CONTRIBUTION TO THE POTENTIAL OF USING FRP MATERIALS IN THE REHABILITATION AND STABILIZATION OF TIMBERED BUILDINGS

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ABSTRACT

Wooden log, timbered perimeter and interior walls ranked among the most common building constructions used from the Early Middle Ages. In most cases, the local natural resources, i.e. wood, clay, straw and stone, were used for building houses with wooden framing. This article outlines typical defects and failures of timbered houses, “classic” techniques for the rehabilitation of these defects and failures indicating the potential of using composite materials based on high-strength fibres and epoxy resin in the rehabilitation and strengthening of timbered buildings.

KEYWORDS

rehabilitation, strengthening, timbered buildings, FRP fabrics

INTRODUCTION

The timbered constructions (Fig. 1), whose origins may be traced to mainly Central and Eastern Europe, were a widespread construction technology for residential and farm buildings used in our country from the Early Middle Ages. After the 12th century, timbered houses represented the predominant type of residential development on our territory, and their use in rural areas prevailed until the late 18th and the early 19th century, in northern and western Bohemia even until the late 19th century. The decline of building timbered constructions was primarily due to the prohibition of wooden constructions because of the risk and spread of fires in 1816. According to Schedel’s World Chronicle from the end of the 15th century, timbered framing was also found in urban buildings. There are timbered houses with a timbered wall construction on the ground floor and their upper floor construction is supported on the so-called pedestal formed by protruding columns and beams (ground plates) and constructions with a single living space resting on a masonry, mostly stonework, construction.

Fig. 1: Examples of timbered houses a) Příbram; b) Přerov nad Labem

Timbered walls are usually made of horizontally mutually superposed solid logs or beams, most often joined in corners by the dovetail joint, or a dovetail joint with opposite inclined sides without overlaps to prevent the bond loosening and beam slippage; there may also be gaps between slabbed sections. From the late 18th century, the above bond was replaced by more demanding, so-called interlocks, with perpendicularly cut horizontal and vertical surfaces – mortises with perpendicular walls. Figs. 2a, 2b and 2c show examples of carpentry corner joints of timbered buildings. The gaps between horizontal wall elements were sealed with moss and subsequently puddled with clay, cob, reinforced with straw, animal hair, etc.

Fig. 2: Examples of carpentry corner joints of timbered houses

The ceiling of the timbered construction was made of timber girder floors or logs, either planar or cranked up to reach the roof truss at the strutting beam and rafter level; the so-called log or timbered wooden vault with joints between the logs of the floor construction was puddled with cob.

Typical features of historic timbered buildings are gable roofs or gable roofs with small hipped ends, greatly extending beyond the perimeter structure and protecting it against the weather.

DEFECTS AND FAILURES OF TIMBERED BUILDINGS

The most frequent causes of failures of log and timbered buildings include particularly volume changes of the wooden construction of timbered walls. These changes are caused by shrinkage, the attacks of wood-destroying fungi and insects or by rot, and are often accompanied by strong non-uniform vertical deformations of the timbered wall and a loss in the mechanical properties of wood which may reach values affecting stability. For this reason, timbered walls were reinforced and their stability was secured by wooden pegs (vertical pins), square dowels (short chips) inserted in the grooves cut across the logs mainly close to holes and often protruding to the timbered wall face, or they were interconnected with lath inserts, hammered iron blades, etc. (Škabrada, 2007).

The most common defects of half-timbered and timbered constructions include insufficient thermal insulation properties of perimeter timbered walls, defects and poor quality of wooden elements, workmanship defects, faulty placement of ground plates on the plinth, poor execution of joints of wooden elements, mounting wood with high moisture levels, mechanical degradation of wood, mounting wooden elements with high moisture levels, excessive shrinkage and creep, inappropriately applied wood treatment, absorbent material of the plinth and a generally rigid connection between interior masonry constructions (Fig. 3).

Fig. 3: Degradation of timbered houses

The deformation of timber (coniferous wood was mostly used) due to the effect of compression and drying is more significant in the direction perpendicular to grain. For this reason, particularly log and timbered walls suffer from considerable creep, which, depending on the size (cross section) of beams (or logs) can reach up to several tens of millimetres (long-term pushing – "creep" – a multiple increase in initial deformations). This leads to the deformation of the wooden construction of the building, the deformation and tilting of the ceiling joist or slab construction, sloping of window and door openings and damage to interior masonry "auxiliary" constructions.

