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Conservation and restoration of timber architecture in the Czech Republic

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Topic: T4.2. Materials and intervention techniques for vernacular architecture

Abstract
This paper concerns the techniques and methods used for the construction, preservation, and intervention of timber structures in the Czech Republic, built of logs and hewn logs in particular. Against the overall European background, the paper endeavors to find a sustainable approach to preserving these structures out of consideration for their character, credibility, and information value.

Keywords: *timber heritage; deterioration; damage; intervention techniques.*

1. Introduction

Vernacular architecture has been built of fir and spruce wood in today´s Czech Republic for a long time. Round logs were used at first and squared throughout the country thereafter, even in regions completely transformed because of wood shortages as well as anti-fire measures. As an example, Slaný Region in central Bohemia can be mentioned. Local stones were used since the Middle Ages here. Another example is southern Bohemia, where entire villages were rebuilt with bricks during the 19th century. Log constructions have hardly been preserved in the territory of the Czech Republic, except for archaic building traditions in the case of some regions and building types as well as in combination with prevailing hewn logs.

1.1. Definition

Cyril M. Harris (1975) has differentiated a log cabin from a log house: *A **log cabin** is constructed of straight, round logs stripped of their bark and laid horizontally, one above the other, to form a structure. In contrast, a **log house** is constructed of logs that are hewn to form square timbers before they are assembled as a structure. The construction of these two types of buildings differs concerning tools, skill, and time. In both, the logs are notched or otherwise fastened together to prevent their spreading at the corners and to provide rigidity and strength, but in a log cabin, all the logs protrude beyond the joints.*

1.2. Terminology

Srub from ***roubený dům*** can be accordingly differentiated in the Czech language. In the first case, we can use "*das blockhaus*" or "*blockhütte*" in German, "*en bois massif empilé*" or "*cabane*" in French, "*capanna di tronchi*" en Italian, "*cabaña de troncos*" in Spanish, and „*zrub*" in Slovak. In the second case, there is also another English term, namely "*timbered house*". But the "*log house*" is more often in use as well as the same in French "*en rondins*", in Italian "*di legno*" and Spanish "*de troncos*". In German, the general "*das Zimmerwerk*" is used. In Slovak, it is similar to Czech, i.e. „*zrubený*". Because not only houses are included in the paper, the term „*log structure*" or „*timber structure*" will be used in the following text.

1.3. Method and scope

The classification below was carried out of consideration for log structures in today's Czech Republic; nevertheless, the European context was taken into account. The primary method used was field research in the course of the author's professional experience (https://lidova-architektura.cz).

2. General principles

There are several principal documents regarding interventions and preservations on heritage including timber architecture, not counting lots of general documents. At the international level, ICOMOS charters and other doctrinal texts (https://www.icomos.org/en/resources/charters-and-texts) can be mentioned in particular.[1] Except for these, there are many methodological manuals and practical guides as well as many papers at the national level. From the design, construction technology, and realization point of view, technical standards or building codes are particularly important as well as other specific recommendations. In this context, we cannot ignore the Eurocodes (EN) (https://eurocodes.jrc.ec.europa.eu/) which were developed by the European Committee for Standardization (CEN).[2] In the case of the Czech Republic, the national Czech technical standards (ČSN) were replaced by the EC (now ČSN EN). Out of consideration for the topic, it is naturally the most important section Eurocode 5: Design of timber structures (EN 1995)[3] except for Basis of structural design and Actions on structures. Equally important are technical standards relating to the wood and timber itself[4], and the others concerning diverse aspects of durability and wood preservatives.

