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Lithuanian wooden architecture
Materials, ancient tools and constructive technologies for the safeguard of cultural heritage

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Abstract
Traditional wooden buildings are a valuable part of European cultural and architectural heritage. Construction of wooden buildings presents a wide variety of technological, formal and typological types of buildings between various European countries as it is strongly influenced by the nature, availability of local materials and cultural aspects of various communities.
For the construction of wooden buildings in Lithuania all local natural resources were used: various species of wood for building construction, a compact stone for groundworks, clay and bricks, lime mortar, dried moss used for building insulation and straw or wooden shingles essential for roof cladding etc. Also, each region presents specific architectural features which are often associated with different choices of constructive materials and decorative elements.
This study would analyze the wood species and other construction materials traditionally used for cultural heritage in Lithuania (stone, brick, mortar, metal, ...), woodworking processes carried out using specific traditional tools which can be found in various Lithuanian ethnographic museums. Most of these carpentry tools still could be applied for the safeguard interventions using a still actual philological handicraft techniques during consolidations, recovery works and partial reconstructions.
To preserve the local culture heritage, it is necessary to expand the knowledge of original building materials and construction technologies to be able to carry out restoration works correctly.
Degradation of wooden structures depends on maintenance and recovery works and interventions which often contribute to deterioration of timber. Furthermore, it often occurs that new structural elements used for replacement and strengthening have under dimensioned sections and materials used for protection of wood and wood coating are often incompatible.

Keywords: Lithuania, wood, construction, technics, heritage.

1. Know for recognize. General categories and features of construction materials
1.1 Stone materials
Stone materials were only used for the realization of groundworks and in some cases for external and internal flooring of wooden buildings. Stone materials, frequently used for Lithuanian historical building construction, are granite, gneiss, trachyte, some types of magmatic rock and sandstone. Lithuania has vast land of forests which provide huge quantities of timber, however, this territory does not offer large amounts of natural stones. Stones can be found in small quantities in the close proximity of rivers, some forests and especially in the agricultural fields. Stones of various sizes were taken from these fields as they obstructed the cultivation works.
Boulders and smaller stones taken from fields, were brought to the construction area by horse-drawn carriages. Large stones were used only for foundations, because they didn't have to be crushed. Only in nineteenth century workers began to modify large stone blocks in polygonal shapes or squared blocks to make solid foundation footer. Hewn stones were also used to make flooring and outdoor staircases (Fig. 1).

Fig. 1: Stone used for foundation structures, external flooring and stairs.

Fig. 2: Clay used for foundation reinforcement, indoor flooring, and to fill the spaces between the wall trunks.

1.2 Artificial stone materials: bricks

Clay is mainly composed of silicate minerals, hydrocarbons, silica, alumina and calcium [1]. In Lithuania, there are several areas rich in clay which is situated in a sandy soil at a depth of about 10 cm. Clay was used for different functions at different parts of the building, in some cases raw or associated with other materials (Fig. 2). Usually clay is used as a main binder for construction of stone foundations; in this case mortar is composed of clay, sand and water. Clay was also used for internal flooring: just extracted, it was transported to the places of construction for commissioning of a jet with constant thickness of about 10-15 cm. Afterwards, newly made pavement was dampened with water before adding the next layer of clay, in order to guarantee adequate adhesion between the layers. Then new layer was well levelled, beaten and smoothened by a large wooden mallet. The rustic surface was then finally finished with a mixture of clay and water, well leveled using a wooden board and left to dry for 3-4 days [2]. Production of raw or baked bricks was carried out by beating clay with a wooden mallet to eliminate air bubbles after adding straw and, sometimes, flax tow. The brick shape was realized using wooden moulds [3]. Clay bricks of rectangular, square and trapezoidal formats and sizes were used for internal flooring.

Clay, which was used to manufacture interior plaster of wooden vertical walls, required special preparation. It was mixed with water and battered to obtain a perfectly smooth mass; later finely sieved sand was added to the mixture. The obtained mortar must be sufficiently dense to adhere perfectly to the wooden walls [4].

Clay was also used to fill the spaces between the wooden vertical walls, consisting of logs positioned horizontally: the mixture was prepared by pouring water, animal dung and chopped straw. The space between two adjacent logs was manually saturated with this mixture, forcibly inserted between the cracks, regularizing any inaccuracies.

