffolding, with special attention to the columns that bear propping systems, are located over the grottoes:*

- 3. Props inside the grottoes.*

*The first propping system may be located in the middle between two trusses, but the Contractor \* will be responsible for its structural stability on the basis of the number of workers and quantity of materials that will be moved on the roof; if necessary, more prop lines (parallel to the main trusses) might be provided.*

*The second group of props will be located in the plane of the trusses that need prosthesis and/or replacement of wood elements.*

*The third group of props may be necessary if important loads are transferred to the grottoes by the scaffolding columns.*

*Furthermore, it is very important to ensure that the stress state induced in the scaffolding elements (beams, columns) and in the contact area between columns and floor and in the underneath grottoes by the load transmitted through the props is safe and does not cause any type of damage to the Church's elements (floor, walls, existing boards and purlins not to be replaced, etc.) and to the grottoes. The contractor should assume that no propping is permitted and that the solution should provide minimal disruption to access for pilgrims into the nave and grotto.*

*Finally the Contractor must keep into account that the scaffolding and the working operations must allow a sufficient flow of pilgrims. The final scaffolding design proposed by the Contractor must be authorized by the Employer's Technical Representatives and by the Churches.*

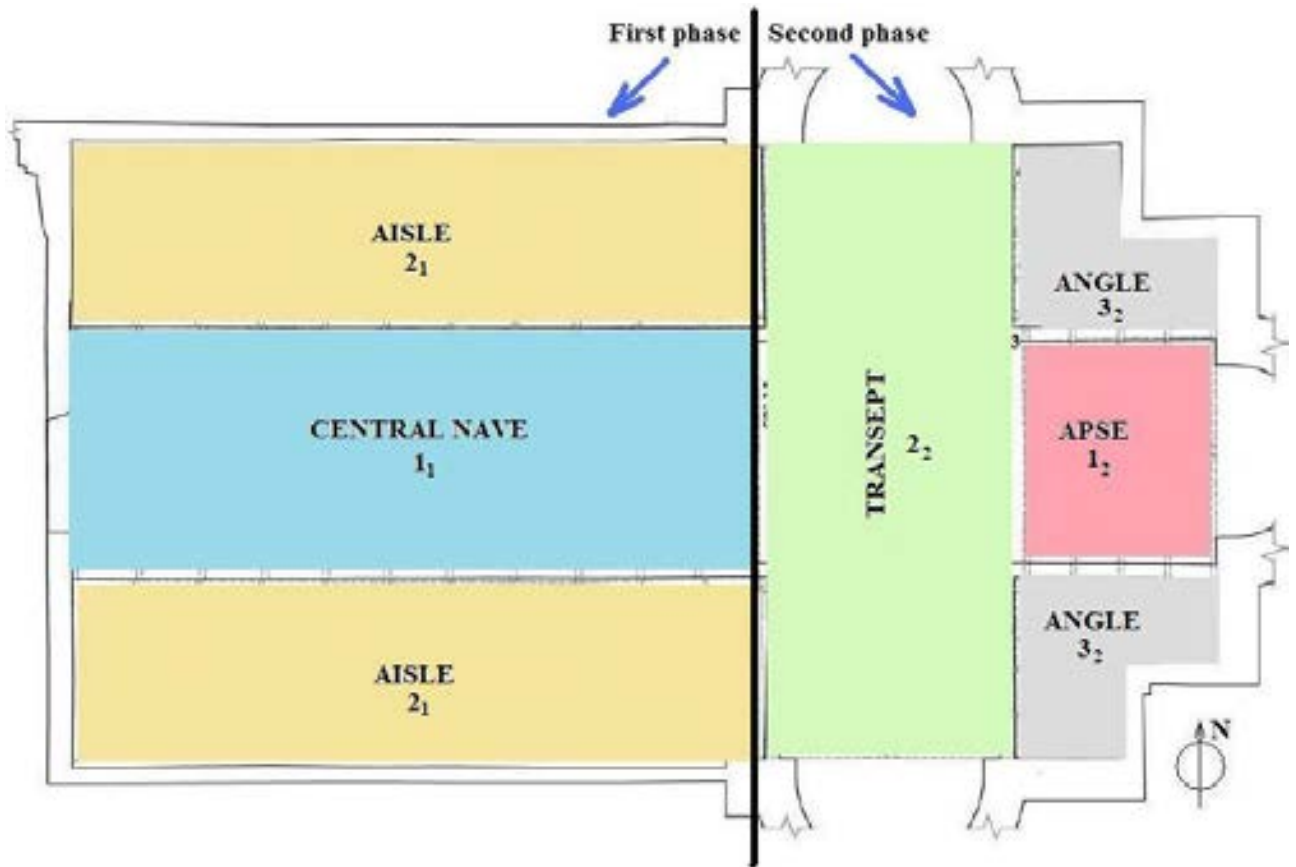


Figure 57: the internal scaffolding may be built in two phases: phase 1(nave and aisles), phase 2 (apse, transept and corners)

After completing the protection works for columns and architraves, the scaffolding started being assembled in the nave and in the first part of the aisles (Figure 58) by leaving a suitable space in the center of the nave for the safe movements of pilgrims and visitors. The scaffolding in the aisles could be easily extended up to the end of the aisles, according to the progress of the works.

The proposed scaffolding consists of two platforms, one at the lower level as an additional protection imposed by the technical safety norms and the other, at the truss level, as a work deck for all works to be done on trusses, purlins and boards.

Figure 59 shows the transverse section of the internal scaffolding needed to work at the truss level. It unloads its own weight and the additional loads due to props, work activities, workers etc. directly on the ground without interacting with the lateral walls in order to avoid any damage to plasters and mosaics. **This will be done for all the other parts of the scaffolding.** The base of the metallic piers was enlarged by means of proper wooden pieces so as to have a more uniform distribution of the loads on the floor and to avoid the occurrence of cracks in the floor tiles (Figure 60). **The same will be done in all other parts of the scaffolding still to be built.** Figure 61 shows further details of the internal scaffolding in the nave.





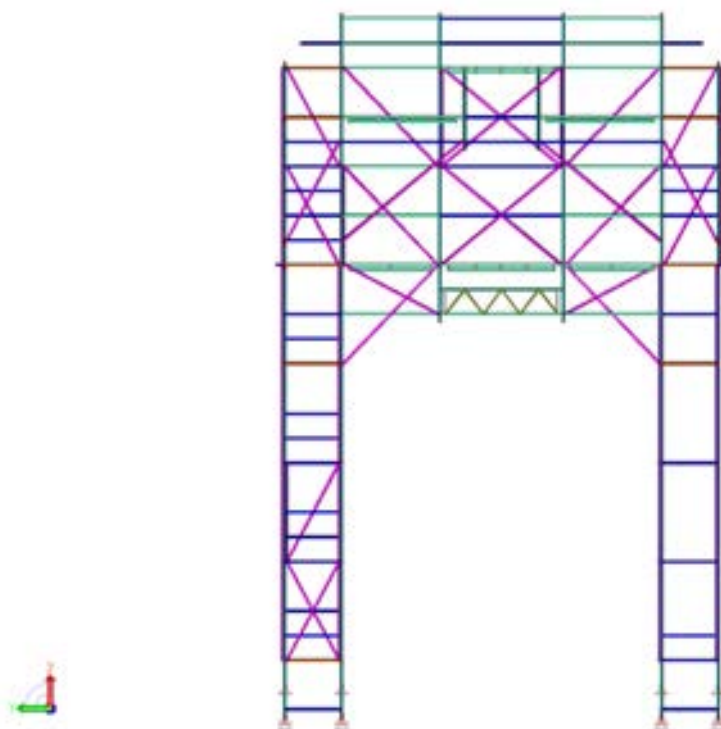


Figure 59: the internal scaffolding to work at the truss level



Figure 60: enlargement at the base of the scaffolding

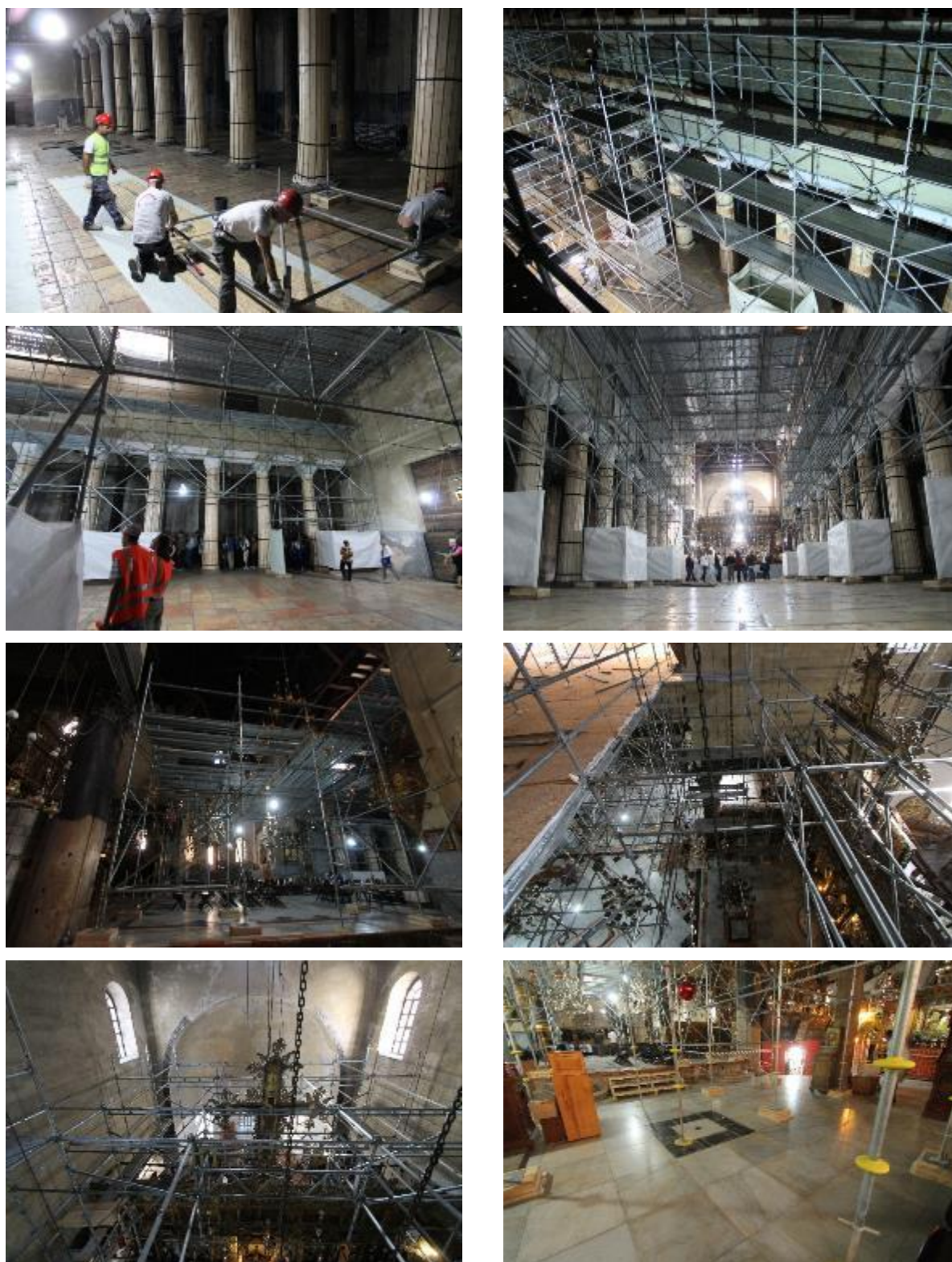


Figure 61: details of the internal scaffolding in the nave



The internal scaffolding was then built also in the transept and in the apse (Figure 62, Figure 63) by following the same criteria and by using the same precautions as for the one in the nave. In this case, more than in the nave, particular care was paid not only in avoiding the areas with grottoes but also in positioning the piers sufficiently distant from the perimeter of the grottoes so as to avoid any harmful interaction with them. The top of the wooden iconostasis was protected with wooden boards (Figure 64)

In particular the following items were taken into account:

- no interaction with the walls so as to avoid any damage to plasters and mosaics
- double deck, one for additions protection and the other as work level
- enlargement of the bases of the piers so as to avoid the floor tiles be damaged by high concentrated loads
- proper positioning of the piers so as to avoid the grottoes, in particular the one of the Nativity, and to allow the usual religious services take place regularly
- protection of all decorated surfaces (mosaics, wooden architraves, columns and wooden iconostasis)

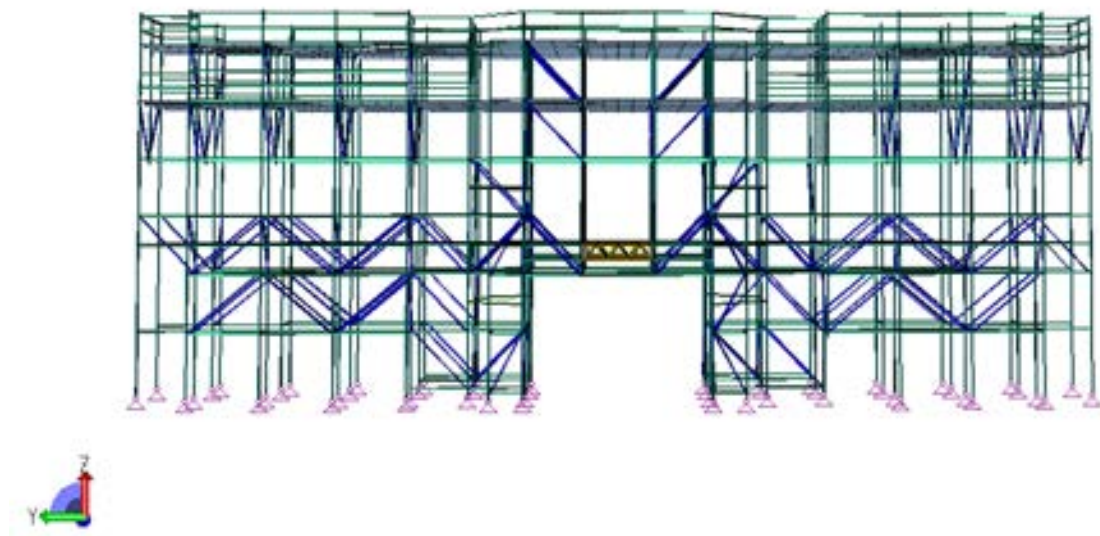


Figure 62: design of the scaffolding in transept

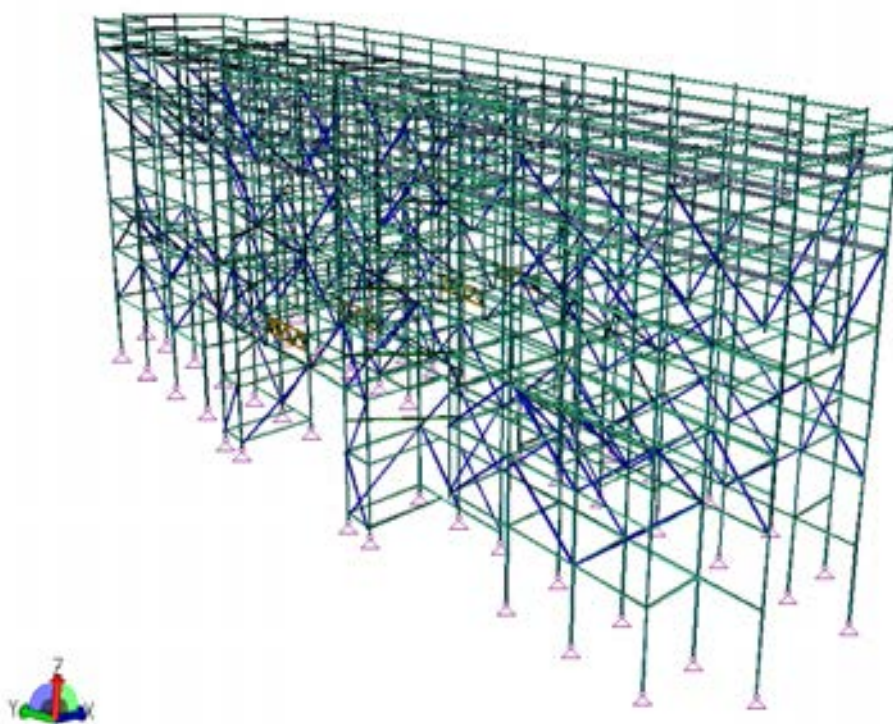


Figure 63: perspective view of the scaffolding in the transept



Figure 64: scaffolding in the central area – double deck and protection of the upper part of the iconostasis

### **3.4.2 Temporary roof for nave, aisles and corners**

*A temporary roof covering is necessary to all works which must be carried out to restore the roof wooden trusses and to replace the waterproofing layer safely and in the absolute assurance that rainwater cannot infiltrate during the restoration works.*

*The temporary roof covering must be integrated with the system of the internal scaffolding without causing harmful interferences.*

*It is not possible to start working on the roof before the temporary roof covering has been completed and the drainage system of rainwater has been checked.*

*As for the temporary roofing material, proper, certified plastic sheets must be used, such as to avoid the following drawbacks:*

- *tearing of the fabric;*
- *deterioration due to climatic conditions,*
- *loss of seal and continuity.*

*In the case of sheets an adequate support layer must be foreseen so as to prevent excessive deformations.*

*In any case, suitable systems of wind resistance have to be adopted, e.g. by turning the sheets on the supports or by controlling the coupling between metal sheet and substructure.*

*The temporary horizontal and vertical gutters for the rainwater drainage may be made of plastic or metal and must be adequately secured to the scaffolding so as not to lose the right conformation.*

*The support system of the temporary covering must consist of cantilevers which protrude from the windows so as to create a beam-column system (scaffolding frame) on which the temporary covering of the nave is built (Figure 54).*

*At the intersection between the nave and transept there will be the diagonal gutters for the rainwater drainage .*

*The rainwater is collected by horizontal gutters which convey the water towards vertical gutters on the aisle. Flexible terminations are recommended in order not to burden on the aisle.*

*Such a solution is not viable for the small areas at the angles between transept and apse due to the lack of windows and, hence, to the impossibility to build a cantilever structure. Other proper solutions will be provided for such specific cases.*

*The scaffolding system should be able to pass through the windows. Appropriate measures have to be taken to avoid to damage the wall surfaces which might hide fragments of mosaics.*

*It is necessary to protect even the vertical surface of the structure with plastic sheets which should turn round above the aisle in order to guarantee a secure protection against heavy rain and possible sandstorms.*

*In order to further protect the aisles it is recommended to build, just in this Step, also the covers of the aisles and of the angles between the transept and apse.*

*As for the **aisles**, the temporary cover makes use of the scaffolding built in the inner courtyards on either sides of the aisles and of an external support protruding from the windows of the nave. The system consists of a frame of beams and columns (scaffolding frame) on which the temporary covering of the aisles is built.*

*The rainwater is collected in horizontal gutters which, in turn, convey the water towards the inner courtyards by means of vertical gutters or adequate pipelines predisposed for the water drainage. Flexible terminations are recommended in order not to burden on pavement.*

*It is necessary to protect carefully the points of passage of the scaffolding system through the windows.*

*It is necessary to protect even the vertical surface of the structure with plastic sheets which should turn round on the walls in order to guarantee a secure protection against heavy rain and possible sandstorms.*

*These turning round parts of the temporary structure must also be extended below the overhang of the roof of the nave and transept.*

*In the **corners** two options are possible: The choice is in charge of the Contractor that will pursue the one that will take less time.*

*First option: The temporary roof covering the Corners during the works on the Central Nave's roof is kept. The replacement of the roof in the Corner is carried out from the border line going towards the windows. The last strip of roof can be completed after removing the above said scaffolding.*

*Second option: The replacement of the roof on the Corners is to be replaced without temporary roof.*

*Comment: it is not possible to establish a priori which option minimizes the time in which the working area remains without temporary roof; it strongly depends on the Contractor.*

The temporary roof, as built by following the given recommendations given, is supported partly by the internal scaffolding and partly by the roof of the Franciscan cloister (North side) and the wall confining with the Armenian garden (South side) (from Figure 65 to Figure 68) by means of additional truss structures which are used also as temporary roof for the aisles. In this way, as happens with the internal scaffolding, there is no harmful interaction with the walls of the nave, and in particular with plasters and mosaics. In Figure 69 - Figure 71 further images of the internal scaffolding and of temporary roof. It is worth noting that the temporary roof in the remaining part of nave and aisles, as well as in the transept, apse and corners has not been built because the works in these areas are carried out in Spring and Summer when there are no rainfalls. Nevertheless, some precautions have been taken in the case of some exceptional event.



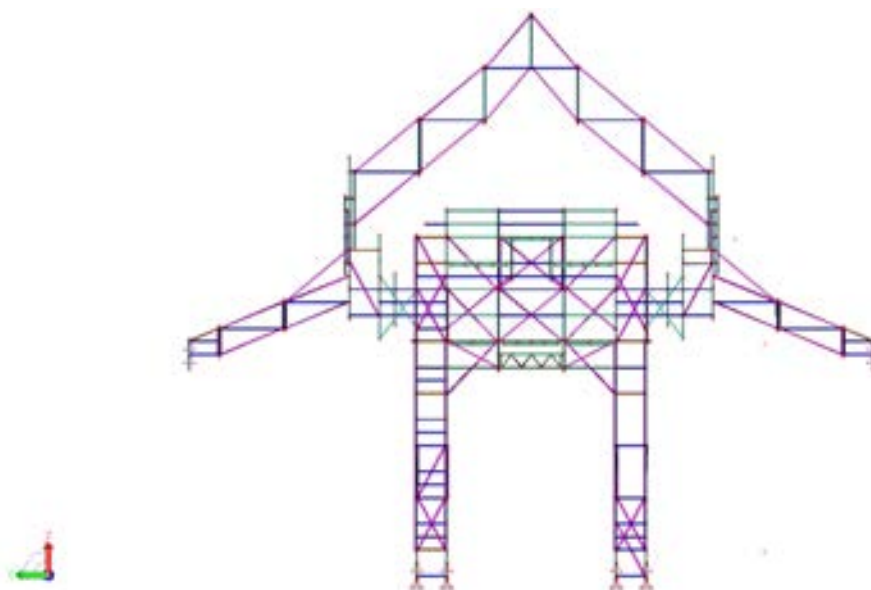


Figure 65: transverse section of internal scaffolding in the nave and temporary roof

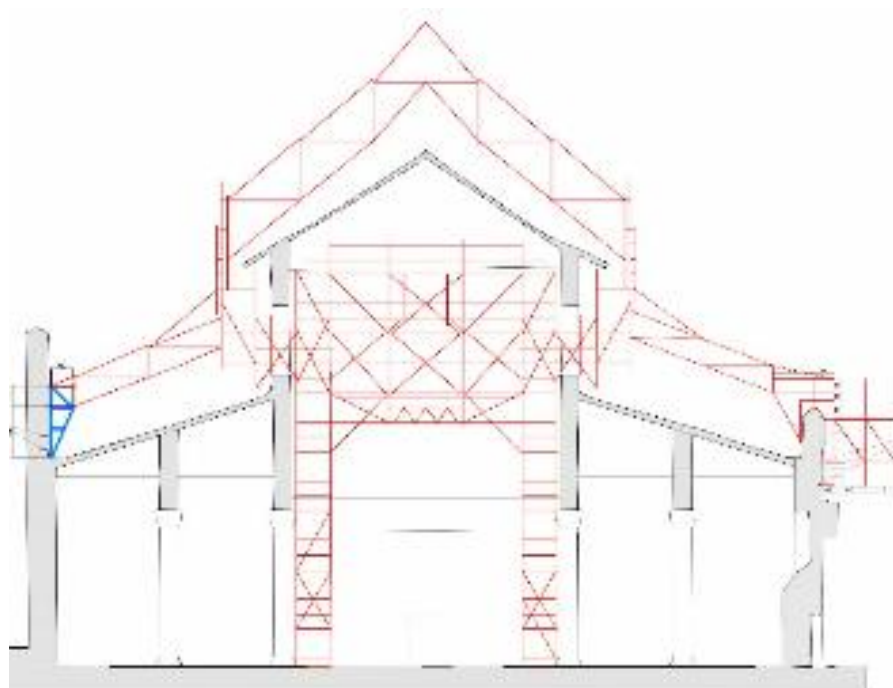


Figure 66: transverse section of the whole scaffolding in the nave and of the temporary roof



Figure 67: temporary roof above the North aisle (Franciscan side)



Figure 68: temporary roof above the South aisle (Armenian side)