3. Climate change and Green Deal

Although cultural heritage has always been exposed to the climate, its vulnerability increased due to the effect of climate variability and change apace. This also applies to timber heritage to a large extent. For that reason, the threat from either drought and fire or rainfall/snowfall and flood cannot be ignored. Flood hazard is likely to increase across much of Europe (Sabbioni et al., 2008). Creating a sustainable built environment must be also included, particularly for reducing whole life-cycle carbon emissions in the construction sector. Repair and reuse of existing timber buildings and components may be the optimal or even the best option in some cases. This is true in the case of the appraisal of the life-cycle including energy and resource consumption from a long-term point of view, not even counting the heritage values degradation themselves. (ICOMOS, 2019; Larsen & Marstein, 2000)

4. Damage, deterioration, and defects

Timber structures are very vulnerable to water in all states of matter as well as to fire for various reasons. Biocolonization by wood-destroying fungi or insects (Caneva et al., 1991; Goodell et al., 2020) is also a common cause, closely related to moisture. There are many damage manifestations, which can vary in extent and seriousness. Many technical terms correspond to these manifestations.

D	damage, dilapidated
DIS– (opposite)	disrepair, disrupt
DE–(remove, reduce)	decay, deformation, degradation, deterioration, defect, delamination, defibration, demolition, destruction, desolation, decrepit, deposit, decoloration

Table 1. General terminology concerning different types of damage manifestation (a selection illustrating the diversity of terms beginning with prefixes dis-, de-)

First of all, however, it is necessary to know their concrete causations. This knowledge is crucial for proper intervention in all respects. Among the common causes of wood deterioration (Gril, 2010;

[1] Charter on the Built Vernacular Heritage (1999), Principles for the Preservation of Historic Timber Structures (1999), Principles for the Analysis, Conservation, and Structural Restoration of Architectural Heritage (2003) etc.

[2] Two CEN (https://www.cencenelec.eu/about-cen/) technical committees are close to the subject, e. g. TC 124 Timber structures and TC 346 Conservation of Cultural Heritage.

[3] Part 1-1: General – Common rules and rules for building and Part 1-2: General - Structural fire design

[4] EN 335 Durability of wood and wood-based products – Use classes (incl. the biological agents' occurrence), EN 338 Structural timber – Strength classes

Uyielli, 2009; Rivery, 2014; Rosato, 2017) and timber structure damage fall:

- **climate and natural conditions**
  / water and temperature
  - dampness, moisture, humidity
  - dew point

  / biological colonization
  - fungi – Ascomycota, Basidiomycota (spore, hypha, sporocarp) (brown rot, white rot, soft rot) *(Serpula lacrymans, Coniophora puteana, Gloeophyllum sepiarium, etc.)*
  - insects – Anobiidae, Cerambycidae ... (larva, adult) (apertures, beetlesdust, joined cavity) *(Hylotrupes bajulus, Ant, etc.)*
- **construction conditions**
  / timber
  - hard or softwood, age, dressing
  - surface, previous treatment

  / oxygen
  - air access, i.e. construction detail
- **use conditions**
  / human being
  / building services engineering

Some of the often-repeated building defects are (Šimůnková, 2000):

- **damage, poor maintenance, neglect**
  / leaking from outside or inside
  / rainwater, surface water, bottom water
  / tap water, service water
- **air-tight closure**
  / facing, cladding, tiling, lining, panelling
  / wall in, line with (immure)
- **contact with cold elements**
  / plumbing
- **thermal bridge**
  / missing or poor thermal insulation
  / condensation of water vapour
- **construction waste**
  / unsuitable placement, e. g. in the loft
- **unsatisfactory ventilation**
  / natural, mechanical

5. Measures, intervention, and protection

Apart from the legislative and the enlightened administrator or owner, regular upkeep and opportune intervention are highly important. This is usually preceded or should be at least by an inspection within the condition survey and mycology survey. These surveys include measurement and gauging in situ as well as potential sampling for laboratory tests (Rosato, 2017). The personal experience and knowledge of building pathology (Watt, 2007; Freitas, 2013; Brito & Flores-Colen, 2021), which are imperative for the pre-intervention diagnosis, are equally important. There are many intervention techniques and methods as well as technical terms (Camino & Bustamante, 2012), complementary or overlapping in meaning.