1.3 Artificial stone materials: mortars

Lime was used as a binder for the construction of the masonry foundation and for indoor plaster mortars. To perform the shutdown (extinguishing) cycle of lime, it was placed in rectangular shape wooden container up to the half of it and covered with water until it fills the entire chest; mass had to be well mixed and compacted to obtain a liquid and smooth texture. The mixture was stored in deep

graves in the ground and left to mature up to ten years. The lime used for the foundations was taken from these graves and mixed with small and / or medium-sized aggregates, in the same proportions. This method allowed to obtain a very resistant mortar suitable to be used for masonry works.
Lime for interior plaster was mixed with water to reach the density of the milk, then from this compound very fine sand was extracted. It's density had to be a little more liquid than clay [5].

1.4 Plant materials

In Lithuania many plant materials were used for the wooden constructions to provide thermal insulation: among these materials are the dry moss (sphagnum), flax tow, foliage, wood shavings, wooden tar, straw, reeds (Fig. 3).
Most of these materials are collected during the summer period, such as moss, that is found in very humid forest soils and must be dried in the sun. Moss was used for filling existing empty spaces between the horizontal logs or as an intermediate layer in the ceiling systems, like flax tow. The preparation of flax tow is long and laborious: after uprooting, the stalks of flax are tied together in bundles and left to dry; afterwards the seeds are threshed, while the stems are trampled and combed. In this way flax tow is separated and ready to use.
The foliage and wood shavings which are already dried, were applied on the extrados surface of the ceiling of the building, to ensure thermal insulation. Straw was used as a secondary material associated to the mixture of clay and was also placed above ceilings as a thermal insulation; straw and reeds together often constituted the completion of the cover layer and coating.

1.5 Metallic elements

In Lithuania iron is the metal most commonly used for the construction for its easy workability. Collected from wetlands full of minerals, its production was entirely based on craftsmanship, using simple equipment and tools, such as anvils, pincers and hammers. Heated with fire iron was reinforced by adding a small amount of carbon; this process made it suitable to produce various parts of tools, such as axes, hammers, saws, knives, drills, blades. In addition to the carpenter's tools, small elements of studied architectures such as hinges, reinforcement brackets, hinges, nails of various kinds and type, bolts, crosses, stiffening elements with different profiles, harpoons, metal fences, etc.
In rural areas iron was a very expensive material and for this reason it has been used only when it could not be replaced by other materials; that's the reason why so many wooden buildings until the second half of the eighteenth century were built without metal nails but using only pins and wooden nails or, in some cases, entirely without nails. In the nineteenth century the metal stiffeners began to be used in structural wooden nodes subject to high risks of instability. In the late nineteenth and early twentieth centuries metal connections were used widely in many traditional wooden buildings.
Iron was commonly used for decorative elements. The valuable work of simple or adorned iron crosses, became part of UNESCO heritage list.
In the twentieth century lead and zinc started to be used, especially in flat sheets of corrugated formats otherwise useful to the roof coating, or in hollow tubular profiles for the realization of downspouts, or in thin metallic plates useful to coat the external window sills and to constitute flashings for the parts of the building exposed to direct contact with rainwater.

1.6 Wooden species

Wooden buildings were predominantly built using coniferous trees, which still represent 60% of Lithuanian forests: pines, spruce pines and larches. These types of trees are the most suitable for the construction of buildings as they have fewer defects of constitutive growth and their intercellular gaps

Fig. 3: Dry moss, and flax tow used to ensure thermal insulation between the logs (a,b), straw for the roof coating (c).

