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THE DETERMINATION OF CAUSES FOR DEFECTS OCCURRING IN THE SEVENTEENTH-CENTURY CHURCH BUILDING IN PRÓSZKÓW, OPOLE PROVINCE, POLAND

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ABSTRACT

The ideal solution for the church described in the article, as well as other damaged objects, is to eliminate the reasons and then the effects of their destruction. Within the acquired aid funds so far it has been possible to renovate the upper part of the building, which means the roofing, rafter framing and external coating, up to the first cornice. But the fundamental problem still remains unsolved, i.e. to assure safe exploitation of the temple. In this article the extent of necessary works that have to be done is pointed out, as well as the cost that this may generate, with lack of possibility of financing the work from owned resources. This is another problem that most of historical monuments must face in Poland and Europe. And "time", that affects the damaged objects or just its parts, doesn't leave us any illusions.

Keywords: *Church, Escarpment, Proszkow*

1. INTRODUCTION

Every civil structure is subject to the ageing processes (technical deterioration) from the very start of construction works until its service lifespan ends [1, 2, 9]. Defects of civil structures are hardly an unnatural phenomenon and occur during the entire service lifespan, which depends on many factors, among others, external environmental conditions; the quality of incorporated materials; improper handling owing to the lack of maintenance and repair work; the lack of regular technical reviews; and limited financial resources and technical capabilities. Each discovered defect requires, above all, the identification and elimination of the cause or causes of the destruction process and, only then, the removal of the effects [1, 3]. Reasons should be clearly defined in order for rescue actions to produce tangible results. The first stage of renovation has already been completed in case of the church building that is the subject of this article. Using obtained financial support, it was only possible to refurbish the upper part of the building, i.e. the roofing, roof truss and external coating, up to the first (upper) cornice. However, the main problem indicated and highlighted in the article [2] (i.e. ensuring the safe use of the church) remains unresolved. This article includes only deliberations based on rational calculations regarding how the structure is founded, as the basis for its safe use. As part of this study, a simulation was carried out regarding the stability of the foundation of the building for various options of the load-bearing capacity of the escarpment, and the extent of necessary work was determined. This is one of the main problems of most heritage buildings in Poland and Europe; and the passing time – having a devastating impact on their deteriorating technical condition – leaves no illusions in this respect.
Since 2008 when the evaluation was made, which indicated the possibility of extending the scope of previously existing defects in construction and decorative elements of the church building, no reinforcements were made apart from the renovation of the roof and the attic of the building. In 2010, trees located on the escarpment around the church building were cut down, but their root systems remained. The technical condition of the escarpment continues to deteriorate. The reason for this is its low stability and heterogeneity as well as the questionable support of the church foundations.

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2. BRIEF DESCRIPTION OF THE CHURCH BUILDING

This structure was erected using a traditional technology in which the main building materials included lime and fired clay bricks. Walls and vaults of the building were made of full clay bricks, on lime mortar, with the exception of the mezzanine floor made of light wood technology. The roof construction comprises of wood roof trusses covered with plain ceramic tiles – double lapped tiles. Today the structure is fitted with electrical wiring, an alarm system, own heating, lightning protection and roof drainage system that drains rain water directly into the storm drainage system. It still fulfils its function of a building for religious worship and, thus, is a place that, periodically but also regularly, houses hundreds of people at the same time.

3. HISTORICAL OUTLINE – HISTORY OF DEFECTS

The basis for the construction of the church in its present shape and form were the foundations of a previously existing parish church from 1578, which had been severely damaged in a fire [6]. This is a detached building set up on an elevation (escarpment) in the immediate vicinity of a very busy provincial road on the Opole-Prudnik route [Fig. 1].
The new church building was constructed on the projection of an elongated rectangle, with a narrower square-like presbytery. This is a single-aisle church with side chapels and two additions, the southern one containing a patron's pew. The church aisle is covered with a barrel vault with lunettes and rich stucco decorations. The façade of the building is reinforced by pilasters; a massive tower on a square plan was constructed above the façade, including its highest part on an octagonal plan.
Stages in the history of the church building at which major repairs and reinforcements [6] were done:

- **1735** – Establishment of anchor iron ties along walls,
- **1644** – Building destroyed,
- **1687** – Church rebuilt in the new Baroque style,
- **1815** – Replacement of the roofing and truss of the tower dome
- **1897/1898** – Structure anchored again; at the same time, the retaining wall around the church square repaired,
- **1904-1907** – engineering evaluation ordered and performed [7] to determine reasons for occurrence of new scratches and cracks of brick elements; the evaluation recommended to reinforce foundation walls from the outside and the inside, as well as the foundation itself, using sections of about 1.0 m in length, and concrete lining,
- in subsequent years, only repairs of internal and external plaster on walls of the church.

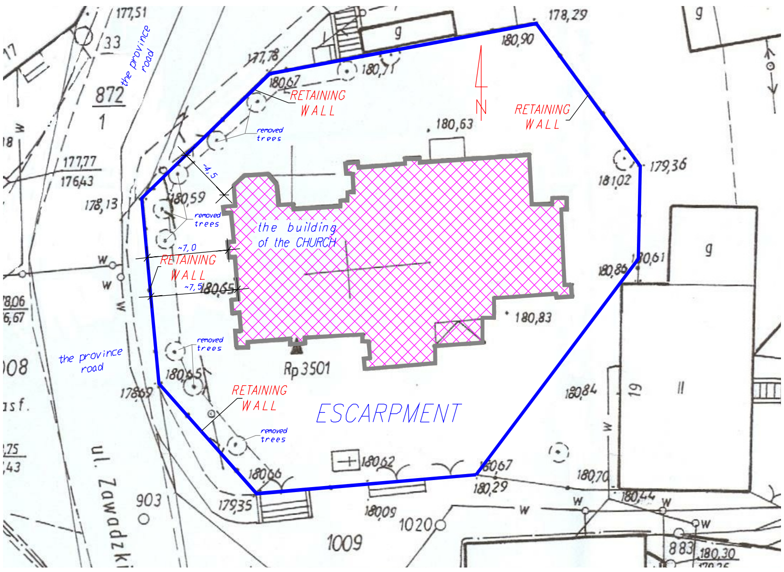

Fig. 1 Location of the church building on the escarpment

The engineering evaluation [7], made w1904 confirmed the real threat of a construction disaster and, in late December the same year, the church building was put out of service. Because of the extremely poor technical condition determined in the evaluation, the possibility of demolition and construction of an entirely new building in a different place was considered – it was clearly stated that the main cause of defects was the location of the church on the escarpment. Finally, after protests of the local community, the parish priest and administrative authorities of Opole, a decision was made to save the existing monument. In fact, the reinforcement of the foundations of the building was provided using traditional methods – full clay bricks and lime mortars with the addition of cement [4]. In the early twentieth century, concrete was not yet commonly used in the load-bearing constructions; therefore, people responsible for the technical condition of the building did not yet implement the innovative – at that time – method involving concrete. Hence, the church is still seated on brick strip foundations.

4. SAFE USE OF THE CHURCH

A simulation regarding the stability of the church building is presented further in the article; it seems that no works will be soon carried out to reinforce its foundation due to the lack of funds allocated for this purpose [11-17]. The preliminary design of the reinforcement of the church building foundation and the escarpment (2010) suggested to underpin foundations with high-quality concrete in the shape of irregular cylinders or introduce micro-piles. Brick retaining walls of the escarpment would be reinforced with steel perimeter bands, supplemented by composite meshes on mineral mortars and peripherally connected with massive retaining block foundations.

Due to the inability to carry out the proposed scope of reinforcing works, the only remaining possibility was to check the degree of safety regarding the stability of the foundation of the church as is, i.e. without any reinforcements (Fig. 2, Fig. 3).