CON– (together)	conservation, consolidation, construction, conversion
RE–CON	reconstruction
RE– (do again) +*ion, ment for process*	restoration, reparation, reintegration, renovation, replacement, reinforcement, revitalization, rehabilitation, rebuild, replication, remodeling

Table 2. General terminology concerning different types of building intervention (with prefixes con-, re-)

The subject and term relationship to medical terminology can not be unnoticed including other synonyms (convalescence, recovery, recuperation, remedy, etc.) as well as filling, prosthesis, and replacement hereinafter. In connection with the aforementioned terminology, many traditional and contemporary interventions can be found in situ. These can be categorized into (a) preventive measures; (b) emergency measures; (c) woodworking; (d) surface treatment; (e) structural strengthening; and (f) material improvement. The combination of several methods is often needed. It should be reminded that it depends on the specific cause of the damage or deterioration and its degree and extent. The intervention in compliance with cultural heritage values is taken for granted.

5.1. Preventive measures

This category covers the precautions against the risk or damage it precedes. It can concern the building itself as well as its vicinity to wood protection primarily. It can be differentiated:

- **physical protection**
  / dry, wet, design (structure, detail, etc.)
- **chemical protection**
  / surface, undersurface
- **installation**
  / climate control (ventilation, humidity, heating, operation, etc.)
  / anti-fire system (detector, water supply, sprinkler, water mist) (Karlsen, 2015)

Dry protection is the most appropriate preventive measure. This can include both wood preparation (logging, bark removing, storage, drying) and the suitable placement of timber members in the structure. This is aimed at moisture content rapid reduction in the first case and water long-term action prevention in the second case. This already refers to precipitation, capillary moisture, and surface or interstitial condensation. It is recommended to keep the moisture content in the wood below 20 % against fungus attacks. In the case of insects, around 12-18 % is sufficient. (VVÚD, 2005)

5.2. Emergency measures

This category includes the issue of securing the building itself as well as its vicinity, e. g. bank or hillside. In contrast to the preventive measures, it follows especially after the damage and a visible or at least detectable risk.

Fig. 1. Façade of the pub "Dřevěnka Inn" No. 92 (house formerly) supported by interim oblique back shores with balk and stone footing that is secured by iron anchor rods in the drilled opening, Úpice Village, Trutnov District, Hradec Králové Region © Martin Cernansky, 2008, NHI

The measures can be categorized into:

- **supporting** (Fig. 1.,2.)
  / prop, strut, stanchion, shore, etc.
- **wind bracing**
  / diagonal, cross, chevron brace, etc.
- **hanging**
  / webbing, strap, etc.
- **holding together**
  / collar, etc.
- **wedging**
  / joint wedge, etc.
- **covering**
  / canopy, tin hall, etc.

Fig. 2. Watermill No. 2 (82) and intervention requiring the support of the first floor with the aid of hydraulic bottle jack rest on a firm, level surface, Zubrnice Rural Reservation, Ústí nad Labem District, Ústí nad Labem Region © Martin Cernansky, 2015, NHI

5.3. Woodworking

Woodworking is related to the carpentry profession itself, alternatively joinery. Since mechanical properties reduction often precedes a visual disruption and complete decomposition of the timber, the lifetime of the member can be shortened despite its seemingly good appearance. Not just for this reason, a replacement of the members has been already common in the past. The usual example is the lower beam, made of hardwood because of capillary rise action and possible contact with the moisture-retentive soil. However, even when using hardwood, the replacement with the aid of a mechanical screw jack was necessary sometimes. Waterproofing (asphalt-impregnated felt etc.) was inserted into this bed joint later. In other cases, the lower part of the timbered building was underpinned as a stone or brick masonry socle was walled up.

The present interventions also consist of the replacement of the entire member or its part. Both handcrafted (Kloiber et al., 2020) and milled members are used. The appropriate choice should depend on the structure origin and import, not just the lower cost. For structural reasons, it is not possible without the use of steel elements sometimes. The use of the same or at least compatible wood is particularly important as well as the two-way joint secured by pins or even adhesive material. (Brentnall, 2008) For completeness, new methods are also mentioned in brief.

