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Reliability Assessment of Saint Joseph Church in Prague

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Abstract. Monitoring provides valuable information to be used for the decision making about the maintenance and rehabilitation of existing structures. The case study of a masonry church shows that numerous problems have to be commonly resolved during the optimally plan and perform monitoring; the major issues include the selection of technique, suitable position of monitoring devices on structures, data transmission and backup, consideration of uncertainties in measurements and defects of hardware. The study reveals how inspections and monitoring can support decisions related to optimal upgrade strategy and further use of the heritage structure.

Introduction

Reliability assessment of heritage structures is a demanding task which commonly requires co-operation of different specialists [1]. Monitoring of structures is an important part of their reliability assessment. Monitoring during the preliminary assessment can contribute to planning of later monitoring during detailed assessment [2]. Presently Eurocodes are to be used for the verification of structures in all the CEN Member countries. However, a supplementary guidance is commonly needed for the verification of existing structures including heritage ones; this might be found in ISO 13822 [3]. For the operational applications in the Czech Republic, the new standard CSN 73 0038 [4] has been developed including information on properties of existing materials, on updating the basic variables, and also on experimental testing and monitoring.

The Klokner Institute was asked for the reliability assessment of the St. Joseph Church in Prague which is listed as a Czech national cultural heritage monument. The church was built within 1636-1653 as a part of the Capuchin monastery. The monastery was later rebuilt to neo-Romanesque barracks and recently transformed into a shopping centre Palladium. At present the church is thus situated closely to the shopping centre, hidden behind the wall which separates the church from the Republic Square and which creates a small courtyard decorated by two Baroque statues (Fig. 1). The interior of the church is quite simple. Lateral altars are decorated by two large paintings by the famous Czech painter Karel Skreta. The vertical walls of the church are made from stone masonry and ceilings include cylindrical vaults. The church is partly provided with cellars.

Fig. 1.

Fig. 2.

Various damages of the load bearing structures of the church appeared in the past and also during the construction of underground line B in 1990's of the last century. Partial reconstruction of some parts of the church was carried out from 2005 to 2007 when also the new shopping centre was built up. The appearance of various deformations and cracking in that time could be attributed to the construction of a new underground station and also the new shopping centre with underground parking garages.

After archaeological investigations, the Klokner Institute made the first survey of damages in 2004 in order to support decision about strengthening of the church foundations adjacent to the Palladium construction site by jet grouting. The findings made it possible to plan structural interventions. Selected walls were strengthened by Helifix ties and all rooms were renovated. However, it was shown that the strengthening was partly inefficient. damages across walls, paintings and various architectonic elements of the church

Several locations of the church were monitored for several years, focusing on structural movements, deformations and cracks in masonry walls and floors. The evaluation of monitoring results revealed that movements in some parts of the church are insignificant and in some cases even within the tolerances of a measurement technique. However, settlements of the whole structure in the direction to Palladium were identified.

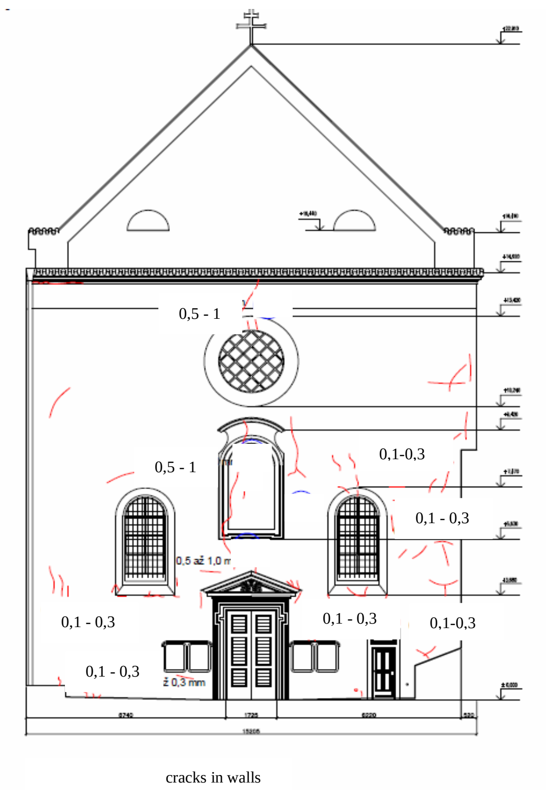


Fig. 3. Cracks in the front part of the church (in mm).

The results of the long-term monitoring carried out from 05/2005 to 06/2013 indicate that some monitored points settled about 5 mm, and the wall in the vicinity of Palladium up to 15 mm. Some damages and cracking resulted from the accidental horizontal movement of the sheet-pile wall during the construction of the Palladium centre which was also used for the stability assurance of the church foundations. The movement of the sheet-pile wall led to minor settlement and rotation of the church peripheral wall. Despite the fact that some church walls were partly strengthened by the Helifix bars, the cracking and other damages newly appeared and progressively developed.

