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Le Vie dei Mercanti

Carmine Gambardella

WORLD HERITAGE and DEGRADATION

Smart Design, Planning and Technologies

La Scuola di Pitagora editrice

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Collana fondata e diretta da Carmine Gambardella

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Via Monte di Dio, 54
80132 Napoli
Telefono e fax +39 081 7646814
www.scuoladipitagora.it
info@scuoladipitagora.it

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WORLD HERITAGE and DEGRADATION
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Le Vie dei Mercanti
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Scholars has been invited to submit researches on theoretical and methodological aspects related to Smart Design, Planning and Technologies, and show real applications and experiences carried out on this themes.
Based on blind peer review, abstracts has been accepted, conditionally accepted, or rejected.
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Conference report

300 abstracts received from:

Albania, Benin, Belgium, Bosnia and Herzegovina, California, Chile, China, Cipro, Cuba, Egypt, France, Germany, Italy, Japan, Jordan, Kosovo, Malta, Massachusetts, Michigan, New Jersey, New York, New Zealand, Poland, Portugal, Russia, Slovakia, Spain, Tunisia, Texas, Turkey.

More than 550 authors involved.
212 papers published.

Preface

The theme of the XIV Forum “Le Vie dei Mercanti” is an international discussion on the disciplines of architecture, design and landscape through the presentation of research and operational projects on the conservation and valorisation of World Heritage and “smart” regeneration of degradation, with analyses and proposals ranging from the design at all scales, to architectural assets, the territory, infrastructures and the landscape. Academics, along with professionals who have a role in the governing, managing and controlling of public agencies, institutions and the business world are invited to submit papers related to design objects, architecture and landscapes. This is with the aim of conserving and recovering, valorising and regenerating, managing and designing (or re-designing), for the more general improvement of the quality of life, in an innovative and contemporary relationship between man and the environment, through “beauty”, while respecting the history, traditions, identity and principles of sustainable development, as well as being attentive to the needs of our and future generations. Internet of Everything, smart design, planning and technologies, building information modelling, in this age of globalization, have become operational tools – that alongside the traditional ones of the profession – for the protection and promotion of the World Heritage, are considered as well as shared by the whole of Humanity, and the regeneration of the degradation and the “Minor Heritage”, in all aspects, and as contemplated by the UNESCO Conventions on tangible and intangible assets and the European Landscape Convention. The event aims to create a critical transversal dialogue, open to cultural and “unlimited” influences, in a logic of integration between the skills that extends, and is not limited, to the following disciplines: anthropology, architecture, archaeology, history art, cultural geography, design, ethnology and folklore, economy, history, landscape, museum management, philosophy and political science, urban history and sociology, cultural tourism, planning and integrated management. The location is exceptional. Campania, with six sites included in the World Heritage List, two UNESCO Man and Biospheres, two sites on the List of Intangible Heritage, is one of the richest regions in the world for cultural and landscape heritage.

Carmine Gambardella

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Wooden churches in Lithuania
Analysis of failures and degradations, guidelines for restoration

Liucija BEREŽANSKYTĖ[1], Tiziana CAMPISI[2]

(1,2) Department of Architecture, University of Palermo, Italy

liucija.berezanskyte@gmail.com; liucija.berezanskyte@unipa.it

tiziana.campisi@unipa.it

Abstract
Wooden Lithuanian churches represent an architectural heritage which is fairly preserved by the local community, but unfortunately the biggest destroyer is the aging of the buildings, intensified by an inadequate maintenance.
The main causes of damage and structural degradation are the atmospheric agents, infestation of dry rots and insects. Sometimes also incongruous reconstructions contribute to the structural decay, associated to the wrong choice of protective materials and furnishings, the absence of ground works, the economy of the interventions, the inappropriate uses.
In order to preserve this architectural heritage, that witnesses the development of our culture and history, we hope and study for restorations particularly careful in the use of traditional materials while limiting the use of incongruous materials, as well as the uncultivated tamperings, demolitions and replacements.
This research can give a detailed analysis and knowledge of the wooden buildings and their failures and degradations, associated to useful guidelines for technicians and workers that operate in restoration and maintenance interventions [*].