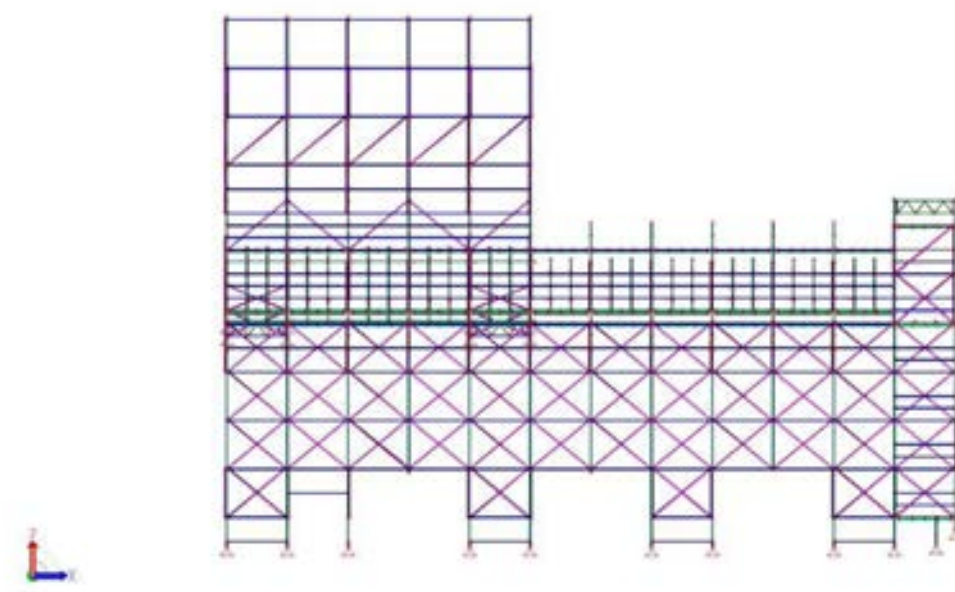


Figure 69: longitudinal section of the designed internal scaffolding in the nave and temporary roof

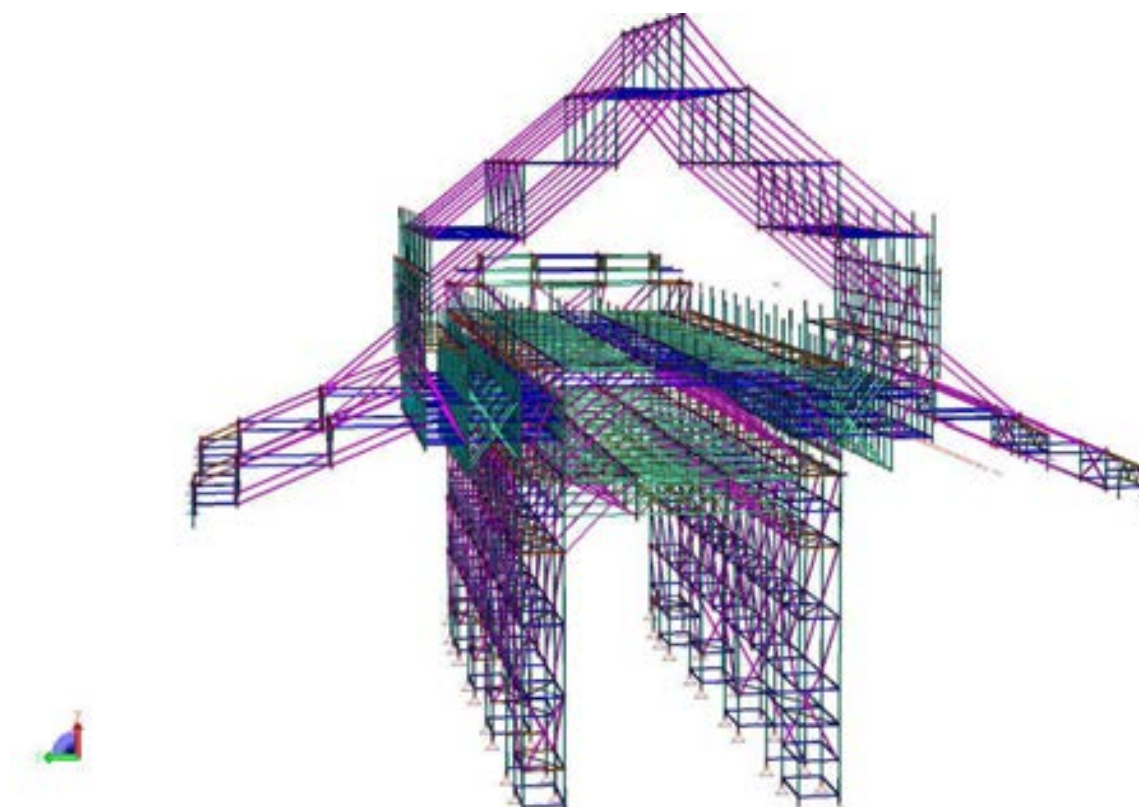


Figure 70: perspective view of the designed scaffolding in the nave and temporary roof



Figure 71: images of the temporary roof



### 3.4.3 Survey and repair of trusses, purlins, boards and big cantilevers

*This Section describes the main activities to be carried in repairing the head trusses, by means of wooden prostheses and the insertion of connecting steel bars, and in replacing decayed/unsuitable elements.*

*The interventions on old timber structures cannot be easily codified, owing to the large variety of circumstances that can occur in real cases. Therefore, the approach chosen in present description is to hypothesize several alternatives for the repair works, in the attempt to include the various reasonable possibilities that actually may arise.*

*It is responsibility of the Employer's Technical Representatives to identify the correct procedure among the various described in the following Chapters, or to correctly adapt one of them to the specific case considered, in a way that the same general principles can still apply.*

**It is mandatory that all interventions (both of repair and of element substitutions) must be carried out by wood carpenters, with specific experience related to wood structures.**

#### 3.4.3.1 Trusses

##### 3.4.3.1.1 Geometrical measurements to be taken before starting the interventions

###### a) Substitution of the whole element

*In the case of substitution of the whole element (e.g., a whole rafter or tie-beam), geometrical measurements (base, height and eventual wanes) have to be taken as closer as possible to the nearby elements: for instance, in the case of a rafter substitution, measurements must be taken both at the rafter-king post and rafter-tie beam joints, as close as possible to king-post and tie-beam, respectively. This kind of measurements has to be taken perpendicularly to the geometrical axis of the element.*

**Furthermore, considering that the diagnostic survey did not allow to take measurements inside the various joints, great attention must be paid to the geometrical survey of the joint areas. For instance, the presence of internal barefaced tenons must be regarded after removing the element or the part of the element to be substituted, and geometrical measurements must be carefully taken, thus to reproduce in the new timber element or in the new portion the same configuration as the original one.**

**Analogously, the same inclination of contact planes in the joint area has to be reproduced also in the new elements.**

**Where original nails are present, their exact position must be surveyed. This allows to reproduce also in the new element the existing holes.** Where the Employer's Technical Representatives considers it necessary or useful, a pre-drill in the new oak element can be executed. In that case, the Employer's Technical Representatives must be aware that the pre-drill diameter must be lower than the nail section.

**For the activities related to present point, the Employer's Technical Representatives must involve both the Archaeologist and the Structural Engineer.**

###### b) Repair of decayed beam-heads

*In the case of substitution of decayed beam-heads by prostheses, geometrical measurements (base, height and eventual wanes) have to be taken close to the cut area, that is, the area closest to the wall where sound wood (or an acceptable level of sound wood) was found according to the diagnostic survey. This kind of measurements has to be taken perpendicularly to the geometrical axis of the element.*

*Furthermore, considering that the diagnostic survey did not allow to take measurements inside the various joints to be repaired, great attention must be paid to the geometrical survey of the joint area. For instance, the presence of internal barefaced tenons must be regarded after removing the decayed ends, and geometrical measurements must be carefully gathered, thus to reproduce in the new prosthesis the same configuration as the original one. Exception to this general rule is only represented by the case described in clause 4.4.3.1.4.*

*The same inclination of the contact planes in the joint area has to be reproduced also in the new elements.*

*Where original nails are present, their exact position must be surveyed. This allows to reproduce also in the prosthesis the existing holes. Where the Employer's Technical Representatives considers it necessary or useful, a pre-drill in the new prosthesis can be executed. In that case, the Employer's Technical Representatives must be aware that the pre-drill diameter must be lower than the nail section.*

#### **3.4.3.1.2 Interventions of total replacement**

- a. *The truss where the intervention is carried out must be properly propped before the removal of the element to be substituted.*
- b. *The wood material for the new elements must be properly selected. The Structural Engineer is responsible for the selection of timber.*

**Rafter substitution.** *For the activities described in present item, the Employer's Technical Representatives must also involve in his decisions the Archaeologist for points (c), (d), (f), (g), (i).*

- c. *When a rafter has to be substituted, roof external layers (e.g. lead), boarding and purlins must be removed along the whole length of the element to be removed. Removals concern all boarding and purlins from the preceding truss to the subsequent one.*
- d. **Boarding and purlins must be adequately renumbered and their orientation registered in order to put them back in the same position after the rafter substitution.**
- e. **Stones of the walls have to be removed from the rafter support area in a way that only the strictly necessary quantity of material is taken out.**
- f. **Original nails between purlins and the rafter to be substituted should be recovered.** *If this is not possible, long screws must be used in the place of the broken nails. In such a case, it is better to pre-drill the rafter, in order to prevent breaking the screw owing to excessive torsion. The pre-drill diameter must be lower than the screw section.*
- g. **Original nails between sleepers and the rafter to be substituted should be recovered.** *If this is not possible, the Employer's Technical Representatives has to consider the possibility of using connecting rods (such as bolts or even glued-in rods) to substitute the broken nails. If glued-in rods are chosen, the same existing holes in the sleepers can be used. On the contrary, if bolts are chosen, a new hole in the sleepers and, of course, in the rafter must be executed.*
- h. **Original nails between tie-beam and the rafter to be substituted (also including those used for the external iron passive bands, i.e., the external iron fasteners) should be recovered.** *If this not possible, the Employer's Technical Representatives has to consider the possibility of using connecting rods (such as bolts, or even glued-in rods) to substitute the broken nails. New holes in the tie-beam and,*

of course, in the rafter must be executed. Screws of suitable size can be used for the external iron passive bands.

- i. **Great attention must be paid to the junctions between rafter and the nearby elements (king-post, sleepers, reverse cantilever, tie-beam). A geometrical survey must be carried out, thus to reproduce also in the new element the original joints.**
- j. After the new rafter has been inserted, all connections with the other elements of the truss and with purlins must be secured before removing the propping. If glued-in rods are used, it is necessary to wait at least one week before removing the propping.

**Tie-beam substitution. For the activities described in present item, the Employer's Technical Representatives must also involve in his decisions the Archaeologist for points (l), (n), (p), (q).**

- k. When the tie-beam has to be substituted, also the lateral elements connected to it must be adequately propped.
- l. Stones of the walls have to be removed from tie-beam support areas on both sides in a way that only the strictly necessary quantity of material is taken out.
- m. Great attention must be paid to the junction between tie-beam and king-post, which are connected by means of a dovetail-type joint. **In such a case, a geometrical survey must be carried out, thus to reproduce also in the new element the original joint.**
- n. Great attention must be paid on the eventual junction between tie-beam and supporting cantilever. **In such a case, a geometrical survey must be carried out, thus to reproduce also in the new element the original joint.**
- o. The connection between the supporting cantilevers and each walls must be kept working during the works, or it must go back to work only after the tie-beam substitution.
- p. Great attention must be paid to the presence of a wedge (usually a "reverse cantilever") between tie-beam and rafter. **In such a case, if a joint is detected after dismantling the elements, a geometrical survey must be carried out, thus to reproduce also in the new element the original joint.**
- q. Original nails between rafter and the tie-beam to be substituted (also including those used for the external iron passive bands, i.e., the external iron fasteners) should be recovered. If this is not possible, the Employer's Technical Representatives has to consider the possibility of using connecting rods (such as bolts, or even glued-in rods) to substitute the broken nails. New holes in the rafter and, of course, in the tie-beam must be executed. Screws of suitable size can be used for the external iron passive bands.
- r. After the new tie-beam has been inserted, all connections with the other elements of the truss must be secured before removing the propping. If glued-in rods are used (see above), it is necessary to wait at least one week before removing the propping.

#### **Prescriptions for both elements:**

- a. **After the insertion of the new element (either a rafter or a tie-beam), if eventual limited errors in the preparation of joints have been made (e.g., in the shape or dimensions of barefaced tenons, or a slightly different inclination of cuts), they have to be adjusted preferably with the element**

*already placed in its final position. However, this occurrence will strongly depend on the type of error, and the choice is under the responsibility of the Employer's Technical Representatives .*

- b. *After the insertion of the new element (either a rafter or a tie-beam), the stones removed from the walls must be put back into the original position. However, an adequate space between lateral and upper wood surfaces and the stones must be provided. A space of 1-2 cm can be considered as adequate; nonetheless, the effective amount of space must be a choice of the Employer's Technical Representatives . To such a purpose, a cork sheet can be used to wrap the wood surfaces. Alternatively, the space can be filled with bricks applied dry, that is, without using mortars or similar. However, in such a case the Employer's Technical Representatives has to be aware that these bricks must not be visible from the outside of the Church. **After the intervention the bricks can be plastered only in correspondence of the internal surface of the walls. Portions of walls which have been re-built must be re-plastered in a way that the new plaster is distanced at least 1 cm from the wood surfaces. This can be ensured, for instance, by using thin wood laths.***

#### 3.4.3.1.3 Interventions where the decayed end-beams are repaired with prostheses

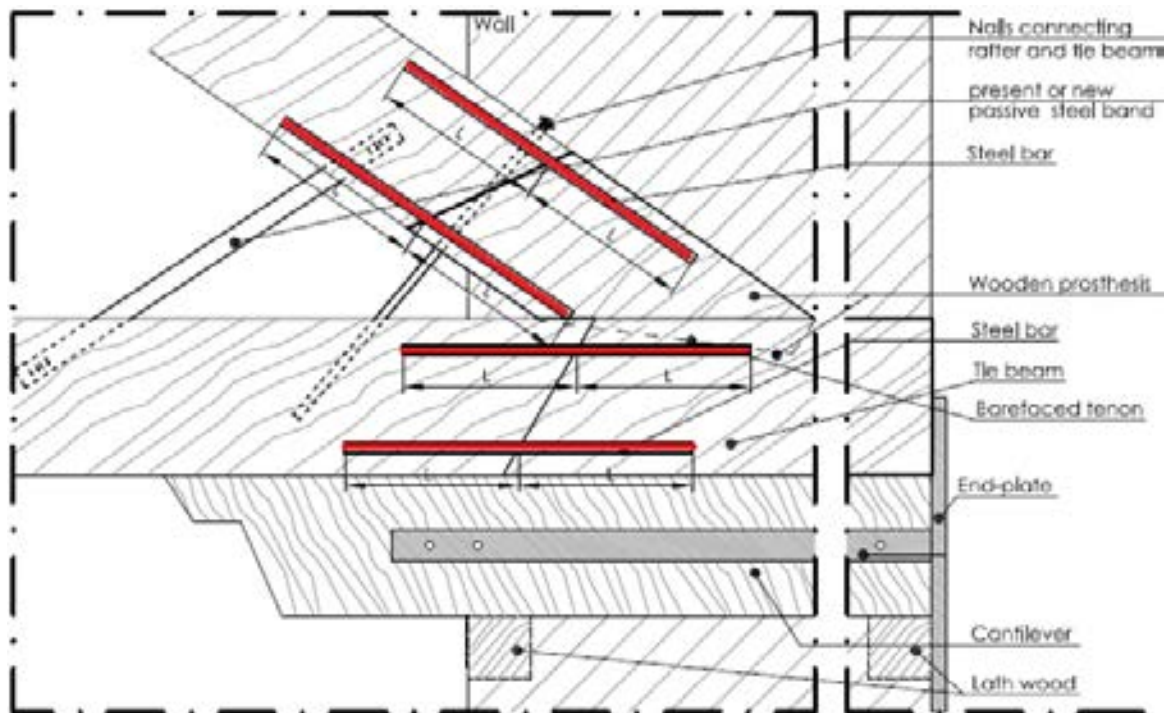


Figure 72: example of prosthesis in a node rafter-tie beam

#### Prerequisites:

*This action will be carried out after the scaffolding has been completed, and after the related part of the roof has been removed. Only the diagnostic analysis from the upper side will be carried out.*

*Personnel must be competent on both structural timber diagnosis and resistographic analyses.*

*This point previews the performing of a specialist analysis of wood degradation through resistographic drillings.*



*Resistographic driller having a needle at least 40 cm long: the complete cross section must be investigated.*

*Inspection phases:*

- 1. Inspection must be performed on both the ends of trusses;*
- 2. End of trusses must be visible from above through the removal of the relevant portion of the covering. From above it will be possible to inspect the extrados of the rafter.*
- 3. When the portion of wood is visible some measurements must be taken: free space between wall and wooden elements; dimensions and distance from the end of the connection joint between rafter and tie beam, length of the tie beam support on the wall.*
- 4. Measurement of wood moisture content of rafter through a wood hygrometer. Moisture content is to be measured according to the European standard EN 13183:2003 Part 2 and 3.*
- 5. Perform resistographic drillings according to the following scheme:*
  - 5.1. two vertical (perpendicular to the tie beam) drillings on the section 10 cm from the inner wall. The two drillings must be 10 cm distant from each other;*
  - 5.2. two vertical drillings as in the previous point, but on the section 10 cm from the external wall;*
  - 5.3. two vertical drillings as for the previous two points, but on the section exactly in the middle of the wall.*
- 6. The analysis of the results must concentrate on the observation of the section relevant to the tie beam: rafters and cantilevers have already been surveyed. Always compare the results to what has already been reported on the Final Report, in particular to what is reported about rafters and cantilevers.*
- 7. The obtained results must be graphically uniform to the specific part of the Final Report of the diagnostic phase. More specifically the presence of possible decay must be reported in decay classes: 0-25% / 25 – 50% / 50 – 75% / 75-100% (percentage of cross section covered by decay)*

**Intervention phases:**

- a. The truss where the intervention is carried out must be properly propped before cutting the decayed parts to be substituted.*
- b. The wood for the prosthesis must be properly selected as detailed. If oak wood of desired size and of moisture content equal or lower than 15% is not available, a laminated prosthesis made onsite by gluing thick oak boards of suitable m.c. must be executed. The Structural Engineer is responsible for the selection of timber.*

**Repair of rafters. For the activities described in present item, the Employer's Technical Representatives must also involve in his decisions the Structural Engineer for points (c), (d), (f), (g), (i).**

- c. When a rafter must be repaired, purlins must be removed from the walls up to at least 0.5 m far from the section where the cut must be executed. Removal of roof external layers (e.g. lead) and boarding is not necessary if the safe removal of purlins only is possible (for instance, this is not possible if boarding collapses after removing the purlins). Removals concern all boarding (if needed) and purlins from the preceding truss to the subsequent one.*
- d. Purlins and eventually boarding must be adequately re-numbered and their orientation registered in order to put them back in the same position after the rafter substitution.*

- e. ***Stones of the walls have to be removed from the rafter support in a way that only the strictly necessary quantity of material is taken out. The Employer's Technical Representatives must be aware that an adequate space must be ensured to take the decayed part out and to insert the new prosthesis. Both removal and insertion are normally carried out laterally.***
- f. ***Original nails between purlins and the rafter to be repaired should be recovered. If this is not possible, long screws must be used in the place of the broken nails. In such a case, it is better to pre-drill the prosthesis, in order to prevent breaking the screw owing to excessive torsion. The pre-drill diameter must be lower than the screw section.***
- g. ***Original nails between tie-beam and the rafter to be substituted (also included those used for the external iron passive bands, i.e., the external iron fasteners) should be recovered. If this not possible, the Employer's Technical Representatives has to consider the possibility of using connecting rods (such as bolts, or even glued-in rods) to substitute the broken nails. New holes in the tie-beam and, of course, in the prosthesis must be executed. Screws of suitable size can be used for the external iron passive bands.***
- h. ***The cut to remove the decayed part must be executed as close to supporting walls as possible, provided that a sound section of wood has been evidenced after the diagnostic survey. As an alternative, the cut must affect an acceptable portion of sound wood. A typical example of this "acceptable portion of sound wood" is represented by 75%; however, only a static analysis can confirm this statement.***
- i. ***Great attention must be paid to the junction between rafter and the tie-beam (or between rafter and the wedge, where present). A geometrical survey must be carried out, thus to reproduce also in the prosthesis the original joint.***

**Repair of tie-beams. For the activities described in present item, the Employer's Technical Representatives must also involve in his decisions the Structural Engineer for point (k), (m), (o), (p).**

- j. ***When a tie-beam has to be repaired, stones of the walls have to be removed from the support areas support in a way that only the strictly necessary quantity of material is taken out.***
- k. ***Great attention must be paid to the eventual junction between tie-beam and supporting cantilever. In such a case, a geometrical survey must be carried out, thus to reproduce also in the prosthesis the original joint.***
- l. ***The connection between the supporting cantilever and the wall must be kept working during the works, or it must go back to work only after the tie-beam repair.***
- m. ***Original nails between rafter and the tie-beam to be repaired (also including those used for the external iron passive bands) must be recovered. If this is not possible, the Employer's Technical Representatives has to consider the possibility of using connecting rods (such as bolts, or even glued-in rods) to substitute the broken nails. New holes in the rafter and, of course, in the prosthesis must be executed. Screws of suitable size can be used for the external iron passive bands.***
- n. ***The cut to remove the decayed part must be executed as close to supporting walls as possible, provided that a sound section of wood has been evidenced after the diagnostic survey. As an alternative, the cut must affect an acceptable portion of sound wood. A typical example of this "acceptable portion of sound wood" is represented by 75%; however, only a static analysis can confirm this statement.***
- o. ***After removing the decayed part, great attention must be paid to the junction between tie-beam and the rafter. A geometrical survey, according to the principles described in clause Error! eference source not found., must be carried out, thus to reproduce also in the prosthesis the original joint.***

- p. *If a wedge (usually a “reverse cantilever”) is present between tie-beam and rafter, the presence of eventual internal joints must be carefully investigated after removing the decayed part. A geometrical survey, according to the principles previously described, must be carried out, thus to reproduce also in the prosthesis the original joint.*

**Prescriptions for both elements. For the activities described in present item, the Employer's Technical Representatives must also involve in his decisions the Structural Engineer for points (r), (s), (u), (x).**

- q. *The procedures reported in following points apply to both rafter and tie-beam prostheses.*
- r. *If an inclined cut is requested after the proper design of the prosthesis, the inclination must be considered with respect to the geometrical axis of the rafter.*
- s. *The same inclination of the cut must be ensured also for the prosthesis. It is highly important that the contact between the prosthesis and the original beam is ensured along the whole cut section. To such a purpose, the two pieces must be put in close contact to one another in order to verify the good contact, and whether they are well aligned along the geometrical axis of the original element.*
- t. *The prosthesis has to be placed in its final position before making the lateral slots for the insertion of the connecting rods. If holes are chosen instead of lateral slots for hosting the rods, it may be convenient that such holes are made on the original element before positioning the prosthesis. However, this will be a choice of the Employer's Technical Representatives . The prosthesis can be blocked to the original part of the element by means of nailed small boards or similar.*
- u. *The connecting rods must fulfil the requirements specified above.*
- v. *The adhesive for gluing-in the connecting rods must fulfil the requirements described above.*
- w. *The tools used to make the slots or the holes must be well sharpened and their rotational speed must be selected so as to avoid any localised wood burning during cutting.*
- x. *The general procedures to connect the new prosthesis to the sound part of the original beam have been described in the Report.*
- y. *After the prosthesis has been placed in its final position, it is necessary to wait at least one week before removing the propping. Moreover, all connections with the other elements (e.g., with purlins) must be secured before removing the propping.*
- z. ***After the insertion of the prosthesis, the stones removed from the walls must be put back into their original position. However, an adequate space between lateral and upper wood surfaces and the stones must be provided.*** A space of 1-2 cm can be considered as adequate; nonetheless, the effective amount of space must be a choice of the Employer's Technical Representatives . To such a purpose, a cork sheet can be used to wrap the wood surfaces. Alternatively, the space can be filled with bricks applied dry, that is, without using mortars or similar. However, in such a case the Employer's Technical Representatives has to be aware that these bricks must not be visible from the outside of the Church. ***After the intervention the bricks can be plastered only in correspondence of the internal surface of the walls. Portions of walls which have been re-built must be re-plastered in a way that the new plaster is distanced at least 1 cm from the wood surfaces. This can be ensured, for instance, by using thin wood laths.***

#### 3.4.3.1.4 Insertion of Z-shaped steel elements in beam-ends to be repaired

- a. *In some trusses, a wedge (usually a “reverse cantilever”) is present between the tie-beam and the rafter.*

- b. *In the interventions where the repair of a tie-beam end is needed or when the whole tie-beam needs to be substituted, if no joint (except for nails) is found between tie-beam and wedge, a new joint between wedge and tie-beam (or between wedge and tie-beam prosthesis) must be put in place.*
- c. *This element must be Z-shaped, and must be made of steel, the characteristics of which must fulfil the requirements detailed above.*
- d. *The example of how put in place this Z-shaped element has been described in the Report. For the activities related to present point, the Employer's Technical Representatives must involve the Structural Engineer.*
- e. *The Z-shaped element must be pre-drilled thus to allow the nails existing between rafter and tie-beam can be re-positioned after the intervention.*
- f. *If it is necessary to apply the Z-shaped element on a tie-beam prosthesis, attention must be paid to the insertion of connecting rods.*

Starting from December 2, 2013 wood experts have been evaluating the current condition of the existing wooden structure supporting the roof; they have also performed several non-destructive tests and direct, visual inspections for central nave, aisles, transept, apse and corners to provide updated information regarding geometry, dimensions, characteristics of connections, wood species, humidity, damages and class of mechanical quality of the wood to prepare the design and shop drawings with respect to the Tender documents. All information, notes, observations and test results are the necessary reference to prepare the design and shop drawings for each truss and for the consolidation of purlins and boards.

