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Consequences of improper renovation decisions in a 17th century half-timbered building

Key words: roof truss, technical condition, renovation

Introduction

In historic buildings, the selection of appropriate methods of renovation works should always take into account the historic character and historical values of not only the objects as a whole, but also its individual elements (Radziszewska-Zielina & Śladowski, 2017; Drozd & Leśniak, 2018; Korentz & Nowogońska, 2018; Hoła & Sadowski, 2019; Monczyński, Ksit & Szymczak-Graczyk, 2019). In the case of historic half-timbered buildings, the consequences of erroneous decisions regarding renovation or neglected conservation lead to irreversible damage processes. The effective undertaking of protection activities thus requires carrying out appropriate diagnostic studies (Hoła & Schabowicz, 2010; Cruz et al., 2015; Nowogońska, 2019; Rogala & Anysz, 2019; Sztubecka, Skiba, Mrówczyńska & Bazan-Krzywoszańska, 2020). The results of these studies will make it possible to put forth renovation solutions which do not interfere with the historic architectural-structural layout of the building.

The aim of the research is to analyze the effects of inappropriate renovation decisions on the example of a chess building. The indirect goal is to raise the awareness of the owners of the facilities that the renovation works should be planned correctly. Renovations of the building should be carried out comprehensively and not fragmentarily. A bad example is the replacement of a wooden foundation beam with a brick substructure only in a few walls of the building and not on the whole perimeter.

Wooden frame constructions have been used in Western Europe since the 12th century. Basing off of German frame architecture, rural houses, outbuildings, were erected in the area of the middle Odra region in the 17th century, peasant houses, outbuildings, taverns and inns, bourgeois house, churches, rectories and parish school (Franke 1936; Klein, 1985). The rich German ornamentation of the facades, however, was reduced to simple systems of posts, angle struts and stiffeners. The village of Sękowice (formerly Schekendorf) was first mentioned in 1301. The source materials from 1442 give the name of Has Wesenberg as its owner until the year 1482. Up until the 16th century, the village was under the ownership of the von Kocktritiz family. In 1523, Sękowice (at that time known as Schenkendorf) was bought by the former Master of the Order of Joanites – George von Schlabendorf. During the Thirty Year's War, similarly to other towns and villages, fire was set to churches. In Sękowice, the castle of the owner and church were destroyed at this time. In the second half of the 17th century, most likely in place of the former temple, a half-timbered octagonal structure was erected, covered by an octagonal-slope roof with drum and lantern. The temple is maintained in such state to this day. In the 18th century, nearby the church, a wooden, free-standing tower covered by a hip roof was added on. In 1813, the village also came under royal ownership, and this is when renovation of the church was carried out. Later major renovations were done at the beginning and near the end of the 20th century [Karta ewidencyjna zabytków architektury i budownictwa kościoła filialnego pw. Św. Rodziny w Sękowicach]. During World War II, the building was taken on by Catholics, with the church being blessed at the beginning of 1946.

Short description of the building

In Sękowice, a village located approximately 7 km south of Gubin, there is a church on a small hill, surround by old trees. The temple was erected in the second half of the 17th century. It is a single-naive building constructed using traditional frame technology. The outside walls are created by wooden posts, rafters and angle struts, with the areas lying between them laid with brick and plastered on both sides. The building was set up on the layout of a regular octagon with additions: a church porch from the south and a sacristy from the east. The structure of the church is formed by perimeter walls and eight inside posts supporting the galleries and structure of the drum, as well a roof framework.

The foundation was constructed as strip foundations made from erratic boulder on lime mortar. The depth of the foundation is 50 cm below the level of the terrain. On the foundation, there is a plinth made of solid fired brick measuring, on average, 28 × 14 × 9 cm, on lime mortar with the addition of clay. Over the plinth in the southern, south-eastern and north-western elevation, there are wooden 30 × 30 cm ground beams. The remaining walls lack beams; the original elements underwent biological corrosion, and, most likely in the first half of the 20th century, were removed and replaced with a brick wall base (Fig. 1).

