5th International Conference on Structural
Health Assessment of Timber Structures

25-27 September 2019, Guimarães, Portugal

REPAIR OF THE INDOOR SWIMMING POOL TIMBER STRUCTURE

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Keywords: Indoor Pool, Structural Assessment, Rot, Cracks, Repair Interventions

Abstract

In this paper damages and repair interventions of the indoor swimming pool structure in Kruševac, Serbia are presented. The facility is composed of main part and annexes, built in reinforced concrete and timber. The roof structure is made of glulam Gerber beams over two spans 35 + 15 m, supported by interior timber columns. The annex load-carrying structure consists of glulam beams, supported by reinforced concrete structure and timber columns.

The pool was built in 1982, and due to inadequate maintenance and exposure to adverse climatic influences, significant damages to roof cladding, secondary structural elements and main girders occurred. In the past, due to wood degradation and other damages, some repair interventions were undertaken. These interventions did not have the expected positive outcomes and resulted in closing of the pool for public.

The repair interventions included replacement of the entire roof cladding, replacement and repair of damaged timber elements, repair and reinforcement of steel connection elements. Firstly, structural rehabilitation was performed to reduce stresses and deformations in certain parts of the structure. The glulam girders were supported by new steel columns, which almost completely relieved the existing timber columns. In addition, new steel columns were added to the annexes. Cracks in timber elements were injected with two-component epoxy resin of appropriate viscosity and mechanical properties. The epoxy resin was also used as a filling at the places where rot was removed within the beams and columns in the support zones. Larger rot damages on the lateral sides of the beams were repaired by removing damaged laminations, and then gluing new ones using resorcinol glue. All steel elements that had significant corrosion were replaced, and others were cleaned of rust and re-protected.

As a conclusion, guidelines are given for monitoring and maintaining the facility during further exploitation.

1 INTRODUCTION

The indoor swimming pool in Kruševac (Serbia), with prevailing glued laminated timber (glulam) structure, was built in 1982. Due to inadequate maintenance, as well as due to exposure to unfavourable climatic influences, degradation of timber occurred in several vital places, which jeopardized the structural integrity and the facility became unsuitable for further use.

First appearance of damages dates back to 1998. Since then, several local repair interventions have been undertaken, which did not have the expected positive results. The Institute of Materials and Structures of the Faculty of Civil Engineering in Belgrade first performed the Expertise of structure condition, and then developed the Rehabilitation Design Project. Repair interventions were carried out in accordance with this project.

2 STRUCTURE DESCRIPTION

2.1 Designed structure description

The facility in question consists of the main part where pools and stands are located, and the side parts - annexes where the accompanying facilities and offices are located. The annexes surround the main part of the facility on three sides, and in relation to the main facade, they are denoted as left, right and central annexes. Within the annexes there are two floors: ground floor and first floor.

Structure of the facility is partially reinforced concrete and partly timber. Pool shells, stands and exterior walls of the main part, as well as foundations are concrete. Pool shells are not directly supported on the ground, but on short concrete columns that are supported by concrete foundations. The stands consist of webs and slabs, which were constructed on site so that they represent a monolithic structure. The stands structure is supported by concrete frames at every 5.0 m.

Timber structure includes the load-carrying roof structure of the facility's main part and the complete load-carrying structure of the annexes (Figure 1). The load-carrying roof structure of the facility's main part consists of main glulam girders with cross-sectional dimensions of 22/165 cm. These girders are Gerber beams over two spans 35 + 15 m, with a hinge within a larger span. The supports of the girders are outer (facade) columns in the F and Z axes, and the inner columns in the T axis. The distance between the main girders is 10 m. Secondary beams (purlins) are supported by main girders and are made of glulam with cross-sectional dimensions of 12/50 cm. Purlins are simply supported beams with spacings of 2.5 m between them. Profiled metal sheets were used as roof cladding which was mounted directly over the purlins.