Keywords: Lithuanian churches, wood, degradation, cultural heritage, restoration.

1. Analysis and recognition of failures and degradations
The main part of Lithuanian wooden sacred buildings becomes into a sensible decay condition, because of absence of the necessary attention and technical competence, able to preserve these buildings. The churches represent an heritage of wooden technical culture which remains all to explore for the conservation of the valuable architecture of this Country.
Frequently many incorrect restoration works were made, often executed using incongruous materials or products scarcely compatible with the existing ones, that resulted in defective implementation of the supporting structures and completion, also associated to the original absence of fundamental constructive elements, able to preserve and give stability to the building [1].
During the restoration works of wooden churches is usually taken into consideration the outer cladding, forgetting the interior structural elements, which are also affected by different underlying causes; also the same replacement works of the outer coating are often made without taking into account the original appearance of worship.

2. The most vulnerable wooden building areas
Usually the most damaged parts of the wooden building are those that remain directly in contact with water, in that areas where an excessive percentage of moisture accumulates. The most vulnerable structures are also those exposed to strong winds or affected by vibrations of church bells, likewise the roof structures which bear the large loads of snow.

The extent of damage and decay can be largely determined by the general state of the building and by its ancientness, as antique buildings are more susceptible to the damage of external agents such as damp weather, temperature changes or negative effects of ultraviolet rays. The deterioration due to these factors occurs imperceptibly and slowly over time.
Unlike fungi and insect attacks, wind force and incorrect restoration or maintenance works as well as the risk of fires cause more rapid effects and are microscopically more evident [2].
It's very important to track the causes of damage on the wooden material immediately and promptly, to remove them quickly, performing appropriately the necessary restoration and/or the replacement of the damaged parts (Fig.1).
These wooden elements must be kept under observation and constant revision, because their degradation can also provoke a damage to the other connected structures.
Therefore causes of deterioration must be recognized and removed by adopting suitable measures and implementing any necessary consequential structural changes.