FIGURE 1. The south-western elevation. Damaged and damp foundation plinth, corroded wooden structure, significant missing areas of plaster in the masonry wall filling the post and beam structure

The post and beam structure of each outside wall comprises four posts measuring 30 × 30 cm placed directly on the foundation plinth, four levels of beams with 20 × 20 cm cross sections, as well as angle struts in corner areas, measuring 20 × 20 cm. Modern-day masking boards 2.4 cm in thickness and 30 cm (posts) and 19 cm (beams and struts) wide are nailed onto all original wooden structural elements (with the exception of the walls of the additions). The fill between wooden elements is a wall of fired solid brick, with dimensions of 28 × 14 × 9 cm on lime mortar, and mortar depth of 2 cm on average, plastered on the inside and outside.

The perimeter walls along with eight inside posts support the galleries and structure of the drum as well as the wooden roof framework. The western part of the gallery turns into a balcony on the layout of a circle segment, protruding and bracket-mounted in the direction of the main naive. The galleries are structures supported on inside posts, with cross sections measuring 25 × 31 cm and beams 20 × 20 cm, as well as on posts of outside walls. The ceiling beams with dimensions of 20 × 25 and 20 × 20 cm, in a radial layout, are supported by beams and inside posts, as well as posts in the outside walls. Rigidity of the structure is increased with angle struts between the inside posts and ceiling beams as well as wooden supports between the posts of the inside walls and ceiling beams. The supports are attached to the posts with screws. They were most likely applied during renovation works during the first half of the 20th century. The structure of the drum is post and beam. From the outside, it is covered by pine boards laid vertically; the connections between the boards are covered with strips of wood. The structure of the crowning tower wall is a post one, with areas between posts filled in with plastered brick.

The cover over the galleries is a wood-beamed ceiling with sound boarding without a floor and a ceiling from boards. In the tower part, the ceiling is beamed, at the same time functioning as horizontal elements of the roof framework. The boards are nailed from the bottom to the wooden structure creating a ceiling over the main naive. In the middle of the ceiling there is an octagonal opening, most likely the remains of a former lighting (lantern), currently covered up with boards (Fig. 2).

The area of the galleries is separated from the main naive by a wooden penal wall, creating a balustrade with a parapet wall. Painted scenes from the Stations of the Cross from the 1960s are found on the panels. In the western part, between the balcony and the main naive, there is a wall with vertical boarding. The gallery over the parapet is covered by mod-

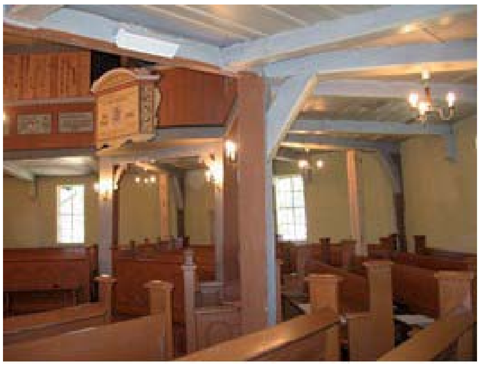

FIGURE 2. Inside of the church

ern wooden plank paneling. In the tower part, there is a post and beam wall without angle struts, with brick infill, plastered and painted with chalk paint. The church roof is comprised of a three-story wooden structure. The lower part covers the space over the galleries. The middle part, along with the structure of the drum, covers the middle part of the main naive, the upper – the tower.

The structure of the roof over the gallery is a single monopitch, with a slope of 90%. The trusses are supported by roof purlins and a roofing wall plate, which makes up the upper girt of the wall structure. The roof over the drum is also a monopitch. The trusses are supported by the girt beam of the drum wall and the girt of the tower. The roof over the tower is a tented, truss roof. That of the addition (the porch) is a monopitch inclined roof. The roof covering is of double-lapped plain tiles laid on lime mortar. The eaves are of profiled trusses supported by a beam with profiled ends. The crowning cornice is made of profiled boards coated with oil paint, nailed to the eave and protruding beyond the external face of the wall.