This new survey (Figure 73) was necessary because the previous survey had been carried out by the Consortium team only by inspecting the structures from the inside only. Moreover the heads of the trusses could not be inspected because it was not possible, at the time of the inspection, remove plaster and stones around them, so as to check their actual physical conditions. In the end, the rainfalls of the last two years have probably increased the level of damage of many timber elements, which has made it necessary to update the existing survey data.



Figure 73: recent surveys in the roof structure

Every truss has been surveyed according the methodology outlined above and its geometrical configuration has been represented accurately together with all existing metal connections such as nails and bars. The level of damage has been represented by means the usual four ranges previously identified (0-25%, 25-50%, 50-75%,



75-100%) and the causes of damage (insect and fungi attacks, moisture etc.) as well as the most visible irregularities in wood (shrinkage, inflection, sinuosity etc.) detected and declared (Figure 74). Moreover, for each truss member the wooden species and the structural grading were defined.

In most cases the results of the previous surveyed have been confirmed. The majority of the divergent results concern the heads of the trusses, which in the second campaign could be inspected both from inside and outside.

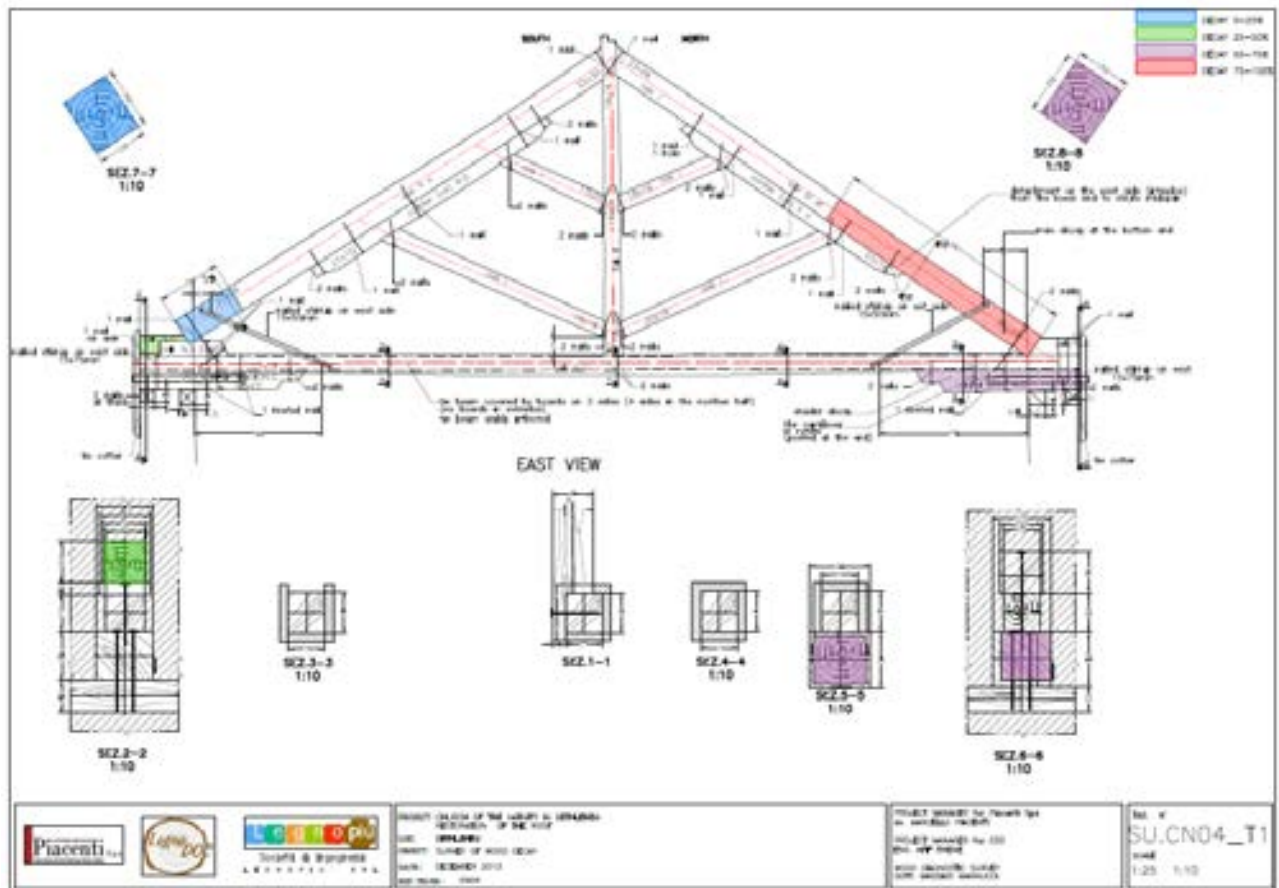


Figure 74: example of truss surveyed (CN04)

For each truss the structural analysis was carried out by taking into account the load conditions prescribed by the current technical regulations and the effects of the surveyed physical damage on the resistant transverse sections. Usually the intervention (either total replacement or prosthesis) (Figure 75) is carried out when the result of the structural analysis confirms the scarce reliability deduced from the surveyed decay. In the case of great uncertainties, for instance when the level of reliability defined by the structural analysis is at the last threshold of admissibility, preference is given to the evaluation based on the onsite inspection. That is justified by the exceptionality of the intervention, the impossibility to intervene in the short term, the risk of a not continuous and planned monitoring of the structures.

The most significant damaged parts of the removed elements have been numbered, referenced and stored in appropriate spaces indicated by the Municipality of Bethlehem in agreement with the three religious Communities waiting for being used in a forthcoming Museum of the Church. Those parts of the removed elements which were still in good conditions have been mostly re-used wherever it has been possible.

The technique used for prosthesis (steel bars and epoxy resins) allows the less waste of existing material and the least amount of new material, a durable resistance over time and it is minimally invasive. All removed elements



have been replaced by wooden elements of the same species. The new elements can be made either of young wood (usually 15 – 20 years old with a moisture percentage higher than 15%) or ancient wood (hundred years old with a moisture percentage lower than 15%). All prosthesis with steel bars and resin (the great majority) are made with ancient wood; only a few prostheses have been made until now with young wood by using mechanical (not glued) joints. The use of ancient wood (nearly as old as most of the wood now present in the Church) guarantees not only a greater material and structural homogeneity within the same truss but also a lower visibility of the intervention (Figure 77, Figure 79).

Most of the existing nails, once removed to allow the intervention, have been either re-used or catalogued and stored (Figure 76).

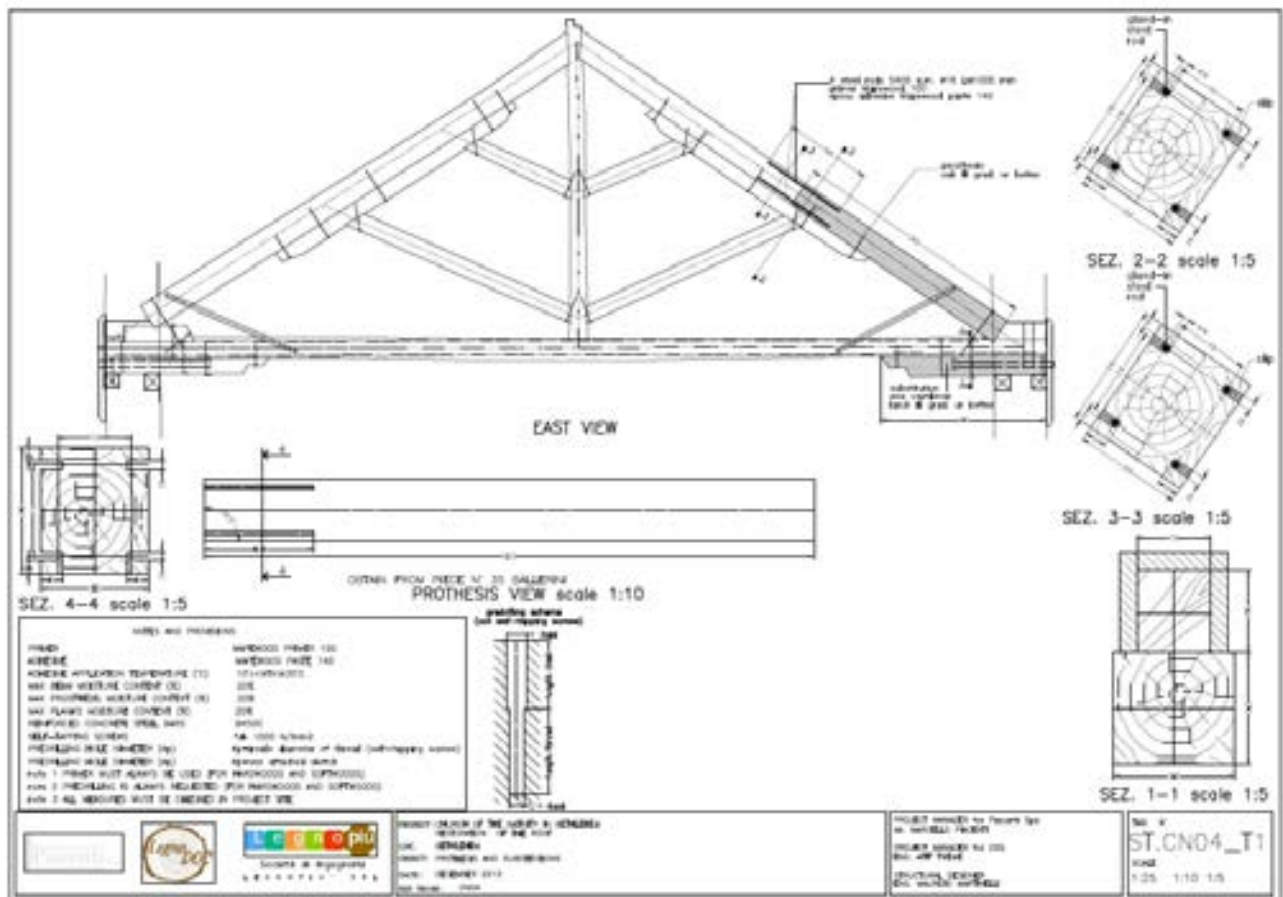


Figure 75: design of intervention of consolidation by prosthesis (in the rafter) and replacement (in the cantilever)



Figure 76: nail catalogued and stored

Figure 77 shows all steps for an intervention of restoration by prosthesis ( in this case on LNN08, a truss of the North aisle). Figure 78, Figure 79 show in detail the grooves to host the steel bars and the intervention by prosthesis already completed.

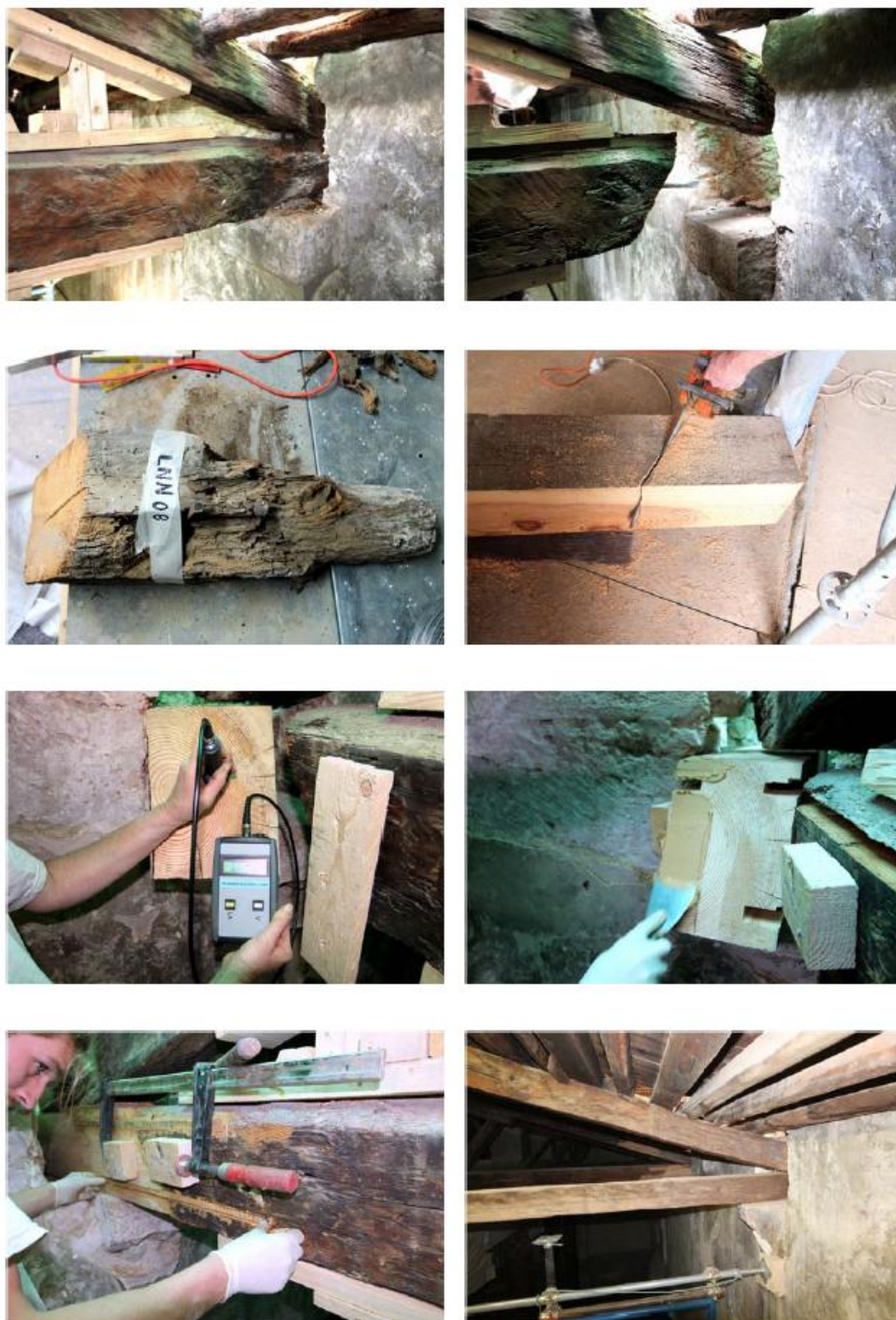


Figure 77 : (from the top – from left to right): damaged tie-beam end, removal of the damage part, damaged part catalogued, cutting of the new part, check of the moisture content, application of epoxy resin on the section of the beam, insertion of bars and resins in the grooves, tie-beam end after the intervention





Figure 78: groove to host the steel bars and resin



Figure 79: prosthesis already finished

In the following (Figure 80) the state of the works in June 2014.

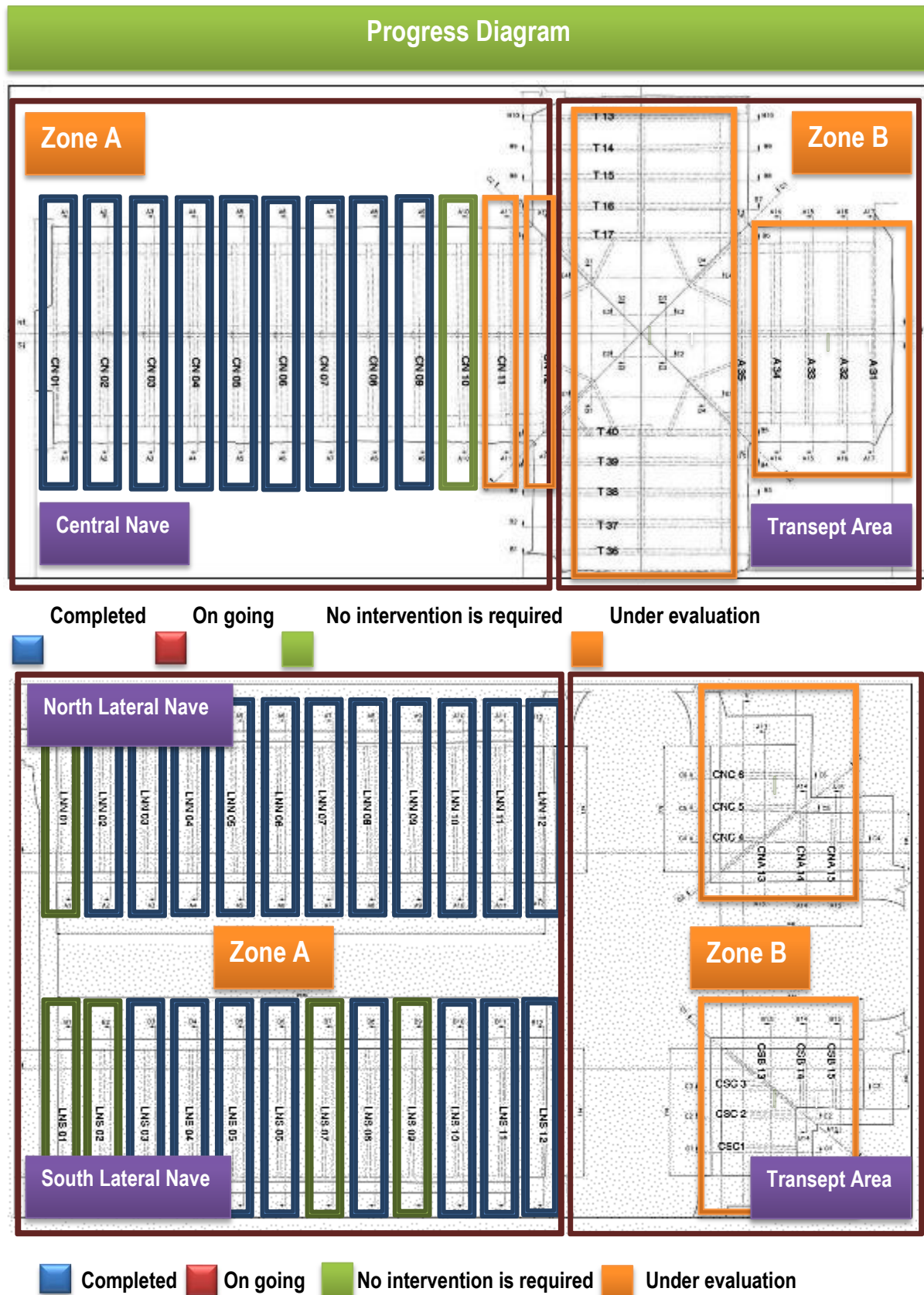


Figure 80: state of the work at the end of June



### 3.4.4 Work sequence for board/purlin and big cantilevers

#### 3.4.4.1 Boards

##### 3.4.4.1.1 Prerequisites

*This action will need the removal of the covering of the roof in order to have access to the extrados of the boards. The Final Report shows, among the results, the state of preservation of the boards, based on the observation of the intrados. The mapping of the decay of boards on the Final Report must be controlled during the inspection. With the present composition of the roof covering and with the actual possibility of water infiltration and condensation damp between wood and metal, the decay is more likely to occur at the intrados of the cover boards.*

**Personnel expert in the evaluation of wood decay must make the necessary observations and selections.**

##### 3.4.4.1.2 Inspection phases

1. Removal of the tar sheet;
2. Removal of the lead sheet;
3. If a board will break during the removal operations of the covering sheets, it means that it must be substituted due to rot decay;
4. Complete access to the extrados of the boards;
5. **Other unexpected materials, found between tar sheets and boards, must be removed after being controlled by a structural Engineer. In this case, archaeologist should be consulted for cataloguing;**
6. The selection of the boards to be replaced must be made through visual and penetrometric analysis. Using a blunt pointed tool, gentle probing is carried out on the external surface to reveal the presence of softened areas;
7. Discolouration due to the attack of wood destroying fungi shall be mentioned and reported;
8. Boards must be considered severely attacked when the testing tool can easily penetrate inside them up to ½ cm;
9. The decay has to be mapped on areas, as for the boards in the Final Report;
10. Decisions concerning substitution must be then taken by comparing the decay mapping on both sides;
11. In order to remove the rotten boards, the nails connecting the boards to the purlins should be pulled out or, alternatively, truncated.

#### 3.4.4.2 Purlins

##### 3.4.4.2.1 Prerequisites

*This action will be made after the analysis of boards. The Final Report shows among the results the analysis of the purlins state of preservation, based on the observation of the intrados. The mapping of the decay of purlins, as reported in the Final Report, must be controlled during the inspection.*

**Personnel expert in the evaluation of wood decay must make the necessary observations and selections.**

#### **3.4.4.2.2 Inspection phases**

1. *As the extrados of purlins is visible only by removing the boards above, purlins will be analysed only when the boards above are rotten and therefore need to be substituted. In particular, if a board is to be substituted, even the purlins below should be substituted, if they were already judged rotten by visual inspection from below (see Final Report).*
2. *The observation of the state of preservation will be made through penetrometric analysis. Using a blunt pointed tool, gentle probing is carried out on the extrados surface to reveal the presence of softened areas. If the tool penetrates more than ¼ of purlin thickness, the purlin must be substituted.*
3. *Pay attention to the purlin conditions at the connections with the tympanum wall. The restoration involves a strong connection between purlins and tympanum walls. Consequently the state of preservation of the purlins must be good. If the penetrometric analysis will show more than 5 mm of decay, the purlin must be substituted.*
4. *The connections between new boards and new or existing purlins should be performed by using screws. The connections between new purlins and trusses should be performed by using screws.*
5. *Any new connection of purlins by screws, whether they already exist or are new, should be made by pre-drilling. In particular, the screws used for connecting the new boards to the existing purlins should not be inserted into already existing holes. If necessary, in order to avoid drilling too close to the purlin free edges, the screws may be inserted obliquely.*

After the removal of the lead sheets, boards and purlins can be inspected even from above. That allows to update not only the map of the damaged purlins and boards but also the level of damage already surveyed. For each area of the roof a more detailed map of damaged purlins and boards has been drawn on the basis of the criteria already given for the selection of the damaged elements (Figure 81, Figure 82). In order to make it easier for the local technicians to distinguish the timber elements to be replaced from those that can be preserved further and more detailed instructions have been given, as reported in the next paragraph.