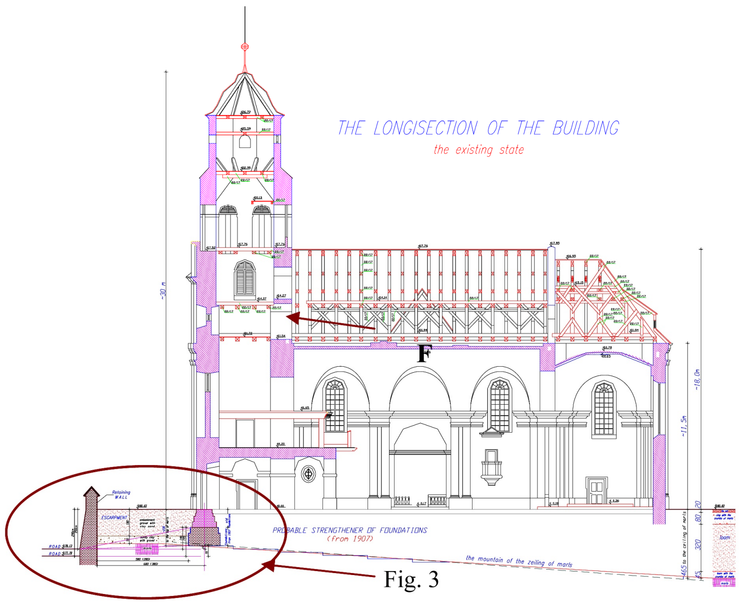

Fig. 2 Longisection of the building

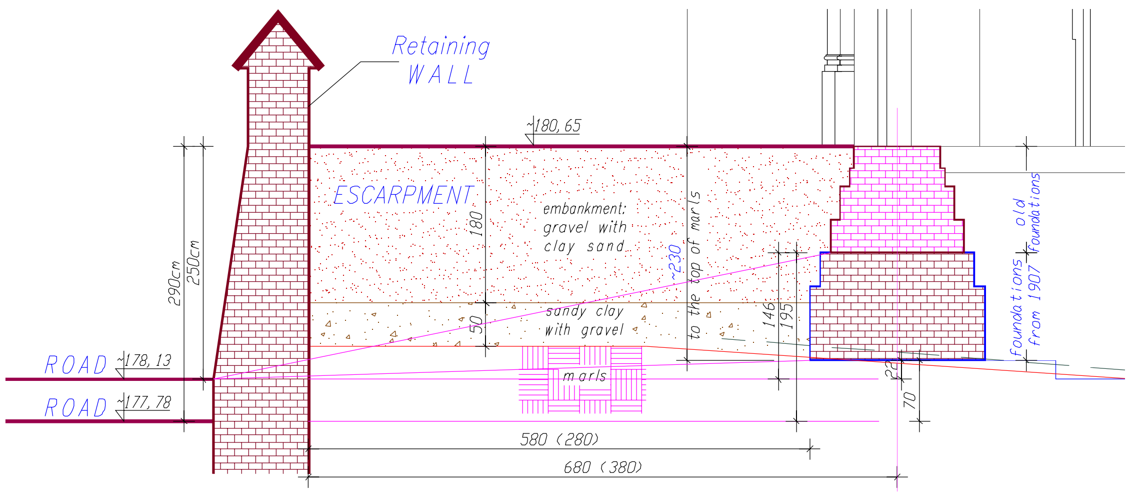

Fig. 3 Location of the foundation at the wall of the escarpment

Because at this stage we still have no sound knowledge regarding the actual width and depth of all strip footings, especially the north-western wall of the tower, in relation to the highest point of the escarpment, their width is assumed based on the study [4]. The wall thickness of the tower is about 100 cm here; foundation pieces itemised during the uncovering made in 1964 in a similar location were about 50 cm. Therefore, it was assumed that the total width of the brick footings should be 200 cm in width, and its penetration depth in relation to the ground level – about 230 cm [4]. Based on the geological survey carried out in 2008, it was assumed that there should be marls or even chalk limestone in the current level of the tower foundation (bottom of the foundation) (Fig. 3). They are characterised by very good load-bearing parameters, suitable as a stable and direct support of the church.
The completed check calculations for the foundation elements of the tower have shown that, without much reserve, the foundations could bear the load concerned [16]. Because the ground structure is not homogeneous under the whole church building, we are dealing here with the variable size of settlements in different parts of the structure and, thus, with the different range of scratches and cracks of its load-bearing and finishing elements.
The check calculation for the escarpment stability on which the church was erected were carried out for three options. In case of the first and second option, it was assumed that the retaining wall of the escarpment did not fulfil its function and the escarpment itself was maintained only through its proper formation [5, 8]. For option I, the penetration depth of the foundation below ground level is 1.25 m, whereas for option II and III – 2.30 m. The lowering of the foundation in a given location down to 2.30 m below ground level took place in 1907 [4, 6]. For the third option, the possibility of a landslide of the escarpment together with the retaining wall was assumed, in the width up to 2 m on the perimeter; this is a likely situation due to the intensive and heavy traffic in the immediate vicinity that generates vibrations transmitted through the ground.
The depth of the foundations of the church building (after their reinforcement in 1907) can reach 2.3 meters below ground level or even further; thus the extent of their impact on the retaining walls of the escarpment (with the maximum height of 2.9 m) will be significantly reduced as compared to the previous situation. The distance of the foundation axes from the inner edges of retaining walls varies here between 6.8-3.8 m (5.8-2.8 m – internal dimension between internal surfaces of these elements). The pit on the underside of the foundation existing here originally in relation to the elevation of the adjacent road was at the level of 1.40-1.95 m, whereas after the completion of reinforcing work, the values dropped, respectively, to 0.22-0.70 m. This arrangements provides greater opportunity to maintain the stability of the escarpment. This situation is shown in Fig. 2, 3.