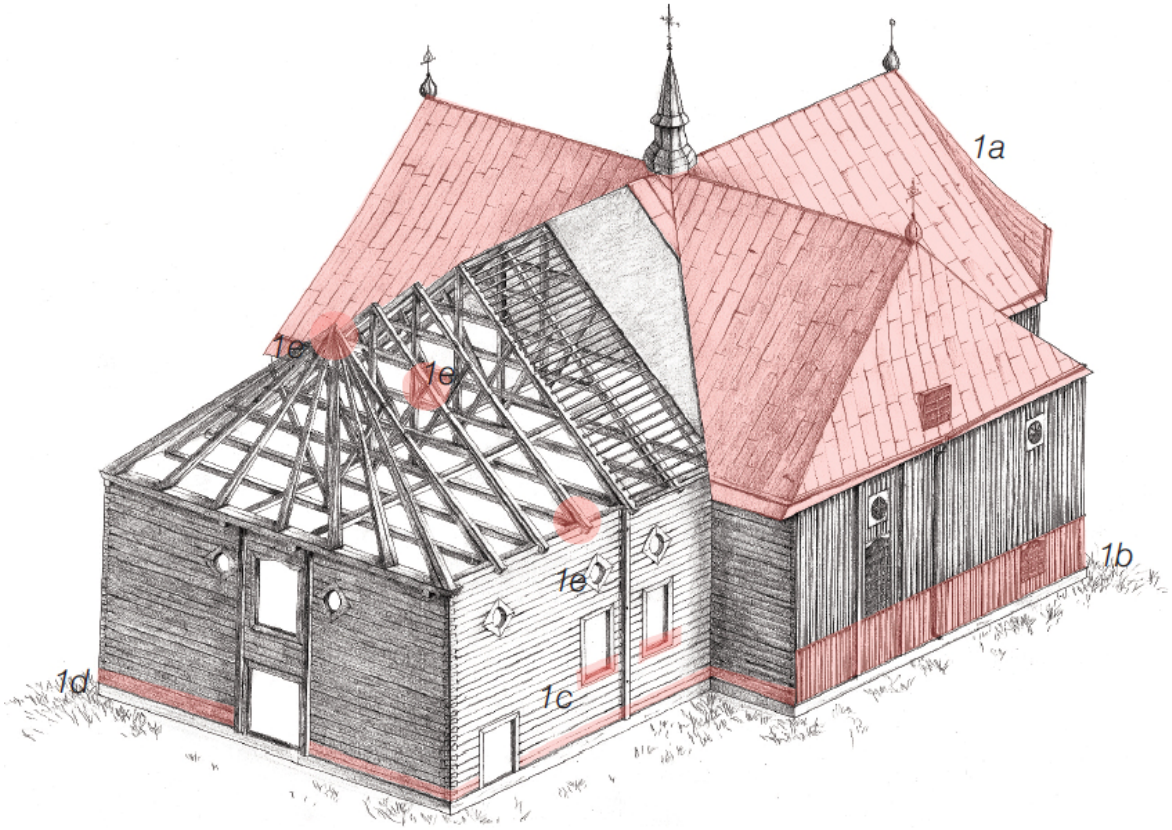

Fig.1: The wooden building elements that require more frequent maintenance works:
1a - wooden shingles, that are often the main coat of the roof;
1b - wooden boards of the outer wall-covering, together with the copper flashings;
1c - wooden frames of the windows and doors, together with the outer windowsill;
1d - lower trunks of the *Blockbau* system, directly connected with the stone foundations;
1e - some elements of the roof structure; in particular, the constructive nodes of the structural frames.

3. Recognition of the main causes of damage and deterioration

3.1 Environmental influences

The deterioration caused by environmental influences such as water, temperature changes, sun and wind are manifested especially in outer parts of the buildings, noticeably the degradation of the window and door frames, cladding of the vertical wooden walls, wooden covering of the roof structures and also the wooden fences, that often enclose the land pertaining to the churches.
When the wooden external coating is damaged the rainwater frequently penetrates into internal structures, causing further more serious structural degradation, that is very difficult to recover.
In particular, temperature variations cause significant degradations: thermal excursions in Lithuania can reach extreme limits, from -35°C (this thermal condition causes the expansion of the ice in the cracks of the wood) to +35°C; in this last case, if some structural elements exposed to the sun, (such

as the wooden boards of the coating, the wooden door and window frames) are not well protected with an appropriate coating, UV rays can determine a surface degradation of the wooden structures, causing initially a browning or yellowing of the color of the wood and progressively a subsequent decay.
The part of the building facing the South is always the most vulnerable; the effects of temperature changes can also bring a damage not only to the wooden elements of the building but also to the stone structures, such as foundations, which also suffer from contact with the water resulting from melting snow or from intense summer rains. This kind of water exposure can also affect the stability of the ground on which the stone structures are located [3]. (Figg.2,3).

Figg.2,3: On the left: the walls cladding of the wooden boards is one of the most frequently replaced elements. Lack of maintenance of the external cladding can lead to irreversible degradations.
On the right: damage to the outer covering of the roof accumulates water into the attic area, increasing the moisture level (over 20%). This disruption can cause fungal attacks to the roof structures.

