INTERVENTIONS ON THE VAULTE D ROOF CEILING OF THE LUTHERAN CHURCH A.C. IN BISTRIŢA

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Keywords: vaulted roof ceiling, nave, chancel, rib, ceramic voussoir, wall painting.

Abstract. The Lutheran Church A.C. in Bistriţa, dating back to the 14th century, suffered major transformations between 1559 and 1563, which were performed by Petrus Italus de Lugano, a well-known craftsman, who carried out many exceptional interventions in 16th century Central Europe. On the occasion of the 450th anniversary of the re-sancification of the church – further to the Renaissance transformations brought by Petrus Italus – the vaulted roof ceiling was rehabilitated, through both consolidation works and enhancement of the Renaissance decorative painting, which was discovered during the building archaeology study prior to the consolidation interventions. The vaulted roof ceiling covers both the nave and the chancel of the church, and is built of brick masonry. The domes of the vaults are supported by ribs made of 4-5 cm thick burnt clay voussoirs that are laid out perpendicularly on the longitudinal direction of the ribs, integrated in the masonry of the domes, with a geometry that shapes the long profile of the ribs. The ribs are made up of four types of voussoirs according to strict rules. Some of the voussoirs gave way in operation and were locally replaced with stucco longitudinal elements, which were anchored to the dome by metal elements. Other deteriorations in operation were caused by the flooding of the roof ceiling during the 2008 fire extinction operation, which led to the destruction of the tower roof structure and of the nave in the area adjacent to the tower. In order to replace the stucco rib elements and the broken ceramic voussoirs, which were macerated, four types of ceramic voussoirs were ordered and integrated in the vaulted ceiling. The quality of the interventions was locally tested by in situ trials, consisting in overcharging the ribs. The domes of the vaulted ceilings were rehabilitated too, as reweaving and matting interventions were necessary each time cracks occurred in operation because of implementation technological errors. The presence of decorative paintings made the interventions more difficult, as these paintings were conserved simultaneously with the consolidation works.

This paper presents the whole intervention process, focusing on mechanical and technological aspects that are specific to exceptional load-bearing structures.
1 INTRODUCTION

The Lutheran Church A.C. in Bistrița is made up of eight different volumes (bodies), which are organically linked to each other: the chancel, the sacristy, the nave, the church tower, and the four porticoes, of which two in the south and two in the north:

(1) the church chancel contains sub-units of Gothic roof structure, net vaults, load-bearing walls made of mixed masonry and flanked by buttresses and continuous foundations made of stone masonry;

(2) the church sacristy includes an Eclectic roof structure, a cylinder vault, load-bearing walls made of mixed masonry and continuous foundations made of stone masonry;

(3) the church nave is made up of a Gothic roof structure, stellar vaults, load-bearing walls made of mixed masonry and flanked by buttresses and continuous foundations made of stone masonry;

(4) the church tower is made up of an Eclectic roof structure, a cross vault, load-bearing walls made of mixed masonry and continuous foundations made of stone masonry;

(5) the south-western portico contains an Eclectic roof structure, a cross vault, load-bearing walls made of brick and continuous foundations made of stone masonry;

(6) the south-eastern portico contains an Eclectic roof structure, a cross vault, load-bearing walls made of brick and continuous foundations made of stone masonry;

(7) the north-western portico is made up of an Eclectic roof structure, a cross vault, load-bearing walls made of brick and continuous foundations made of stone masonry;

(8) the north-eastern portico is made up of an Eclectic roof structure, a cross vault, load-bearing walls made of brick and continuous foundations made of stone masonry.
2 DESCRIPTION OF THE ROOF CEILING ABOVE THE NAVE AND THE CHANCEL OF THE CHURCH

2.1 Composition of the roof ceiling above the nave and the chancel of the church

In the initially Gothic volume of the nave, Petrus Italus de Lugano introduced stellar vaults resting on pillars and longitudinal walls in the 16th century.

Figure 2: Vaulted upper ceiling of the nave and the chancel

The chancel is provided with vaults that rest on longitudinal walls, namely on the five sides of an octagon.