are filled with resin; accordingly, this type of timber is more resistant to decay, has more constant colouring and texture, is easier to cut and plane. Coniferous wood is lightweight and has relatively short periods of maturation; the wood species can, in those latitudes, grow to a height of about 30-40 meters, with a trunk diameter of approximately 1 meter [6]. It is preferred to use pine wood, because in the maturation phase it presents less minor cracks formed by shrinkage in comparison to spruce. Coniferous wood, especially pine, is used for all load-bearing structures (logs for foundation, structure of wooden vertical walls, beams and isolated supports, roofing systems, frame structure of bell towers, ...), pine wood is also used for technological finishing and external covering (internal and external coating of the wooden vertical walls, and the roof coating) and for the production of doors, windows and external fences. Other types of wood species were used for interior decoration and furniture.
Usually the conifer trees are cut at the age of 80-120 years, because at this age they no longer change in volume and are more resinous.
To identify the best quality of trees it's necessary to pay special attention to the soil in which they grow: if it is full of nutrients, trees are stronger and full of resin. The best tree for bearing large loads is the one that is compact and has fewer branches, with a large marrow and with dense annual rings. It is better to cut down the trees that grow in middle of the forest, because those growing in the margins are more contorted due to the winds and have larger number of branches.
Sometimes removing a small piece of bark from the tree helps to see if the same tearing is straight or oblique, so we can understand the trend of tree fibers. In order to produce the best quality of timber it was preferred to cut the trees during the winter season, taking an advantage of the stasis of the vegetative cycle. In winter trees contain a minor amount of liquids, which remain in the roots, so wood quality could be better preserved during this season. Furthermore, all wood types used for building construction could be left at the open air to facilitate the desiccation.

2. Safeguard of handcraft works. Carpenter's tools, accessories and procedures

2.1 Felling, Transportation

Cut tree trunks were bound together and individually drawn by a horse or loaded in groups on special sleds. Sometimes sleds proved to be too short for trunks loading so they were connected to a smaller sled to facilitate the transportation of timber from the forest to the construction zone. One end of the trunk was placed in the first sled, the other one in the second small sled: in this way it was possible to carry a maximum of four logs at a time. In dense parts of the forest, impossible to reach by sleds, tree trunks were directly tied to a horse and pulled one by one.

2.2 Debarking

Once reached the construction site, logs were loaded on two other logs placed perpendicularly on the ground to keep logs raised from the ground and to facilitate preparation work. The following phase was debarking, as leaving the bark on could proliferate insects and dry rots which would affect wood quality. Debarking was usually performed only after the wood drying phase, in order to facilitate separation of the bark. Debarking was performed with axes, knives and/or debarks (Fig.4 a, b).
To perform this operation, it was necessary to have movable trunks to be able to rotate them easily and to debark them from all sides. If the trunk appeared very unstable, woodworkers quickly made grooves with the axs on the trunks on which the debarked trunk leaned to secure them in place or alternatively the were bound by a vise (Fig. 4c).

Fig. 4: Tools for debarkling (a,b), vise tool for consolidation of logs.

2.3 Wood forming

To treat the squared section logs with an axe, at first cutting line had to be marked using a thread coated with sprinkled carbon, stretched between two nails attached to the log ends, then this operation was repeated for all four sides of the trunk which was later cut along these markings. Following operation of grooves or slots were completed using axes and / or saws. Another type of squared section logs processing is made using a saw. Once the bark was removed, trunks were placed on wooden trestles. This work was carried out by two workers: one carpenter standing on the trunk; the second one is cutting the log with a special saw into planks. Cut planks were left to dry outdoors, stacked in a particular way: following a triangular pile or one above the other. Unlike the planks, logs could be used for wooden construction just after debarking, because it was considered that they could dry later. Wood was processed using ancient carpentry shaping, which were elementary but essential for the construction of buildings that required much time and a significant number of workers.

2.4 Preparation of the log grooves

The upper and lower parts of the logs which were used for the support of vertical walls were shaped through the grooves to overlap perfectly and to obtain maximum air and water tightness.
To do this, it was necessary to draw the profile of the lower trunk on the upper trunk, using a tool with two tips as a pantograph which brings the silhouette of a lower trunk (Fig.5a).
Subsequently, following the cutting line, larger parts of the trunk were eliminated with an ax, and afterwards with a smaller ax with semicircular blade the final groove of the trunk was made (Fig. 5b,c).

2.5 Realization of the holes and hollows

Each log positioned horizontally had to be made integral with the lower ones using long wooden nails. During the installation of the second log of perimeter walls, holes were made with a thin shape drill and long wooden nail, which connects and consolidates two or three trunks, was subsequently inserted. This operation was repeated for each new pair of upper logs, until the top of the wooden wall. Woodworkers used two types of nails: ones with narrow in the centre or at the bottom and ones with oval tip, to ensure adequate consolidation.

