Long-term review to the rehabilitation of the collegiate church in Königslutter, Germany

S. Niederhagemann
Deutsches Bergbau-Museum [DBM], Informationssysteme, Am Bergbaumuseum 28, D-44791 Bochum, Germany

Abstract

The collegiate church Königslutter was erected in two steps. In the first period the eastern section with choir and transept was built by the emperor Lothar von Süpplingburg (1075-1137) with groined vaults and lavish ornaments. The western parts were completed less expendable and only with a flat roof. Later on the master builders erected also groined vaults in this section, but the load bearing walls were not strong enough to compensate the shear loads from the vaults. This was the reason for the recurring statically problems. In 1693 the vaults collapsed under the big pressure. Nevertheless the vaults were rebuilt without the necessary reinforcing measures. In the 70's of the last century similar problems had been detected in the construction. Cracks in the apex of the vaults and in the joints to the walls signalised the relenting of the load bearing walls, because of changing soil behaviour. Extensive rehabilitation works were made under the direction of Prof. Dr. Klaus Pieper. He decided to fix the walls with prestressed tendons, which were arranged above the vaults. Within the scope of an international research project the collegiate church of Königslutter is at the focus of attention again. This gives us the chance to estimate the success of the rehabilitation after 20 years. In this review we have to record that the statically problems could be compensated for a long period of time, but because of physical changes in the masonry moisture appeared at the injected sections. These irreversible changes are harmful to the wallpaintings inside the church. Future projects should focus on alternate possibilities of rehabilitation, countermeasures against moisture or the reduction of injected grout.
1. Introduction

In the last few years the technology of reactivating masonry by additional encasing bars into the brickwork became more and more popular. This technique is an efficient method to ensure a structural system from collapsing without changing the appearance [1] [2]. In the meantime there are some studies about the longtime effectiveness of these constructions [3] [4]. But, depending on the structural changes of the materials, this method of reactivating buildings has got further consequences to the building than only the reinforcement of the construction. Some of these technical variances and their physical significance will be examined in this article at the example of the collegiate church of Königslutter in Lower Saxony, Germany.

Figure 1: The collegiate church of Königslutter

2. History

In 1135 the German Emperor Lothar III. (1075-1137) started to build up his funeral church at the old tradeway from Braunschweig to Magdeburg. During his military campaign in Italy the emperor had been amazed by the architecture. Fa-
cinated by the lavish ornaments he engaged local stonemasons for the ornamentation of his cathedral. Just two years after the start of the site Lothar III. died in Füssen (Bavaria) on the way back from his second campaign in Italy. So he did not live to see the complete church and had to be buried in an uncompleted section of the building. His grandson Heinrich der Löwe finished the dome in 1170 in a less expendable way. Originally the roof of the nave was flat and stood in contrast to the choir and transept, which were built during the lifetime of Lothar and were constructed with groined vaults. Afterwards, in the 14th and 17th century, the ceilings of the nave had been vaulted.

3. Structural problems

The supplementary change of the ceilings had been made without reinforcing the walls. Because of the abandonment of vaults these walls had been constructed less expendable. Without further measures of amplification the walls were not strong enough to compensate the high shear loads. This was the reason for the recurring statically problems. In 1693 the vaults collapsed under the big pressure. Nevertheless the vaults were rebuilt with insufficient reinforcing measures. The new vaults had now been constructed with arches but the sidewalls still were too weak to carry the shear loads. In the 70ths of the last century similar problems had been detected in the construction. Cracks in the apex of the vaults and in the joints to the walls signalised the relenting of the load bearing walls, because of a changing soil behaviour.

![Figure 2: sketches from Prof. Dr. Pieper to demonstrate the relenting of the groined vaults [5]](image)

4. Rehabilitation measures

In the 70ths Prof. Dr. Klaus Pieper performed extensive measures to salvage this monument. He arranged prestressed tendons above the vaults to stop the relenting of the walls [6]. For the connection with the walls anchors had been installed. This arrangement outside of the (for the visitors) visible areas has got the advantage that the construction has been reinforced but the appearance has not changed. In connection with soil consolidating measures underneath the footings
and constructive changes at critical joints at the intersection the collegiate church has been saved from collapsing.

![Figure 3: View under prestressed tendon](image)

5. Result

An extensive measuring of the sagged and leaning walls, came to the conclusion, that the 1970 detected movements had been stopped. Within the realms degree of accuracy the settlement and eccentricities of the components kept the same as 25 years before. Prof. Dr. Pieper documented all the cracks in a detailed plan. An examination of the crack development showed, that most of the damages did not increase in the meantime. Most of the cracks could be located again. All of them kept shut or just opened insignificantly.

The measurements have been successful for the stability against collapse. The cathedral got convenient ties to compensate the shear loads out of the groinded vaults. Another crash could be prevented.

5.1 Moisture and efflorescence

Directly after finishing the safeguarding measurements the first damages occurred at the wallpaintings. For the combinding of the shear load bearing anchors must be fixed into the tuffa of the walls. To save these anchors from corrosion and connect them with the walls fresh concrete has been filled into the drills and transported a lot of water into the vaults and walls. This moisture could never evaporate completely.
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Figure 4: Vault at the northern side apse in 1972

Figure 5: The same vault as figure 3 in 2001
In the wintertime the climate in the church is dominated by the heating. The climate of the area above the vaults is the same as outside the building, because the loft is highly permeable to air. The tuffa of the walls has a high rate of air bubbles \([7]\). This gives the material a good heat isolating quality. Because of the concrete injections the physical attributes changed in a unfavourable way. The heat leating injected sections of the walls stand in contact with the cold air outside the building.

In the wintertime, when warm air from the inner side of the church penetrates the masonry and meets the cold sections, water precipitates and increases the moisture in the tuffa. The comparative watertight concrete aggravates the evaporation of the moisture in the summertime. The damaging consequences of moisture inside the masonry are sufficiently known. The water unsolders salt inside the tuffa and concrete and transports it to the surface. Plaster bursting efflorescenses are the consequences of this procedure. Historical plaster and wallpaintings get irrecoverably lost.

Figure 6: Damaged plaster and wallpainting
6. Rehabilitation

The changes in the injected areas are irreversible. The physical attributes of the material can not be restored. Therefore the unfavourable situation of having cold material inside the warm walls must be changed. With arranging a heat insulation the concrete injections could be disposed into the warm site and the precipitation of water could be stopped. By choosing a practical heat insulation it is very important to select a water permeable material. This is important to allow the latent moisture to leave the construction in the summertime.

To preserve the appearance of this monument the heat insulation can not be fixed onto the visible outer walls. So the installations must be limited to the areas above the vaults and upon the invisible outer walls. This can reduce the desired effects but will definitively reduce the moisture and the associated damages. It is imaginable to arrange a system, which can be removed in the summertime to speed up the evaporation process in the first few years.

Conclusion

For coming rehabilitation projects it should be carefully examined if the irreversible infiltration with concrete can be accepted. The technique of prestressed concrete components is a very effective way for stabilisation against collapse and the stability has first priority against all other technical tasks, but the immense physical changes of the material should be preconceived. It should always be examined if there are alternatives for the rehabilitation of the building or if the extent of the grout can be reduced. In cases of inevitable concrete injection countermeasures against the described damages should be taken. One way of avoiding moisture is to prevent the contact between the injected material and the outer atmosphere. Correctly used the tendon technique is a long-term effective way to strengthen damaged masonry.

References

