On problems with saving of sacral buildings situated on coal mining terrains

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Abstract

The authors have tried to analyse the typical problems connected with saving and rehabilitation of old monumental buildings, especially old sacral buildings situated on terrain subjected to coal mining influences. There are particular problems in the Silesian Industrial Region in south Poland. During the last several hundred years there has been very intensive coal mining exploitation in this area. As a negative result of such a situation, damage of many existing buildings is observed. Most of them need immediate repair works. Strengthening of monumental masonry sacral buildings is especially difficult, because all the parameters of ground deformations (in horizontal and vertical directions) are usually not well known and this type of building do not have an intensive saturation of internal load bearing walls. Based on the example of the 200 year old evangelical church in Wałbrzych, the methodology and procedure of analysis of this type of buildings are presented.

1 Introduction

As a result of mineral removal by mining operations different ground deformations are observed. In Poland, this type of deformation took place in the Silesian Industrial Region. An exact description of the influence of subsidence on the behaviour of the structure of buildings is still not well established. According to knowledge in Poland, a theory developed by Budryk and Knothe [1], there are three main types of deformations connected with coal mining:

- vertical deformations – as a result of vertical displacements of the ground surface;
- horizontal deformations – as a result of horizontal displacements of the ground surface;
- horizontal and vertical deformations – as a result of the curvature of the ground surface.

All these deformations have the negative influence on the behaviour of the buildings. Most of all existing buildings, including made of masonry, are typically apartment buildings. This type of buildings is characterised by considerable saturation of internal load bearing walls. Therefore the protection of them against results of deformations, described above, is not so difficult. For many years, there are some regulations and methods given in professional literature, e.g. in [2, 3].
Quite different situation is concern with old masonry sacral buildings. Usually, in this type of structures there is no intensive saturation of internal load bearing walls. The specific of sacral buildings is connected with large span of the central naves and aisles. Moreover, in old monumental buildings, external load bearing walls are masonry made of weak lime mortars. All this facts with connection with some limitations regarding to interference into the internal space and structure of building, caused that problem of protection this type of buildings against coal mining subsidence is often a very complicated.
Based on the example of analysed 200 years old church in Wałbrzych, the methodology and applied method of strengthening, in case of necessity of guarantee the long period of further exploitation, based on the incomplete knowledge of influences, were presented.

2 General characterization of the church construction

The Evangelical Church in Wałbrzych (Fig.1) was erected in 1786 according to project of Langhans who was one of the most famous German architects.
It's a three-body building, consist of one nave main building and connected with them: bell tower (in front of the building) and one storey outhouse (in the back). Whole building is executed with main external load bearing walls made of masonry, timber roof structure and also timber district-galleries. The overall dimensions of the horizontal projection (Fig.2) of the church are approximately 45 m × 22 m.
Main part of the building has regular, rectangle form and overall dimension 36,7 m × 14,75 m. In the central part of the main nave were built two storeys timber district-galleries (see Fig.2). Construction of these galleries was made of timber elements (columns and beams) with surface plaster works.
Main body of the church crowned the timber, larch roof truss construction. From the front of building, the rectangular, masonry tower with overall dimensions 13,7 m × 8,14 m, is connected. Total high of this tower is about 60 m. Top of

them is crowned by masonry spire. In the backside of the church, the one storey outhouse is connected with the gable wall.