If the escarpment was damaged in the perimeter, in the width of about 2.0 m, then we would have to deal with a slightly different situation in which the distance of the edges of church tower's foundations from the new edge of the escarpment would considerably reduce outside of its natural wedge and, therefore, the resistance of the solid lump remaining after de-bonding would drop. It should be emphasised that there is a real threat of damage to the church building in the place where it is closest to the escarpment, with its highest elevation, and in the immediate vicinity of the intensive dynamic impacts caused by vehicle traffic on the provincial road.

5. ANALYSIS OF CALCULATIONS

The analysis of the situation that could cause the damage to the church building still confirms the necessity to save this monument as well as others whose situation is similar. Every postponed date of repair work brings the moment of the total destruction dangerously closer [9, 10]. In the analysed case, this situation has been continuing for many years; even through the structure has been causing documented problems for almost 300 years in relation to the stability of its foundations, it still stands on its original site. During this period, there have been numerous attempts to rescue the church before its collapse [7]. The most extensive reinforcing works were performed in the early twentieth century, significantly stabilising deformations of the building that posed a threat of a construction disaster; subsequently, the deformations only involved slight scratches and cracks. The primary cause of the current condition of the church building is its foundation, similarly as it was in the past. Even through the reinforcing measures involving its construction conducted over the three centuries have reduced the progress of the destruction process, they have not completely eliminated its causes.
The Construction Law in force in Poland provides for that "a construction disaster is an unintentional violent destruction of a building or a part thereof, and of structural elements of scaffolding, components of formers, sheet piling and trench sheeting..." However, if the information on the present

risk for any civil structure is available, are actions of people responsible for structure's condition truly unintentional since they tolerate the condition and enable to use the real properties under their control? As described above, the article shows a situation involving the continuous monitoring of the technical condition of the church building and the structure on which it is founded; if there are any signs indicating the danger for these two structures, they will be put out of service and properly secured. Such actions, however, do not solve the problem and do not eliminate the causes; therefore, they will escalate over time, steadily increasing the scope of rescue actions the date of which is postponed to an undetermined date, at the same time generating higher costs of such actions.
Below, diagrams on Fig. 4a, 4b and 4c show three models accepted for calculations of the escarpment stability on which the foundations of the church are situated. Fig. 4) shows the current condition of the escarpment with the foundation (F-1) with the penetration depth of about 1.25 m below ground level, Fig. 4b presents the current condition of the escarpment with the foundation (F-2) with the penetration depth of about 2.30 m below ground level, whereas Fig. 4c shows the anticipated condition of the escarpment with the foundation (F-2) as above after its partial landslide.

