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Mistakes in diagnostics and rehabilitation of concrete structures

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ABSTRACT: The paper describes frequent mistakes in diagnostics and rehabilitation of building structures which will be demonstrated on a real reinforced concrete conduit in Wastewater Treatment Works. Primary diagnostics of damaged reinforced concrete constructions is over and over again ignored and this situation brings about subsequent unsuitable choice of reconstruction techniques. Together with poor method of execution, the structure rehabilitation became much more expensive and at the end the final result could cause much more serious problems and damages of concrete structure. Nowadays the reinforced concrete discharge conduit which was rehabilitated in 2001 is again in critical condition. Today condition of mentioned construction requires another and much more expensive renewal in relatively short time.

1 INTRODUCTION

At the beginning, this paper is not about new progressive techniques and materials used in rehabilitation of constructions. On the contrary, this paper tries to point nowadays situation in the building industry out. In the name of new, excellent, progressive (etc.) materials, the basic sequence of rehabilitation working process is often trampled down. Everything is about cause and consequences. The ground of the rehabilitation is to repair the cause of the problems, not only the visible consequences. And there is the biggest problem of nowadays rehabilitation works, the diagnostics. The right diagnosis of the construction condition is necessary and crucial requirement for effective reconstruction proposal. The careful examination of diagnosed construction is helpful for choice of optimal technology for reconstruction, range of executed works and choice of the correct repair materials. Mainly the beginning of all problems is very irresponsible thinking of construction keepers or owners. They try to rehabilitate the impacted building for less money and of course in the shortest time. This is the first and cardinal mistake. The execution of careful diagnostics of the construction before reconstruction seems to be uselessly expensive and therefore unnecessary. The investor is glad that he doesn't need to spend a lot of money for reconstruction, but he can't imagine that this way of reconstruction will cause a lot of problems in the future. Consequent rehabilitation could come to higher amount than would necessarily need to be invested (unsuitable choice of expensive materials or technologies of reconstruction etc.). Next difficulty is the accomplishment of the reconstruction. Here we can mention incorrectly executed pretreating of the surface or incompatibility of repair materials with base. These problems results in considerable lifetime shortening of executed rehabilitation and the construction can even get into the same or worse condition as was before its rehabilitation. That's why the construction has to be rehabilitated again in a very short time and with more need of finance.

As the example of thus executed rehabilitation can be used following case of reconstructed reinforced concrete discharge conduit in Wastewater Treatment Works.

2 PRESENT CONDITION OF THE CONSTRUCTION

The Central Wastewater Treatment Works (WTW) located in Ostrava, which was put into operation in 1996, has gradually fully replaced the obsolete wastewater treatment works, which had already been extremely overloaded. The concept of treatment is based on a mechanical and biological treatment of sewage and industrial waste water on the principle of low-loaded activation together with nitrification and antecedent denitrification, draining away the sludge, stabilized using an anaerobic process on centrifuges and system of automatic technological process control.

We will focus only on the part of WTW that is at the very end of water treating process – the discharge conduit from final setting tanks. This reinforced concrete discharge conduit is divided into ten dilatation segments. (Fig. 1a).

The bottom of the discharge conduit is made in declivity and this gravity layer is from simple concrete that was laid separately into a prepared reinforced concrete construction of the discharge conduit. Through this discharge conduit filtered water flows in mild gradient and continues into the river nearby.

Figure 1. Reinforced concrete discharge conduit from final setting tanks.