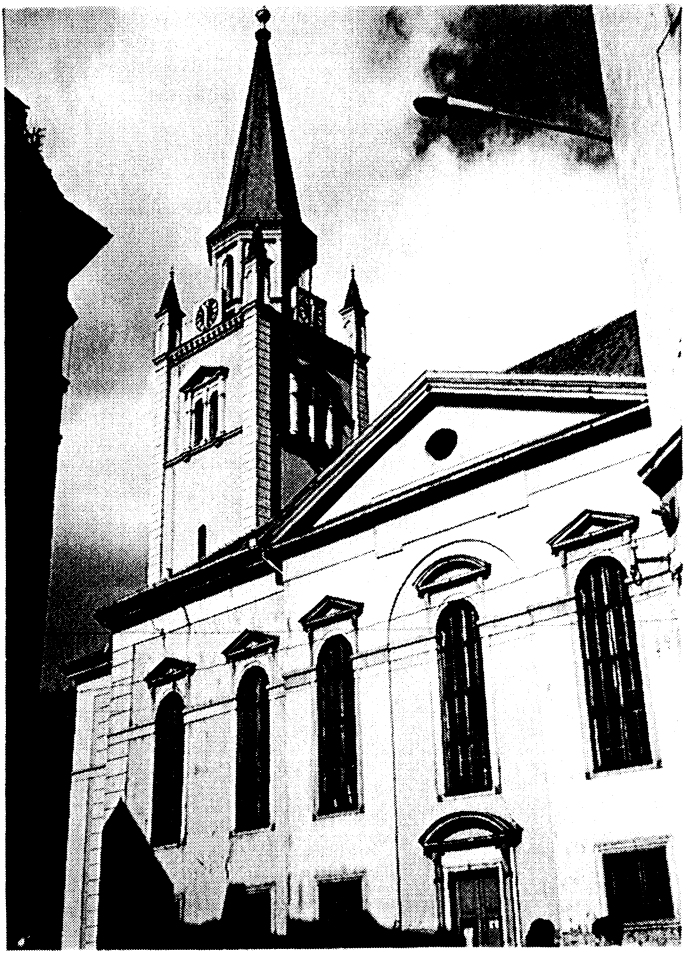

Figure 1: View of the façade of the Evangelical Church in Wałbrzych.

3 Description and analysis of observed damages

Analysed building, during a long period of exploitation (200 years) was experienced many different types of damages. Most essentials of them are:

- large damages of load bearing elements of the building (masonry external walls, arches and masonry vaults, lintels in external walls and many timber beams);

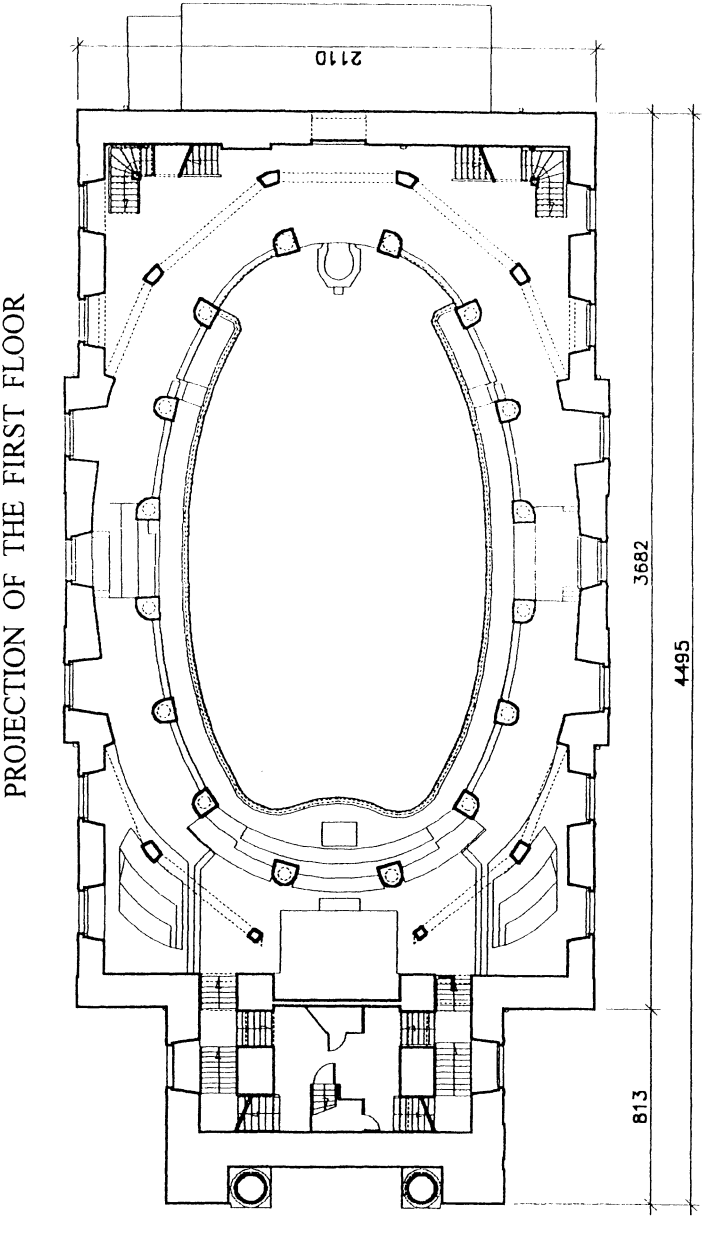

Figure 2: Shape and overall dimensions of horizontal projection of the church.