The ribs – made up of special burnt clay elements – were most likely made on scaffold before the set up of the domes.

Figure 3: Detail of the vaulted roof ceiling with burnt clay ribs
There are two types of burnt clay ribs that are interlaced: a first type was embedded in the vault dome during its completion, while the other type, as it does not have a prolongation necessary for embedding (see figure 4), is connected to the dome though the only tensile resistance of the mortar.

Figure 4: Types of ribs used during the 16th century interventions

Figure 5: Rib elements used during the 16th century interventions
The more complex burnt clay elements are likely to have been used first, as the building of churches mainly starts from the chancel.

2.2 Decorative paintings of the roof ceiling above the nave and the chancel

During the same intervention of Petrus Italus, the decorative paintings around the vault keystone are performed. The Renaissance decorative paintings have a big heritage value and therefore their presence made the consolidation interventions on the vaulted roof ceiling extremely difficult.

![Decorative paintings on the roof ceiling above the nave](image)

3 DETERIORATIONS OF THE VAULTED ROOF CEILING AND THEIR CAUSES

In general, the ceilings suffer of two categories of building-mechanical insufficiencies: (i) that manifest as deformations that maintain the continuity of the material (buckling, deflection, etc.) within the load-bearing structure elements, and (ii) that manifest as deformations that break the continuity of the material (fissures, cracks, etc.) within the load-bearing structure elements.

No building-mechanical insufficiencies that manifest as displacement of rigid body were found in the ceilings.

The deformations with maintenance of the continuity of the material (buckling, deflection, etc.) on the vaulted ceilings are not considered building-mechanical insufficiencies, because – visibly – they do not exceed the limits of normal operation.

The insufficiencies that manifest as deformations that break the continuity of the material refer to the vaulted ceilings with displaced supports. The support displacements may occur because of settlement or rotation of the supporting load-bearing structures.

Support settlement occurred in the case of the pillars supporting the gallery, which settled unevenly and caused cracks in the roof vaults.
Support rotation occurred in particular in the roof ceiling between axes 4 and 6. It consisted in the rotation of the intermediary pillars and thus of the southern longitudinal diaphragm. Rotations led to dislodgement of the supports and consequently to fissures in the vault keys and in the quadrants. These insufficiencies are deteriorations in progress (active), due to carelessness or errors during the subsequent transformations.

Both types of displacements are also maintained by dynamic actions resulting from seismic actions and from traffic loads.

The building-mechanical insufficiencies at the level of the vaulted roof ceiling of the nave are caused by the uneven settlement of the intermediary pillars, which led to fissures in the vaults. The settlement may be due to the additional loads originating in the roof structure as a result of the changes in the static scheme of discharge on the intermediary pillars, and of the modification of the water infiltration level.

![Figure 7: Detached ribs – crack and cause: no weaving](image)

### 4 CONSOLIDATION INTERVENTIONS ON THE VAULTED ROOF CEILING

The consolidation interventions – where the uneven settlements are consumed – only refer to ensuring compliance with the performance requirements by ensuring continuation of the vault domes with fissures and by attaching the ribs that were detached from the vaulted domes.

In order to ensure continuation of the domes, they were reweave and matted in the areas with fissures and lime mortar was then injected in the treated joints.

The ribs were consolidated by inserting burnt clay elements – manufactured according to a special order – having the shape of the existing elements, and by sticking the ribs in the area of the longitudinal cracks using Sikadur 31 adhesive.

The adhesive layer for the ribs was tested by applying local overcharge on them.
5 TECHNOLOGICAL ORDER IN THE CONSOLIDATION OF THE VAULTED ROOF CEILING

5.1 The technological joints had not been woven, and their reweaving consisted of the following stages:

- the joints were cleaned, on the extrados, by removing the existent lime mortar layer in the area of the technological joint, namely by removing the mortar from the joint and vacuuming the resulting dust;
- the bricks from the adjacent vault fields were removed approximately every 5 rows and new bricks were introduced in order to connect the two vaults, working on the extrados;
- the existing joints were wedged using pieces of bricks (for openings wider than 4 cm) and hardwood wedges, working both on the intrados and on the extrados;
- the joints were matted using lime-cement mortar on the intrados;
- cement milk was injected on the extrados.