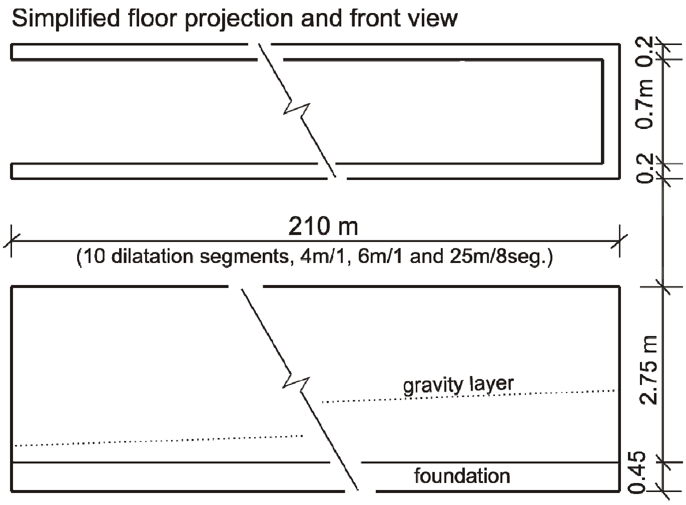

Figure 1a. Simplified floor projection and front view of the discharge conduit.

There were made reconstruction works in 2001 that should extend lifetime of this construction. After eight years the very critical condition of this discharge conduit moved the keeper of WTW to repeated intervention. After previous experience and our intervention he decided to have a detailed diagnostic research execution made as the first step of the rehabilitation.

3 DIAGNOSIS OF A CONSTRUCTION

The first half of year 2009 took place diagnostic works on the construction of the discharge conduit to find out actual real condition of the structure and determination of suitable method of reconstruction technology. There are no official standards for construction diagnostics and rehabilitation in Czech Republic, that's why diagnostics were made according to general accepted rules – Technical requirements for concrete constructions rehabilitation TP SSBK II.

It follows from the first visual inspection of the structure and acoustic mapping that the structure is in an emergency condition. It is highly possible that this situation has been caused, to a large extent, by the previous rehabilitation and non-conforming rehabilitation materials. The surface of the discharge conduit construction is interrupted by fallen repair mortar, leachate and horizontal and vertical cracks. The acoustic mapping has revealed areas with non-cohesive layers. In many places on the conduit front wall, the upper layer of the repair mortar has swollen out (Figs. 8 and 9). Water penetrating through conduit cracks as well as rain water cumulates in created hollows and deteriorates, in turn, the structure of the discharge conduit. The construction of the conduit is considerably interrupted by vertical cracks. These cracks are as much as 0.5mm wide and are located close to reinforcement (Figs. 4 and 6). Vertical cracks go through the whole thickness of the reinforced construction. Totally, more than 630 cracks have been revealed on the renovated surface of the outside side of the front wall. Leachate has been found in more than 40 per cent of these registered cracks. Horizontal cracks on the front wall were located in places of the sealing plates next to the connection of the vertical and horizontal parts of the discharge conduit structure. The crack is located about 700 mm above the foundation bottom (Fig. 5). The surface of the horizontal section wasn't treated before the vertical wall was cast and the neighbouring layers of concrete did not connect with each other. A test core into the horizontal crack has proved that water leaked out onto the wall of the sealing plate.

The facing wall of the discharge conduit shows leakage traces in many places – renovation mass is swollen or even separated. Repair mortar peels also off on the surface of the structure closed to places where formwork spacers were left - they are fastened with PVC packing only. During rehabilitation, some guards were removed and a layer of repair mortar only was applied.

Figure 2. Front face of discharge conduit construction. Detail of crack between foundation and construction of discharge conduit.

Figure 3. Surface of the wall structure No. 1, external surface. Crack near the dilatation joint, connection of foundations and conduit structure.

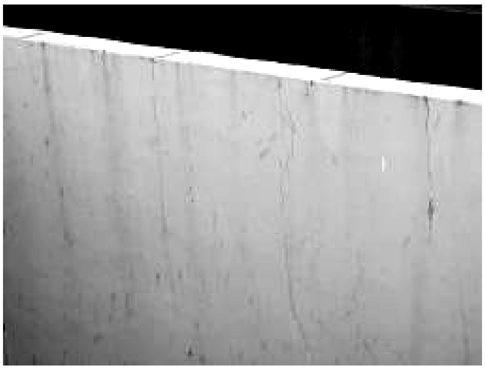

Figure 4. Front face of discharge conduit construction. Vertical cracks from the top to the bottom.