- regular and irregular cracks visible on the surfaces of the many finishing elements (plasters, timber elements of the galleries); damages of roofing, windows, architectural decorative details and many others.

Main damages of the load bearing elements are concerned the external walls of the building. There are vertical cracks running across the whole high of the building. These cracks have the maximal width up to a few or even more than 10 centimetres (Fig.3) and they occurred rather regularly. The similar width of these cracks in the lower and upper part of walls was observed. In cornice area these cracks are not disappeared, on the contrary, sometimes they are expanded and damaged the cornice.

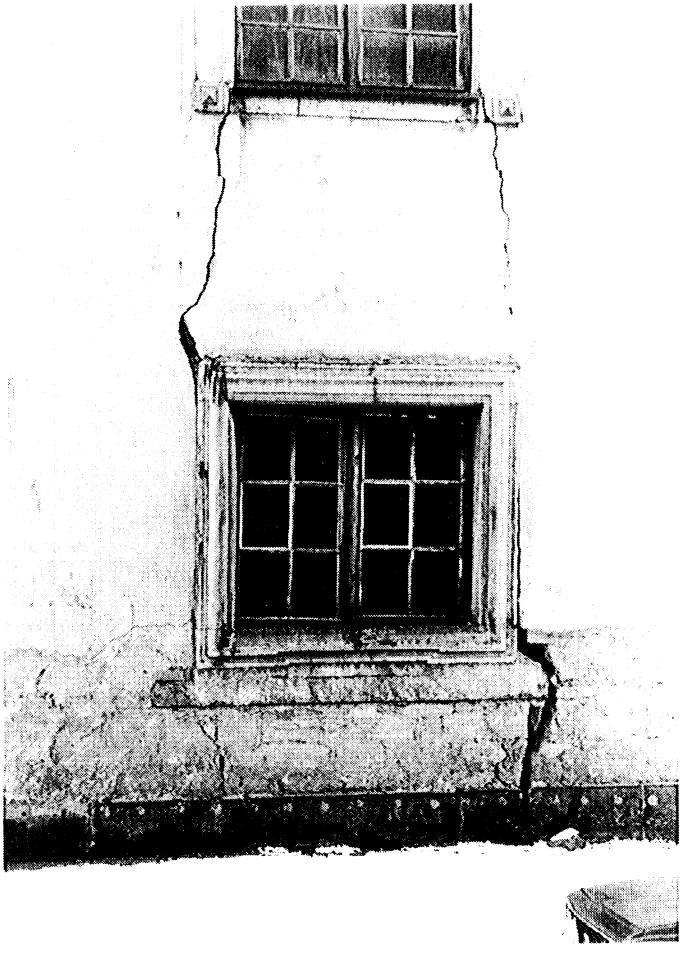

Figure 3: View of the width crack at lower part of the external wall.

Moreover, also in the underground part of the external load bearing walls, the cracks have a similar width like in the other parts of the walls. Directions and configuration of the cracks on the both longitudinal, external walls are also very similar to each other. All lintels in the external walls are damaged, sometimes very seriously.
The considerably damages and devastation's of many elements of the timber roof truss constructions of the church. There are the typically effects of long penetration of water (leaky roof surface) and dampness (bad damp-proofing).
Similar reasons were caused the damages of the other finishing elements of the building.

4 A short history of arising of the church

Analysis of the available historical sources was permitted to state, those vertical cracks of the longitudinal external walls were first observed before about 100 years. First information about the appearance of this type cracks dated back to the year 1888. The fracture with the maximal width was registered both the north and south external wall of the main nave of the church in the area of the firs row of windows – counted from the bell tower. Practically, this fracture is "cutting" across the building into the two pieces. According to the historical sources from 1938, the width of the cracks on the level of foundation was between 15 and 20 millimetres, but on the level of cornice – about 10 mm wider. In 1997 the fracture on the level of foundation has 20 to 20 mm width.
Quite similar situation with the others cracks and fractures were observed. It was found that the crack width is on the going out.

5 Analysis of reasons of the damages, observed

Most seriously damages of the longitudinal load bearing walls have rather regular character of vertical cracks. The most width fractures are in junction of main body of church with the tower. This fracture is entailed irregular vertical displacement of lower windows lintel beam and deformation of the window opening. In effect of them the lintels are also damaged. This type of failure suggested the occurrence of unequally settlements both parts of the building. In mentioned above, historical sources the different reasons of damages observed are presented.
Analysis made by authors with connection with performed calculations (based on the investigations of the soil parameters), permitted to define three following, main reasons of damages:

- irregular settlement – as a result of variations in the groundwater level;
- modification of construction of the church and raise a additional part of the bell tower;

- proximate influences of ground deformations – as a result of long and intensive coal mining.