5.2 The rib consolidation was performed using two methods depending on the status of the ribs:

- where the displacement in relation to the plan of the vault was above 5 cm, attempts were made to bring the ribs back to their initial position or to undo and redo the affected part using lime and cement mortar;
- where the displacement in relation to the plan of the vault ranged between 2 and 5 cm, the ribs were consolidated using the Sikadur 31 adhesive for sticking 3 times two bricks on both sides every 1.00 m; moreover, matting with lime and cement mortar was performed and milk cement was injected in the area between the ribs and the vault.
5.3 **Vault extrados treatment:**

- the vault extrados was treated with diluted lime milk (prepared as a solution of 1/20 – lime paste/water volume); this was performed after the vaulted area was cleaned by compressed-air jet and preliminary wetting with water of the upper area using a brush or a sprayer (2-3 hours before the application of the lime milk, on areas of 3-4 m²); the lime milk treatment was applied in 3 – 5 successive stages, starting from the springers, concomitantly (symmetrical loading starting from 1 – springers, 2 – key, 3 – quadrants); the consistency of the lime milk was increased from one stage to the other depending strictly on the permeability of the vaulted area (maximum ratio of 1/10);
- a 5 – 25 mm thick layer of lime mortar was applied (the ratio lime paste/0…3 sand being of approximately 1/3) on the vaults, by pressing with a scrub brush; this was performed after preliminary wetting with diluted lime milk of the upper area (2-3 hours before the application of the mortar layer, on areas of 3-4 m²); the mortar was covered with burlap maintained permanently wet for 5 days;
- a 20 – 30 mm thick layer of lime mortar was applied (the ratio lime paste/0…3 sand being of approximately 1/3) on a fiberglass net fixed to the first layer; in order to prevent fissures in the mortar, after its application, it was covered with burlap maintained permanently wet for 5 days and measures were taken to prevent fissures by regular rubbing of the plastered areas.

5.4 **In order to replace the stucco rib elements** and the broken ceramic voussoirs, which were macerated, four types of ceramic voussoirs were ordered to a brick factory – with simple profile and with complex profile, short and long, respectively. A number of 500 simple profile pieces, of which 80 long pieces and 420 short pieces, and 600 complex profile pieces, of which 100 short pieces and 500 long pieces were thus supplied. The implementation technology used for the brick voussoirs was similar to the technology described above. Four drawings at a 1:1 scale were drawn up for the necessary ceramic elements.

According to the laboratory tests performed on the samples taken from the vault and wall masonry, both the mass humidity and the soluble salt saturation were low (they were high for 6 samples out of 32), and consequently no mass desalting of the masonry was necessary.

The vault deplastering works were made in several stages: 1 – deplastering of the areas indicated by the wall painting conservation practitioner; 2 – stripping of the 1926 plaster from the original plaster between the opened areas and the painted areas; 3 – removal of the detached original plaster, which was subsequently marked out. At the level of the ribs, 80% of the plaster was stripped off entirely and 20% was stripped only from the old plaster.

6 **CONCLUSIONS**

- The consolidation and the enhancing of the vaulted roof ceiling were performed in several stages.
- The whole area of the nave and the chancel was covered with scaffolding and the first action was the stripping and the fixing of the Renaissance decorative paintings, which were covered during the 1926 interventions.
- The consolidation of the vault domes was performed by reweaving, matting of the cracked areas, by soaking with lime milk of the whole area and by applying a mortar layer on the vault extrados.
- The ribs were completed by burnt clay elements – where possible, and fixed to the vault domes by adhesive – on a case by case basis – so as the contact between ribs and vault domes could be entirely ensured.
• The final actions consisted in painting the vaulted roof ceiling and in conserving the decorative paintings.

Figure 9: The vaulted roof ceiling after the consolidation-rehabilitation interventions

• As a result of the consolidation-rehabilitation operations, the vault above the nave and the chancel recovered its Renaissance appearance created by Petrus Italus de Lugano in the period 1559-1663.

REFERENCES