The columns of the facility's main part are made of glulam with a rectangular cross-section. The outer columns in the F axis have a variable height. Columns in the F axis are positioned at an angle of 12° in respect to the vertical plane, while the inner columns in the T axis and the outer columns in the Z axis are vertical. All columns are hinged to the concrete structure. The outer columns are connected by facade beams so that they form a longitudinal wall. Facade beams are made of glulam with a rectangular cross-section. Gable walls of the facility's main part were constructed as concrete walls with a thickness of 20 cm.

In the roof plane there are longitudinal and transverse roof bracings. These bracings were constructed in a form of intersected steel diagonals with a circular cross-section. For horizontal loads in the longitudinal direction, vertical bracings in the end sections of the longitudinal walls were provided, also in a form of intersected steel diagonals with a circular cross-section. Horizontal loads in transverse directions are transferred by concrete shear walls (gable walls).

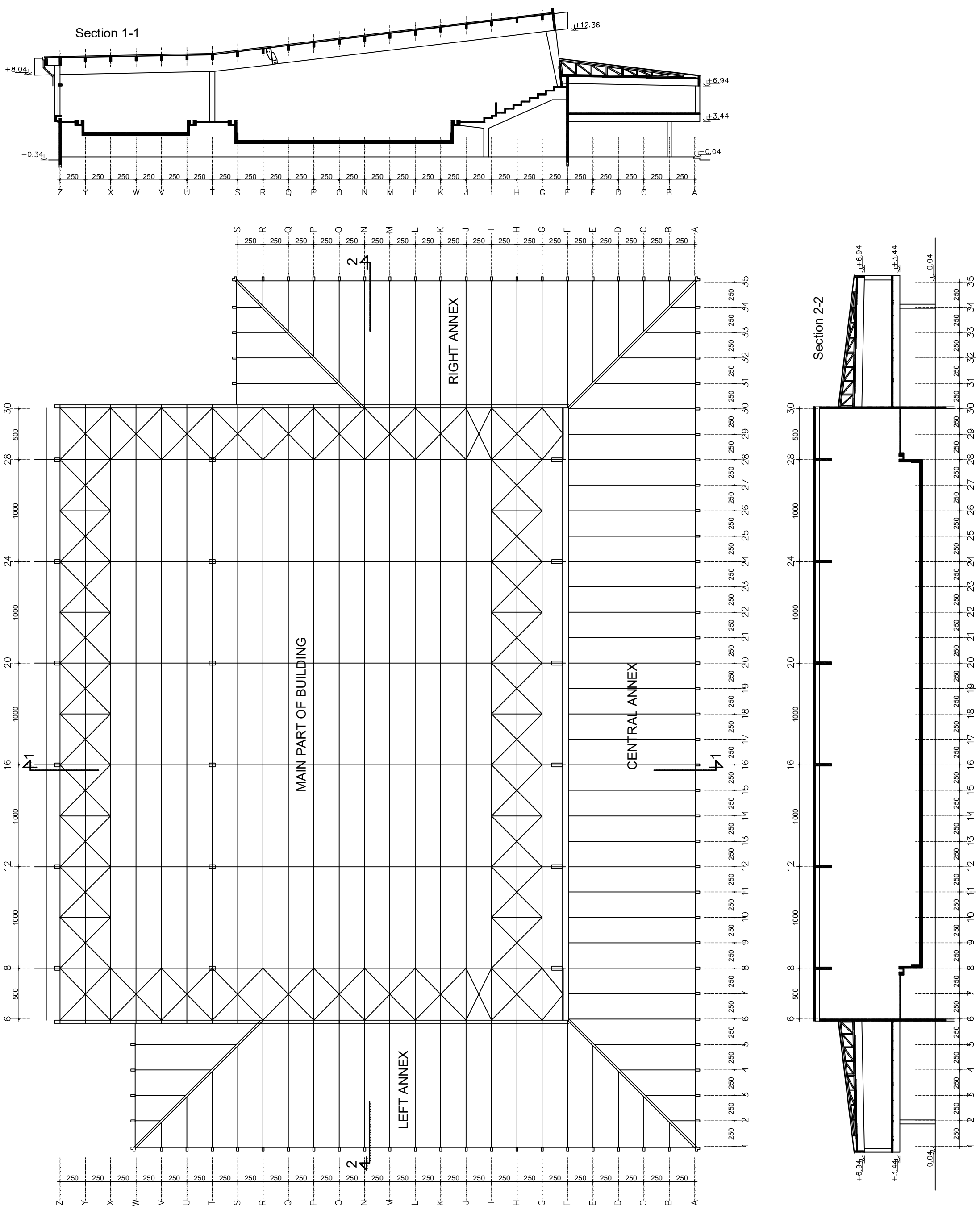

Figure 1: Roof framing plan with longitudinal and transverse sections.

The load-carrying roof structure of annexes is composed of simply supported glulam beams, with rectangular cross-sections and 12 m spans. These beams are on one end supported by the columns in the annex first floor longitudinal wall, and on the other end by the concrete structure of the facility's main part. The spacing between the roof beams is 2.5 m. Over these beams a composite structure formed of profiled steel decking and concrete slab was constructed, and then covered with layers of flat roof.

The floor structure within the annexes is formed of overhanging glulam beams (spans 10.0 + 2.5 m) with rectangular cross-sections, and spacing between them of 2.5 m. This structure is supported by columns within the longitudinal wall of the annex ground floor and by the concrete structure of the facility’s main part. Over these beams a composite structure also formed of profiled steel decking and concrete slab was constructed.

Columns in the longitudinal walls of the annexes are made of glulam with rectangular cross-sections, supported by beams or concrete foundations.

2.2 Existing structure description – design changes

Due to necessary adjustments to exploitation demands, but also due to observed shortcomings and threats to functionality, serviceability and load-carrying capacity of certain structural elements and the structure as a whole, the following interventions were carried out:

- *Modifications on the roof structure of the facility’s main part*. Due to roof cladding damages and water leaking into the space with pools and stands, the roof structure of the facility’s main part was reconstructed – new roof cladding with a suitable substructure was constructed.
- *A new solution for the gutter of the facility’s main part*. Due to lack of functionality of the originally designed horizontal gutter on the lowest side of the roof, which was especially noticeable in the winter months when very large quantities of ice were present, a gutter reconstruction was performed.
- *Reconstruction of glass surfaces on longitudinal facades*. Due to problems with glass parts of the facade within the facility’s main part, while performing works on the roof reconstruction, the glass facade surfaces in the F axis were "closed" with sandwich panels. Furthermore, within the facade in the Z axis additional short columns were subsequently placed (between main columns) which divided large glass surfaces in a number of smaller surfaces.
- *Addition of shear walls instead of vertical bracings*. Within the previously described interventions on the longitudinal facades of the facility’s main part, the reinforced concrete shear walls were constructed along the entire height, which assumed the role of old bracings. The existing vertical bracings have not been removed.
- *Modifications on the annex roof structure*. Due to annex roof leakage, which was explained by the shortcomings of the constructed flat roofs, the conversion of the flat roof into the sloped roof was performed.

3 THE STRUCTURE CONDITION

3.1 The structure condition assessment

Determination of damage degree and their categorization was performed based on visual-macroscopic examination, whereby certain "openings" of individual characteristic details were made in order to obtain the best possible insight into the structure condition. The openings in question were carried out to a lesser degree so that the facility’s function was not damaged and that, until the beginning of repair interventions, the facility was not exposed to unfavourable environmental effects and occurrence of more damages. In addition to the visual inspection, the assessment of the structure condition included taking out material samples and their laboratory testing in order to determine the mechanical characteristics [1]. All this was done primarily so that based on the obtained findings the positions of necessary repair interventions would be defined.