On the plinth and foundations is cement-lime plaster. The walls of the ground floor and gallery are covered by lime plaster with a smooth finish, with the entirety covered by an integrally colored (sand color) sand-lime coating. The half-timbered walls are covered by a smooth-finish lime plaster on the outside, which had been painted multiple times, most recently with emulsion paint.

Technical condition of the building

During on-site visits, detailed inspections of all structural and finishing elements of the building were carried out. Two foundation uncoverings were carried out, in the north-western building as well as in the corner between the sacristy and the main naive in the south--western part. Surface damp from rainwaters as well as some minor loosening of the stones was confirmed (Figs. 3, 4, 5). The mortar is washed away in some areas, with missing areas partially refilled with cement-lime mortar. Based on

FIGURE 3. Northern elevation – fragment. The corroded wooden post and beam structure. Loosened brick connections, missing plaster. Corroded attached canopies over the ground-floor window

FIGURE 4. Northern elevation. Corroded ground beam, loosened connections of plinth brick, missing areas of plaster. Between the post and the corroded and crushed ground beam, the crevice is filled with an insert from boards

FIGURE 5. North-western elevation – fragment. The corroded and compressed ground beam. Damp foundation plinth

current geotechnical documentation, it was confirmed that the existing geotechnical conditions are favorable, the ground waters are at a level of approximately 3.4 m below the surface of the terrain.

At the time of site inspections, the masking strips were removed with the aim of uncovering the wooden construction. The wooden construction elements have undergone damage by pests (old-house borer and common furniture beetle). The woodworking joints are separated, with movement of the beams reaching as much as 7 cm. Numerous secondary strengthening elements are visible – iron clamps and ties. The wooden structure requires general repairs, partial reinforcement, and partial replacement of elements. Additionally, it is recommended that pesticide and fungicide impregnation be carried out.

The infill between the wooden elements is a wall from solid fired brick. In the western and south-western wall, there is a clear vertical crack of the plinth in the area of the base of two middle posts, and in the corner from the north-western side (Fig. 6).

FIGURE 6. Fragment of the south-western elevation. Cracking of the plinth in the corner between the south-western wall, missing plaster, cut-out fragment of post

On the western and north-eastern and south-eastern walls, from the inside of the church, two vertical structural cracks along the posts (vertical and diagonal) can be seen along the central posts, at the level up to the height of the galleries (Fig. 7). There are also two cracks of each kind (vertical and diagonal) on the northern and north-western side, between the

FIGURE 7. Inside part of the north-eastern wall. Vertical cracks of the wall along the posts

window and the post, and two structural diagonal ones on the eastern wall.

Abundant cracks and scratches can be found on the outside of all walls of the church. In addition to this, two brick areas on the north-western side protrude outwards and deviate from the vertical by approximately 10 cm. The entire south--eastern wall is leaning in the direction of the interior of the church. Insulation in the form of a bitumen-based membrane can be found on the northern elevation as well as in the walls of the sacristy. The membrane has flaked away, is cracked and in bad technical condition.

The deflection of the ceiling in the middle of its spread reaches 5 cm under dynamic loading. Due to changes in the geometry of the structure of the gallery, there is loosening in the woodworking joints reaching as much as 3 cm in some places. The structure of the ceiling had undergone rather significant superficial biological pest infestation by the common furniture beetle.

The post situated in the main naive of the inside of the church, between the southern and south-eastern part, is reconnected at a height of 1.65 m from the level of the floor with the lower part, which had been replaced. The ceiling beams in the middle of their spread have been temporarily supported with wooden shoring posts due to their deflection and displacements.

In the structure of the roof, there are numerous missing areas in the form of cut out elements of the roof framework. Sprockets are partially enforced by boards. Some elements (angle struts, beams, posts) have been replaced by new ones. The entire structure of the roof framework has undergone infestation with wood-boring pests.