Figure 5. Horizontal crack close to the sealing plate at the height of cca. 700 mm. The crack crosses the entire structure of the conduit.

Figure 6. (left) Detail of the top of the conduit wall with corrupted protective coating and typical vertical crack that goes through the whole thickness of the wall.
Figure 7. (right) Detail of the injected place – cracks where water from the discharge conduit penetrates again.

Figure 8. Typical separation of renovation plaster on the front wall of the conduit.

Figure 9. Detail of degraded repair mortar.

Figure 10. Typical place with left formwork spacer. Water leaks and concrete degrades near the spacer and spacer sealing area.

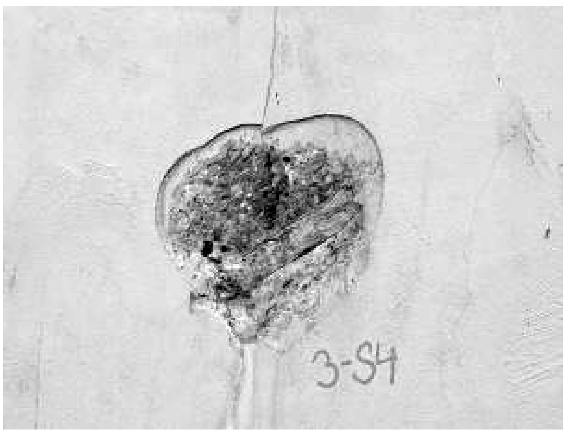

Figure 11. Detail of the place where some formwork was left during construction of the discharge conduit.

The area of the guards is now largely filled up with the water or the water flows around the guard body from its outside part (Fig. 10). In the rehabilitated structure, remains of timber formwork have been found – that formwork was used when concrete was cast into the discharge conduit structure. This is also a proof for poor quality of construction and sluggish approach to the rehabilitation. Timber elements have been found out in places where the plaster peels off on the surface of the concrete. Moisture creeping of the timber caused the surface of concrete to peel off (Fig. 11).

Other diagnostic tests were carried out in order to check the strength of the concrete cohesion of layers to the background materials, and depth of carbonation. Such tests included core tests and chiseled samples. All works were carried out in accordance with TP SSBK II and other testing standards in force.

During inspection, locations for core tests were chosen in the structure of the discharge conduit. In order to check the strength of the concrete were totally taken 47 core samples – 9 samples from foundation, 30 from the discharge conduit construction (10 samples in fissures direction) and 8 from gravity layer of the discharge conduit. In cracks, the core samples revealed the depth and direction of the cracks. A drill bit, 100 mm dia., was used to take the core samples. It follows from visual inspection of the core test samples that the concrete originated from two different concrete mixing plants. Differences are clearly visible for coarse gravel aggregate with the grain size above 8 mm: one concrete mixing plant used pre-crushed gravel aggregate, while the other one used crushed gravel aggregate. In some core test samples, the gravel aggregate with the size exceeding 8 mm was not found (Fig. 12).

Cohesion of the repair mortar was based again on TP SSBK II requirements. On the outside wall, the discharge conduit structure is coated with renovation plaster and coating, the water permeability of which is not sufficient – the water remains in the structure and deteriorates, in turn, the service life of the structure. The renovation material that was used for the previous rehabilitation has a rather high tensile strength – it is higher than 1.1 MPa, on average. In some places, however, the repair mortar was applied onto untreated, degraded concrete. The issue is, in particular, the cohesion of the repair mortar on the background material and the tensile strength of the upper layer of the concrete bed - it is too low and the measure values do not reach the minimum of 0.8 MPa, the average being less than 1.1 MPa. The reason is, in particular, lack of technology discipline during the previous rehabilitation when little attention only was paid to pre-treatment of the surface. General chemical tests were conducted in order to find the depth of concrete carbonation in individual dilatation sections of the discharge conduit. It has been found out that the carbonation reaches the depth down to about 12-25 mm. The cohesion of the protective barrier coating on the inside of the discharge conduit does not meet requirements of TP SSBK II either. The strength of the protective barrier coating should be higher than 0.8 MPa.