However, true image of damages was obtained only after removal of non-bearing elements, which were hiding certain parts of the structure. During the repair interventions, a large number of hidden defects were identified and the extent of damages was found to be significantly

higher than recorded in the previous observations. These damages primarily related to the following parts of the facility's main part structure:
- The main girders of the roof structure, at the supports on the outer columns;
- Outer sloped columns, in facade zones;
- Facade timber beams, especially in the support zones.

Given the circumstances, structural engineers were practically permanently involved in solving technical problems during the repair interventions, together with a contractor and a supervisor, so that in the shortest time possible, the contractor was successively delivered design solutions in accordance with specific situations.

3.2 The damaged structure description

The roof cladding of the facility's main part was extremely damaged, despite the previously implemented repair interventions. Part of the roof covered with profiled metal sheets was completely degraded and no longer fulfilled the function of protection from atmospheric precipitation, nor the thermal insulation function (Figure 2). On the part of the roof covered with flat metal sheets, there was no visible tearing, but there was evident rotting in timber structure and wetting of the thermal insulation, caused by water penetration from the roof part covered with profiled metal sheets. By examining the ceiling surface of the facility's main part, the corrosion in the profiled sheets was observed. The condition of the roof cladding on the annexes, after previous reconstruction of the flat roof, was completely satisfactory.

Figure 2: Roof cladding damages.

Within the facility's timber structure several types of damages (defects) have been identified. Rot in certain places was observed as a dominant damage that was registered during visual inspection. In all the cases, rot was a consequence of timber exposure to direct water influences, whether it was caused by condensation inside the facility, or it was caused by penetration of atmospheric precipitation. In the first case, this condition was caused by the failure of ventilation and air conditioning systems, and in the second, it was a consequence of unprotected structure from the weather conditions. The unprotected structure was, in some cases, a result of inadequately constructed finishing details, and on the other hand, a result of inadequate surface protection of timber.

In most cases, the appearance of rot was of local character, but there were also elements that were rotten along their length (Figure 3). The rot was present in several places within the load-carrying roof structure of the facility's main part. Due to adverse unfavourable weather conditions, the overhangs of the main girders outside the facade level had very significant damages. In addition, the main girders were damaged by rot at the supports on the exterior (facade) columns in the F and Z axes. In case of purlins, rot was noted in the end sections, that is, in the support zones on the concrete structure. Columns beneath the main girders in the F axis were damaged by rot to the extent that they had practically lost their load-carrying capacity. Degradation is a result of inadequate protection of facade parts from external atmospheric influences. Columns in the Z axis also had defects caused by rot. This applies to the support zones, both on the lower ends (as with the columns in the F axis), and on the upper ends, where the rot occurred due to water leaking from the roof caused by malfunctioning of the previously present horizontal gutter. On the roof and floor annex beams, rot was mostly located at the supports on the concrete structure, as well as at the points of connection with the columns of the first-floor longitudinal wall, where the end grains were directly exposed to weather conditions. The columns of the annexes also had rot damages on the upper and lower ends.

Figure 3: Rotting of timber elements.

One of the most noticeable defects in timber structure was the appearance of smaller or larger fractures and cracks (Figure 4). These cracks were mainly in the direction of wood grain and were mostly caused by thermo-hygrometric factors, especially in the case of cracks on the overhanging parts of the main girders. These elements were directly exposed to atmospheric influences and temperature changes. The appearance of horizontal cracks primarily in the support zones was registered in the annex beams. Similar damages were noted in the columns of the main part and the annexes.

Figure 4: Appearance of fractures and cracks in timber elements.

Significant damages to timber structure were also deformations (deflections) of the members, as a result of rheological characteristics of wood. The deflections were particularly large in the overhangs of annex floor beams and could be clearly seen without measuring with geodetic instruments (Figure 5). Measured deflection values of these beams were 5-6 cm.

Figure 5: Deflection of the floor beams overhangs.

In addition to the aforementioned damages during the visual inspection, it was observed that almost all steel connection elements within the timber structure had corrosion due to moisture; that is, due to inadequate maintenance.