In the main naive, the floor finish is of ceramic tiles. Along the north-eastern part of the wall, the floor is deflected parallel to it, at a distance of 80 cm, and sagging near the wall up to a depth of 10 cm; a crack 2 cm in width has emerged. Along the western wall, loosening of the floor tiles is observed.

Numerous cracks of the outside plasters and areas of missing plaster have occurred. Near the ground, the plasters are damp and covered with mosses; under the cornice, water stains are visible. The plasters gave off a hollow sound in many places when being tapped, which signifies their separation from the base. The boards covering the wooden structure are damp.

Analysis of changes in the geometry of the building

Measurements of deviations and displacement of the post structure of the church were carried out. The deviations from the vertical were measured for all corner posts of outside walls to a height of 5.5 m (to the level of the cornice) as well as inside posts to a level of 3 m from the level of the floor of the main naive (to the level of the gallery beams).

Deviations from the vertical of outside posts at the level of 5.5 m fall within the range of 100–360 mm. The results of measurements of all posts have been shown in Figure 8.

In the case of the inside posts, all deviations from the vertical are directed towards the inside of the building; in the northern part, the deviations are directed to the south, and to the north for posts in the southern part. The greatest values when it comes to deviations were noted in posts in the south-eastern part of the building, reaching up to 360 mm.

Deviations from the vertical of inside posts are smaller; at the height of 3 m, they fall within the range of 40–130 mm (according to Fig. 8).

In the northern and western part of the church, the posts lean towards the inside walls. In the southern part, leaning is in the direction of the inside of the main naive. The highest values of deviations from the vertical (up to 130 mm) were observed in posts in the southern part of the building.

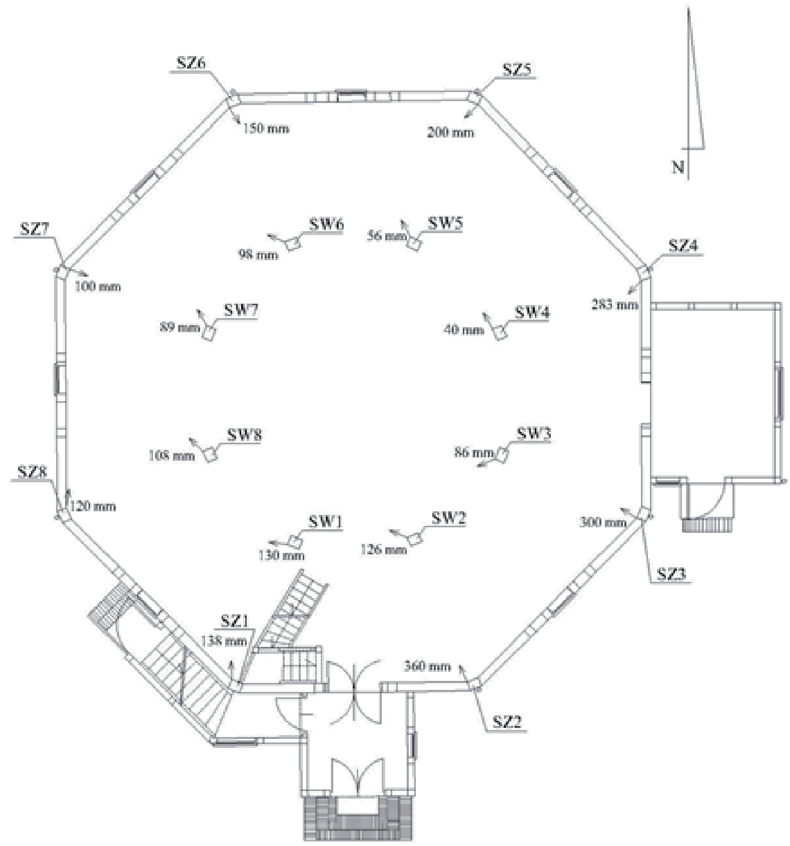

FIGURE 8. Values of deviation from the vertical of inside posts (SW1–SW8) and posts in the outside walls (SZ1–SZ8)