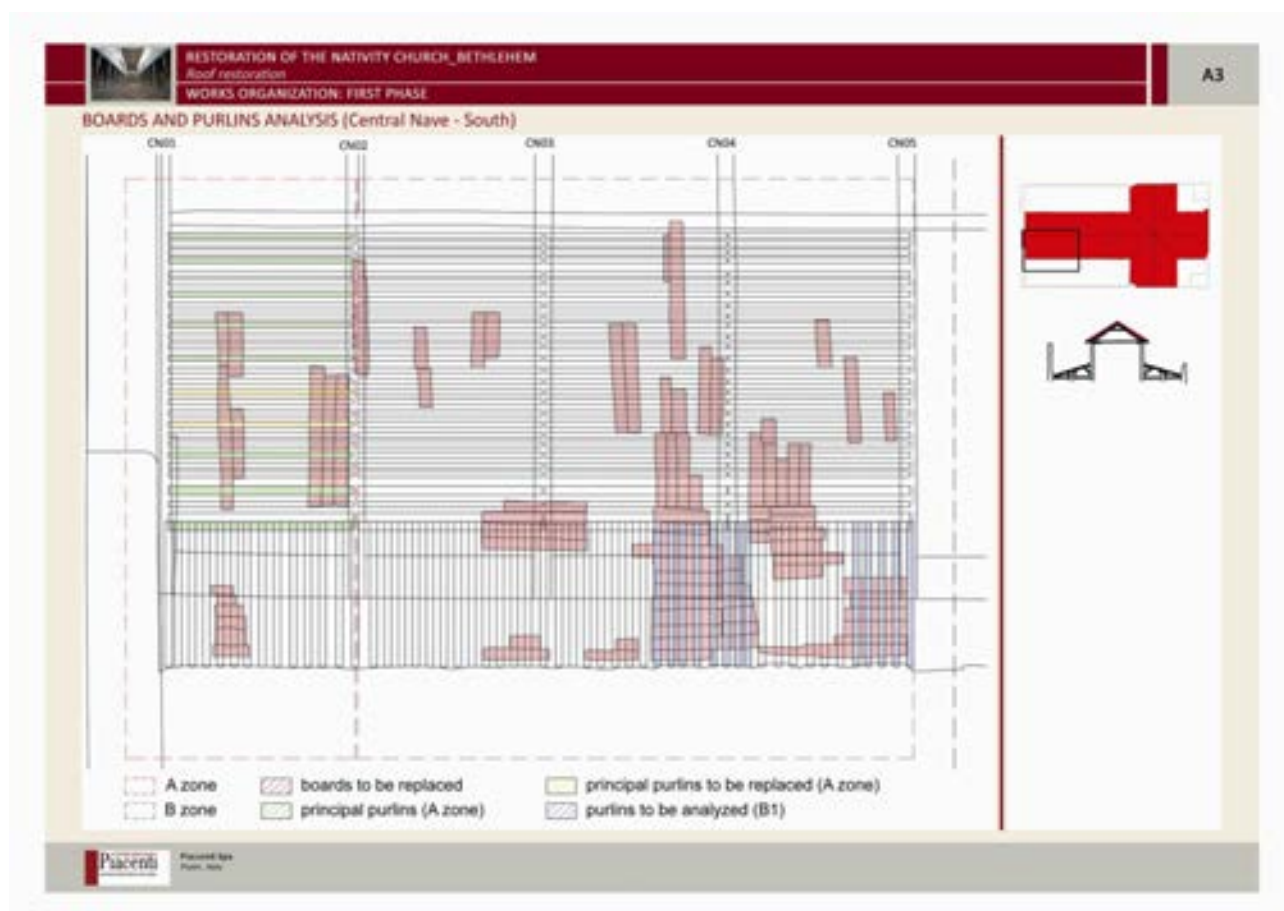


Figure 81: detailed map of purlins and boards to be replaced

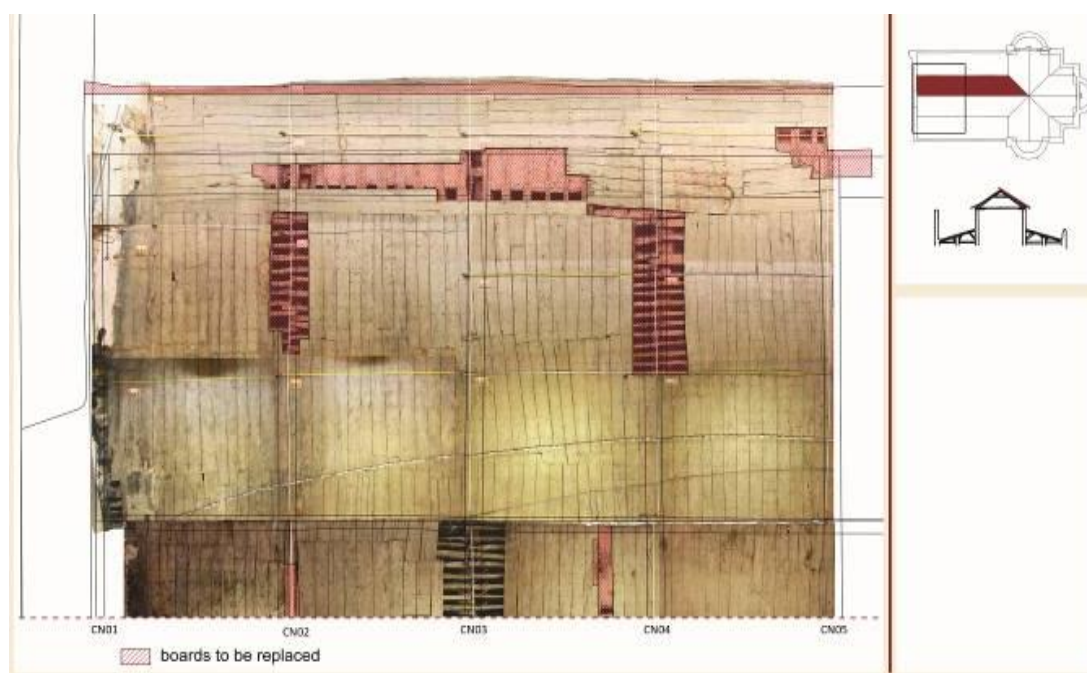


Figure 82: detailed map of boards to be replaced

### **3.4.4.3 Decision flow-chart to establish a criterion for the replacement / acceptance of existing boards and purlins**

The proposed procedure has been prepared, in addition to the guidelines already provided, to take account of all aspects related to both wood technology (including the presence of possible biological decay, shrinkage cracks, wood splitting etc.) and static analysis (including the presence of the reinforcing plywood layer, the planar distribution of stresses, the correct anchorage to tympanum walls etc.) and to provide the local professionals and technicians with simple criteria to make the most suitable choices .

The proposed procedure is reported in the flow-chart in Figure 88.

It is worth to note that this decision procedure has been divided in two parts:

- the first part (on the right in the flow-chart) is related to the majority of boards and purlins, and it is divided in two different levels. The first level of decision is only related to boards, which have to be kept if their surface damage is lower than 50% (Figure 80), in order to allow for an efficient cooperation between the boards and the above plywood layer. A second level of decisions is that one related to the eventual replacement of purlins. Considering the huge number of purlins, this possibility is only considered when the number of biologically decayed boards is higher of 50% in a pitch sector, because this occurrence denotes a possible risky situation for the underneath purlins. In that case a diagnostic analysis on purlins is recommended. Of course, both this latter diagnostic analysis and that one related to board surfaces mentioned above are in charge of LegnoDoc (or, however, of the Contractor) but a detailed report must be provided to CDG for a preliminary approval;



Figure 83: two adjacent boards evidencing a completely different extent of decay (both have been removed from the purlins): the board within the rectangle in red is in an excellent state of preservation and it can be kept without any additional treatment; the board within the oval in green has been attacked by fungi, and it needs to be partially or totally replaced (the decayed surface is >50% of the board surface).

- the second part (on the left in the flow-chart) is related to the spans close to the tympani (that is, when a reliable connection between the tympanum walls and the seismically active plywood/boarding layers must be ensured). In that case the boards close to the purlin supports (that is, the ones at the wall and at the truss) must be always removed, irrespective on the presence of any biological damage in the same boards. Then, the conditions of the purlin supports must be carefully considered. In the photos below (from Figure 84 to Figure 87), made in one of the trusses of the central nave, some examples of possible situations are presented. Of course, they have to be considered just as examples.

In Figure 84, examples of two different purlins that need to be replaced are shown. In both cases, the presence of through-thickness cracks makes useless the nailed connection between purlins and rafter,



thus preventing the purlins to withstand loads along their longitudinal axis (loads perpendicular to nails and parallel to purlins).



Figure 84: two examples of purlins to be replaced.

In Figure 85 some examples in which the purlins do not need to be replaced is shown. Figure 85a shows a purlin in which the shrinkage crack stops to the pith. Figure 85b and Figure 85c show two examples in which, although a crack is present, the lateral contact between nails and wood (which allow the longitudinal stresses to be transferred from rafter to walls through purlins) is still present and active.





a)



b)



c)

Figure 85: some examples of purlins that do not need to be replaced.

Figure 86 shows an example in which the presence of an extensive biological decay (mostly due to fungal attack) may prevent the efficient transmission of loads along the axis of the element, which is mostly important for purlins to be connected to tympanum walls. In that case, the element needs to be replaced.



Figure 86: example of a purlin that need to be replaced because of the presence of an extensive biological decay.

Finally, Figure 87 shows the example of a purlin in which an apparently limited biological attack is present. However, in similar cases only a more accurate diagnostic analysis can ensure that the purlin may be considered as capable in fact of withstanding longitudinal loads.



Figure 87: a purlin where a more accurate diagnostic analysis is needed to ascertain its effective static efficiency.

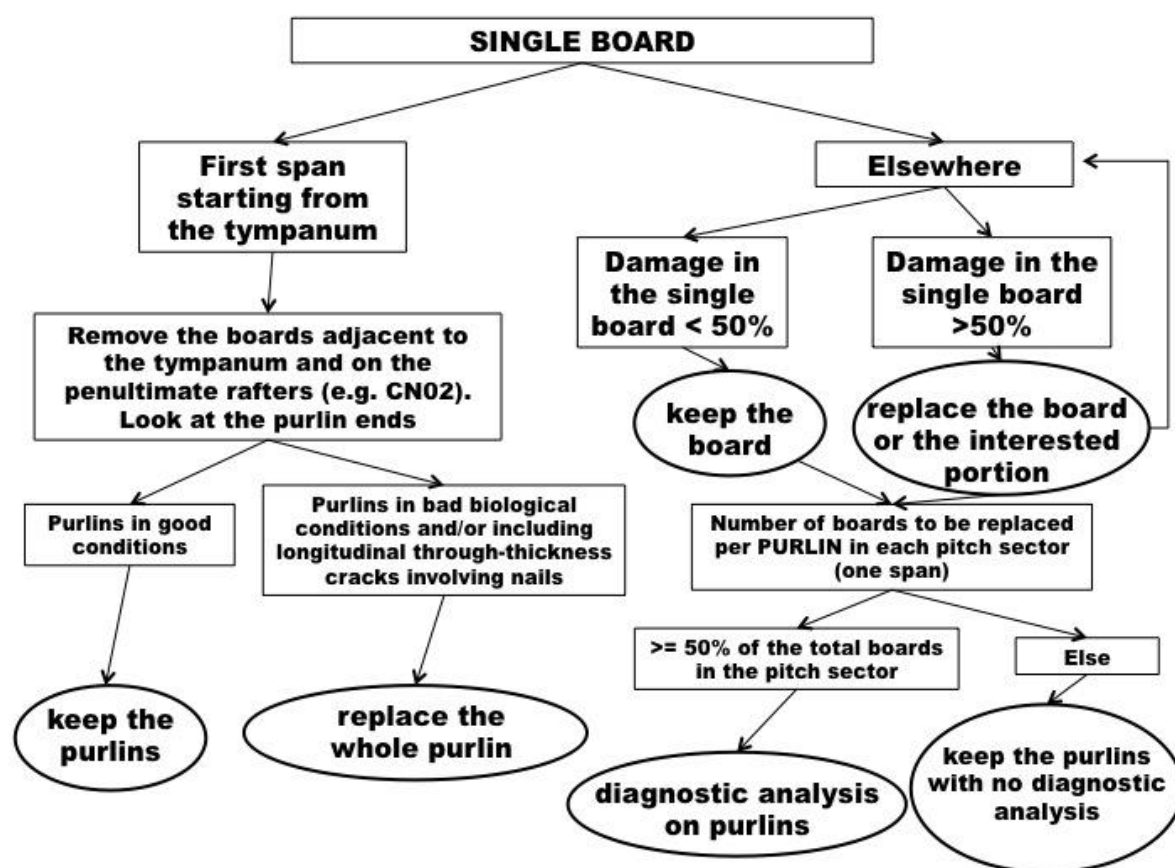


Figure 88: flow-chart for selecting boards and purlins to be replaced



In the following (Figure 89) the most relevant work steps in the replacement of purlins and boards damaged



Figure 89 (from the top – from left to right): delimitation of the area with timber elements to be replaced, removal of purlins and boards, damaged purlins catalogued, replacement of a new purlin, replacement of the new board, the area at the end of the intervention

#### **3.4.4.4 Big cantilevers**

##### **3.4.4.4.1 Prerequisites**

*According to what was possible to survey, the structural part of each cantilever (Figure 90) is made of one horizontal beam on the upper part, supported by two inclined, parallel props, one from the external extremity of the horizontal beam to the wall corner, and the other from half of the beam to the corner wall.*

*The inspection must take into account the resistographic survey of the wood portions included into the walls: the ends of the horizontal beam and of the two inclined props.*

- *Personnel must be competent on both structural timber diagnosis and resistographic analyses.*
- *This point previews the performing of a specialist analysis of wood degradation through resistographic drillings.*
- *Resistographic driller having a needle at least 40 cm long. The complete cross section must be investigated.*

##### **3.4.4.4.2 Inspection phases**

1. *Removal of the covering boards. Connections with walls of the structural beams must be completely available.*
2. *When the portion of wood is visible some measurements must be taken: dimensions of the two sides of the section of each element; wood moisture content by means of electrical wood hygrometer.*
3. *Perform resistographic drillings: two diagonal drillings from the two lower corners of each beam. Drillings must be inclined about 45 ° in order to perform the inspection in the portion of beam included into the wall.*
4. *In the presence of decay, perform diagonal drillings from the lower corners, but on a section perpendicular to the inspected element, at the connection between wood and wall.*
5. *In the presence of decay at point 4, continue inspecting, performing drilling as in point 4, a section each 20 cm moving from the wall, up to when no more decay is detected.*
6. *The obtained results must be graphically uniform to the specific part of the Final Report of the diagnostic phase. More specifically the presence of possible decay must be reported in decay classes: 0-25% / 25 – 50% / 50 – 75% / 75-100% (percentage of cross section covered by decay).*





*Figure 90: internal structure of the cantilevers*

### 3.4.5 Interventions of seismic improvements

The seismic improvement proposed in the Report stems from two main considerations:

1. to improve the connection between trusses and the masonry walls of the nave
2. to increase the in-plane stiffness of the roof.

The first goal is reached by introducing the fasteners described in the Report (see Form 0) both in some tie-beam-rafter-masonry joints (Figure 91) and in some purlin-masonry connections (Figure 92).

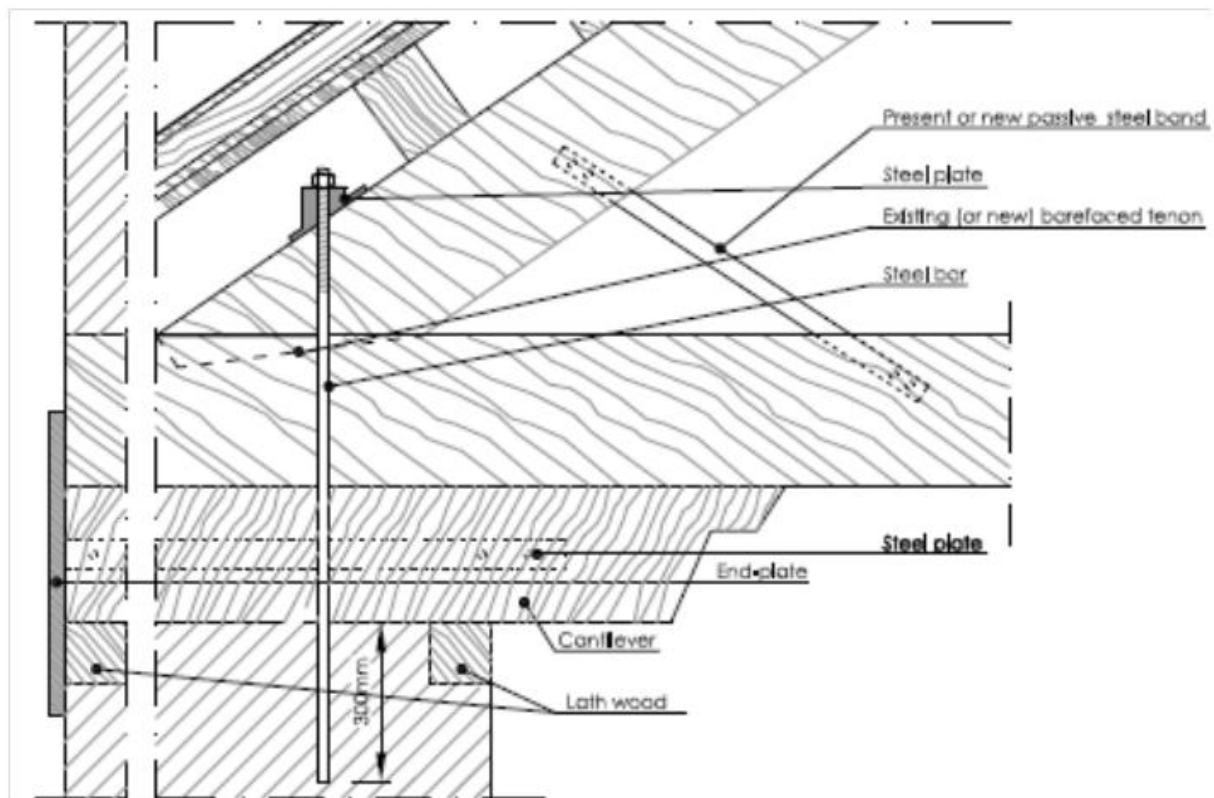
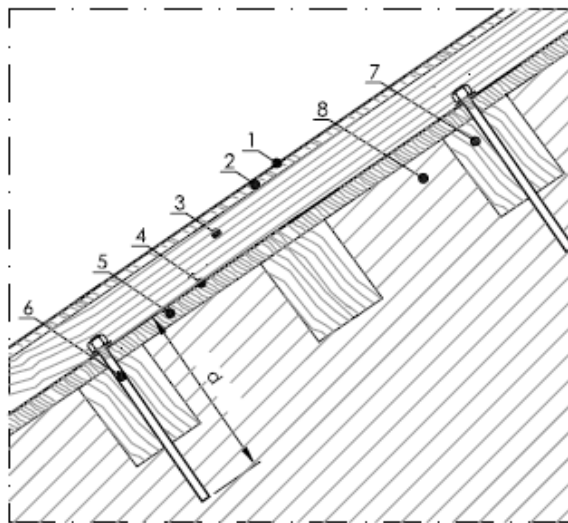


Figure 91: truss head – wall connection



- 1 - Lead - thickness mm 2
- 2 - Phenolic plywood with sheath - thickness mm 15
- 3 - Strips - sect. mm 50x60
- 4 - Steel tape
- 5 - Plank - thickness mm 30
- 6 - Steel bar with epoxy resin to connect the purlins to the tympanum masonry
- 7 - Wooden beam - thickness mm 120/170
- 8 - Tympanum masonry

Figure 92: purlin – wall connection

The second aim is obtained by introducing steel crossed strips nailed on the existing boards as depicted in the Report (see Forms C-05 and C-06) (Figure 93) and a plywood that supports the lead sheets and is strongly connected to the underlying structure (Figure 94)

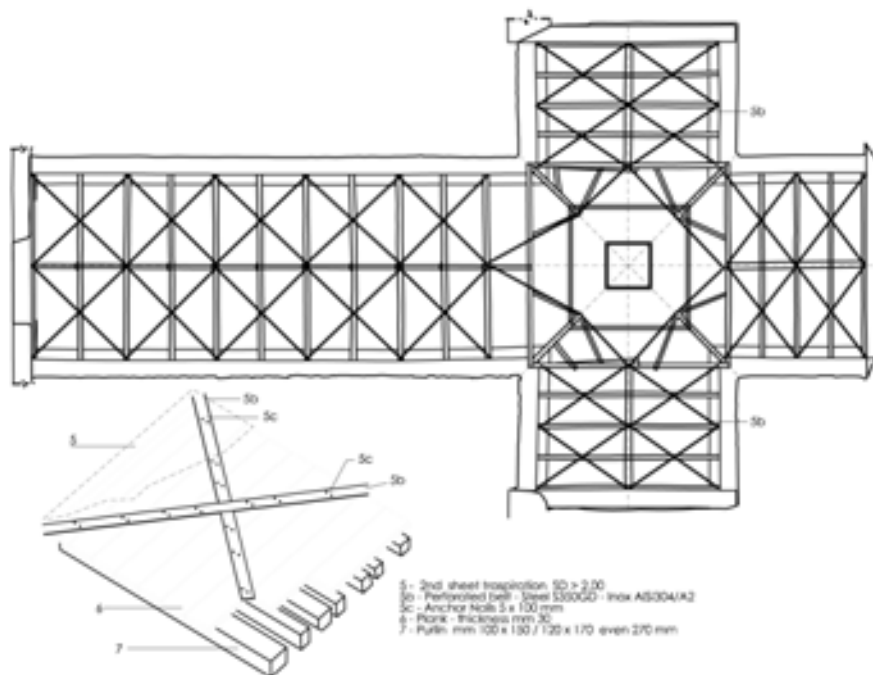


Figure 93 : steel crossed strips connected to the existing boards







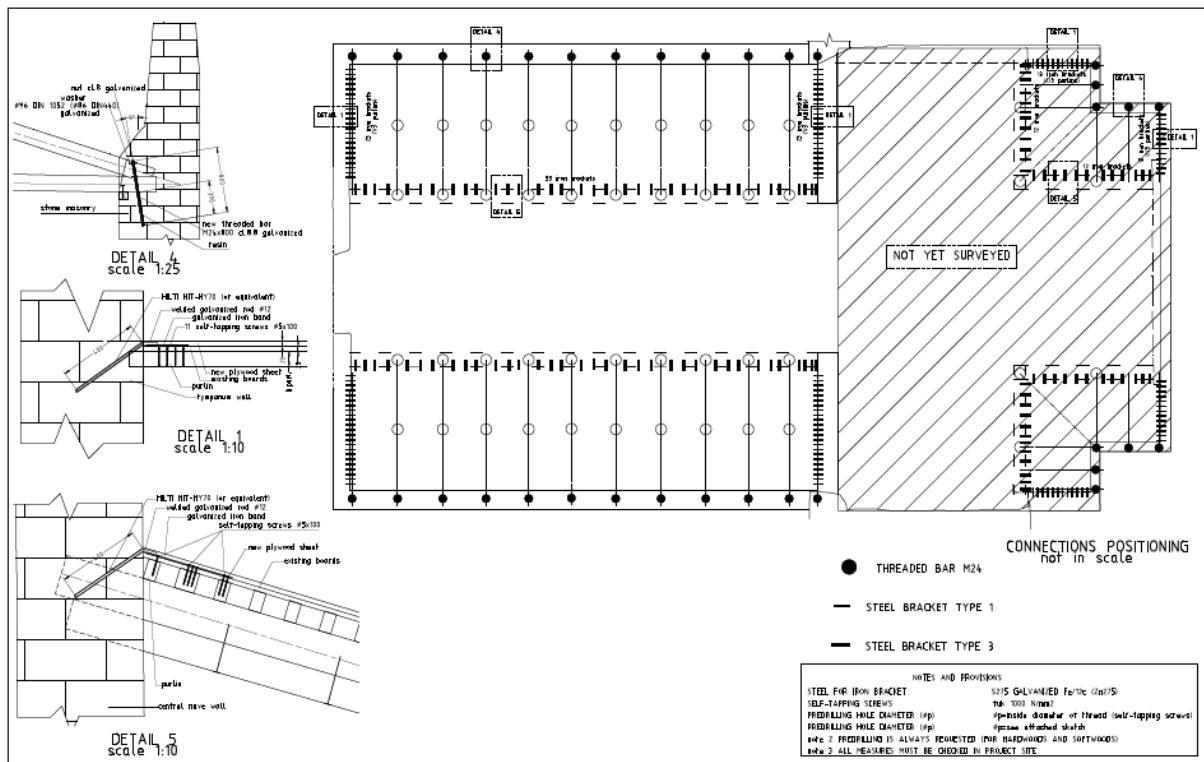


Figure 96: seismic connectors at the lower level (+6,00 m.)

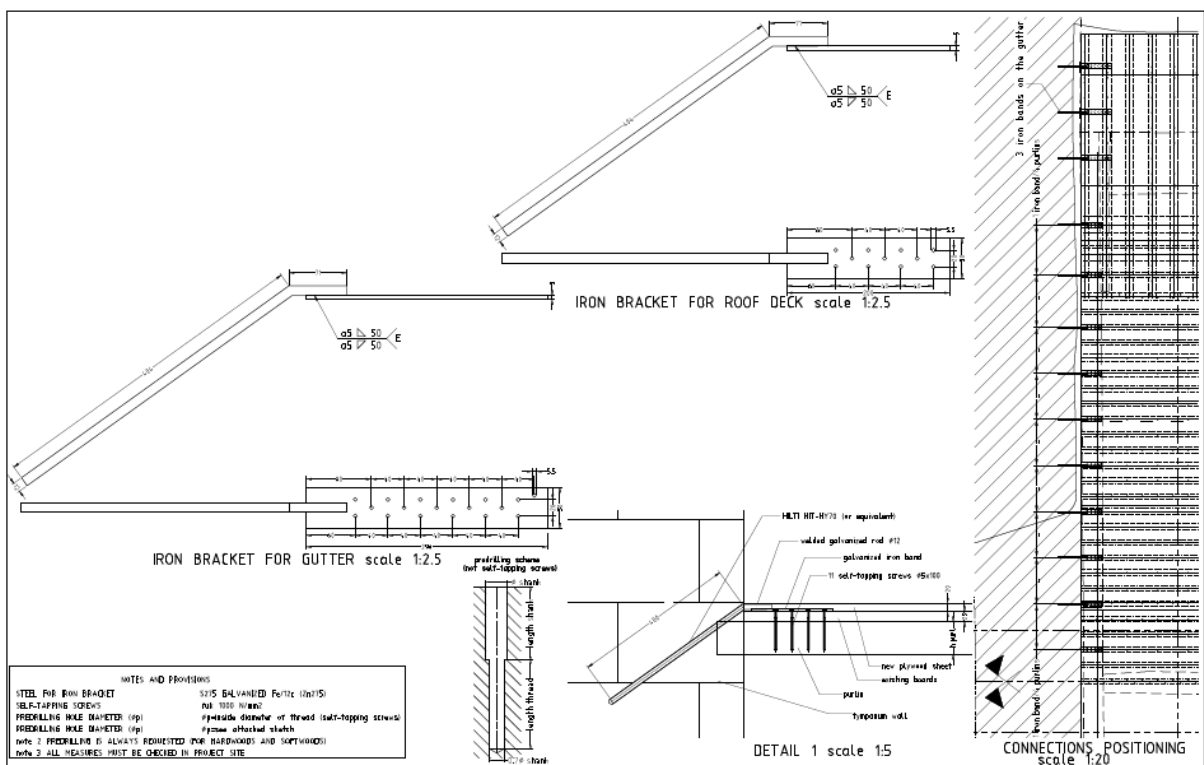


Figure 97: seismic connector for purlins and rafters in the aisles

The average percentages of the seismic actions transferred by connectors to the resistant walls are approximately:

- Upper level: 75-80% in the longitudinal direction; 67% in the transverse direction
- Lower level: 70% in the longitudinal direction; 65% in the transverse direction

These percentages turn out to be higher than the ones usually required by Tenders as transferred actions to masonry walls (60%) and they can be considered as a good achievement.