Moreover, it was found that since 1970 the influences of ground deformations as a result of variations in the groundwater level could be recognized as stabilized. Now the value of settlements is not greater than 1 mm during one year and they have regular character. The load capacity of the ground foundation, according to calculation performed, is sufficient.

6 Method of proposed protection of the church

Presented building, in respect of both architectural and constructional aspects, is an old masters work of art. As a building registered in the Register of Monuments is in care of law and needs protection of conservator. Unfortunately, now this object has more of 200 years of exploitation and is situated on the intensive coal mining terrain's. Since more than 100 years, it's demonstrating many damages, sometimes very dangerous. In order to stop the technical degradation process, analysed building needs the realization of the structural strengthening and other repair works.
Analysis of reasons of observed damages, was permitted to precise the method of protection of the church. A vertical cracks and fractures, coursed along the whole high of the building suggested the appearance of horizontal movements of the ground. It's a typically phenomenon on terrain's subjected to coal mine exploitation. Taking into consideration all facts described above, the following method of finally structural protection of this object, was accepted:

- performance of the reinforced concrete band around the building in the upper part of the foundation masonry walls (see Fig.3) in order to integration both parts (main body and the tower) of the church. It was made an assumption that RC band will take all additionally tensile forces produced by further horizontal ground displacements;

- anchorage of the main nave walls in two levels and in both directions by steel bowstrings. This anchoring should be made between upper and lower belt of window openings on first floor galleries level and on the cornice level. This strengthening should protect the object against the tilt (as a result of irregularity of settlement) of the ground under building;

- repair and strengthening of damaged lintels by performance of the reinforced concrete lintel beams and arches – like shown on Fig.4;

- repair of damaged walls using well known standard-methods [4,5] by removing and replacing shaded and cracked bricks and blocks with new and filling the cracks an appropriate (commonly 1:1:6) mortar mix, well rammed in, and repointing the surface. When the cracks were large, additionally the expansion bolts of modified mortar fixings should used;