2.6 Turning and planing

Turning is a method of wooden shavings removal: it is defined by a rotary motion of the wooden element and by a mostly straight tool. Blade penetrates into the wood, removing the excess and shaping the element as a solid of rotation. The machine tool used for turning is the lathe. Turning was carried out to manufacture decorative elements such as railings, some shaped parts of the pulpits, the altar and confessionals (Fig. 6).
Planing is a process that serves to make the surface of the wood more regular and smooth, eliminating surface residues caused by cutting operations, ensuring a higher level of finishing and make the wood ready to receive the subsequent finishing treatments. Planing is also a preliminary step, essential for the definition, for example, assortment of wooden boards, widely used in the construction and in particular for the pavings, the cladding of the interior ceiling structure, the covering of the perimeter bearing walls, both inside and outside.

2.7 Auxiliary elements

For realization of the vertical wooden walls, logs which had to be placed on the top, were lifted above, used two wooden canes which were employed as a binary: one end of cane lays on the ground, the other on the walls, subsequently, using strings, logs were lifted to the desired position. Inside the

Fig. 5: Preparation of the log grooves.

Fig. 6: Tools for turning and planing (a), lathe (b), turning (c).

perimeter of the wooden supporting walls was installed a small scaffolding, mobile or fixed, in order to perform works at high altitude. Raised logs were placed with care in order to ensure maximum adherence to the lower logs. Sometimes woodworkers erected a new building using remains of a pre-existing building as a internal scaffolding, these remains were finally removed when the new wider perimeter wall was finished.

3. Assortment of sawn elements

All parts of the tree were fully utilized: in fact, the longest and straightest logs are perfect for the beams, the most resinous and free of bends were suitable for the base parts of the wooden vertical walls, the most compact and solid logs - for the columns; less resinous wood - for the window fixtures, not perfectly straight wood was used for decorations and finishing elements, stumps - for foundations. Wood residues were used to make pins, nails and handles for tools; from the bark resin and shavings were obtained and small pieces were used for the thermal insulation or heating, while the foliage could also be used for isolation or as a soil fertilizer.

It was considered, that all wood used for the constructions must dry well in the air before it can be used. Newly cut trunk contains about 40% relative humidity and in these conditions timber is not suitable for constructions, because it later loses about half of humidity while drying. For this reason, trunk's density tends to decrease and form typical shrinkage cracks, causing various and serious deformation and structural damage.

From portioned and debarked logs beams, rafters, battens and boards were obtained.

Only logs, prepared for the wooden vertical walls were utilized without drying and straight away were placed in horizontal position, because the weight of the same structure, together with the weight of the roof construction, prevents the further deformations.

Wooden material, selected for window and door fixtures and the coverings, must be well dried because otherwise thin and still wet boards, already used or placed tend to deform while drying.

Trunks and boards prepared for constructions must be dried in well ventilated areas, without direct sunlight, preferably in the shade, as they do not favour quick drying, which can result in timber cracks and various deviations of the fibres that would weaken the mechanical characteristics of the wood.

Solid wood and planks were placed in a row one above the other and separated from each other by battens, while boards of smaller dimensions were arranged in a triangle without spacers.

4. Improvement of the wooden features

Sometimes, to improve characteristics of the logs, especially of those which would have to support large loads, after drying logs were immersed in water for about 5 -10 years. At the end of this long period, logs were left to dry completely. In rare cases, another method was used – it consisted of immersing logs in spacious tanks filled with cow's milk for a period of one year: wood, as a result of impregnation with milk, developed such a strong resistance, that it could hardly be scratched with an ax. Some existing examples built using this procedure and are found in the Žemaitija region. The effectiveness of this practice can be seen in very minor, for that age, degradation and structural damage. Logs, that were in direct contact with foundations, were impregnated with pine resin to protect wood from moisture. Sometimes before cutting coniferous trees, woodworkers removed all branches and bark and left the tree bare for some time. In order to resist against atmospheric agents, tree produced large amount of resin in the outer part of the trunk. These logs were placed in the lowest parts of wooden walls to protect walls from ground moisture.

Note – In this unitary work, coordinated by prof. Tiziana Campisi, we can attribute to eng. Liucija Berežanskytė the paragraph 1 and 3, to prof. eng. Tiziana Campisi the paragraphs 2 and 4.
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