It is worth reminding any way that for historic buildings it is not compulsory to fulfil the same seismic requirements defined for new buildings; consequently, Designer and Client are free to choose the level of improvement in structural performance they want to achieve.

Figure 98 shows the successive steps for the insertion of the seismic connectors truss head – wall.

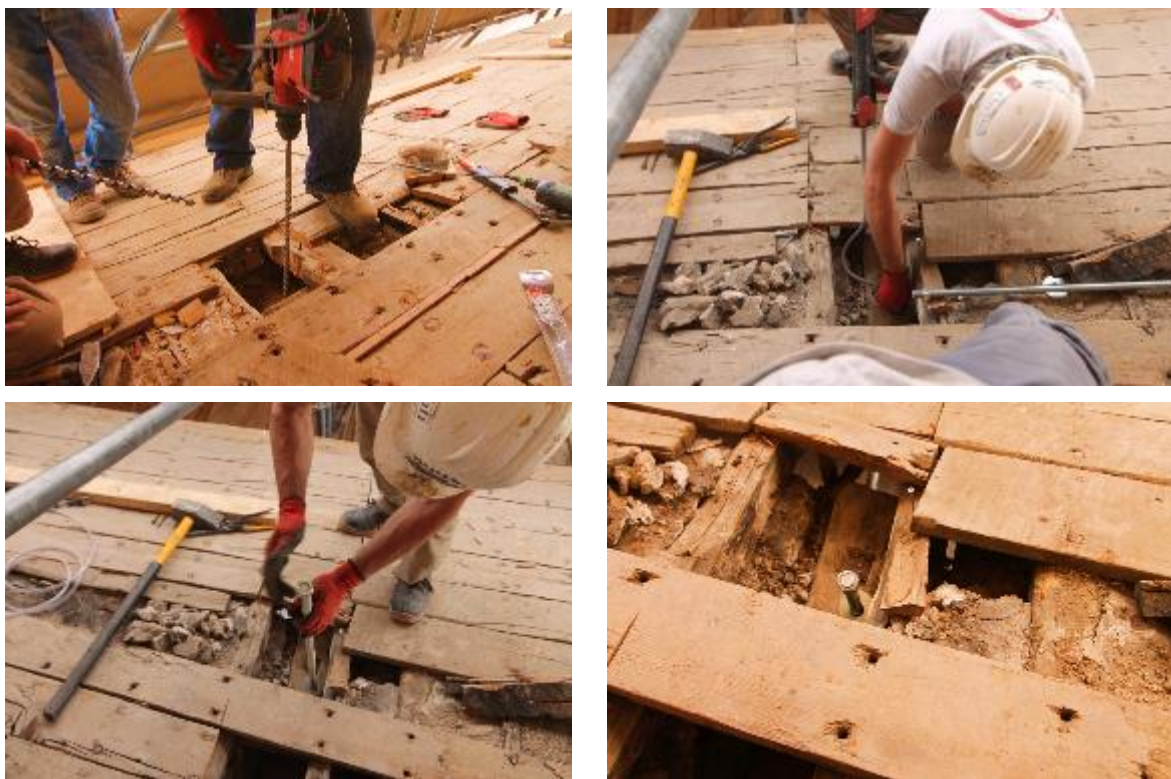


Figure 98 (from the top and from left to right): drilling the hole in the truss head and in the masonry, insertion of the resin in the hole of the masonry (only), insertion of the threaded bar, tightening of the bar

Figure 99 shows the successive steps for the insertion of the seismic connectors purlins – wall.



Figure 99 (from left to right): drilling a hole in the wall and insertion of resin, insertion of steel bar and connection steel plates-boards

#### 3.4.5.4 Plywood deck in the actual intervention

In the actual intervention the plywood layer has been put not immediately under the lead sheets, as in the T.O.R. and as shown in Figure 94, but directly in contact with the existing boards (Figure 100) and connected with boards and purlins by more than 50.000 screws. That allows to increase considerably the stiffness of the roof pitches in their plane and, thanks to the connection of trusses and purlins with the walls, to obtain a rigid box-like behavior of the whole Church in the case of an earthquake.

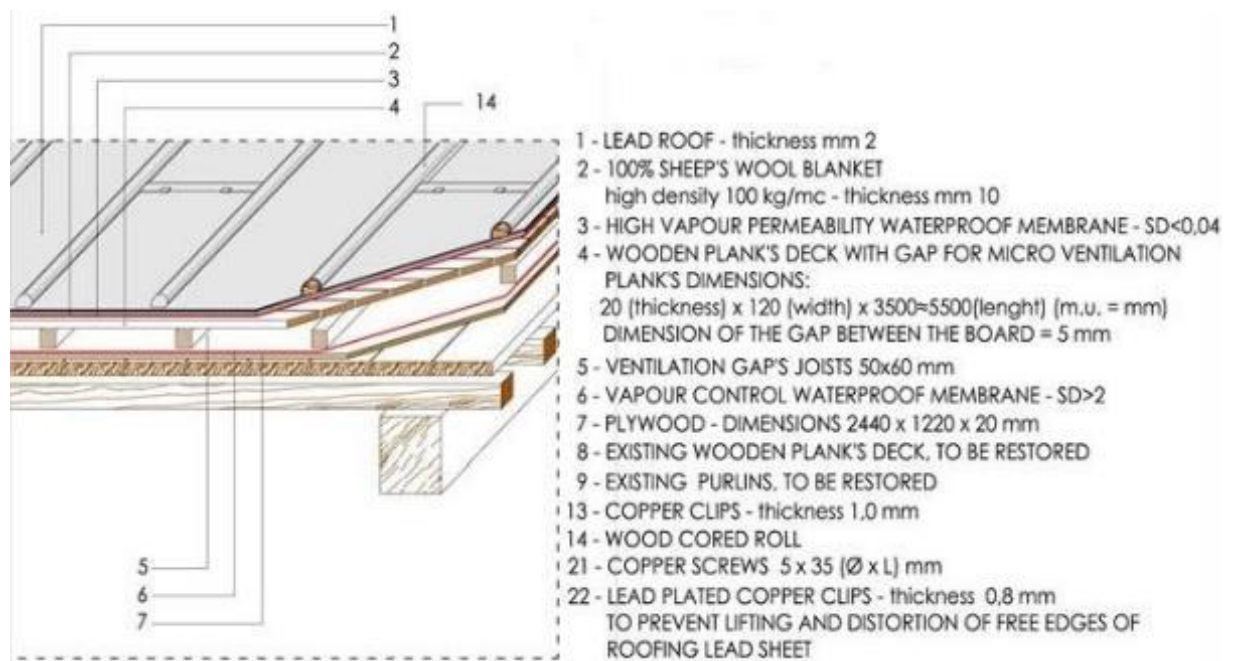


Figure 100: plywood layer in contact with the existing boards in the new roof



### 3.4.5.5 New roof under construction versus the roof proposed in the T.O.R.

With reference to the three types of roof coverings, the existing one, the one proposed in the T.O.R. (and in the guidelines) and the one being built, it is important to note that none of the two new roof coverings has a weight /m<sup>2</sup> greater than the one of the existing roof covering. Therefore, in no way will the consolidated roof structures be loaded by weights greater than the current ones.

The TOR roof covering has only one new wood layer (plywood) instead of two as in the Contractor's proposal because one of the main concern, together with the increase of the global stiffness, was the reduction of the self-weight of the new roof covering. The plywood was placed above the wooden laths in order to support the transpiration sheet and the lead sheets (Figure 101).

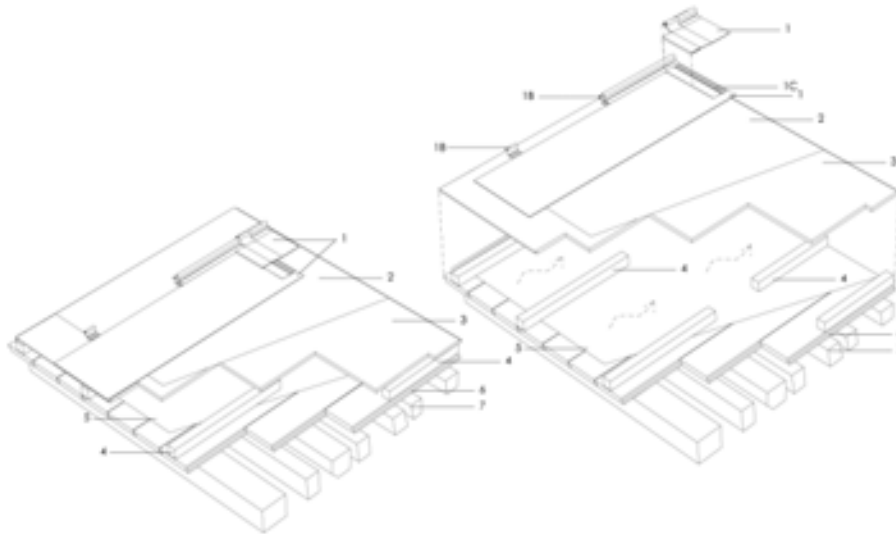


Figure 101: roof proposed in the T.O.R.

The new roof proposed in the T.O.R. , is surely stiffer than the existing one and the lightest among all (existing roof: 1.07 kN/m<sup>2</sup>; T.O.R. new roof: 0.55 kN/m<sup>2</sup>; roof Being built: 0.85 kN/m<sup>2</sup>) as reported in detail in the following:

### Weight /m<sup>2</sup> of the roof covering

#### Existing roof covering

- Purlins	0.27 kN/m <sup>2</sup>
- Existing boards (3cm)	0.12 kN/m <sup>2</sup>
- Lead sheets (3.5 mm)	0.40 kN/m <sup>2</sup>
- Bitumen waterproof sheet	0.10 kN/m <sup>2</sup>
- Clay and straw (3 cm)	0.18 kN/m <sup>2</sup>

**Total** **1.07 kN/m<sup>2</sup>**

- An average thickness of 3.5 mm for lead sheets has been considered but in some parts it is nearly 5 cm

### **TOR roof covering**

- Purlins	0.27 kN/m <sup>2</sup>
- Existing boards (3 cm)	0.12 kN/m <sup>2</sup>
- Steel strips	0.02 kN/m <sup>2</sup>
- Wood lath	0.02 kN/m <sup>2</sup>
- Phenolic plywood (1.5 cm)	0.07 kN/m <sup>2</sup>
- Lead sheets (2mm)	0.23 kN/m <sup>2</sup>
<b>Total</b>	<b>0.55 kN/m<sup>2</sup></b>

### **roof covering being built**

- Purlins	0.264 kN/m <sup>2</sup>
- Existing boards (2,5 cm)	0.113 kN/m <sup>2</sup>
- Phenolic plywood (2 cm)	0.104 kN/m <sup>2</sup>
- Wood lath	0.025 kN/m <sup>2</sup>
- Boards supporting the wool layers (2 cm)	0.086 kN/m <sup>2</sup>
- Wool layer (1 cm)	0.010 kN/m <sup>2</sup>
- Lead sheets (2 mm)	0.230 kN/m <sup>2</sup>
- Wooden rolls	0.017 kN/m <sup>2</sup>
<b>Total</b>	<b>0.849 kN/m<sup>2</sup></b>

The new roof covering currently under construction (Figure 100) is heavier than the one proposed in the T.O.R. because there are two new wooden layers (instead of one), the first, made of ordinary boards, immediately under the lead sheets, to support both wool layer and lead sheets and the second (plywood, 2.1 cm instead of 1.5 cm) immediately above the existing boards and strongly connected to them.

Nevertheless this kind of roof covering has some important advantages. The plywood performances, as well as the performances of the screws used for connections, can be preserved better over time if the plywood is not exposed to high temperatures, as it would be if placed immediately under the lead sheet, like in the Consortium proposal. And this can be considered as a positive aspect of this proposal. Moreover, the plywood layer is placed in contact to the existing boards (Figure 102) to have a better stiffening effect on the whole planking. In fact, as shown by some numerical simulations, the two roof coverings show different deformed configurations when they are subject to horizontal forces like seismic actions, with smaller displacements exhibited by the roof covering under construction. Therefore, from a technical point of view, this roof covering offers better performances, if compared to both the T.O.R. proposal and the existing roof, despite the greater self-weight which is however lower than the weight of the existing roof covering. Moreover, the plywood directly in contact with the existing boards and strongly connected to them, might allow the preservation on site of a major number of existing boards, even of those boards partially decayed, which otherwise should be replaced.





Figure 102: plywood connected directly with the existing boards

It is worth reminding that the wooden layer immediately under the lead sheets (Figure 103) is made of ordinary wooden boards (pine), not plywood sheets, with a small gap between one another in order to guarantee a better ventilation inside and the absence of any humidity condensation process in the wool layer. It contributes to increase the stiffness of the whole roof package although not in the same way as the plywood layer in contact with the existing boards.



Figure 103: plywood; insulation layer (green), wooden laths and boards supporting the wool layer and the external lead sheets

### **3.4.6 Description of the archaeological recording to be carried out during the restoration work**

*These standards and guidelines want to define best practice for undertaking an archaeological study of the historical building and concomitant reporting, in line with current academic researches, international legislation and the relevant ICOMOS charters. The purpose of this paragraph is to define the archaeological skills needed to carry out archaeological evaluations and to assist the archaeologists in describing the international standard.*

*The archaeological analysis of historical buildings considers each structure as a sequence of events to be examined according to its construction and transformation through time so as to gain a clear understanding of the various phases of construction. This approach formed the basis of the development of so-called Archaeology of Architecture, a branch of Archeology established from the late 1970s in Italy and later adopted in other European countries. In the 1980s and 1990s the movement developed and refined specific methodologies for the analysis*

of historical structures by adopting and adapting techniques derived from the practice and accumulated understanding of the stratigraphic method in archaeological excavation. The individual events of construction and destruction that characterize the life of a building have been defined as Stratigraphic Wall Units, to be documented in a standardized way. Alongside this analysis of the building as vertical stratigraphic units there have been developed criteria for the analysis of various elements contained within this stratigraphy. The differing techniques of construction, along with mortars, plasters and other architectural and decorative elements have been studied not only in relation to known historical, artistic or architectural precedents but also as reflections of the economic, political and social contexts within which they took place. The archaeologist working as part of a restoration team must therefore possess a profound understanding and range of experience in the methods and practice of this branch of archaeology so as to ensure an accurate interpretation of the features revealed during the restoration work.

An archaeologist possessed of these essential skills should be present throughout the disassembly of the roof in order to verify and record the presence and character of the original structures supporting the present roof. This is essential to ensure that a clear understanding is gained of the relationship between the roof timbers and the supporting walls, including the beams nears the top of the walls that have been identified during preparatory work for the restoration as possibly serving to reduce the potential impact of earthquake activity.

The archaeologist must also be present during restoration of the roof timbers above the nave, transepts and aisles.

*In particular:*

1. The archaeological monitoring during the restoration of the roof of the Basilica must be provided systematically. Nevertheless, to assist the restoration process avoiding bottleneck should be possible to collect detailed documentation on a sample basis to guarantee the comprehensive records of the most representative areas. On the basis of the results of the preliminary studies of the Nativity Church it's possible to concentrate the in depth investigation and recording on a limited number of sample of the roof of the main nave, of the aisles and of apses. In particular for the latter, during the propaedeutic studies has been verified the presence of special features, such as small gate between an apse and the other, probably designed from the builders in ancient times to allow maintenance work on the roof of the Basilica. During restoration work it could be useful to check and document more carefully these kind of features. Above all that it must be emphasised the need to ensure the meticulous monitoring and supervision of a team of archaeologists during every phase of the restoration works from the scaffolding erection to the dismantling. The outlook of the chief archaeologist during restoration must be systematically and carefully consulted from the Project Manager.

2. Preliminary results of the archaeological investigations carried out on the external walls of the Basilica have suggested that the intersection between the nave and transepts is characterized by blocking of the original window openings at this point. It is therefore particularly important, when the roof is removed, to check any possible correspondences and/or anomalies that might help to explain this stage in the development of the historical fabric.

3. On the basis of these concerns, it requires the unceasing presence of a team of archaeological aimed to follow carefully the restoration process. Everyday survey will allow ordinary investigation and the collection of the documentation. During inspections the main objective must be the examination through the application of the stratigraphic method developed within the archaeology of architecture and the collection of the documentation of

*the different phase and transformation of the structure. Very detailed documentation (including, record sheet, plan, photographs and 3D models) must be collected to record the most important and representative parts of the building.*

*Types of analysis required:*

- a. Identification and numbering of individual timber elements and compilation of a detailed record documenting and describing each individual feature.*
- b. Reconstruction of the stratigraphic sequence of the various timber elements and creation of a related stratigraphic matrix.*
- c. Selective collection of samples of the roof timbers for detailed analysis in relation to the stratigraphic sequence.*

*4. Before dismantling and restoration of any part of the roof it vital that the archaeologist be allowed to study and document the inner core of the load-bearing walls so as to collect structural information about aspects of the building technique not visible in other parts of the Basilica.*

*Types of analysis required:*

- a. Stratigraphic analysis of the bedding mortars between the roof timbers and the walls of the church, as well as those within the inner core of the load-bearing walls. Macroscopic analysis of the mortars, supplemented by detailed petrological analysis, could make a significant contribution to the understanding of earlier phases of restoration work.*
- b. Graphical and photographic documentation of the upper surfaces of the walls.*
- c. Selective collection of samples from the bedding mortars and plaster for detailed analysis in relation to the identified stratigraphic sequence.*

*5. During the removal of the roof a detailed examination must be made of each stratigraphic unit of the walls, in particular of their upper surface, so as to establish a detailed relationship between the individual stretches of walling.*

*Types of analysis required:*

- d. Identification and numbering of each Stratigraphic Unit.*
- e. Detailed documentation of each Stratigraphic Unit.*
- f. Creation of a resulting matrix (stratigraphic diagram or so-called Harris Matrix).*
- g. Graphical documentation of the individual Stratigraphic Units (see also point 5 below).*
- h. Detailed documentation of the various techniques of construction identified during the stratigraphic analysis.*

*6. Three-dimensional recording. In the light of recent developments in laser-scanning and photogrammetric recording and of the value ascribed in ICOMOS strategies to the 3D documentation of ancient monuments and historical buildings, it is considered essential to carry out 3D recording of representative lengths of the upper parts of the walls, along with the relationships between the walls and the roof structure and of the*

jointing systems used in the timber elements of the roof. The resolution-level of this 3D recording must be sufficient to ensure representation of the archaeological, architectural and structural elements to an accuracy in the region of 2 mm [ $\pm$  2 mm]. The photographic acquisition of textural information as part of the 3D recording is essential in this kind of 3D work. The final result can then consist of digital representations composed of a 3D polygonal mesh supplemented by detailed texture mapping. The results of such recording, in terms of measurement and visualization, can be made widely accessible through the use of file formats such as pdf, vrmf and obj.

The archaeological record must make use of an appropriate x, y, z coordinate system, the collected data then being stored and processed within GIS or CAD software suites.

We would strongly suggest to consider the video recording of the general progress of the restoration work to be essential, in addition to the recording of individual elements or stratigraphic relationships. To get the task recording must involve high resolution cameras (1920x1080) with an uncompressed HD signal and the results of such can be made widely accessible through the use of file formats such as AVI or MOV.

### **Plan for archaeological recording to appropriate ICOMOS guidelines**

The report should contain detailed record forms, drawings, photographs, 3D models and maps including stratigraphic matrix.

There are no agreed minimum ICOMOS standards for inventories, data review or condition Surveys. However it is desirable that the documentation stage is as comprehensive as possible, including the implementation of data base and GIS or CAD data management system.

Following is presented the general plan of the Nativity Church representing the main types of interventions currently distinguishable. Some samples will be chosen along the walls of the nave (Figure 104 a, b), on the intersection between the nave and transept (Figure 104 c, d) and on the connection between transept and the main apse (Figure 104 e, f).



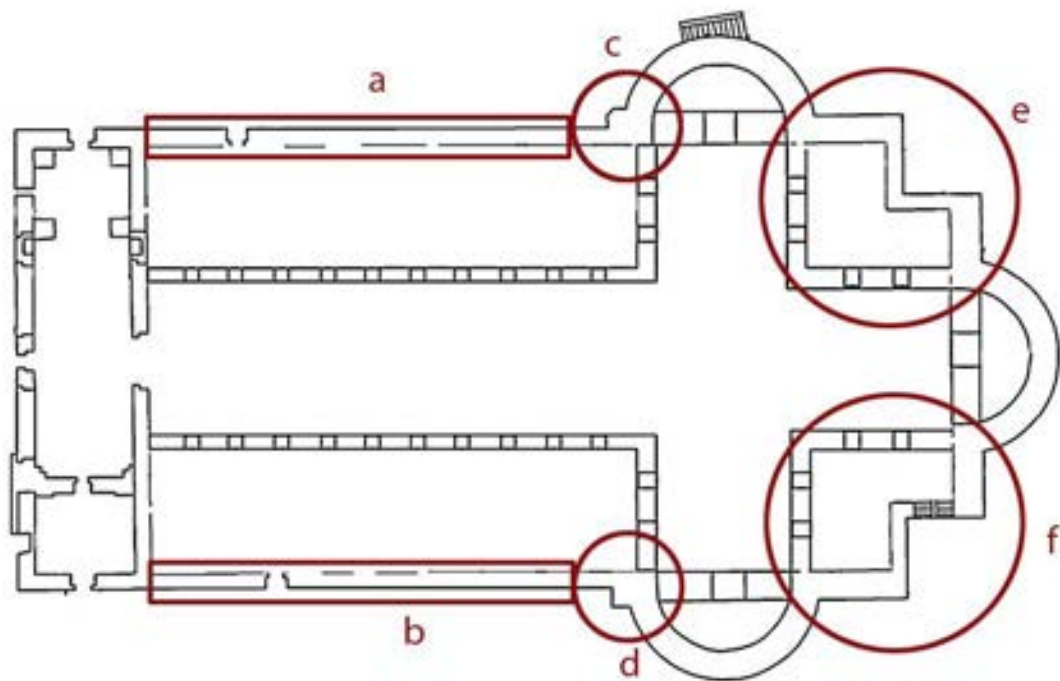


Figure 104 - General plan of the Basilica displaying the principal interventions currently distinguishable

After the scaffolding has been completed and during/after the related part of the roof has been removed the following actions need to be carried out:

- 1) 1:100 plan/drawings representing the main types of interventions;
- 2) 1:20 plans/drawings representing the details of the main types of interventions;
- 3) Guiding principle and procedures to get 3D documentations of any intervention on structures based on photogrammetric techniques using high resolution digital camera. 4) Guiding principle and procedures to share 3D models by using 3D pdf format so as to allow anyone to access data and information, make comments, reviews etc. by means of free Adobe Reader® software.



### **Archaeological recording during the interventions**

During the first archaeological surveys carried out in the church a series of information of considerable importance were collected while the works were progressing . These elements contribute mainly to enrich the wealth of historical knowledge concerning the Basilica itself and at the same time to plan restoration interventions able to respect and to enhance the monument.

The assembly of scaffolding outside the Basilica has allowed to analyze closely the top portions of the walls (Figure 105), at the connection points of the roof with the walls. In particular, the stratigraphic analysis of this part of the walls, the chemical analysis of the mortars used in these parts, compared with the mortars of the lower levels, the analysis of the wooden species of the sleeper under the truss heads (inspected this time from both parts, from outside and inside) allow to advance new hypotheses about the changes undergone over the centuries by the masonry walls and the whole roof. For these reasons the chemical analysis of further mortar samples and the dendrochronological and C14 analysis of some samples of the wooden sleeper have been requested to the Project Manager.