3.2 Presence of moisture and fungi attack

The main causes of the appearance and development of fungi, rot and mold are the high levels of humidity of the wood (when it exceeds 20-21%) and high temperature (from 18°C to 36°C) affecting parts of building which are poorly aerated and with considerable degree of water imbibition.
In these environments conditions, the internal and external constructive elements of the wooden church can be attacked by fungi, especially by so-called brown rot and white rot.
The structural components frequently attacked by fungi are those corresponding to the structural coverage units, located at the attic area; in these parts often rainwater infiltrates through the rotten cover cladding and the level of humidity is increased (Fig.4). Also during the cold season, when the building is not heated, the breathing of the churchgoers induces a warm and humid air flux, rising through the ceiling from ecclesial area. A frequent water imbibition phenomenon is also present in lower trunks of vertical external wall; this phenomenon is caused by the increased soil humidity and the water flow from coverage. The perfect conditions for the proliferation of fungi are caused by the inadequate composition of wall paint, that inhibits breathing and ventilation of the wood.
The areas of the building where it's more difficult to detect a fungi attack are those that lie under the paint coating: the damage appears only when the fungi are already well developed, and the paint tends to peel off. Usually, under the paint coat, the white rot develops; in this case, it's necessary to remove all the paint layers, to protect the wood from fungal attack and to ventilate.(Fig.5)
The presence of fungi causes the longitudinal or transversal trunk cracks, severely damaging the wood. These wooden structural and covering elements attacked by fungi are usually those placed on the outer part of the building. Fungus attack causes the reduction of the mechanical strength of the wood, decreasing the consistency of the material by considerable percentage.
The first condition to identify a fungal attack is the change of the natural color of wood: in fact, at a first time the damaged parts become dark and also a visible reduction in size and weight appears.
Thanks to a rubber hammer it's possible to check if the trunk is already damaged by fungus: if striking the damaged zones - using a rubber hammer - the sound is dull and soft, it means that it is no longer a healthy wood, which has lost its original strength and resistance, its natural mechanical characteristics and functional capacity and thus requiring the implementation of recovery works [4].

3.3 Insects infestation

The most common insects in Lithuania that damage the wood are the bark beetles (*Scolytinae*), they are brown or black; these insects can attack any type of timber, freshly cut or well-seasoned.
Trees cut in the summer are more susceptible to insect attacks and the *laburnum*, the part over the bark, becomes the main zone of infestation. They dig long galleries in various directions, deteriorating the wooden section and also they can proliferate in the wood already attacked by fungus or develop under the bark of the trunk (Figg.6,7). Indeed, the area under the bark, known as *cambium*, is perfect for the development of insects; they can creep into a trunk and then spread to other wooden constructions, rapidly multiplying. Wrong varnishing can facilitate the development of insects by not allowing the wood to breathe adequately and not promoting the identification of infestation. Bugs can be mainly identified by direct visual inspection: the group of different sized holes present in the trunk indicates the work carried out by these parasites, also the sawdust removed by insects indicates which holes are still active. It is also possible to observe the insect attacks using simple tools such as the hammer, the gimlet, the drills that allow to hear the sound or cleft of the examined trunks [5].

Figg.4,5: On the left: logs in direct contact with the water which penetrates the old coating of the cover. In this image it's possible to see not only the discoloration, but also reduction of the volume.
On the right: the first consequence of fungi attack, with the alteration of the natural color of the material. In this example, the plaster and paint are detached from wooden elements because of fungi emergency.

Figg.6,7: Example of wooden beams irreparably damaged; even a small number of holes can hide a very serious state of deterioration.

3.4 Structural instability

A through examination must be firstly carried out for typical wood defects (grain deviation, ring shake, timber splitting and cracking, warping, opening of the joints due to shrinkage and density of the logging nodes) as it may adversely affect the conditions of the elements resistance.

A level of danger of timber nodes depends by their number, location and size; an high density of nodes can provoke, in fact, a remarkable decrease of timber resistance [6]. The shrinkage cracks are also one of the main causes of structural instability.

Wooden sections after water evaporation lose their moisture and then reach a drying point that could cause a contraction of the constitutive volume. Therefore, wood is deformed through a slot that occurs from the edge up to the pith of the trunk, tending to enlarge in a “V” shape.

The trunks, deforming in this way, tend to get separated from the structural nodes to which are bound together with other rods and, consequently, the disconnections trigger, resulting in a risk of instability or collapse. The proper interventions able to reduce the damage due to cracking are the suture of the beams injuries after sealing the edges with strips; the wedges are carefully shaped and placed in the cracks with epoxy resin and the monitoring could prevent the spread of lesions and the gaps in the resistant sections.

The ring shakes - as result of separations between the fibers along two growth rings or within the same ring - are also obvious causes in a partial or total separation between the different crowns.

This type of identification is very difficult as the ring shakes are concealed inside the beams [7]; the cases of ring shakes are infrequent in timber construction of softwood, while they are more common in structures made using the chestnut.