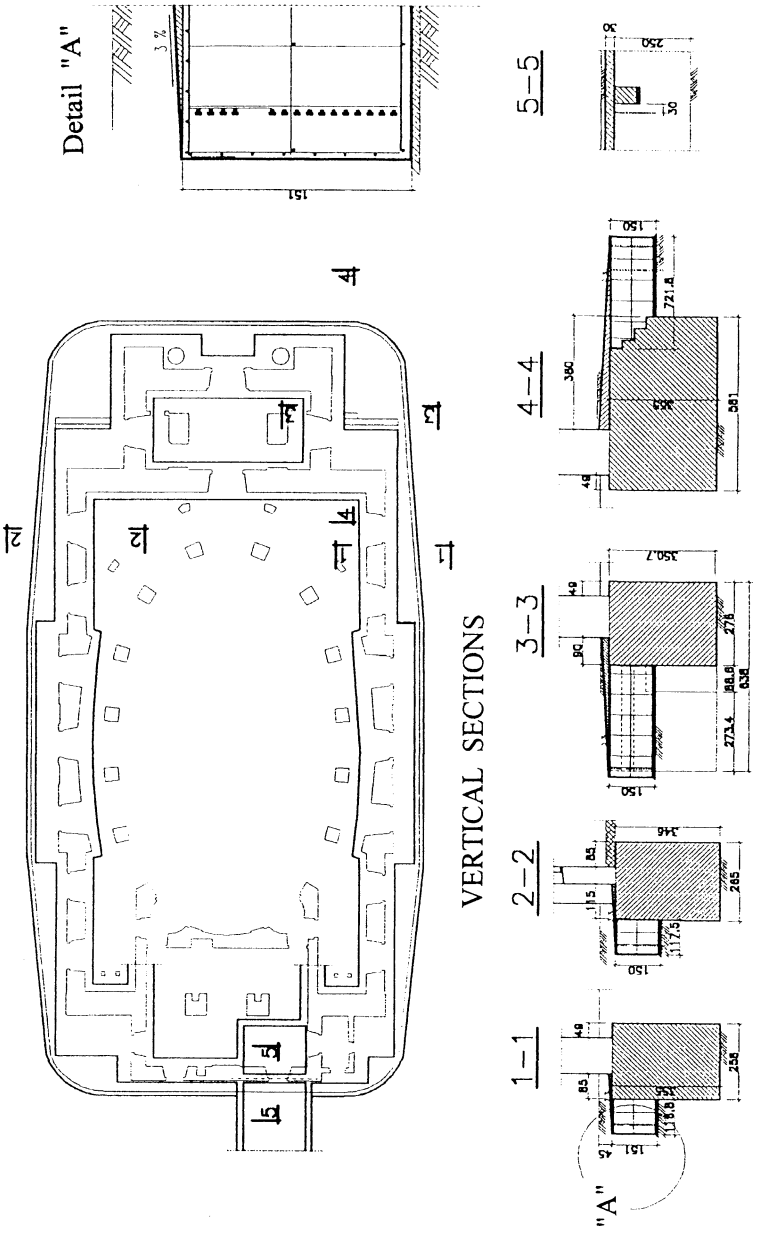

Figure 3: Construction of the RC band around the upper part of the foundation walls.

- renovation and restoration of the whole façade surface and external architectonic details of tower and main entrance into the church. First the façade surface was cleaned and than the gaps was filled with suitable mortar mix.

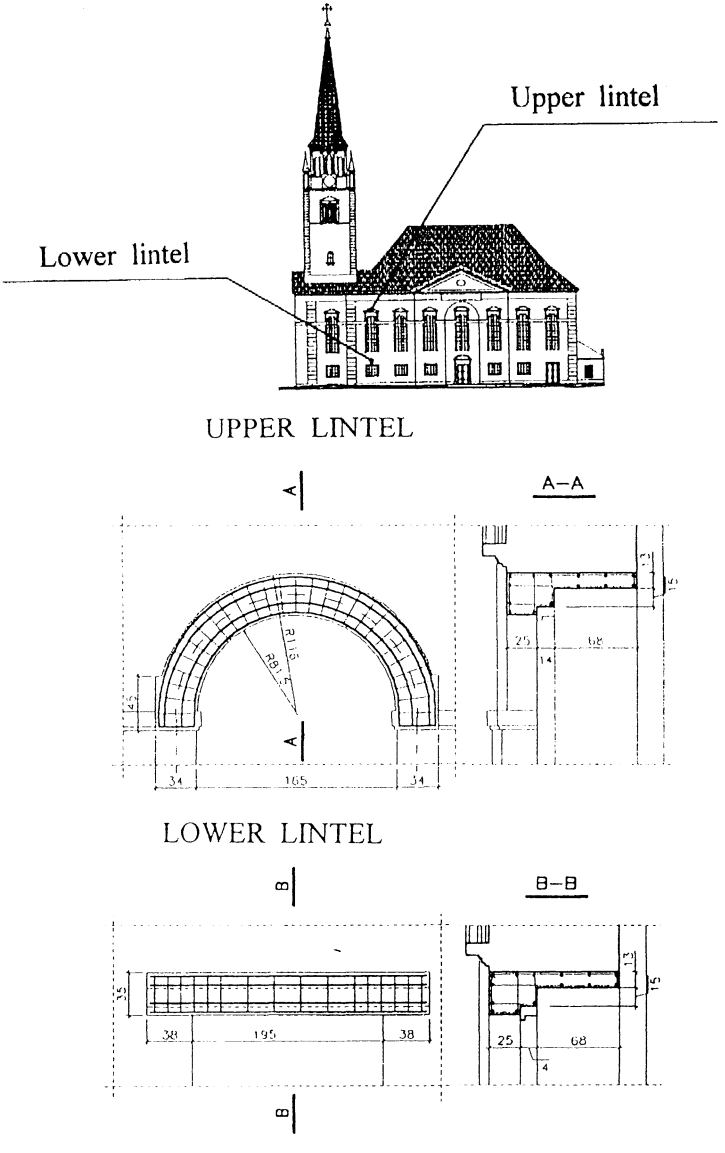

Figure 4: Method of damaged lintels strengthening.

7 Summary

As usual in case of old monumental building, unequivocally determination of reasons of observed damages is not so simple. Sometimes, there is impossible. Usually, there are many different reasons. Moreover, they are appearing with different intensity during whole period of exploitation of the object.
Monumental buildings for the sake of specific construction (low number of internal load bearing walls) need adequate methods of strengthening. Method must take into consideration to influences caused observed damages and which are prognoses.
Based on the example of building analysed were tried to explain the methodology of strengthening this type of object with incomplete knowledge of influences acted and when is necessary to guarantee the long period of further exploitation.

References

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