Figure 105: top portion of the wall with the wooden sleeper

The need of removing some material around the truss heads (mainly loose material added in later ages) has allowed to make some stratigraphic analyses of the plasters in those areas (Figure 106). Moreover, in correspondence of the windows of the upper level a strip of plaster was removed for stratigraphic analysis, to check the mortar in the joints and to confirm the presence of stones only in the thickness of the wall, without any filling material (Figure 107).



Figure 106: South wall of the nave – truss CN04, stratigraphy of the plasters



Figure 107: North wall of the nave, stratigraphic analysis

A systematic sampling of the different types of mortar present in the walls of the Basilica was carried out. All these samples have been subject to specific archeometric analyses (chemical, mineralogical and petrographic), in order to obtain the most information as possible about the technology used to prepare the mortars, the nature and origin of the raw materials and to enable a greater level of details about the construction phases of the monument and its transformation over the ages. At the moment, on the basis of the construction phases

previously identified and on the basis of the macroscopic differences surveyed several samples were taken and subject to archaeometric analyses (Figure 108).



Figure 108: Mortar samples for archaeometric analyses

In the north aisle, at the point where the roof is inserted into the wall of the nave, a deep investigation was carried out to verify the presence (or the absence) of the original stones and therefore the possible changes occurred in the original configuration of the roof during the later interventions of restoration (Figure 109).

It was therefore requested an integral control, with graphic and photographic recording of the present stratigraphy, to be implemented when the coverage of the aisles is removed, in order to record valuable information about the past interventions in the roof covering.





Figure 109: connection area between the roof of the aisle and the wall of the nave

Before removing the lead sheets a stratigraphic and chemical analysis of the various layers of bitumen and fabric forming the external surface of the roof was carried out (Figure 110, Figure 111).



Figure 110: external surface of the roof made of bitumen and fabric



Figure 111: thickness of the bitumen layer changing from 2-3 cm on the top of the roof to 4-5 cm at the lower levels

The removal of the lead sheets and all the roof covering was preceded by a deep historical analysis of the interventions made and it was carried out with great care of all elements to be removed. In particular each all iron nails connecting the lead sheets with the boards have been preserved and stored. Moreover a photographic survey was carried out of the roof pitches and each lead sheet was numbered (Figure 112) and identified with a proper mark (Figure 113)



Figure 112: lead sheets numbered





Figure 113: identification mark on each lead sheet

The lead sheets, temporarily stored on the roof of the Franciscan cloister (Figure 114), are now stored and preserved in a suitable space provided by the Municipality of Bethlehem, waiting for a future use.



Figure 114: lead sheets temporarily stored on the roof of the Franciscan cloister

The removal of the lead sheets allowed to discover an unexpected insulating layer between lead sheets and boards, made of clay and straw (Figure 115).



Figure 115: insulating layer made of clay and straw

Samples of this layer were analysed in their properties and inner composition and measured in their thickness (Figure 116)



Figure 116 : analyses on samples of insulating layer

The removal of the roof covering above the aisles has brought to light those parts of the walls which were hidden by the layers of bitumen and by the lead sheets. It revealed a number of interesting traces that contribute to clarify the past history of the Church and to discover the several changes occurred over the ages. All these data have been properly recorded (Figure 117, Figure 118).



Figure 117: traces of previous roof structures in the areas between walls and present roof covering

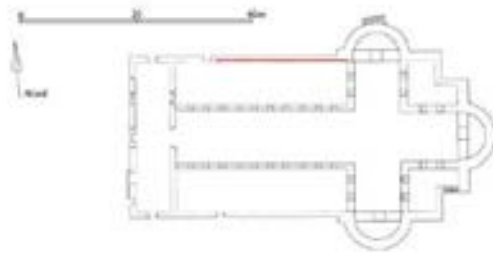


Figure 118: traces of the original drainage and rainwater collection system

The restoration of the truss heads and the seismic reinforcement by means of threaded bars has allowed to open the spaces around the heads (Figure 119), which had been covered for centuries by loose material and stones, responsible, together with the rainwater infiltration and the consequent moisture, of the damage of the truss heads. All these spaces will be kept free to allow a better ventilation of the truss heads.



Figure 119: the original space around the truss head

During the removal of some parts of the plasters in the aisles, seriously damaged and without any possibility of consolidation, the original masonry *apparatus* has once again become visible showing the holes of the metallic



devices used to hang the marble slabs on the wall (Figure 120). Moreover it possible to see crosses, dates, names carved on the stone (Figure 121).



Figure 120: Holes hosting the metallic devices to hang the marble slabs on the walls



Figure 121: cross carved on the stone

In the light of these findings of the utmost importance, which confirm an exceptional level of conservation of the walls of the Church, a detailed documentation has been prepared and will be kept updated , in order to allow the accurate graphic and descriptive recording of all data emerged.

### **3.4.7 Interventions on windows**

*As evidenced by historical information, present windows of the Church are relatively new and (at least from a strictly technological point of view) not really valuable. Moreover, the present design and assembly, in addition to the used wood species, are quite poor, and as a consequence diffused decay has been evidenced during the survey in spite of the limited service life of windows.*

*Therefore, a substitution intervention is suggested for semi-circular windows. This substitution at our advice has to involve all semi-circular windows of the Church, although for different reasons:*

- the semi-circular windows of the Roof level (transept and apse) and of the High level (North and South walls of the central nave, above the mosaics) as they do not guarantee any waterproof efficiency and may not protect properly the mosaics and the trusses,*
- the semi-circular windows of Ground level (transept and apse) for aesthetical uniformity. The substitution of such windows is not strictly necessary for technical reasons (neither water dripping nor similar decay was observed), but it is suggested on the basis of aesthetical considerations.*

*The intervention is described in the T.O.R. in two Forms, one concerning the Roof and the high levels (Form W01) and another one concerning the Ground level (Form W02).*

*It is worth to note that all coated wood windows intended for use in exteriors, like the present ones, need a maintenance plan after their installation.*

All windows were designed according to the given guidelines. The shop drawings are shown in Figure 122, Figure 123. The Representatives of the three religious communities have also chosen the type of wood for the frames. The windows at the upper level will be opened and closed from outside to allow the proper ventilation inside the Church. Automatic opening systems have been rejected because they are still too delicate, they do not fit with the style of these windows and they need a particular maintenance that could be hardly guaranteed on site.



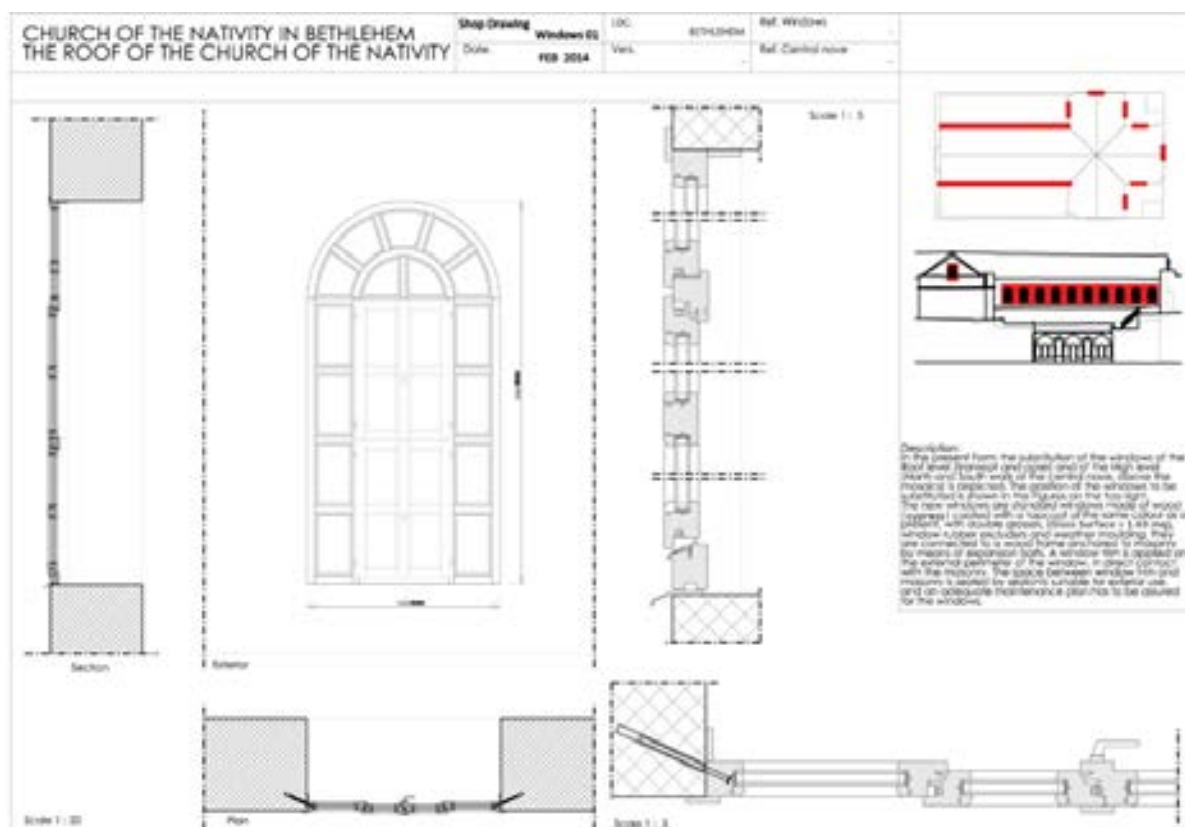


Figure 122: shop drawings of the windows at the upper level

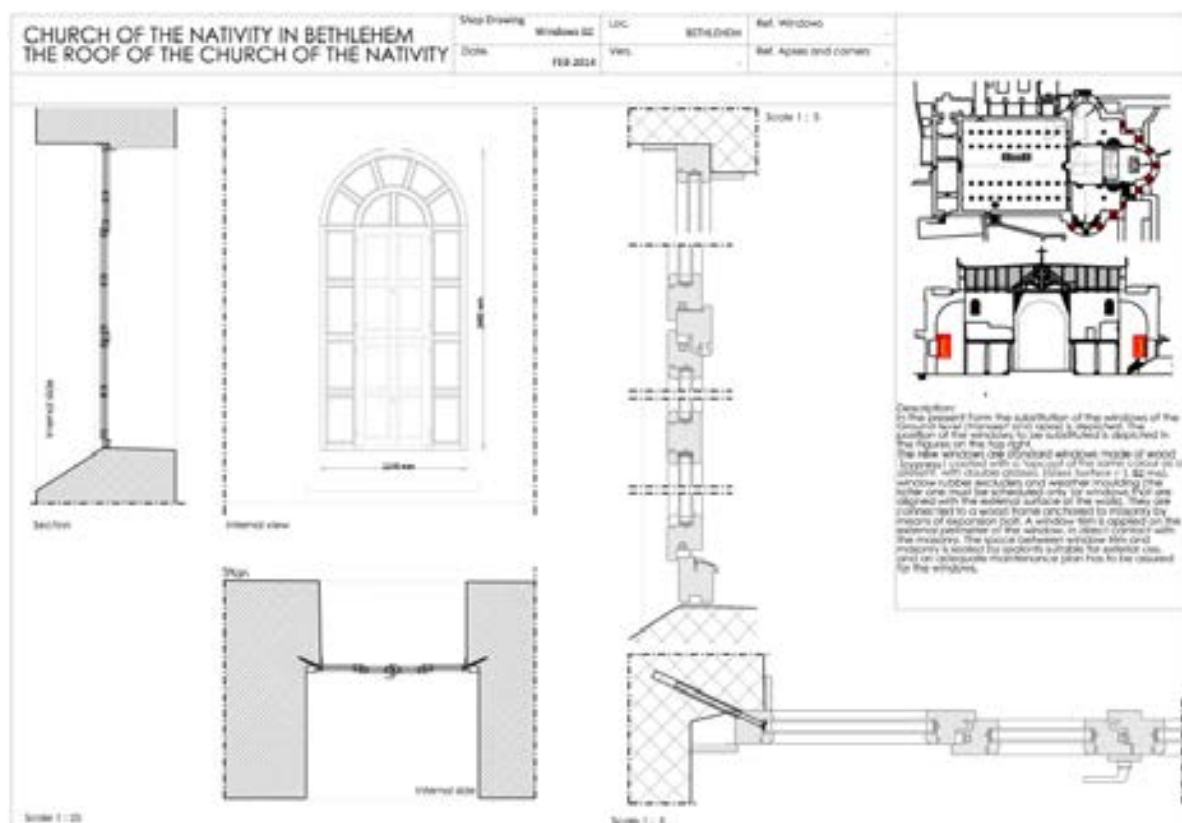


Figure 123: shop drawing of the windows at the lower level

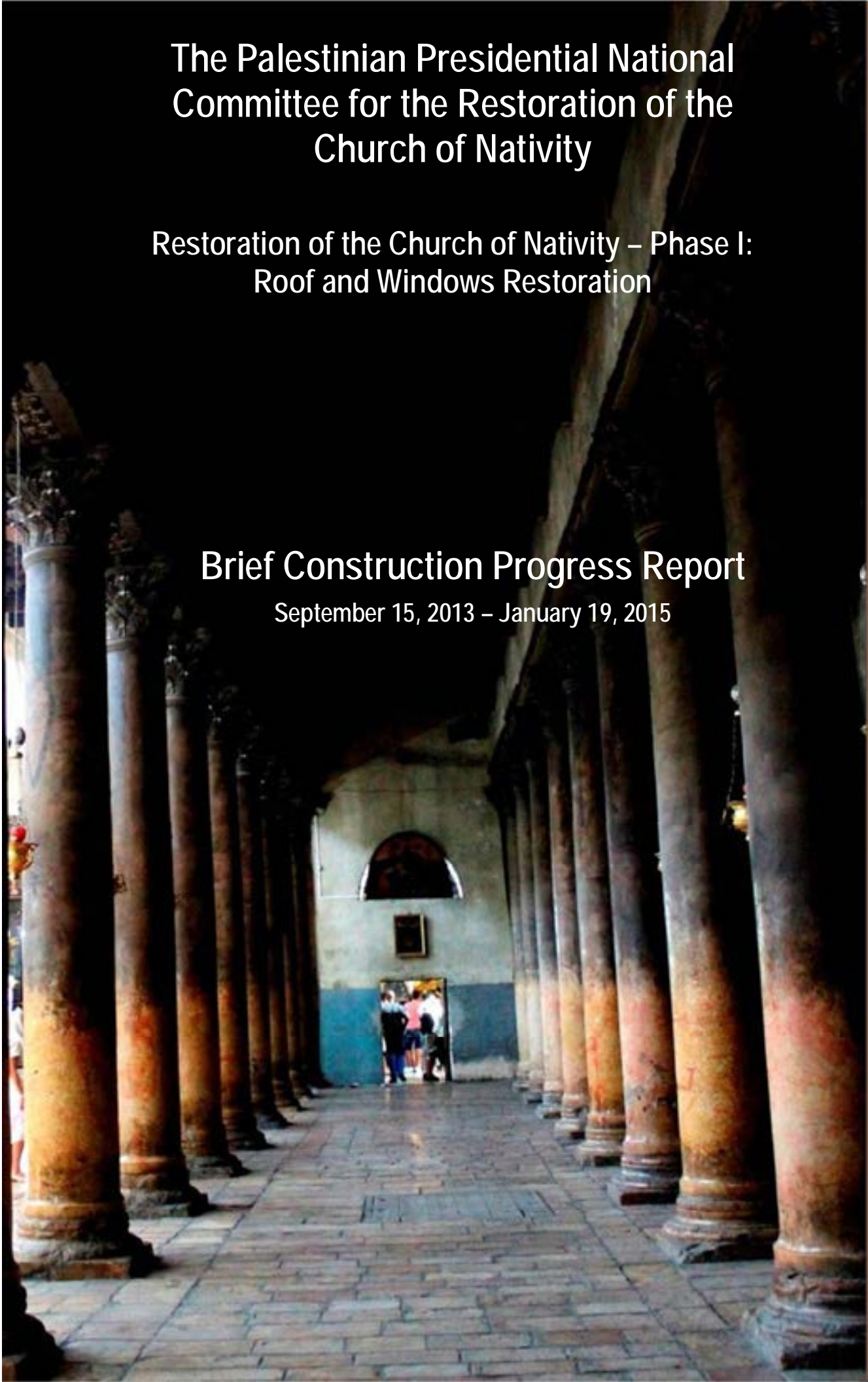
#### 4 ANNEX 4: THE BRIEF CONSTRUCTION PROGRESS REPORT QUOTATION SEPTEMBER 15<sup>TH</sup> 2013 – JANUARY 19<sup>TH</sup> 2015

# The Palestinian Presidential National Committee for the Restoration of the Church of Nativity

Restoration of the Church of Nativity – Phase I:  
Roof and Windows Restoration

## Brief Construction Progress Report

September 15, 2013 – January 19, 2015



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# The Palestinian Presidential National Committee for the Restoration of the Church of Nativity

## Restoration of the Church of Nativity – Phase I: Roof and Windows Restoration

*Contract Number: NCRW-PI-13/1*

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### **Brief Construction Progress Report**

**September 15, 2013 – January 19, 2015**

The committee has awarded "Piacenti spa" the contract of Phase I: Roof and windows restoration on July 25, 2013 since their submitted tender proposal on June 14, 2013 got the higher scores in both technical and financial offers throughout a competitive international bidding process of a total price of 1,925,707.57 Euro.

On August 26, 2013 an agreement has been signed between The Palestinian Presidential National Committee for the Restoration of the Church of Nativity – Bethlehem, as "Employer" and Piacenti S.p.a. – Italy as the "Contractor" in the presence of his Excellency Prime Minister Dr. Rami Al-Hamadallah and representatives of the three churches. The project starting date was September 15, 2013 and the revised completion date 31 August 2015 including the time extension made for the unforeseen and the additional works.

#### **1 TOWER CRANE INSTALLATION: TOWER CRANE INSTALLATION:**

Several measurements, analysis, and tests were made on site to specify the best location to erect the tower crane that will speed up the restoration process and lift / transport the materials safely from one place to another. The results show that the Greek Orthodox garden beside the bell tower is the best location where the crane could be erected and serve the maximum area of the roof (ref. to figure 1).

Further test (Electrical Resistivity and Soil Classification) where performed in the proposed location to assure that no voids or grottos are present and to measure the bearing capacity of the soil where the base of the tower crane to be installed.



## 2 PROTECTION OF COLUMNS AND WALL MOSAICS:

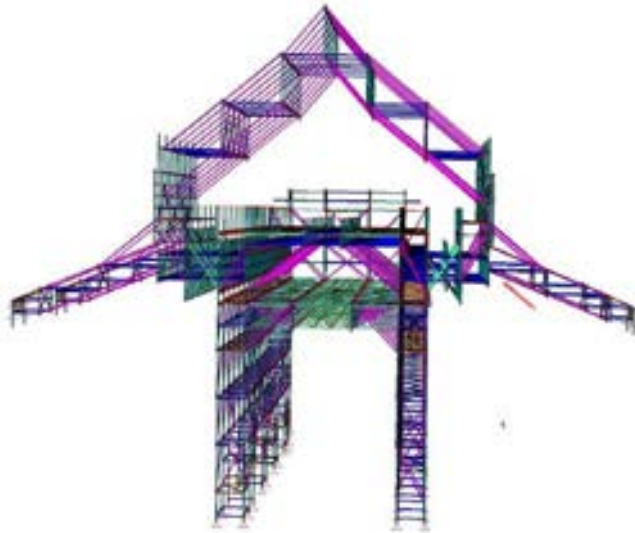
Before starting the assembly, work for the scaffolding inside the church the contractor protected the columns of the church using a special layer of geotextile with vertical wooden rods to achieve the maximum protection level. Prior protection works, dilapidation survey was performed to capture all existing conditions of the church elements including columns, floor, walls, mosaics, paints ... etc by high quality still photos and video so that existing site condition can be easily and accurately defined and determined.

By the completion of the scaffolding platform at the windows level, the contractor becomes able to start installing temporary protection system for the wall mosaics using special materials and wooden cover to avoid any damage during the restoration works.



### 3 ASSEMBLING THE INTERNAL SCAFFOLDING:

After the completion of the protection works for the columns and the architrave beam, assembling of the scaffolding started at the central nave area keeping proper spaces for the safe movements of pilgrims and visitors. Actually; this type of scaffolding is the first time used in the region which allows a high flexibility in assembling. The proposed scaffolding includes two platforms, the lower level form a protection platform and the upper platform forms a floor for the restorers to work at the level of the wooden structures of the church. During May 2014, the contract continued to erect the scaffolding system to cover the transept area and the Altar. Currently the internal scaffolding system is covering the entire church.



It's worth mentioning that before the erection of the scaffolding system, intensive studies, calculations and analysis were made, checked and approved to make sure that the loads transferred to the Church stone flooring are within the permissible limits and taking into consideration the location of the Nativity Grotto and cavities.





#### 4 TEMPORARY ROOF STRUCTURE:

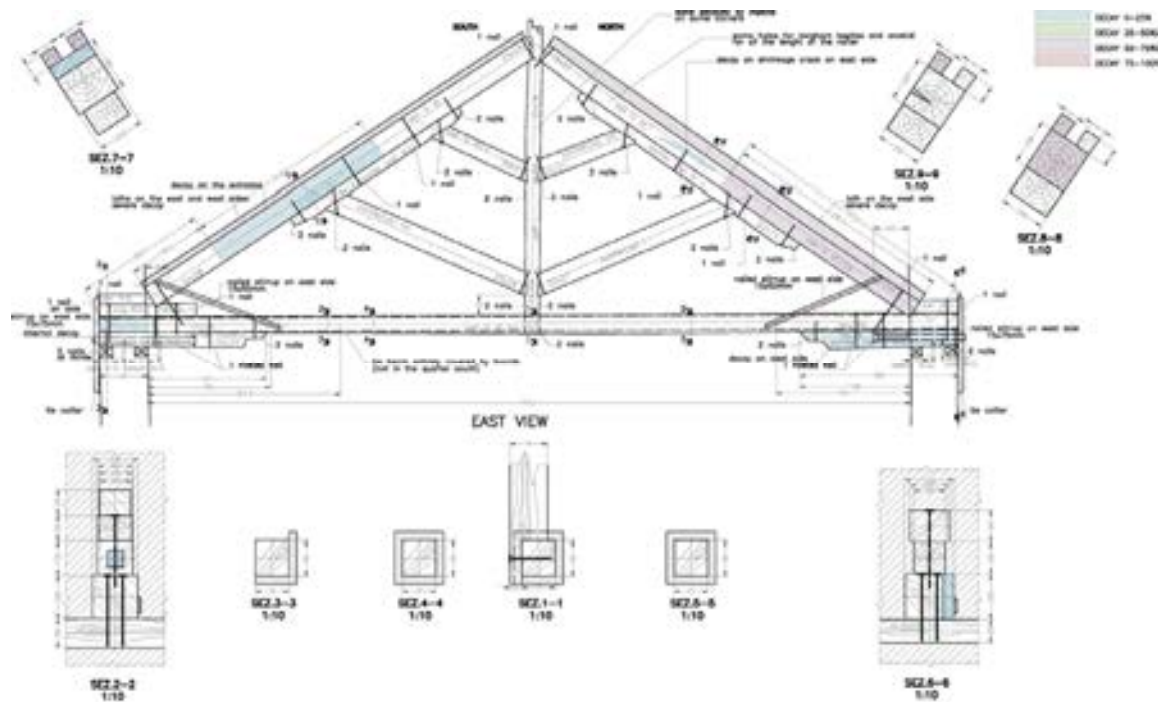
After dismantling the existing wooden windows which are intended to be replaced by new ones, the contractor starts working on the assembly of the roof structure at the central naves and aisles which is supported by the internal scaffolding through the windows. A layer of special PVC was installed on the roof structure as a protection from the rainwater during the restoration works as part of the church roof materials will be removed to allow for the evaluation of the roof condition and start the intervention according to the tender documents.



#### 5 DETAILED WOOD EVALUATION:

Starting from December 2, 2013 until December 11, 2013 and from January 27, 2014 until February 16, 2014 wood experts have evaluated the current condition of the existing wooden structure supporting the roof and performed several non-destructive tests for the central nave and the aisles to provide information regarding geometry, dimensions, characteristics of connections, wood species, humidity and class of mechanical quality of the wood to prepare the design and shop drawings with respect to the tender documents. The same evaluation process onsite for the transept area and the Altar has started again since 2 June 2014 and completed on July 6, 2014. All the information, notes, observations and tests results are the reference to prepare the design and shop drawings for each truss.