As regards the evaluation of the interlocking connections, it must be taken into an account that their state of efficiency constitutes one of the main parameters to ensure the correct working principles of the entire structure.

Structural joints provide the support for various elements are they are often used to link the elements of the bearing structures; wooden or metal nails are also present, as well as metal bracket, in order to tight on the wooden joints.

The predisposition of efficacious joints also constitutes an element of weakness, as it reduces the resisting cross-section, due to a concentration of tensions at that point.

The survey must necessarily start by the execution of such nodal points and should be followed by a careful assessment of the joints ability to transmit efforts between the various elements [8].

In wooden trusses, the strong wind and flexural deformation provoked by snow load or the undersize of constituent sections can cause the loosening of the nodes initially reinforced using wooden nails.

The timber roof structure must be continuously monitored: in fact, always during the spring season is better to control the attics, in order to be sure that there are no loss of shingles after the winter storms and strong winds.

All nodes require a visual analysis, as in case of disruption the structure can tend to get out of wooden nails and pins, that must be reinserted in their housing with the hammer [9]. (Figg.8,9).

Figg. 8,9: On the left: a disconnection between the king-post and the tie beam. On the right: all nodes of the roof structure are disconnected, due to the shrinkage cracks.

4. Guidelines for intervention and restoration

These guidelines would encourage an higher attention of the Lithuanian community and the government to this architectural heritage, not only to improve a general maintenance and recovery, but also to preserve the original character of the wooden structures and the conservation of traditional materials in restoration works.
The principles of enhancement and conservation would direct the local technicians – as well as all that intervening on wooden architectures - to choose the congruous interventions and not to distort the ancient constructive techniques, as well as their original construction principles.

4.1 Intervention of foundation structures

The stone foundations of the old wooden churches were not particularly deep and high but, over the time, the level within the ground tended to increase, due to either settling of the ground or the settlement of the foundation: for these reasons, the lower trunks of the wooden supporting wall, positioned on the stone foundations, resulted in close contact with the soil and, therefore, always accumulated more moisture from the ground. The local workers to avoid these problems preferred to build the wooden churches in higher places, that allowed a better flow of the rainwater on the surrounding area.
It is also appropriate to remove the vegetation around the building and arranged a lay of dry stones of various dimensions all around the foundations, in a wide band at about 30-50 cm [10].
Recovery works of the foundation structures must ensure a stable support for the external wooden walls, with a possible expansion of the bottom section, useful to better spread on the ground loads on the same foundations. Moreover, if the erosion conditions of the mortar occur, it's necessary to restore the continuity of the masonry elements, replacing the mortars into the joints and do all the interventions in correspondence of the masonry substructure.

4.2 Recovery of the wooden supporting walls

The lower trunks of the supporting wall - damaged by the humidity rising from the ground or even because of an inadequate protective coating - often must be restored.
The damaged parts of the trunk must be carefully reinforced or, only in exceptional cases, replaced. When the trunk is completely degraded by fungal attack or cracking from shrinkage extended to the whole section, in that case the recovery works are carried out trying to keep as much of the original material as possible.
The verification of the state of health of the large wooden beams forming the *Blockbau* systems (wooden walls) is often difficult, due to the inner and outer covering by the wooden boards. To verify the actual state of the logs, the works proceed by removing the external or internal covering, in order to ensure a proper inspection and diagnosis, according to where it is easier to intervene.
The type of the restoration works depends on the degradation level and distribution on the surface; if the trunk is slightly damaged, it's better to proceed with a prosthesis that is adapted after a proper preparation of the existing trunk.
The lower logs of the wall are usually damaged at the outside part, while the interior part remains healthy (Fig.10). In such case, it is preferable to operate the partial replacement of the deteriorated trunk by cleaning the surface, removing the decayed parts and disinfect the remaining residue of the trunk with antiseptic products and insecticides.

Figg. 10,11: On the left: the lower wooden wall trunk is in a direct contact to the ground, deteriorating by soil moisture. On the right: in case of total damaged logs, trunks can be replaced raising the wall structure and removing the damaged parts.