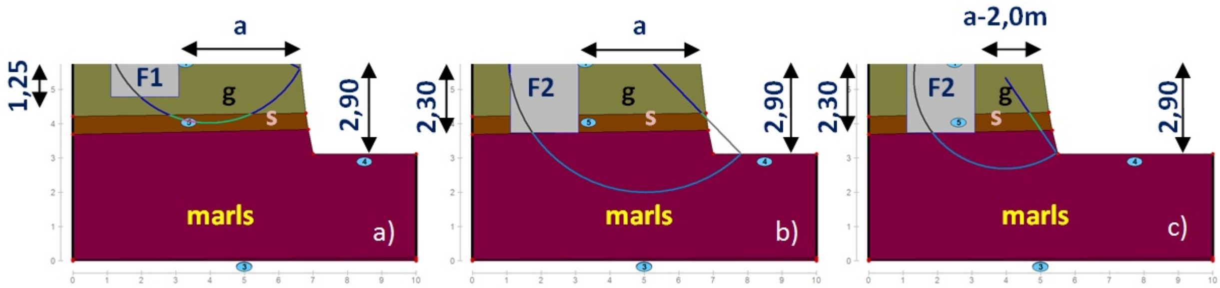

Fig. 4 a) F-1, level of foundations before 1907, b) F-2, level of foundations after 1907, c) F-2, level of foundations after 1907 – damaged (reduced) escarpment

KEY to Fig. 4
F1-F3 – designations of foundations,
a – distance from the face of the foundation to the inner walls of the escarpment,
g – escarpment: gravel with clay sand,
s – sandy clay with gravel.

The stability calculations were done using the Fellenius method [16, 17] assuming that for a given geometry of the escarpment, there is one most dangerous slip surface characterised by the lowest safety factor. Table 1 summarises the characteristic parameters of the selected weakest points of the escarpment.

Table 1

Safety factor	F_1 *) $=M_u/M_w$	F_2 *) $=M_u/M_w$	F_3 *) $=M_u/M_w$
F_{maxmax}	0.80	1.13	0.98
F_{maxmin}	0.90	1.27	1.09
F_{minmax}	0.63	0.90	0.78
F_{minmin}	0.70	1.01	0.87
Soil volume **) $[m^3]$	8.23	19.66	11.55

where:
F_{maxmax} – for max. material factor and max. load factor
F_{maxmin} – for max. material factor and min. load factor
F_{minmax} – for min. material factor and max. load factor
F_{minmin} – for min. material factor and min. load factor

*) – safety (confidence) factor = the ratio of the retaining moment of the escarpment lump in respect of the centre of rotation to the moment of rotating forces – should be not less than 1.0, recommended to be greater than 1.30 – respectively for the tested case no. 1,2 and 3.
**) – volume of soil lying inside the arc of slip on 1 running m of the escarpment

6. SUMMARY

The calculation results presented above clearly show the absolute necessity to rescue the structure. We cannot indifferently watch the poor technical conditions of the escarpment containing root systems of the previous cut-down trees and lacking the adequate retaining constructions. The technical condition of the perimeter brick walls is so bad that they can now only be deemed as self-supporting structures that cannot form an effective resistance to the escarpment itself. Therefore, there is still a high probability of breaching the stability of the escarpment due to the impact of vibrations from vehicle traffic and the load transmitted by the foundation of the church. Prepared calculations showed that if it turned out that in 1907, the depth of the foundation of the church building was reduced to the top of the load-bearing soil, i.e. marls or limestone, then there would be no problems with the support of the structure. Again, this confirms the need of a thorough research regarding the level of the foundation of the church building in respect of the depth of the top of the load-bearing soil and only after the analysis of the results, a decision on how to proceed should be made. Until that time, however, and until obtaining the required financial resources, these two technically interconnected structure have to be continuously supervised. Supervision should be subject to continuous control of the technical condition and accurate surveying observations of the deformations regarding elements of the church building and the escarpment, the failure of which would influence their stability and, thereby, jeopardise their safe use.

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