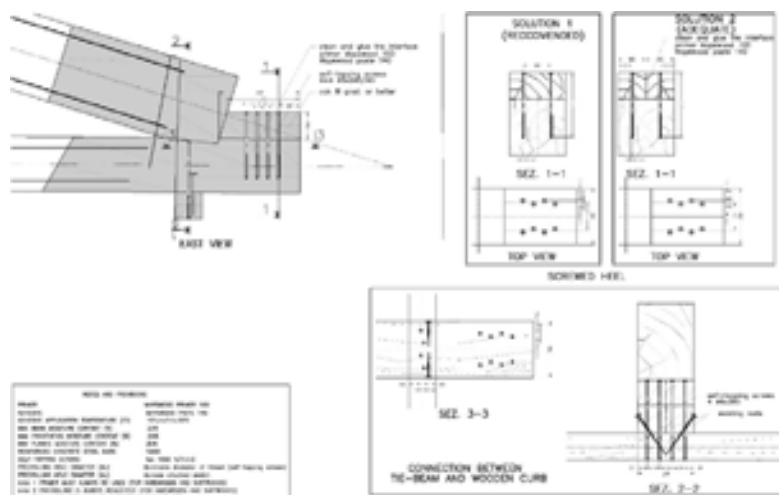




## 6 TRUSSES RESTORATION WORKS:

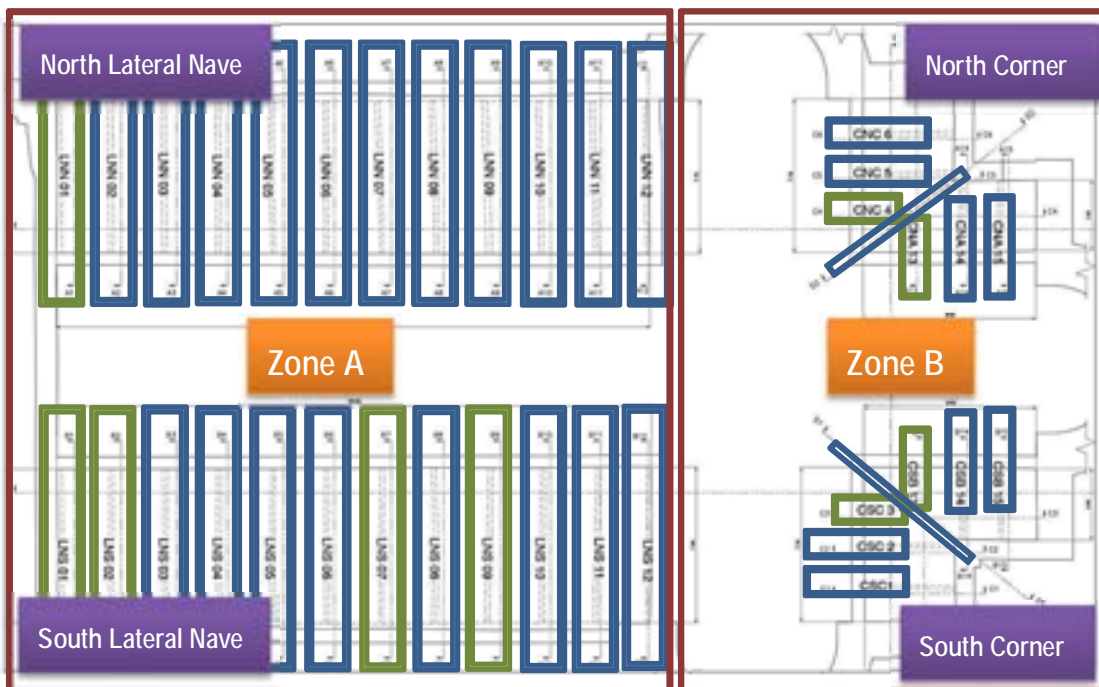
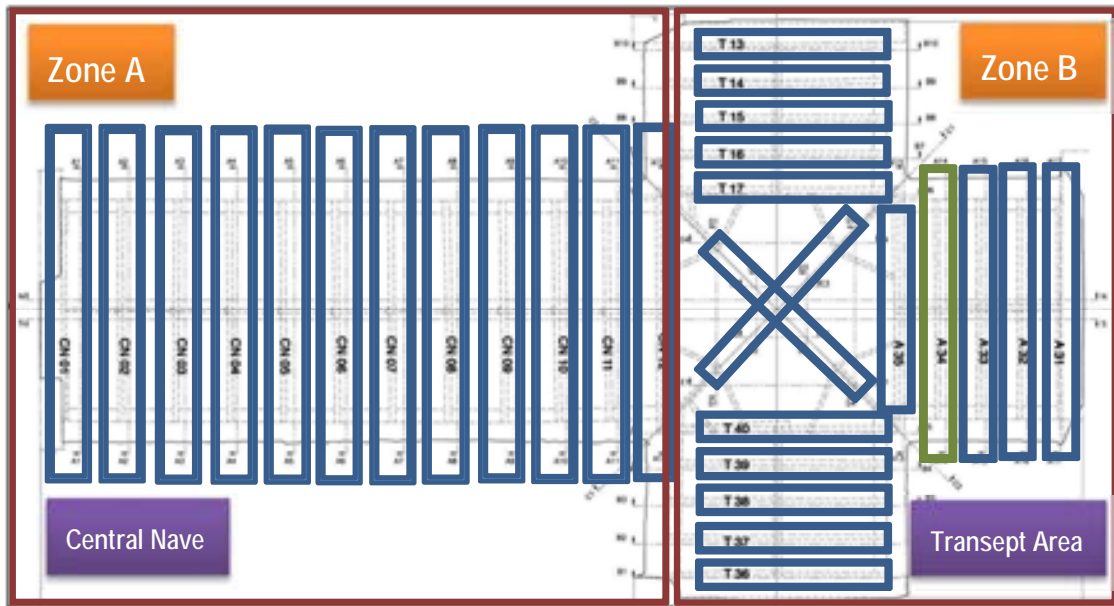
The wooden pieces that will be used in the interventions of the roof structure were gathered, tested and shipped from Italy. Two shipments reached Bethlehem on January 2, 2014 and May 12, 2014 and stored in a suitable place where humidity ratio is controlled.

After submitting the evaluation report and the shop drawings for the trusses intervention, all documents were approved after careful check by the consortium team and inspection on site. Each truss intervention starts after approving a proper and safe propping system. The contractor has completed all the required restoration works of the trusses for the entire roof. All the deteriorated parts of the trusses which were already replaced by the new ancient wood were documented, labeled and stored in a suitable place.





# Progress Diagram



 Completed

 No intervention is required



## 7 PURLINS AND BOARDS:

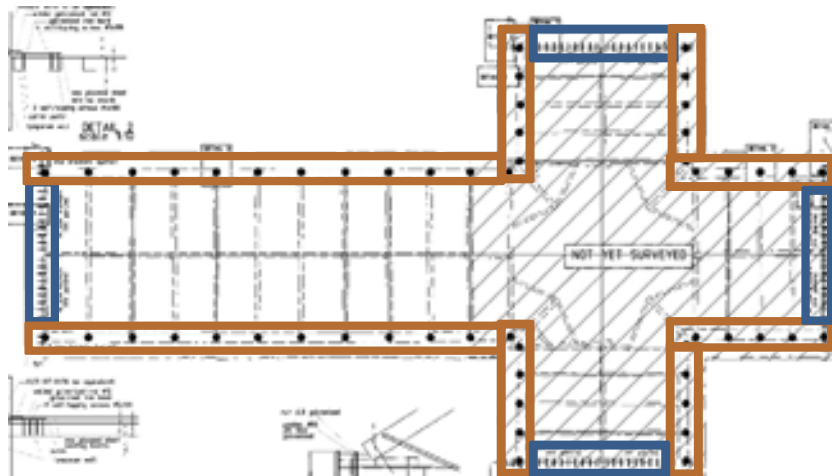
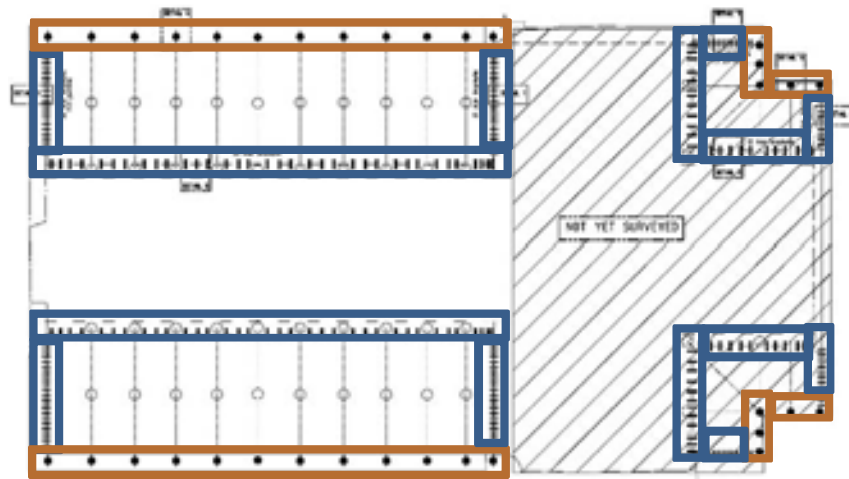
Purlins and boards are part of the existing roofing layers. Purlins are connected directly to the wooden trusses by ancient nails and covered by the wood boards which are connected to the purlins by ancient nails as well. The proposed works are to replace the decayed purlins or boards and consolidate and save as much as possible the existing ancient elements. The replacement elements are also ancient wood which brought from Italy. The contractor has completed the restoration / consolidation of the purlins and boards for the entire roof.





## 8 SEISMIC REINFORCEMENT

The restoration project is not only limited to the repair and restoration of the roof but also includes the seismic performance improvement since Bethlehem is in a seismic area and therefore there is also a danger due to the seismic vulnerability of the Church. Accordingly, roof-masonry connectors are required to be installed to connect the roof structure to the masonry wall in order to transfer the seismic load. The design includes two types of seismic connectors: 1) Steel bars connectors to transfer the seismic loads from the end of trusses to the walls 2) Purlins connectors' that will connect the roof structure especially the purlins to the masonry walls. The contractor has completed the installation of the purlins connectors for the entire roof and the required steel bars insertion for all trusses.



Completed purlins connectors



Completed steel insertion bars



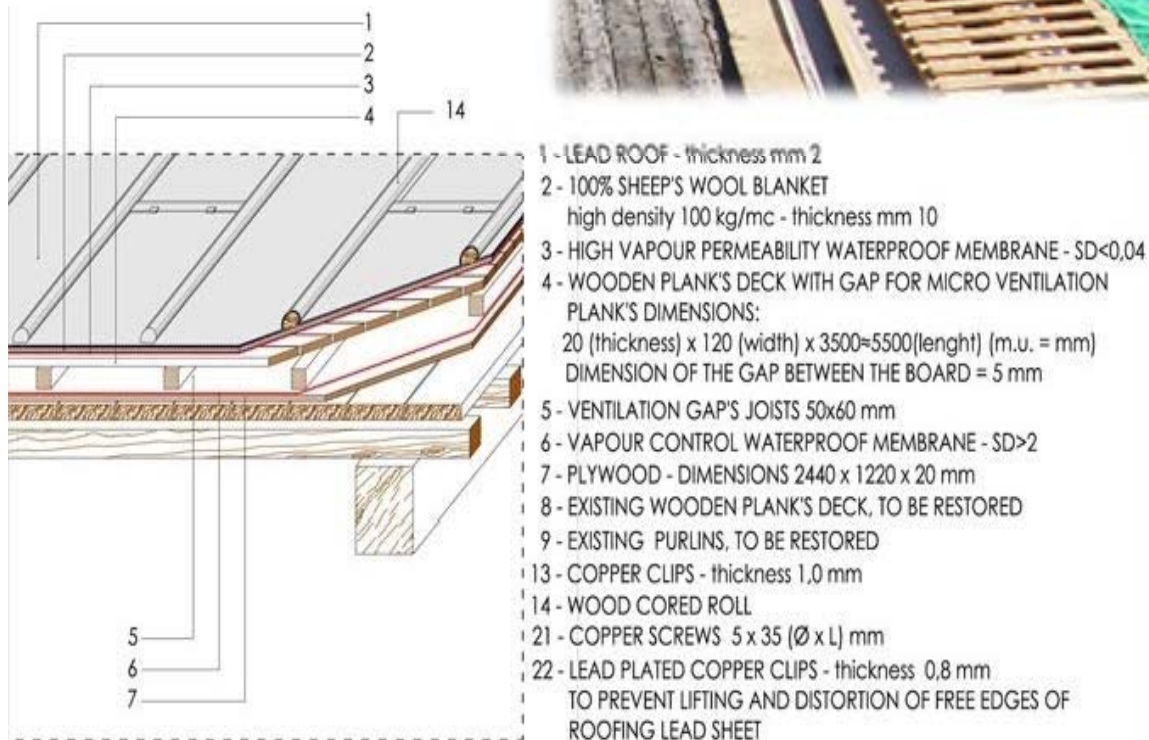


## 9 ROOF LAYER & VENTILATION SYSTEM

After the restoration of the boards and purlins and the replacement of the decayed parts, the roof layers must be installed according to the below detail to create a ventilation system and a durable waterproofing coverage. The roof layers includes the installation of phenolic plywood layer, vapor control waterproofing membrane, ventilation gaps joists, wooden planks deck, high vapor permeability waterproofing membrane, natural sheep wool layer and the lead sheets.

The contractor has already completed the installation of the specified layers including the lead sheets for the entire upper roof while the installation of the lead sheets for the lateral naves and the two corners were postponed to allow for the restoration of the external facades and to avoid any damage for the new lead sheets that could be occurred during the stone restoration works.

By the completion of the stone works at the two corners and the lateral naves the contractor has completed the installation of the lead sheets for the postponed areas and currently the works are in progress at the last part of the roof "lateral nave north". The lead sheets installation works are expected to be completed by the end of January 2015.







## 10 INSTALLATION OF NEW WOODEN WINDOWS

The original contract (phase I) includes the replacement of existing damaged and decayed wooden windows with new cypress wood windows with low emissivity double glassing and special specification to reduce the lighting in the church and to be more suitable for the mosaics, paintings and other delicate decorative surfaces. The new windows have been fabricated in Italy and brought to the site and 21 windows were already installed.



## 11 NARTHEX AND NARTHEX EASTERN WOODEN DOOR (ADDITIONAL WORKS #1):

In accordance with the list of priority restoration works, additional works #1 were awarded to the contractor on March 28, 2014 which includes the restoration of the narthex and the narthex eastern wooden door.

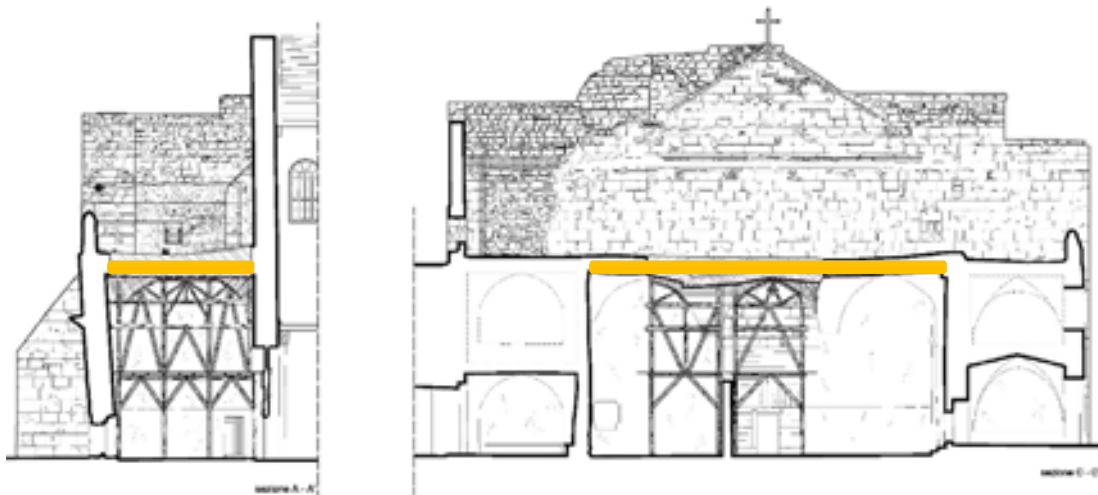
The works has started after installing the required temporary roof and the necessary propping system from below. The archeological excavations on the damaged vault was started after numbering and dismantling of the narthex roof stone tiling. All the works were performed under a comprehensive documentation system and archeological stratification and analysis.



Within the layers have emerged numerous fragments of pottery, animal bones and a coin. The findings that will be useful to trace the exact date of construction of the vaults and the socio-economic context of the builders themselves.

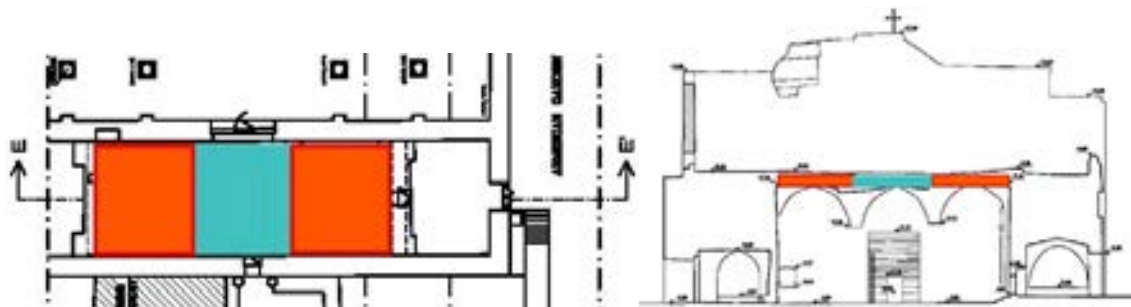


The preliminary structural reports have showed that the existing cracks on the roof are extended from the damaged vault to the adjacent vaults. This fact has made the excavation on additional two vaults to uncover the stone of the vaults are extremely necessary for better understanding of the structural stability of the narthex and to make the structural simulations and analysis more realistic in order to identify the most suitable solution.



 The location of the archaeological excavations





The restoration works for the narthex eastern wooden door has started by erecting a suitable scaffolding system and performing high-resolution digital photographic documentation and diagnostic research. Then followed with a careful consolidation and treatment processes by wood restoration specialists. During the restoration works, it was found that the upper part of the door from the eastern side has wooden boards that hide the original wooden door while the western part has also some part that have been uncovered to show the original carving and the original art work. After the completion of the necessary restoration and consolidation works, the visitors and pilgrims can see the original door and the wood carving art on the other side.







## 12 RESTORATION OF THE WALL MOSAICS INCLUDING SURROUNDING PLASTER, INTERNAL PLASTER AND STONE FACADES (ADDITIONAL WORKS #2):

In accordance with the list of priority restoration works, additional works #2 were awarded to the contractor on July 7, 2014 which includes Wall mosaic, the internal wall plastering, and the external facade restoration's works. The contractor has completed stone restoration works related to the urgent works and about 85% of the cleaning works for the existing plastering layers at the central nave.



**State of Palestine**



**Bethlehem Municipality**



**Regulatory Bylaws for the Conservation of the Historic Centre in  
Bethlehem and the Individual Traditional Buildings**

**2014**

**Based on Draft Organizational Amendment No. 2014/T.B/3 of the Old City  
of Bethlehem and the Classification of Heritage Areas and Individual  
Heritage Buildings**



The “*Regulatory Bylaws for the Conservation of the Historic Centre in Bethlehem and the Individual Traditional Buildings*” was prepared under “*Heritage for Development: Investing in Human Resources for the Protection and Management of Historic Cities*”. The preparation of the Bylaws has been made possible with funding from the European Commission and the co-funding of Swedish International development Agency (Sida) through UNESCO Office in Ramallah. The project was carried out by the Centre for Cultural Heritage Preservation (CCHP) in Bethlehem in partnership with RehabiMed Association, Riwaq Centre for Architectural Conservation and Heritage Techniques Foundation, and in cooperation with the Municipalities of Bethlehem, Ramallah and Al-Salt Greater Municipality. CCHP has drawn up these Bylaws in cooperation with Bethlehem Municipality, the Ministry of Tourism and Antiquities, and the Ministry of Local Government.

The printing of these Bylaws was funded by the European Commission.

The opinions articulated in these Bylaws do not necessarily reflect the opinion of donors.

Bethlehem Municipality:

Based upon the powers bestowed upon Bethlehem Municipality Council in its capacity as the Local Committee for Urban Planning and Construction in the city of Bethlehem, and pursuant to the provisions of the Local Authorities Law No. (1) of 1997, the Towns, Villages and Building Planning Law No. (79) of 1966; and the Law on Buildings and Planning for Local Authorities No. (5) of 2011,

And in accomplishment of the public interest,

Bethlehem Municipality Council, in its capacity as the Local Committee for Urban Planning and Construction in the city of Bethlehem, has hereby promulgated the following decision concerning the Regulatory Bylaws for the Conservation of the Historic Centre in Bethlehem and the Individual Traditional Buildings:

## **Article (1)**

### **Appellation**

The name of these Bylaws shall be “Regulatory Bylaws for the Conservation of the Historic Centre in Bethlehem and the Individual Traditional Buildings” It shall be part and parcel of the organizational plan titled “Classification of Heritage Areas and Individual Heritage Buildings in the City of Bethlehem.

## **Article (2)**

### **Definitions**

In applying the provision of these Bylaws, the following terms and expressions shall have the meanings specified below, unless the context determines otherwise.

The following definitions shall be complementary to the definitions provided for in the Towns, Villages and Buildings Planning Law No. (79) of 1966 and the Law on Buildings and Planning for Local Authorities No. (5) of 2011.

**Landlord:** As stipulated in the Law on Buildings and Planning for Local Authorities No. (5) of 2011 and in the Towns, Villages and Buildings Planning Law No. (79) of 1966 Article (2/62).

**Reconstruction:** As stipulated in and the Law on Buildings and Planning for Local Authorities No. (5) of 2011, the Towns, Villages and Buildings Planning Law No. (79) of 1966, Article (34), Paragraph (4), including renovation and development.

**Local Committee:** Local Planning Committee in Bethlehem Municipality.

**Heritage Committee for Architecture:** An *ad hoc* advisory committee on architectural heritage to be formed under the provisions of these Bylaws.

**Classification Plan:** The classification plan of buildings and individual heritage buildings within the boundaries of the Old City that is attached to these Bylaws and is considered an integral of it.

**Classification:** Classification of buildings and individual heritage buildings within the boundaries of the Old City.

**Manual:** Manual on the preservation of the historic position of Bethlehem city and/or any other manual approved and adopted by the Local Committee.

**Regulations:** The regulations issued by the Local Committee pursuant to these Bylaws for the implementation of its clauses and articles.

**Heritage Property:** Any immovable property and its movable appurtenances whether the property is an urban fabric, a cultural or heritage property, a cultural or natural landmark that has a historic, esthetic, spiritual or cultural value for current and future generations.

**Height of Building:** As provided for in the Law on Buildings and Planning for Local Authorities No. (5) of 2011.

**Heritage Areas:** The locations over 50 years old situated within the boundaries of the Old City of Bethlehem pursuant to the specifications provided for in the Classification Plan. Heritage areas encompass locations and human habitations, or parts thereof, characterized by a special and distinctive architectural fabric, including connected or individual buildings or neighborhoods containing distinctive elements such as streets, alleys, yards and vaults or archways that constitute by virtue of their history, interconnectivity, homogeneity and location in the landscape, architecture and composition a topographically defined location.

**Individual Heritage Buildings:** Heritage buildings located outside the heritage locations specified in the Classification Plan and are not connected with other heritage buildings. Individual heritage buildings must be over 50 years old and must have a historic, architectural, humanitarian or cultural value.

**Public Squares:** Publicly owned squares or spaces usually located in the heart of heritage areas. In the past public squares were used as gathering places as well as places for holding social and economic events.

**Ahwash (sing. hosh) (Courtyards):** The *hosh* is an internal empty or semi-empty space of a heritage building or group of connected buildings surrounding it. In the past, the *hosh* was used for performing house chores such as cooking, washing, and others, as well as for social family events. Generally, the *hosh* was surrounded by a stone-wall with a single entrance or a gate separating it from the alleys.

**Alleys:** Public spaces between the buildings and other elements of architectural fabric. Alleys are narrow streets scattered in heritage areas.

**Floor:** Section of a vertical building between two floors one above the other, including the thickness of one floor.

**Parapet Wall:** A stone-wall around a roof or a veranda to be approved by the Local Committee for the purpose of public safety, provided that the height of the parapet wall does not exceed 90 cm.

**Addition/Additional Floors/Addition on the Roof/Saturation:** This refers to the addition of a new room (space) adjacent to or on the existing construction. Additions can be in uniformity or discord with the existing construction and its surrounding in terms of shape, architectural features, construction techniques, materials used, and others.

**Architectural Decorative Elements:** Architectural decorative elements include doors, door frames, thresholds, locks, window sills, metal balustrades, protective metal, stone carvings, symbols and other decorative features of the building.