Trunks can not be dried mechanically, because the fast exsiccation does not guarantee they to be completely dry, but they became only superficially dry, and then quickly they will be damaged. So that, it is preferred to use the natural drying process that takes few years. Therefore well-kept old weathered wood - taken from the demolitions of other buildings - is used [11].
Once the appropriate timber for the realization of prostheses is obtained, the work proceeds by retrieving the new timber size of the damaged area of the old trunk. The pith of the new prosthesis is placed in the inner part of the old trunk.
The surfaces of the new prostheses and the old trunk must be well smoothed to ensure the necessary compliance and a perfect adherence. Subsequently, the repaired area is varnished with the pine resin. Finally, there is two absolutely rigid elements, stiffened by wooden pins or nails, or if it is necessary by stainless steel or fiberglass bars.
The new prostheses are inserted into the existing structure and distinguished by the lighter color that is later darkened using iron sulphate or a mixture of diluted resin [12]. As already mentioned, if the trunk is severely damaged, it is preferred to resort to its definitive and total replacement, using new trunks with a very large pith (Fig.11). At the end of the restoration works, all of the deteriorated timbers, attacked by fungi or infested by insects must be quickly removed from the building site.

4.3 Structural interventions of the roof structures
There are many types of timber roof structures in the Lithuanian churches: wooden trusses, structural frames and supporting coverage structures. These wooden structures are very resistant, but however - in the attics without sufficient ventilation - a very high level of humidity is accumulated, which facilitate the proliferation of insects and fungi.
The roof logs, at times, are damaged due to the large overhead snow loads; some elements of the roof system can significantly inflect or break at some points. The strong wind, wood cracking due to the shrinkage, the effect of the vibrations of the bells placed on the bell towers may also provoke deformation and disconnections of the various structural nodes.
If the constructive nodes for any possible causes are weaken and loosen, it's straightly forbidden to bring them back to their original position, but it's necessary to strengthen the entire system without particular efforts to the structure.
We frequently notice that, over the time, some repair works in the roof structures has been carried out using metal clamps or other timber elements to strengthen the structure and to prevent future damage, looseness or possible movements. Today this type of consolidation, widely used in the past, does not appear to be effective. Therefore is better to proceed with the metal hoops.
To proceed the correct stiffening work of the building structures, additional elements should be made using a wood, that presents similar characteristics as that originally used in the construction. In some very special cases, when the constitutive elements of trusses, structural frames and supporting coverage structures appear to be severely damaged, it can be replaced in some parts, trying to leave as much as possible of the original material.

4.3 Protection against water and atmospheric agents
In order to allow a better and faster outflow of the rainwater, the local workers mainly used to nail the wooden boards on the outer walls in a vertical direction. In case of replacing the old and damaged outer boards with the new ones, it's necessary to keep attention to the direction of the existing boards and the orientation of pith (principally, if the pith is directed outward or inward).
It's necessary to check the gutters and the downspouts and constantly remove all dry leaves, as they can block the correct leakage of rainwater from the coverage. The wooden surfaces must be prevented from the natural decay through frequent maintenance and varnishing all the wooden surfaces that are located outward.
The layer of paint, in fact, slows down the moisture transmission through the surface of the wood and seals the extractives capillaries inside. The best types of paint are composed with special oils that allow the perspiration to wooden elements; also a pine resin is often used, which is not a toxic material, that impregnates wood, strengthening and protecting its superficial fibers. The pine resin is a viscous material, usually used with seed oil or/and turpentine.[13] Before painting the external and internal parts of the building, it should always be checked the layers of previous paint, in order to restore correctly the original image and colors of the building.

4.4 Protection from fungal infection
When the wood moisture particularly reaches relevant levels, the timber structures or elements can be easily attacked by fungi, in that case it's necessary to check constantly the most vulnerable parts of the building: this assessment is usually made by a hygrometer.
To avoid considerable damage caused by these pest organisms, the wooden structures must be always kept in good ventilation, especially in the attic areas that must be well ventilate, in order to allow the air circulation both in winter and in summer.