Condition of the glass facade was a great danger to public's safety, as there was a possibility of individual facade segments failure and glass surfaces falling off (Figure 6). Facade beams have suffered major damages in form of rot and larger cracks. In addition, some beams had very large deflections. The earlier intervention in terms of inserting additional short columns was not completely successful.

Figure 6: Damages to the glass façade.

On the concrete structure, a certain amount of damage was observed, which was partly a result of installations malfunctioning, primarily mechanical, but also a result of some other adverse factors. However, these damages were not that serious to call into question the functionality, serviceability, and load-carrying of the facility. In addition, interventions on the concrete structure do not represent a major technical problem and can be carried out in a relatively short amount of time and within the framework of facility's regular maintenance.

4 DESCRIPTION OF REPAIR INTERVENTIONS

Given the structure condition, it was necessary to carry out certain repair interventions, as well as to eliminate the causes that led to the damages. The repair has covered several phases:
- repair of the roof cladding,
- repair of the timber structure,
- repair and reinforcement of the steel connection elements,
- repair of the facade.

Damage to the roof cladding on the facility's main part required radical repair interventions on that part of the roof. These interventions involved a complete removal of the existing roof cladding and all the layers beneath it, and then placing of a new roof cladding (Figure 7). The new multilayer cladding integrated all necessary functions: final protection against atmospheric influences, waterproofing, thermal insulation, vapor barrier and ceiling lining. The application of suitable steel profiles made it possible to obtain air ventilation space. As the last layer of the roof cladding, an aluminium sheet was placed. As a part of cladding works, completely new flashings were made on the connection between roof cladding and exterior walls. For drainage purposes, new horizontal and vertical gutters were made.

Figure 7: New roof cladding positioning.

As a part of works on timber structure, firstly, repair interventions of a structural character were performed in order to reduce the stresses and deflections in certain parts of the structure, and then all parts that were damaged by rot and cracks were repaired. The main girders of the facility's main part roof structure were supported by new steel columns of the corresponding shape (Figures 8 and 9). These columns were formed and designed to transfer reactions from the main roof girders. This completely relieved existing timber columns. As for timber columns in F axis, removal of damaged parts and details alteration in support connections to the main roof girders and facade beams, were performed.

In order to reduce the extremely large deflections of the annex timber structure, new square hollow profile steel columns were inserted on the first floor at the positions of timber columns on the ground floor (Figure 8). These columns were at the bottom end anchored into the concrete slab laid over profiled steel decking, while on the upper end they were appropriately connected with the existing roof beams. As some of the added columns were positioned within the existing partition walls (brick, plasterboard, etc.), in these places double HOP columns were designed on both sides of the partition walls.

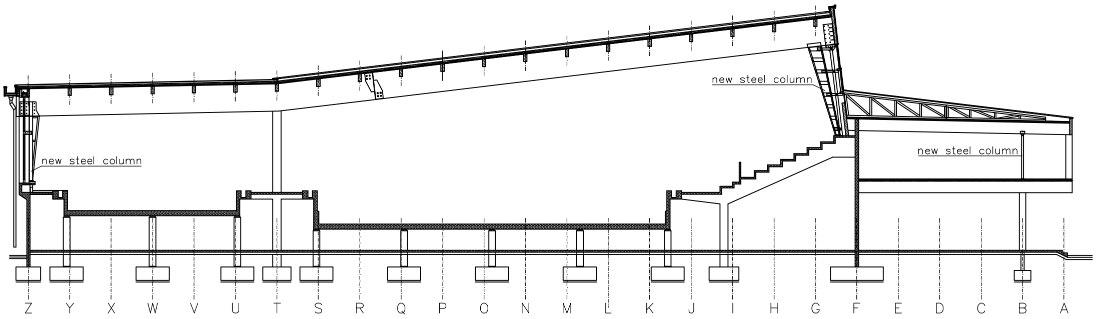

Figure 8: Position of new steel columns as a reinforcement of existing timber structure.

Figure 9: New steel columns next to the existing timber columns in Z axis (left) and F axis (right).