Assessment of the geometry of the building

The results of the carried out measurements indicate significant deviation and displacements of the post and beam structure:

– the posts of the outside walls are leaning in the direction of the inside of the building and partially to the North; the posts of the inside post and beam structure in the main naive are leaning to the North and the West,
– the deviations from the vertical of the outside posts in the south-eastern wall are alarming; the value of 360 mm deviation of SZ2 post measuring 30 × 30 cm indicates the possibility losing its stability,
– the south-eastern wall is leaning in the direction of the inside of the building to a degree that poses a threat to the stability of the structure,
– the direction of changes to the geometry of the inside posts is caused by the settling of the structure on biologically corroded ground beams on the north-western and northern walls,
– the magnitude of changes in the geometry of the post and beam structure of the church points to the undisputable necessity of carrying out additional bracing, reinforcement and protection of the structure from further deformation.

Summary and discussion

In other studies, the analysis of changes in building geometry (Cruz et al., 2015) was also conducted. Geometric changes are a picture of the consequences of wrong renovation decisions. Deviations from the vertical and displacement are an indication of the cause of building damage. Building diagnostics carried out correctly consists in determining the extent of damage effects, determining the cause of damage and then proposing a method of repair. For the building in Sękowice an analysis of changes in the building geometry was performed. The direction of movements is an indication of the cause of negative changes in the building.

The table presents the most important wrong renovation decisions in the building in Sękowice and their consequences.

Conclusions

Uneven deformations of structural elements of the church are caused by the natural wear of elements of the building, the detrimental effect of atmospheric, biological and mechanical factors and, above all, negligence when it comes to conservation and removing the resulting damage. The assessment of the technical condition of the historic half-timbered church in Sękowice and conclusions drawn from it are the first stage of works connected with saving this great building. The obtained results set the stage for further action. Subsequent stages, renovation works with the possible application of modern-day technical and technological solutions, will return the building to the community of Sękowice.

References

Cruz, H., Yeomans, D., Tsakanika, E., Macchioni, N., Jorissen, A., Touza, M., Mannucci, M. & Lourenço, P. (2015). Guidelines for on-site

TABLE. Summary of the most important consequences of erroneous renovation decisions

Type of wrong decision	Consequence	Method of correction
Remove the wooden foundation beams partially and replace them with a brick foundation	Some of the walls settled on the corroded ground beams, and the uneven settling resulted in the distortion of the beam structure. Posts in the outside walls as well as inside posts are leaning in the direction of the interior of the church in varying degrees. Due the missing parts in the brick areas that fill the half-timbered construction, it is necessary to carry out renovation works based on filling in the missing bricks and mortar; the areas of brick between the post and beams diverging from the vertical ought to be re-laid, making partial use of demolition material.	Due to changes in the geometry of the wooden structure, it is necessary to immediately take measures to protect it from further distortions. In the next stage, the structure ought to be straightened, next increasing its rigidity both in the horizontal as well as vertical planes. After repairing and stabilizing the structure, small cracks 4 mm in depth running only through the joints require merely filling with mortar whose structure and physical-chemical properties are close to those of the original, and fragments of the brick walls where cracking and scratches are observed ought to be re-laid with brick.
The use of wood boarding on facades	A significant part of the elements of the wooden structure underwent biological corrosion, due to which it lost its original strength parameters; the original woodworking joints were separated, which led to a loss of rigidity of the structure. The inside perimeter walls form the eastern side settled a few dozen cm vertically as a result of corroded ground beams, which is signified by the drop in the floor of the galleries in the western direction.	The wooden post and beam structure requires renovation based on the partial replacement and filling in of wooden structural elements and impregnation with pesticides and fungicides as well as fire retardants.
When replacing the roof, the drainage of water from the roof was not done properly	All downpipes drain water in the direct proximity of the plinth, which leads to significant dampening of the foundation and plinth as well as washing out of the dust fraction of the granular soil structure in the active zone of the ground.	Missing pieces in the foundations require filling in, loosened masonry elements – relaying, and a damp-proof membrane of the foundation ought to be placed between the plinth and the ground beams, next drying out the foundation and plinth.

assessment of historic timber structures. *International Journal of Architectural Heritage*, *9*(3), 277-289.