The local workers preferred to built windows in the attic area, which, if necessary, should be left open. In attics and foundations of the recently built churches there are always open holes to ensure a good ventilation of such parts of the building (Figg.12,13).
To protect the roof structure from infiltration of rainwater, which would favor the emergence of dangerous moisture conditions, it's necessary to promote the efficient disposal of rainwater, preventing possible water stagnation. It is therefore necessary to control the roof covering, the rain descended, copper flashings, and also provide for other protections for those parts of the building directly exposed to driving rain on wooden elements.
First of all, in case of fungal attack, it will be appropriate to provide for adequate restoration work, identifying and removing the causes and replacing the deteriorated material.
The wood, even if only slightly damaged by fungi, is planed and protected with fungicide products and processed directly with an anti-mold product, in order to avoid further diffusion. When the trunk zones are already strongly attached, these parts are removed and replaced with new wooden elements.
All wood elements must be well protected against moisture penetration, there are mentioned some traditional products that protect the wood from fungi, molds, insects and bacteria: the lime water, the milk of lime and also a mixture consisting of 100 mg of salt dissolved in a liter of water.
All the structural elements already attacked by fungi, should be regularly monitored and evaluated in terms of moisture content.

Figg. 12,13: On the left: in the attic area the local workers during the construction work preferred to install windows that guaranteed a good ventilation of the roof structures, during the year; on the right: in the past, it was preferred to open holes directly in the foundations, to ensure a good ventilation of all foundation zone.

4.5 Protection against insects

The wooden buildings must always be well ventilated and protected, even in relation to possible insect infestations. Into the openings for ventilation, it is necessary to install particularly dense grids, to avoid the entrance of insects. It is required to control any new trunk, planks and boards used for renovations, recovery work and finishing to be sure that these new elements are well debarked and free of small holes, in which the insects could nest. In these kind of operations is suggested to check the surface of examined wood before the general cleaning of the entire surface, because it is possible to find the sawdust produced by these pests that instead, if found, would detect its presence. In such condition, it's necessary to make a correct identification of the insect type, in order to eliminate it and to apply an appropriate remedy to prevent the complete degradation of the timber.
If infested holes are founded in the trunk, the recovery work proceed by injection of a necessary dose of turpentine or permethrin by a syringe [14]. If the wood is strongly attacked by insects, one must proceed with periodic treatments with pesticides, or also with ethylene oxide gas spraying or also methylene bromide. This kind of treatment should be done during the spring season, when insects begins the larvae phase. Performing these treatments, the area must be hermetically closed [15]. After the gas application is required to ventilate the spaces affected by this intervention.

5. Conclusions

Since the 19th century all the Europe witnessed a general decline of the arts and techniques, related to wooden buildings and for a long time no new wooden buildings were made [16].
Architects are no longer able to correctly identify the shapes of the sacred architecture, and this leads to numerous mistakes during the restoration and reconstruction phases [17].
In order to preserve this architectural heritage, that witnesses the development of our culture and history, we hope for restorations particularly careful to use traditional materials while limiting the use of incongruous materials, as well as the uncultivated tamperings, demolitions and replacements.

This research can give a detailed analysis and knowledge of the wooden buildings, associated to useful guidelines for technicians and workers that operate in recovery and maintenance intervention.
We hope that this study can be introduce an operational tool and an impulse to improve and implement the knowledge of this unique building heritage, simply built but rich in history and constructive traditions, that we have to preserve by negligence and uncultivated interventions.

[*] **Note:** This article summarizes a part of the PhD thesis titled *The traditional sacral wooden construction in Lithuania between XVIII and XIX century*, written by ing. L. Berežanskytė, tutor prof. Tiziana Campisi. We would ascribe to ing. L. Berezanskyte the paragraphs nn.4 and 5; to prof. T. Campisi the coordination of the research and the paragraphs nn.1, 2 and 3.
We also would inform the readers that in the proceedings of the XIII international forum of the previous year (2015), the authors present an article that describe the constructive characters of Lithuanian churches, with a detailed report of an atlas of building techniques.

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Table of content


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