Renew
(Cernansky, 2015)

- **replica, reconstruction**
  / entire structure
- **replacement** (Fig. 3.)
  / just member, element, component
- **enlargement, cross-section**
  / cleat
- **„replenishment“**
  / instead of missing the original member

Fig. 3. Watermill No. 2 (82) and new members instead of damaged ones, the replacement requires additional supports and load securing, e. g. by carrying straps/webbing on the right, Zubrnice Rural Reservation, Ústí nad Labem District, Ústí nad Labem Region © Martin Cernansky, 2015, NHI

Repair and restoration
(Šimůnková, 2000; Makýš, 2004; Kim, 2012)

- **filling, carpenter´s method**
  / structure in the first place
  / hollow, large crack
  / chips or a piece of wood
  / solid foam
- **filling, restorer´s method**
  / furniture and works of art in particular
  / cavity, tiny crack
  / mastic (casein, wax, resin, nat. rubber)
- **prosthesis**
  / rotted end or head
  / wood, steel, laminate, carbon fibers

Reinforce

- **visible piece**
  / tension rod, anchor rod, heel strap
  / flat or rectangular bar
- **invisible reinforcement** (gouge, layer)
  / rolled-steel I, H, U
  / composite bar, i.e. glass or carbon fibre
  / fibre-reinforced composites

5.4. Surface treatment and impregnation

Surface treatment covers the dressing inclusive of different types of natural or man-made covering and coating. These were applied as protection against different agents:

- **biotic**
  / bacteria
  / wood-decaying insects
  / wood-destroying fungus
- **abiotic**
  / conflagration
  / weathering
  / moisture fluctuation
  / noxious substance, pollutants
- **anthropogenic**
  / chemicals, coatings

Surface treatment can be divided into traditional application methods:

- **daub**
  / thick clay coat, so call "fur" in Czech
- **rendering and plastering** (Fig. 4.)
  / mud plaster, lime plaster
- **cladding**
  / shingles and boards, slates, asbestos-cement slates, metal sheets
- **painting**
  / monochrome, polychrome paint

Fig. 4. House No. 14 and mud plaster application on reed mesh, the plaster is coarsened for easy topping coat adhesion as well as prevention of shrinkage cracks, Lhota Rural Reservation, Česká Lípa District, Liberec Region © Martin Cernansky, 2020, NHI

Erstwhile coats of paint were mainly used to finish the appearance, like chromaticity or gloss, (Šefců et al., 2000), although preservative effects can not be completely excluded:

- **limewash**, i.e. whitewash, most often
  + earth pigment of minerals
  / vermilion, ochre, ultramarine
- **oxblood** + whitewash
- **varnish**
  / boiled linseed oil, i.e. flaxseed oil
- **wax**
  / beeswax

A wide range of products used for carpenter´s and joiner´s work (wax, oil, or resin base) under various trademarks is currently on the market. Later, the wood protection itself is of equal or even capital importance to painting. The protection can be used not only as part of the above-mentioned preventive measures but also for later **chemical treatment** (Fierascu et al., 2020), i. e. biotic sterilization, and disinfection or abiotic protection:

- **wood preservatives**
  (biocide and/or fungicide)
  / inorganic compound
  / organic compound
  / polymers
  / disinfectants
  / nanoparticles
- **fire retardants**
  / inorganic compound solution
  / intumescent substance