RESTORATION OF TIMBERED AND HALF-TIMBERED BUILDINGS

While restoring historic timbered and half-timbered buildings, especially listed ones, it is necessary to preserve the original historical value of the building, prevent its further damage and the degradation of the historic construction and, above all, extend the life of the listed structure. Based on a detailed historical, construction and technical survey (or other surveys), the restoration work sequence may be designed in an expert way to avoid any losses in the building's value.

In the construction and technical perspective, the rehabilitation of damaged structural members and joints may be carried out as follows. Loosened connections must be wedged out or strengthened with suitably placed prostheses, stiffening elements, partial resin grouts, reinforcement (e.g. glass fibre connections, special steel bars), etc. (Fig. 4).

Wooden elements and their connections may also be rehabilitated using diffusion-permeable and transparent fabrics of high strength fibres and nanofibres. In less significant, unlisted buildings, the major structural interventions may be designed, apart from the above specified rehabilitation measures, to reach a reasonable conformity to the current requirements for the indoor environment quality without compromising the original architectural character and the historical value of the building.

Fig. 4: Rehabilitation of elements and joints of timbered wall using the classic method – replacement, sealing

The possibility of using composite materials based on high-strength fibres and epoxy resin in the renovation of timbered buildings is primarily affected by the loading pattern of the joints used for the interconnection of individual beams into walls, both in corners or along the elements' height.

In the case of vertical structures, the use of prestressing or non-prestressed composite strips based on high-strength fibres and epoxy resin is preferred to capture the horizontal forces exerted by the roof truss to avoid the tilting of timbered walls - opening up of the building - and the slippage of the upper beams of the wall. It is advisable to place these strips on the surface of joists (Fig. 5) and anchor them to the outer wall surface. The composite strips placed in this way increase the rigidity of the building and may partly replace transverse (interior) timbered walls securing the spatial stability and rigidity of the construction.

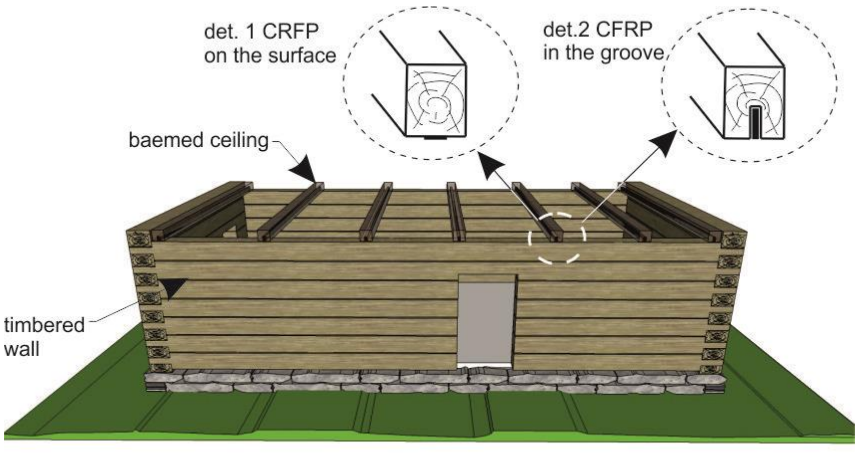

Fig. 5: Securing the spatial rigidity of a timbered construction in the case of degraded tie beams – reinforcing FRP strips or lamellae are led along the surface or in the groove of joists and anchored to the outside

surface of timbered walls

In the case of a multi-storey timbered building, like in a masonry building, adding a “reinforcing collar beam” at the floor construction level over the 1st overground storey using prestressing lamellae may be an effective solution (Fig.6).