Survey of Damages and Monitoring

New survey of damages was undertaken (Fig. 3) and compared with the results of the previous one. Inspection revealed that several new damages appeared in the main church nave. In the wall neighbouring to the Palladium shopping centre, several new cracks of the width from 0.3 to 4 mm are visible. Main cracks extend to the arches and also to the ceilings, damaging the paintings. Cracks up to 4 mm in the masonry and considerable floor deformations appeared in the main nave.

The largest cracks of width of 5 mm were found in the east side of the church. In the west wall, the cracks in tops of the vaults width from 0.5 to 2 mm appeared. Considerable cracks exist between the west wall and the vault of the main nave. The cracks are present in most rooms of the church. Several wider cracks exist in the gable parts of the church. It might be assumed that some of them could be present before the construction of the new underground.

During the new survey, the cracks were documented in all rooms of the church including their shape, width and length. All the plaster targets which were placed on the church load bearing structures in the past (2005-2007) were checked. Inspection revealed that some of the monitored points suffered from no damage, while some others were affected by cracks.

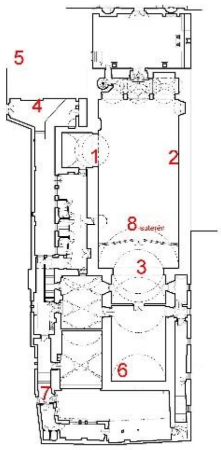
The findings of the recent survey are critically compared to those from the 2004 survey. It is apparent that in some parts of the walls, ceilings and floors new cracks and deformations have occurred, e.g. cracking in tops of the vaults and bulging of the floor in the main church nave.

Effects of Traffic

To estimate the influence of surrounding environment on the church, the traffic was monitored by a one channel vibrometer in May 2014. Passages of trams, buses, impacts of human activities and some other sources of vibrations were measured and evaluated as is reported in Table 1 (indicating maxima) accompanied by a floor layout with locations of the monitored points.

Table 1. Maximum monitored responses in mm/s.

No.	Response v_{ef} (mm/s)	vertical	laterally horizontal	longitudinally horizontal
7	lorry	0.05	0.06	0.03
4	tram	0.08	0.045	0.03
7	bus	0.05	0.03	0.03
4	pedestrians	0.03	0.02	0.02
3	minor impacts	0.04	0.02	0.02
8	bump	0.02	0.01	0.15
all	other	0.01	0.01	0.01



The results of monitoring are compared with the limiting values recommended in the national standard ČSN 73 0040 [5]. The load-bearing structure of the church might be classified as Resistance Class A (monument, deteriorated structure, built without prescriptive documents) and as Significance Class III (specific economic and social significance). For such a structure, the following limits are provided by the standard:

- $v_{ef} \leq 1.2$ mm/s – dynamic assessment is not required
- $v_{ef} \leq 4.5$ mm/s – no progressive damage is assumed to develop
- $v_{ef} \leq 7$ mm/s – minor damage including cracks of width up to 1 mm in joints of ceilings is expected to develop with likelihood 5%.

The measured maxima of the traffic effects are about two orders lower in comparison with the limiting values which might potentially have some influence on the cracks formation. It is thus concluded that the traffic in the vicinity of the St. Joseph church has insignificant influence on cracking of masonry structures.

Destructive Test of Floor

One destructive test was made in the location of the floor deformation. The aim was to investigate the composition of the floor layers and reveal the cause of deformation. It was suspected that the floor might be influenced by the pressure of underground water. The composition of floor is illustrated in Fig. 4 where the cavity of the thickness from 0.03 m to 0.15 m under the layer of historic terrace.