Drozd, W. & Leśniak, A. (2018). Ecological wall systems as an element of sustainable development – cost issues. *Sustainability*, *10*, 2234. https://doi.org/10.3390/su10072234

Franke H. (1936). *Ostgermanische Holzbaukultur* [*East German wooden building culture*]. Breslau: Wilh. Gottl. Korn Verlag.

Hoła, A. & Sadowski, Ł. (2019). A method of the neural identification of the moisture content in brick walls of historic buildings on the basis of non-destructive tests. *Automation in Construction*, *106*, 102850. https://doi.org/10.1016/j.autcon.2019.102850

Hoła, J. & Schabowicz, K. (2010). State-of-the-art non-destructive methods for diagnostic testing of building structures – anticipated development trends. *Archives of Civil and Mechanical Engineering*, *10*(3), 5-18.

Karta ewidencyjna zabytków architektury i budownictwa kościoła filialnego pw. Św. Rodziny w Sękowicach [Registration card of architecture and building monuments of the filial church of the Holy Family in Sękowice]. Archiwum Wojewódzkiego Urzędu Ochrony Zabytków w Zielonej Górze.

Klein, U. (1985). Datierte Fachwerkbauten des 13. Jahrhunderts [Dated half-timbered buildings from the 13th century]. *Zeitschrift fur Archeologie des Mittelaltres*, *13*, 109-130.

Korentz, J. & Nowogońska, B. (2018). Assessment of the life cycle of masonry walls in residential buildings. *MATEC Web of Conferences*, *174*, 01025. https://doi.org/10.1051/matecconf/201817401025

Monczynski, B., Ksit, B. & Szymczak-Graczyk, A. (2019). Assessment of the effectiveness of secondary horizontal insulation against rising damp performed by chemical injection. *IOP Conference Series: Materials Science and Engineering*, *471*, 52-63.

Nowogońska, B. (2020). A methodology for determining the rehabilitation needs of buildings. *Applied Sciences*, *10*(11), 3873. https://doi.org/10.3390/app10113873

Radziszewska-Zielina, E. & Śladowski, G. (2017). Proposal of the use of a fuzzy stochastic network for the preliminary evaluation of the feasibility of the process of the adaptation of a historical building to a particular form of use. *IOP Conference Series: Materials Science and Engineering*, *245*(7), 072029. https://doi.org/10.1088/1757-899X/245/7/072029

Rogala, W. & Anysz, H. (2019). Modelling the set of earthworks machinery with the use of computer simulation. *Scientific Review – Engineering and Environmental Sciences*, *28*(1), 161-168.

Sztubecka, M., Skiba, M., Mrówczyńska, M. & Bazan-Krzywoszańska, A. (2020). An innovative decision support system to improve the energy efficiency of buildings in urban Areas. *Remote Sensing*, *12*(2), 259. https://doi.org/10.3390/rs12020259

Summary

Consequences of improper renovation decisions in a 17th century half-timbered building. In the case of historic half-timbered buildings, the consequences of erroneous decisions regarding renovation or neglected conservation lead to irreversible damage processes. The effective undertaking of protection activities thus requires carrying out appropriate diagnostic studies. The results of these studies will make it possible to put forth renovation solutions which do not interfere with the historic architectural-structural layout of the building. The article presents the results of the assessment of the technical conditions of a 17th century church in Sękowice, built using traditional frame construction. As a consequence of earlier, inappropriate decisions pertaining to renovation works, a significant portion of the elements of the wooden construction underwent biological corrosion, as a result of which it lost its original mechanical properties. Some of the walls settled on corroded ground beams, with the uneven settling leading to distortions of the entire structure.

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