Impregnation can be divided into modern application methods, namely (a) spraying and painting; (b) soaking; (c) immersion and pouring; and (d) full-cell process, i. e. vacuum, pressure, diffusion. However, a lot of wood preservatives and fire retardants are neither time-tested nor certified. Some of them are even unsuitable for the wood itself, as it is a porous and fibrous organic material. The coatings which are not air-permeable belong to a wide group of modern interventions that led to irreversible damage as they prevent water vapor diffusion. Other examples are chemical fire retardants based on inorganic compounds *(ammonium sulphate, ammonium phosphate)* (STOP, 2020) because their application resulted in the defibring of the wood grain. The water glass *(sodium silicate)* did not prove to be useful due to the wood mineralization itself. A lot of wood preservatives are harmful to any organism and thus also a human being. At the same time, there can be environmentally unsound as in the case of volatile organic compounds. Wood preservatives containing coal-tar distillates (*carbolineum and creosote*) or chemical elements (*copper, chromium, and arsenic*) are also dangerous, restricted, or banned by the European directive (EUR-Lex, 2005). Besides chemical preparations, there are also **physical methods** for short-lived sterilization listed below for completeness.

- **warming**
  / microwave, hot air, etc.
- **singeing**
  / flame
- **electromagnetic radiation**
  / gamma-ray, X-ray, ultraviolet
- **vacuuming**
- **acoustics waving**
  / ultrasound
- **fumigation**
  / hydrogen cyanide, methyl bromide, carbon dioxide, etc.

Application and use of these methods are also limited concerning both practicality (element size, metal fasteners, etc.) and harmlessness.

5.5. Structural strengthening

Structural strengthening covers supporting and bracing elements including the possible use of steel. The reason for their application is mostly to prevent deformations on account of the low compressive strength of wood in the direction orthogonal to the grain in particular.

Fig. 5. House No. 53 built of logs used for walls and ceiling. Apart from this profiled bracket, there are also simple shape brackets under the supporting beam. Rtyně v Podkrkonoší Village, Trutnov District, Hradec Králové Region © Martin Cernansky, 2008, NHI

In both cases, it is most often done by the permanent addition of wooden profiles (Fig. 5.) or steel rods. In the second case, only tension load is transferred. Except for the individual structural member (e. g. joist beam), the whole building can be strengthened with a system of support bearing, struts, and/or wind bracing. There are several historical as well as contemporary techniques. Among the historical ones, we can mention especially the ground floor frame of two-storey houses. Brackets supporting a beam placed at the wall are another example of additional and reversible intervention.

5.6. Material improvement

Material improvement consisting of consolidation is carried out by impregnation or micro-injection. Among the historically and recently documented conventional **consolidants** (Rivery, 2014; Walsh-Korb & Averous, 2018) for structural elements (and furniture) we can mention:

- **oils**, vegetal and mineral
  / linseed oil, Tung oil (in Czech later)
  / used motor oil (until recently, fence)
- **waxes**
  / beeswax
- **natural resins** (Fig. 6.)
  / rosin, i.e. colophony (wood, pine)
  / shellac (wood, lac bug)
- **bitumen**
  / tar (wood creosote)
  / asphalt (petroleum)

In addition to the abovementioned consolidant, there are chemical compounds (Fierascu et al., 2020) in use or research as well as contemporary substances like (a) alum; (b) sugars or sugar alcohols; (c) metallic (nano)particles; (d) polymers and polymeric resins; and (e) cellulose, chitosan, keratin, etc.

Fig. 6. Watermill No. 2 (82) and improving material properties using resin injection, Zubrnice Rural Reservation, Ústí nad Labem District, Ústí nad Labem Region © Martin Cernansky, 2015, NHI

6. Conclusion

Naturally, each of the methods or techniques is limited based on local conditions, resources, experience, craftsmanship, and funds. For this reason, there are a lot of options relating to the degree, suitability, efficacy, and economy of intervention. Present building codes and design standards play an important part in any case as well as the elimination of environmentally unsound material or even toxic chemical compounds. For that reason, it is increasingly difficult to find both suitable and effective coating against fungi and wood-destroying insects. Another problem is the elimination of modern interventions that have damaged historic buildings. In many cases, it is not only architecture from a heritage point of view but also the material substance itself. The great challenge is also manual woodworking, both from the point of view of conservation attitude and the demanding character of craftsmanship. Financial and time constraints are more difficult to overcome.

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