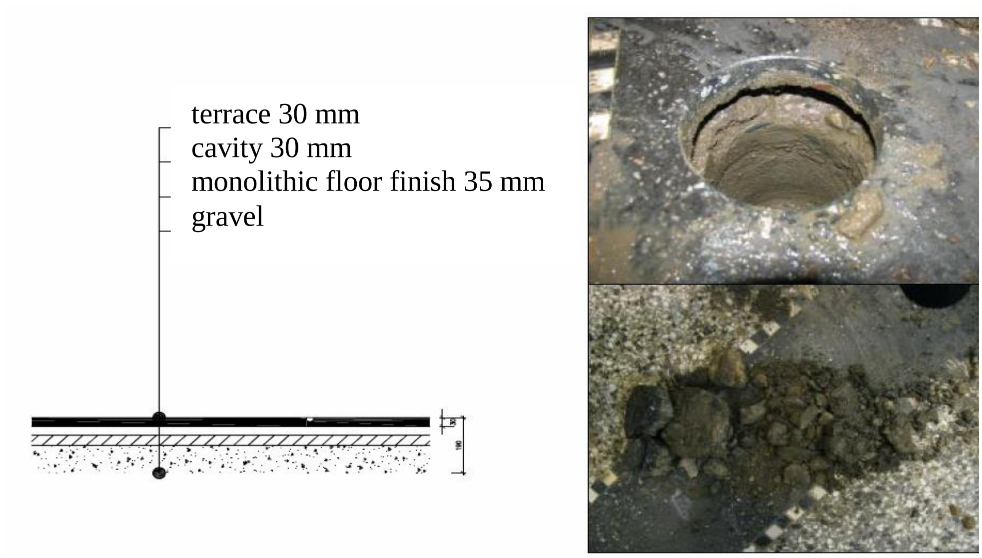


Fig. 4. Test pit in the location of the deformation of the floor.

No underground water nor injected mortar used for the soil strengthening were not detected by the test. It appears that the deformation of floor is caused by the horizontal movements of the neighbouring shopping centre.

Conclusions

The construction survey shows that the walls and vaults of the church, rehabilitated about ten years before the present investigations, are in many places newly damaged by cracks, mostly of about 0.4mm widths. In some cases, cracks exceeding 4 mm were found, mostly in the gable walls and in tops of the vaults. Some of the cracks were caused by the construction of the Prague underground line B, the others during the execution of the Palladium shopping centre. Recently, new significant cracks have appeared in the ceiling and tops of the vaults in the main church nave. In the lateral bays adjacent to the Palladium shopping centre, the floor is newly deformed, elevated up to 0.2 m.

The results of monitoring indicate the local settlement of foundations in some parts, deformations or movements of structures. An influence of a former embankment under the church foundations which could consolidate due to significant geotechnical activities during execution of Palladium shopping centre, might be assumed. Despite the injection of the soil and application of the sheet-pile walls for safeguarding the church and geotechnical works on Palladium building, their safeguarding effects might be locally reduced (also due to the technical problems with sheet-pile walls during execution of the shopping centre).

A destructive test of the deformed floor revealed a hollow without underground water or injection mortar due to former geotechnical protective works. It might be concluded that there might be an influence of local lateral pressures of structures, potentially in combination with uneven settlements of the foundations having impact on the deformation of floor in the main church nave.

It was recommended to further monitor movements of the structures, their possible effects on further progression of cracking and deformations. Results of such campaign would support enhanced reliability verification of the damaged masonry structure [6-8] On the basis of monitoring new effective measures can be accepted.

Informative monitoring of the effects of tram and road traffic leads to the conclusion that the public transport is insignificantly affecting reliability of the church. The current conditions of the load-bearing structural system of the church might be considered as acceptable and the church might be further used for its purpose by the Capuchin order and also by tourists.

Movements and crack development of selected structures of the church are being monitored. When no significant progress of cracks is observed, it is possible to repair the church. Otherwise relevant structural measures should be taken to increase stiffness and robustness of the load bearing structures of the historic monument.

Acknowledgments

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References

[1] M. Sýkora, M. Holický, J. Marková, T. Šenberger, PROBABILISTIC RELIABILITY ASSESSMENT OF EXISTING STRUCTURES focused on industrial heritage buildings, 1st ed., CTU Publishing House, Prague, 2016.

[2] Joint Committee on Structural Safety, Probabilistic Assessment of Existing Structures, RILEM Publications S.A.R.L., 2001.

[3] ISO 13822 Bases for design of structures - Assessment of existing structures, ISO, Geneva, 2010.

[4] CSN 73 0038 Assessment and verification of existing structures - Supplementary guidance, ÚNMZ, Prague, 2014.

[5] CSN 73 0040 Loads of technical structures by technical seismicity, ÚNMZ, Prague, 1996.

[6] J. Witzany, T. Čejka, M. Sýkora, M. Holický, Strength assessment of historic brick masonry, Journal of Civil Engineering and Management 22 (2016) 224-233.

[7] J. Witzany, T. Čejka, M. Sýkora, M. Holický, Assessment of compressive strength of historic mixed masonry, Journal of Civil Engineering and Management 22 (2016) 391-400.

[8] M. Sýkora, T. Čejka, M. Holický, J. Witzany, Probabilistic model for compressive strength of historic masonry, Safety, Reliability and Risk Analysis: Beyond the Horizon - Proceedings of the European Safety and Reliability Conference ESREL 2013, Amsterdam: Netherlands; 29 September - 2 October 2013, 2014, pp. 2645-2652.