**Balconies:** A balcony is a terrace protruding from the wall of a building buttressed with stone frames, a bearing wall made of different materials, steel bridges, concrete or others.

**Wells:** Wells are underground water tanks or reservoirs.

**Suspended Stairs and Corridors:** These are distribution elements that connect the different levels and sections of the building. Usually suspended stairs and corridors are constructed in open space and are used by all occupants of a building.

**Home Systems:** The systems that supply buildings with necessary services such as the water supply system, sewer system, landline and communications system and electrical system. Usually the water system is connected to the water tanks and solar mirrors on the roof.

**Heritage Fund:** Necessary financial resources are streamed through the Heritage Fund, which aims to protect and develop Palestinian heritage and ensure its goals and purposes are realized. The Fund collects donations and fines, and imposes revenues on public and private planning in line with the Towns, Villages and Buildings Planning Law No. (97) of 1966, Article (52) and other articles. The Heritage Fund has its own budget separate from that of the Municipality, which is the local planning authority, and is supervised by the Municipality through the Local Committee.

**Use of Heritage Buildings:** The landlord or the alienor shall use heritage buildings in a protective manner without adversely affecting their physical condition or structure. In the event the landlord or any other person holding the right to use the buildings fails to protect them or causes damage to them, the Local Committee for Architectural Heritage shall be entitled to dispossess the landlord or the user of the buildings and to demand change of use consistently with the preservation and protection of heritage.

**Buffer Zones:** Buffer zones are protection zones located between heritage cities and modern construction and expansion areas. Two of the most significant features of buffer zones is that they contain some scattered heritage structures and that they encircle heritage cities with modern constructions and road networks. Buffer zones also include land plots located outside municipal boundaries within an area of 60 meters around their circumference, including land plots the boundaries of which crosscut partially or wholly with the 60-meter line.

In the event of negligence of the fundamental principles of construction in terms of altitude, relation with the perimeter and nature of the earth as well as the addition of new buildings that are disproportionate to heritage sites, buffer zones will have an adverse effect on the delineation of heritage cities and distinguishing them from surrounding areas. They also lead to cutting off of the visual continuity between heritage cities and the surrounding urban landscape as well as to the disappearance of the urban landscape and its waning into the buffer one of the city of Bethlehem.

**Preservation:** According to the provisions of the Palestinian Charter for Cultural Heritage Preservation of 2013 (Palestine Charter), preservation of cultural heritage comprises one or more of the following interventions: maintenance, conservation, restoration and revitalization.



Any intervention must respect the authenticity and integrity of cultural properties, their location and fabric, and allow for the recovery and restoration of the condition of cultural properties into their original state as it was before the intervention.

**Maintenance:** Maintenance refers to the regular activities that take place in accordance with a predetermined timescale and aims to protect the physical fabric and the perimeter of the cultural property.

Maintenance works must be conducted whenever indicators reveal that the cultural property is generally in good condition and needs only minor interventions. Maintenance shall be conducted by qualified and trained technicians using materials, techniques and traditional tools similar to or compatible with those used in the construction of the original property.

**Protection of Cultural Property:** Measures taken to preserve cultural properties and stop their degradation without direct intervention in their perimeter or fabric. Protection of cultural property may also include measures taken to secure the integrity of cultural properties until a suitable plan for their preservation and management has been developed.

Protection of cultural property takes place when indicators reveal that the cultural property is vulnerable and requires immediate intervention for its preservation.

Protection works shall be launched only after a thorough assessment of the architectural and construction status of the perimeter of the cultural property has been conducted.

If the restoration process involves the introduction of provisional elements to protect and stabilize the surrounding and fabric of the cultural property, these provisional elements must be removable in order to restore the property to its previous condition as it was before the intervention. Moreover, the intervention must not adversely affect the cultural value of the property, or its perimeter and authentic fabric.

**Restoration:** Restoration aims to preserve and/or keep the authentic perimeter and fabric of the cultural property and stop its degradation. Renovation can be partial or whole.

**Partial Restoration:** A procedure that aims to restore the perimeter and fabric of the cultural property to its previous state. The procedure encompasses minimum intervention to maintain the earlier state of the cultural property as it was known before, using traditional material and/or solid material, techniques and similar tools and/or tools compatible with the existing state and general design of the cultural property.

**Comprehensive restoration:** A procedure that aims to restore the existing perimeter and fabric of the cultural property to its original state by way of removing additions and/or reassembling existing elements. Whole renovation includes interventions using traditional and/or solid material, techniques and similar tools and/or tools compatible with the existing state and general design of the property. Minor additions and/or changes shall be acceptable inasmuch as they do not affect the value, perimeter and fabric of the cultural property.

On-site reconstruction is an exceptional procedure that occurs in special circumstances only, and it must be based on historic evidence. Reconstruction based on intuition and guesswork is

unauthorized. In addition, reconstruction, on-site transfer, transfer from the original perimeter to another site or the dismantling of parts of the cultural property must be a last resort. Furthermore, transfer of the cultural property, its reconstruction or assembling of its dismantled parts must be documents.

**Rehabilitation:** This is a complex process that encompasses all social sectors in an urban heritage area or rural heritage landscape. Urban development must comply with certain specific criteria set forth beforehand including consistency with the environs and fabric, and preservation of the integrity and values of the urban heritage area or the rural heritage landscape. All rehabilitation programs in heritage areas must be based on a holistic preservation approach. Rehabilitation may include modifications made to the cultural property to accommodate for contemporary operational standards and needs. The purpose of the modifications is to make the property suitable for new uses.

### **Article (3)**

#### **Objectives of the Bylaws**

The objectives of these Bylaws include the following:

1. Provide heritage areas and individual heritage buildings (architectural heritage) in Bethlehem with protection, and preserve the traditional architectural fabric of heritage areas and the different elements composing it.
2. Organize construction works, additions, demolition, reinforcement, preservation and use of heritage areas and individual heritage buildings.

### **Article (4)**

#### **Architectural Heritage Committee**

A. The Architectural Heritage Committee shall comprise five members as follows:

1. A representative of the Local Committee to be named by the Municipality Council – Committee Coordinator.
2. Head of the Engineering Department at Bethlehem Municipality – Bethlehem Municipality Architect or his/her deputy.
3. A representative of CCHP – Deputy Coordinator.
4. The Director of the Antiquities Office at the Ministry of Tourism and Antiquities or his/her deputy.
5. Secretary of the Regional Committee for Planning and Construction or his/her deputy.

B. The Architectural Heritage Committee shall perform the following tasks:

1. Provide advice, studies and technical recommendations to the Local Committee for Planning and Construction on the addition of structures to the list of existing buildings, and determine their classification if it deems this necessary.
2. Provide advice, studies and architectural and construction recommendations for the reconstruction and preservation works in the Old City as well as for individual buildings, and/or reconstruction works in buffer zones.
3. Submit recommendations to the Local Committee, which shall be entitled to accept, reject or amend the recommendations as the case may be. The reasons for rejection or amendment must be stated explicitly.

## **General Provisions**

### **Article (5)**

Licensing procedures shall take place pursuant to the Towns, Villages and Planning Law No. (79) of 1966 and the Law on Buildings and Planning for Local Authorities No. (5) of 2011. Construction and/or renovation shall be allowed only if appropriate materials and techniques are used as prescribed in the Manual.

### **Article (6)**

Additions to heritage buildings shall take place using techniques and materials as prescribed in the Manual and in uniformity with the existing stone. In addition, construction of additions must take place using traditional finishing and decorations.

### **Article (7)**

Modern additions shall be prohibited in distribution spaces such as *al-ahwash*, internal courtyards, squares and stairways.

### **Article (8)**

The Local Committee shall be entitled to require the rehabilitation of new licensed additions and the removal of unlicensed additions in order to secure their compatibility with the existing architectural context if the additions

- Have an adverse effect on the structural and architectural state of heritage buildings
- Strip heritage buildings of the values of authenticity and integration.

### **Article (9)**

Heritage buildings in the Old City and individual buildings listed in the table and plan annexed to these Bylaws must be preserved and protected from destruction, demolition and sabotage. Likewise, sabotage, destruction and backfilling of wells or using them as cesspools shall be prohibited. The landlord shall be obliged to reinforce and maintain heritage buildings or parts of thereof that threaten public safety and prevent their collapse. The landlord must also preserve all the structural and architectural elements of the building in line with the provisions of the special terms and conditions relevant to heritage buildings and in accordance with the written guidelines of the Local Committee that determines the way and timeframe required for implementation.

### **Article (10)**

Pursuant to these Bylaws, the Local Committee shall issue reconstruction licenses for the renovation and maintenance of heritage buildings, and oblige the landlord to preserve and maintain the old architectural and decorative elements using techniques and materials proportionate to those used in heritage buildings and in accordance with the Manual and the special terms and conditions relevant to heritage buildings. Moreover, when issuing construction licenses for the addition of verandahs in line with these Bylaws, the Local Committee shall oblige the landlord to use materials, techniques and ornaments proportionate to those used in the traditional building and in line with the Manual.

### **Article (11)**

License petitions for the reconstruction of buildings and individual heritage buildings in the Old City must include the renovation and reuse of existing wells, if any. In case there are no wells within the perimeter of the building, the construction of a new well must be imposed as a condition in order to fulfill the needs of the inhabitants if it appears possible to the Local Committee without affecting the heritage building and neighboring buildings.

### **Article (12)**

In the event the landlord fails to carry out renovation works and improve the general appearance of the buildings and gardens after being notified in accordance with Article (38) and (39) of the Towns, Villages and Buildings Planning Law No. (79) of 1966, the Local Committee shall be entitled to demolish and remove the buildings, and/or renovate and restore them, and/or make the necessary reparations on behalf of the landlord and at his/her own expense, in accordance with the provisions of Articles (42), (43), (45), (61), and (64).

The Local Committee shall also collect the costs and expenses from the landlord in accordance with the valid Law of Domanial Money Collection.

### **Article (13)**

The addition of necessary services to heritage buildings may take place if they are not available in accordance with the provisions of Article (5/T) of the Higher Planning Council Decision No, 65 in its session (5/2011) and upon the approval of the Local Committee.

### **Article (14)**

All works of intervention including reconstruction and preservation shall take place under the guidance and supervision of the Local Committee for Architectural Heritage and under the control and monitoring of the standing Local Committee.

### **Article (15)**

In the event the landlord has completed the works mentioned above contrary to the specifications and method determined by the reconstruction license issued by the Local Committee, the Local Committee shall be entitled to remove or correct the works completed by the landlord and perform reconstruction tasks on behalf of the landlord at his/her own expense. The Local Committee shall collect the costs and expenses from the landlord in accordance with the provisions of the valid Law of Domanial Money Collection.

### **Article (16)**

All construction works in the buffer zone shall take place under the guidance of the Local Committee for Architectural Heritage while accommodating for neighboring buildings.

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## **Buildings within the Old City Boundaries Designated for Protection**

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### **Article (17)**

Construction shall be permitted on land plots located within the Old City boundaries that do not contain any buildings, taking into account the following planning provisions for unclassified land plots:

1. When determining the setback, the Local Committee shall take into account the adequate provision of lighting and ventilation for the proposed building and for neighboring buildings. The setback must be adequately wide to allow for easy and smooth passage.



2. The building shall not exceed 60 percent of the total area of the land plot and the floor area ratio of the building must not go beyond 180 percent.
3. The building shall be three floors high, 12 meters above the main street level. The total height of the building must not exceed 16 meters (excluding the parapet wall) provided that the natural gradient of the earth is taken into account.
4. The height of the stairway shall not exceed 2.3 meters above the surface of the upper floor.
5. Building a roof floor shall be prohibited.
6. The Local Committee shall take into account the general appearance, shape, sizes and architectural style of neighboring buildings when issuing a construction license.

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## **Special Provisions for Buildings within the Old City Boundaries Designated for Protection According to Classification**

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### **Article (18)**

#### **Buildings within the Boundaries of the Old City Classified “1/Old City”**

Horizontal and/or vertical additions to heritage buildings classified “1/Old City” shall be prohibited. Likewise, any new additions to heritage buildings shall be disallowed.

### **Article (19)**

#### **Buildings within the Boundaries of the Old City Classified “2/Old City”**

- a. The incomplete floor of the heritage building may be completed consistently with the authentic design of the building and in accordance with the special provisions of the Classification Plan.
- b. Horizontal additions may be made to heritage building after obtaining a license for that matter from the Local Committee with the following terms and conditions:
  - i. The height and number of floors shall not contradict the specifications provided for in the special terms relevant to the heritage building.
  - ii. When determining the setback, the Local Committee shall take into account the adequate provision of lighting and ventilation for the proposed building and neighboring buildings through providing a passage wide enough to allow for easy and smooth passage.
  - iii. The ratio of the building after the addition has been completed shall not exceed 70 percent of the area of the land plot provided that the addition does not hide the frontal façade of the building and/or any other distinctive façade of the heritage building.

- iv. The height of the stairway shall not exceed 2.3 meters above the surface of the upper floor.
- v. Building a roof floor shall be prohibited.
- vi. The Local Committee shall take into account the general appearance, shape, sizes and architectural style of neighboring buildings when issuing a construction license.

## **Article (20)**

### **Buildings within the Boundaries of the Old City Classified “3/Old City”**

Additions may be made to heritage buildings classified “3/Old City” taking into account the following terms and conditions:

1. When determining the setback, the Local Committee shall take into account the provision of adequate lighting and ventilation for the proposed building and neighboring buildings through providing a passage wide enough to allow for easy and smooth passage.
2. The building shall not exceed 60 percent of the total area of the land plot and the floor area ratio of the building must not go beyond 140 percent, provided that the addition does not hide the front façade of the building and/or any other distinctive façade of the heritage building.
3. The height of the building shall not be more than 9 meters above the level of the main road, with two floors only, and the total height of the building shall not exceed 16 meters (excluding the parapet wall) provided that the natural gradient of the earth is taken into account.
4. The height of the stairway shall not exceed 2.3 meters above the surface of the upper floor.
5. Building a roof floor shall be prohibited.
6. The Local Committee shall take into account the general appearance, shape, sizes and architectural style of neighboring buildings when issuing a construction license.

## **Article (21)**

### **Buildings within the Boundaries of the Old City Classified “4/Old City”**

Additions may be made to heritage buildings classified “4/Old City,” taking into account the following terms and conditions:

1. When determining the setback, the Local Committee shall take into account the provision of adequate lighting and ventilation for the proposed building and neighboring buildings through providing a passage wide enough to allow for easy and smooth passage.
2. The building shall not exceed 60 percent of the total area of the land plot and the floor area ratio of the building must not go beyond 180 percent, provided that the addition does not hide the front façade of the building and/or any other distinctive façade of the heritage building.
3. The height of the building shall not be more than 12 meters above the level of the main road, with three floors only, and the total height of the building shall not exceed 16 meters (excluding the parapet wall) provided that the natural gradient of the earth is taken into account.
4. The height of the stairway shall not exceed 2.3 meters above the surface of the upper floor.
5. Building a roof floor shall be prohibited.
6. The Local Committee shall take into account the general appearance, shape, sizes and architectural style of neighboring buildings when issuing a construction license.

## **Article (22)**

### **Buildings within the Boundaries of the Old City Classified “5/Old City”**

Additions may be made to heritage buildings classified “5/Old City,” taking into account the following terms and conditions:

1. The Local Committee shall take into account the general appearance, shape, sizes and architectural style of neighboring buildings when issuing a construction license.
2. The Local Committee shall refer to the special terms and conditions for each building in order to determine the terms and conditions of the acceptable addition to the building in accordance with the provisions provided for in the classifications mentioned above.
3. The slab of the heritage building may be demolished for reconstruction provided the following terms and conditions are met:
  - a. Documentation of the building prior to demolishing the slab by way of architectural plans (horizontal and vertical planes and façades), and videotaping and photographing it from inside and outside and depositing the architectural blueprints and photographs at the archive of the Heritage Committee.
  - b. Demolition of or making changes on external façades of the building shall be prohibited.

- c. Depositing the insurance pursuant to the insurance clause no. 32 of these Bylaws.
- d. The Municipality and the Antiquities Department may take construction materials (or parts thereof) from the heritage building after demolition, and the landlord shall be obliged to hand over the materials upon request.

### **Article (23)**

#### **Buildings within the Old City Boundaries Classified “6/Old City”**

1. The buildings classified “6/Old City” may be demolished if the Local Committee deems it necessary provided that the Committee documents the building in full through architectural blueprints (vertical and horizontal planes and façades), and videotapes and photographs it from inside and outside and deliver the photographs to the Municipality.
2. The Local Committee shall refer to the special terms and conditions for each building in order to determine the terms and conditions of the acceptable addition to the building in accordance with the provisions provided for in the classifications mentioned above.
3. Depositing the insurance pursuant to the insurance clause no. 32 of these Bylaws.
4. The Local Committee shall take into account the general appearance, shape, sizes and architectural style of neighboring buildings when issuing a construction license.

### **Article (24)**

#### **Buildings within the Old City Boundaries Classified 7/Old City”**

These are buildings or additions that have an adverse effect on the urban fabric and cultural heritage of the city of Bethlehem and therefore must be demolished. The demolition shall be exempt from the insurance clause according to Article (32) of these Bylaws unless the demolition of the building will have an adverse effect on neighboring buildings.

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## **Individual Heritage Buildings Designated for Protection**

### **Article (25)**

The land plots on which heritage buildings are built may be partitioned in accordance with the Law on Buildings and Planning for Local Authorities No (5) of 2011 taking into account not to incur any damage to the heritage building.

### **Article (26)**

The use of individual heritage buildings shall be subject to the provisions concerning the use of the area in which the heritage buildings are located.

**Article (27)**

**Individual Heritage Buildings Classified “1/Individual Buildings”**

Vertical and/or horizontal additions to individual heritage buildings classified “1/Individual Buildings” shall be forbidden and likewise any new additions to heritage buildings.

**Article (28)**

**Individual Heritage Buildings Classified “2/Individual Buildings”**

- a. The incomplete floor of the heritage building may be completed in line with the authentic design of the building and in accordance with the provisions the special terms and conditions of the Classification Plan.
- b. Vertical additions to heritage buildings shall be allowed only after obtaining a license for that matter from the Local Committee and with the following terms and conditions:
  1. The height of the building and its floors must not violate or contradict the specifications provided for in the special terms and conditions concerning the heritage building.
  2. Setbacks from all sides shall not be less than what the stipulations of the area where the heritage building is located provide for.
  3. The ratio of the building shall comply with the stipulations of the area where the heritage building is located.
  4. The height of the stairway shall not exceed 2.3 meters above the surface of the upper floor.
  5. Building a roof floor shall be prohibited.
  6. The Local Committee shall take into account the general appearance, shape, sizes and architectural style of neighboring buildings when issuing a construction license.

**Article (29)**

**Individual Heritage Buildings Classified “3/Individual Buildings”**

Additions may be made to an existing heritage building classified “3/Individual Buildings” provided that the following terms and conditions are taken into account:

1. The addition must not hide the frontal façade and/or any other distinctive façades of the building or any parts thereof.
2. Setbacks from all sides shall not be less than what the stipulations of the area where the heritage building is located provide for.
3. The ratio of the building shall comply with the stipulations of the area where the heritage building is located.



4. The height of the building shall not be more than 12 meters above the level of the main road, with three floors only, and the total height of the building shall not exceed 16 meters (excluding the parapet wall) provided that the natural gradient of the earth is taken into account.
5. The height of the stairway shall not exceed 2.3 meters above the surface of the upper floor.
6. Building a roof floor shall be prohibited.
7. The Local Committee shall take into account the general appearance, shape, sizes and architectural style of neighboring buildings when issuing a construction license.

### **Article (30)**

#### **Individual Heritage Buildings Classified “4/Individual Buildings”**

Additions may be made to an existing heritage building classified “4/Individual Buildings” provided that the following terms and conditions are taken into account:

1. The addition must not hide the frontal façade and/or any other distinctive façades of the building or any parts thereof.
2. Setbacks from all sides shall not be less than what the stipulations of the area where the heritage building is located provide for.
3. The ratio of the building shall comply with the stipulations of the area where the heritage building is located.
4. The height of the building shall not be more than 15 meters above the level of the main road, with four floors only, and the total height of the building shall not exceed 19 meters (excluding the parapet wall) provided that the natural gradient of the earth is taken into account.
5. The height of the stairway shall not exceed 2.3 meters above the surface of the upper floor.
6. Building a roof floor shall be prohibited.
7. The Local Committee shall take into account the general appearance, shape, sizes and architectural style of neighboring buildings when issuing a construction license.

### **Article (31)**

#### **Individual Heritage Buildings Classified “5/Individual Buildings”**

Additions may be made to an existing heritage building classified “5/Individual Buildings” provided that the following terms and conditions are taken into account:

1. The addition must not hide the frontal façade and/or any other distinctive façades of the building or any parts thereof.
2. Setbacks from all sides shall not be less than what the stipulations of the area where the heritage building is located provide for.
3. The ratio of the building shall comply with the stipulations of the area where the heritage building is located.
4. The height of the building shall not be more than 15 meters above the level of the main road, with four floors only, and the total height of the building shall not exceed 19 meters (excluding the parapet wall) provided that the natural gradient of the earth is taken into account.
5. The height of the stairway shall not exceed 2.3 meters above the surface of the upper floor.
6. Building a roof floor shall be prohibited.
7. The Local Committee shall take into account the general appearance, shape, sizes and architectural style of traditional heritage building when issuing a construction license.
8. The slab of the heritage building may be demolished for reconstruction provided the following terms and conditions are met:
  - a. Documentation of the building prior to demolishing the slab by way of architectural plans (horizontal and vertical planes and façades), and videotaping and photographing it from inside and outside and depositing the architectural blueprints and photographs at the archive of the heritage Committee.
  - b. Demolition of or making changes on external façades of the building shall be prohibited.
  - c. Depositing the insurance pursuant to the insurance clause no. 32 of these Bylaws.
  - d. The Municipality and the Antiquities Department may take construction materials (or part of them) from the heritage building after demolition, and the landlord shall be obliged to hand over the materials upon request.

## **Article (32)**

### **Individual Heritage Buildings Classified “6/Individual Buildings”**

1. Individual buildings classified “6/Individual Buildings” may be demolished if the Local Committee deems it necessary provided that, before obtaining the demolition approval, the Committee documents the building in full through architectural blueprints (vertical and horizontal planes and façades), and videotapes and photographs it from inside and outside and deliver the photographs to the Municipality.

2. Buildings classified “6/Individual Buildings” shall be exempt from the insurance clause in accordance with Article (32) of these Bylaws.

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## **Financial Insurances**

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### **Article (33)**

With regard to individual heritage buildings identified in the plan that are subject to these Bylaws, applicants for a license within the boundaries of the Old City shall present financial insurance in line with the terms and conditions, and amount and timeframe determined by the Local committee. In the event reconstruction works have not finished by the end of the period determined for implementation, the guarantee shall be renewed in order to secure compliance with the instructions, specification and terms and conditions of the construction license issued by the Local Committee, as well as the proper execution of work, as follows:

- a. 6 percent of the commercial value of the land where the heritage building is located if reconstruction works include the demolition of part of the building.
- b. 2 percent of the commercial value of the land where the old building is located if the license is limited to making additions to the building.
- c. 1percent of the commercial value of the land where the old building is located is the license is limited to renovation works.

The commercial value of the land shall be determined pursuant to Article (73) of the Law on Buildings and Planning for local Authorities No. (5) of 2011.

### **Article (34)**

The insurances stipulated in Article (33) above shall be considered an amendment to the provisions of Article (75) of the Law on Buildings and Planning for Local Authorities No. (5) of 2011 and/or any other law relevant to the boundaries of the Old City and individual heritage buildings specified in the plan. In the event the reconstruction license includes more than one type of work, the value of the insurance shall be calculated in accordance with the highest item of those works.

### **Article (35)**

The insurance amounts stipulated in Article (33) shall be earmarked for the account of the Local Committee if the landlord fails to carry out required works within 60 days as of the date of his notification.

### **Article (36)**

The provisions of the Towns, Villages and Buildings Planning Law No. (79) of 1966 and its amendments shall apply in the event of the perpetration of an act violating the provisions of these Bylaws.

### **Article (37)**

Bethlehem Municipality Court shall have the competence and jurisdiction to look into violations relevant to these Bylaws and impose punishments pursuant to the Municipalities and Local Commissions Law.

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## **General Provisions**

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### **Article (38)**

The Local Committee may renew or refuse to renew any unused license issued before these Bylaws have entered into effect and contradicts its provisions. Likewise, the Local Committee may make necessary amendments to the license in order to make its terms and specifications compatible with the provisions of these Bylaws.

### **Article (39)**

The provisions of these Bylaws shall be complementary to the provisions of the Towns and Villages Planning Law No. (79) of 1966 and the Palestinian Buildings Law No. (5) of 2011.