Giving the recorded appearance of rot, within the roof structure of the facility's main part, replacement of all purlins in the zone of gable walls was conducted, as well as the replacement of the edge purlins within the Z axis. Dimensions of the new purlins and their connection with adjacent elements of the structure were identical to the existing ones. Before removing the old purlins, it was important to remove the existing roof bracings and steel connection elements. After the installation of new purlins, they were restored to the previous positions.

The rot recorded on the overhang portions of the roof girders of the facility's main part was eliminated in such a way that all the beams were shortened practically to the facade surfaces. Since these parts of the girders are directly exposed to adverse weather conditions, they were covered with flat aluminium sheets. In identical way, coating of annex roof beam faces and floor beam faces was performed.

Cracks in timber beams were injected with a two-component epoxy resin of appropriate viscosity and physical-mechanical properties. The injection was preceded by preparation which involved cleaning the cracks, sealing the cracks with an epoxy kit and inserting inlets for resin injection.

Parts of timber elements with local appearances of rot, which primarily relates to beams and columns support zones, were sealed with the epoxy resin used for injection, with addition of suitable filler. The procedure in question included removing all the rotten parts of "healthy" timber from the damaged zones, placing the appropriate "formwork" around the treated area and then injecting the pre-prepared resin into the space thus formed.

In the case of major damages in form of rotting along the elements, the repair was carried out by "lamination process". This procedure involves removing damaged laminations until "healthy" timber is reached, and then gluing new ones using resorcinol glue. This adhesive is applied in layers with a thickness of 0.3 mm. When "lamination process" is performed it must be ensured that there are no stresses in the bonding planes.

Since the existing horizontal and vertical timber elements within the longitudinal facades of the facility's main part were no longer able to perform structural load-carrying function, the entire glass surfaces were repaired or replaced. The repair intervention on the facade in the Z axis involved the production of new facade beams with new columns in accordance with the existing state (see Figure 10). The new glass facade was embedded in spaces surrounded by the existing columns of the roof structure. This facade was made of aluminium structure with thermal insulation glass, with corresponding number of windows that have a possibility of opening for ventilation of the facility. Within the facade in F axis, which was previously closed with profiled sandwich panels, the installation of a new glass facade was planned. In order to allow the insertion of this facade, a construction of new steel lattice girders above the existing facade beams was carried out (see Figure 10). In the areas that were formed by the existing columns of the roof structure, the upper edge beam and, on the lower part, the steel lattice, aluminium structure of the facade with thermal insulation glass was inserted. Also, on this facade, there is a number of windows with a possibility of opening for ventilation of the interior space. The final works on this facade included covering with profiled steel sheets with thermal insulation of parts above and below glass surfaces, as well as parts in the column zones. In the interior of the facility, area between the glass surfaces of the facade (between the columns) and the floor (stands) was covered with plasterboards.

Figure 10: Elements of the new glass facade structure in Z axis (left) and F axis (right).

Upon completion of the described repair interventions, the entire timber structure was protected by appropriate fungicide and insecticide agents.

All steel elements that were significantly damaged by corrosion were replaced with new ones, and the others were cleaned of rust and coated with surface protection.

5 CONCLUSIONS AND RECOMMENDATIONS

The causes of damages to timber structural elements can be different: design and construction errors, inadequate exploitation, inadequate protection and maintenance, atmospheric influences, accidental actions. To avoid complicated and expensive repair interventions, it is of utmost importance to implement an adequate monitoring and assessment methodology.

During exploitation of the facility, a regular annual monitoring of structural elements should be carried out in order to detect possible damages due to temperature effects, changes in humidity and other unfavourable factors. Protection in visible and accessible parts of timber elements and steel connection elements should be done once in two years with appropriate coatings. In addition to maintaining the structure itself, it is also necessary to ensure that all installations are working properly during exploitation of the facility. First of all, this refers to mechanical installations related to air conditioning and ventilation, but also to water supply and sewage installations. The malfunctions of these installations can undoubtedly lead to significant damages to structural elements.

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