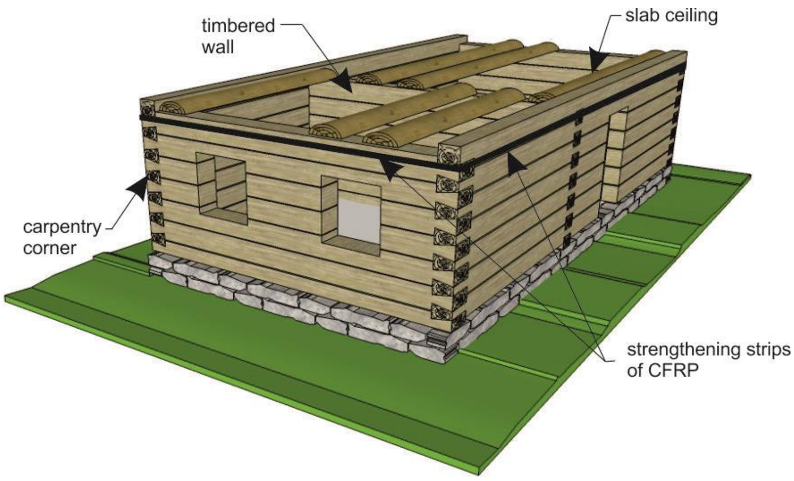

Fig. 6: Securing the spatial rigidity of a timbered construction by a reinforcing collar beam at the floor construction level

Vertical bracing or prestressing of joints of horizontal members (corners of the building) with composite strips based on high-strength fibres and epoxy resins limits the potential slippage of individual members from the joint in the case of degraded dovetail joint surfaces. It is advisable to place vertical stiffening strips or lamellae in the vertical groove to ensure the functionality of the joint reinforcement increasing, at the same time, the fire resistance of the remediation measure. This remediation method requires the adjustment of the anchoring surfaces of wooden elements so that they are cohesive, planar, without increased moisture contents (Fig. 7).

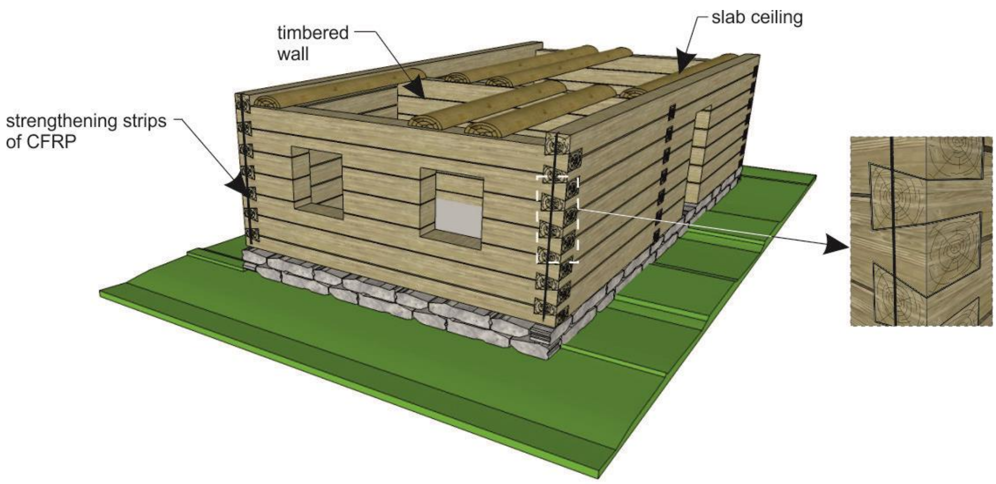

Fig. 7: Vertical stiffening of beam joints – limitation of the slippage of wall elements from joints, enhanced resistance of the timbered construction to seismic effects

The disadvantage of using composite materials based on high-strength fibres and epoxy resins is their high diffusion resistance, which, in the case of larger surface applications, may be the cause of an increase in the moisture content of a wooden structural member and associated degradation and biodegradation processes.

Anchoring elements allowing the elimination of volume changes of wood should be used in the case of using composite materials based on high-strength fibres and epoxy resin, mainly lamellae, in order to increase the spatial rigidity and secure the stability of a timbered construction.

CONCLUSION

The application of composite materials based on high-strength fibres and epoxy resin in timbered constructions is advisable, if the parts of the construction capturing horizontal forces from the roof truss are damaged or loosened, to prevent the tilting or falling apart of the supporting structure (e.g. walls).

Due to the properties of wood (especially in relation to volume changes caused by moisture or degradation processes) and the type of timbered structure and joints of wooden wall elements, the beneficial application of composite materials based on high-strength fibres and epoxy resin is limited to mainly the stabilization and reinforcement of the floor construction members and roof truss elements and joints.

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