Figure 12. Core samples and visible differences in used aggregate.

A lot of problems in extensive concrete structures result from the failure to perform well and correctly dilatation sections of the structure. Consequently, the concrete degrades because of tension resulting from movement of individual sections. In this case, the vertical dilatation sections of the discharge conduit were constructed in line with documentation but no attention was paid to the section during application of the renovation plaster. The dilatation sections were covered with the repair mortar that, of course, peeled off soon.

Figure 13. Repair materials were applied on carbonated layer of concrete.

Figure 14a and 14b. Vertical dilatation joint were covered with repair mortar (14a). Typical result of thus rehabilitation is shown on the right (14b).

Another problem occurred in the rejection of expansion joints between the foundation and itself structure of discharge conduit. The foundation of this construction acts as a unit and they aren't connected with the construction of the conduit. The foundation of this construction acts as a unit and they aren't connected with the construction of the conduit.

During rehabilitation, no attention was paid to the transfer between the foundation structure and the discharge conduit – the connection was covered with the renovation plaster only without any dilatation. In connection points, places are visible where the renovation plaster peels off or separates, and cracks where pockets are appearing. Rainwater and water penetrating from cracks in the structure cumulate in such pockets, the renovation plaster peels off and the concrete degrades.

4 CONCLUSION

Rehabilitation accomplished in 2001 was concepted very generously, but without diagnostic of rehabilitated structure with poor quality and mistakes in technological procedures.

Results of the diagnostic procedures executed in 2009 show a lot of basic mistakes. Many of them came from the construction phase in 1996, but no attention was paid to those failures during the rehabilitation in 2001.

The failures and mistakes made during the rehabilitation works include inadequate pre-treatment of basic layers, failure to take into account horizontal dilatations between the foundation and structure of the discharge conduit, application of the repair mortar onto the horizontal dilatations and, last but not least, non-conforming rehabilitation materials. The failure to carry out the primary diagnostics prior to the rehabilitation and failure to supervise the works reliably resulted in expensive rehabilitation that took about two years and focused, in fact, on visual aspects only.

It is assumed that no structure is performed with absolute care and some failures and mistakes that might reduce the durability of the structure always exist. The main goal of the correct rehabilitation of concrete or other structures is to prolong the service life of such structures. The problem is if technology procedures are not followed during the rehabilitation – this results, if everything runs well, in a mere visual improvement of the structure that is very expensive. Otherwise, this being the case of the rehabilitation described above, concrete degradation accelerates and its durability decreases. Reasons include choice of non-conforming materials and incorrect rehabilitation procedures and, in particular, the failure to take into account reasons for degradation of the structure and lack of technology discipline during the rehabilitation. Many failures have typically their origin at start of works when the cheapest solution is often chosen at any cost. For financial reasons, an important part of rehabilitation - diagnostics of the structure - is often omitted. The diagnostics of the structure and correct assessment of such diagnostic is often a key to the successful rehabilitation. On the basis of assessment of tests conducted in the degraded structure, it is possible to choose the best method for rehabilitation and correct renovation materials. Though the input price seems to be higher, the diagnostics of the structure is able finally to define the best possible rehabilitation technology, reducing, thus, the costs of the rehabilitation works. The issue is frequently that the investor is not experienced in that area. The task of leading companies and experts involved in rehabilitation of concrete structures is to educate, while the investor should arrange an experience site supervisor who will supervise performance of all rehabilitation works. If these principles are followed, the result – the increased service life of the structure – will be accomplished.

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