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THE KNOWLEDGE OBTAINED FROM THE MAIN INSPECTIONS OF PEDESTRIAN BRIDGES IN PREŠOV

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Abstract. The maintenance and inspection of bridges is often a neglected component of necessary technical bridge care. One of the factors contributing to this can be the insufficient financial resources available for repairs under town and municipality administration where financial resources may be restricted. The most severe problem is the underestimation of the importance of bridge inspections. Preventive measures, in the form of regular inspections, can reveal structural issues caused by constructional defects during production or by changing external conditions. We can nevertheless still prioritize and effectively use financial resources for repairs. The knowledge obtained during inspections is an essential part of the draft process for new bridges and lessons learned on maintaining them effectively. This study sums up the most severe faults on selected pedestrian bridge structures and provides findings acquired during the inspections. This article presents findings from the inspection of pedestrian bridges in Prešov, Slovak Republic: Segmental pedestrian bridge next to the University of Prešov; Pedestrian bridges over the railway line in the direction of Rusínska – Lesík Delostrelcov; Pedestrian bridge over the Torysa river on Mukačevska street**.** Main inspections have been carried out in the first half of 2021 by the company ProPonti s.r.o, in cooperation with the Department of Concrete Structures and Bridges (KBKM) STU Bratislava.

Based on the executed main inspections, we can sum up the main following findings: immediate grouting and repassivation of the prestressing reinforcement can prevent a significant shortening of the service life, despite substantial manufacturing error; in the case of segmental constructions, a detailed inspection of the interior of the chambers as well as the condition of the prestressing reinforcement located in cement mortar is needed on a regular basis; for all types of structures, it is important to monitor the function of the bridge´s drainage system and any water penetration manifested by wet stains and efflorescence. Such problems must be solved immediately and will, in turn, significantly reduce the contamination of concrete with salts, greatly extending the service life of the bridge.

Keywords: post-tensioned beams, prestressing reinforcement, load-bearing structure, pedestrian bridge, tendons.

Introduction. In general, the widely recognised deterioration of structures and the technical condition of bridge structures in Slovakia applies for road bridges as well as for pedestrian bridges [1]. The main inspection should be performed every four years for both road and pedestrian bridges. Negligence of maintenance and inspections will eventually lead to the shortening of the bridge's service life. Depending on the load-bearing type of the structure, it is necessary, during the inspections, to monitor specific manifestations that indicate the possible development of a future problem before it arises. Unsolved problems with load-bearing structures can develop into irreparable damage, severe

problems and complications, as the bridges represent a substantial component of municipality property. At the same time, they are an essential part of the infrastructure and their malfunction causes complications for the population and the country´s economy.

The type of pedestrian bridges construction found in the city of Prešov is very diverse, from prefabricated atypical beams, additionally prestressed segments, prestressed roof panels used in civil constructions and ranges up to combined steel and steel-concrete bridges with monolithic panels and ledges. Main inspections have been carried out in the first half of 2021 by the company ProPonti s.r.o, in cooperation with the Department of Concrete Structures and Bridges (KBKM) STU Bratislava.

Analysis of the latest sources and statement of the problem. Based on worldwide research, the engineers agree [2, 3] that even if the construction of bridges is built in accordance with applicable regulations, their durability may not be ensured under certain exposure conditions. For this reason, it is necessary to carry out regular inspections of bridges in the road infrastructure set by individual countries based on their legislation. In Slovakia, it is required that each bridge has its own documentation in the form of bridge sheets in which all inspection result are recorded, possibly also with the residual load capacity of the bridge. Due to neglected maintenance, some bridges are missing all information about their state. A series of bridge collapses in Slovakia led the managers of these bridges to take the steps needed to obtain this missing information regarding the state of the bridges they are responsible for.

Purpose of the study. This study sums up the most severe faults on selected pedestrian bridge structures and provides findings acquired during the inspections.

Methods of the study. The way to perform inspections is not strictly stated. It is assumed that the engineer inspecting the bridge will be able to identify the bridge's structural system and, based on their expertise, be able to predict its behavior affected by deterioration processes. The inspecting engineer should also be able to detect critical parts of the bridge from a durability point of view. These can be various details, such as the waterproofing system, the grouting of tendons, drainage, etc. Knowledge of individual types of structures and their critical details is invaluable in determining the risk of individual bridges.

Results of the study. *Assessment of defects of pedestrian bridges***.** *Segmental pedestrian bridge next to the University of Prešov.* The pedestrian bridge structure consists of concrete segments fastened together with prestressing tendons located in the chamber. The tendons near the bottom slab are covered with additional cement filling (Fig. 1).

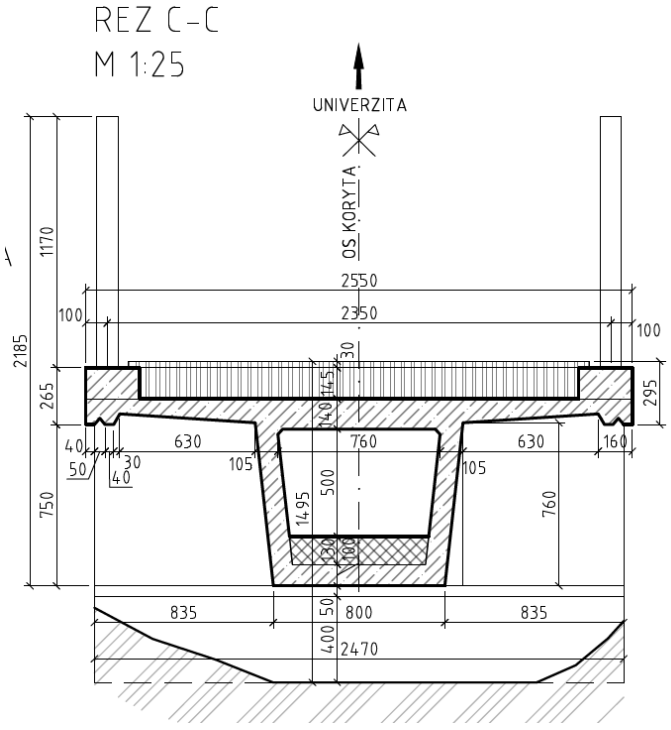

Fig. 1. Schematic cross-section of the structure

On inspection of the bridge, a significant deflection was visible. This deflection was noticeable on the bottom slab and the bridge's handrail. After a more detailed inspection of the structure, it was discovered that the opening of joints at the contact of beam segments occurred (10 – 15mm) in the middle of the second span. This phenomenon indicates problems with prestressing reinforcement (Fig. 2). After removing the inspection holes in the area of the abutments, it was found that the filling mortar had completely deteriorated due to the very high humidity and freezing cycles.

Fig. 2. Opening of the joints between the segments in the middle of the second span

Cementitious mortar, initially protecting prestressed reinforcement, is cracked, carbonated (on-site test on fragments by 1.0% phenolphthalein solution) and does not fulfil its protective function. Water is held in the bridge chamber due to the absent drainage of the chamber. Due to the water, the mortar and the prestressing reinforcement has completely deteriorated in the chamber. Prestressing reinforcement is a critical load-bearing element in this type of structure, and corrosion significantly decreases the bridge's load-bearing capacity (Fig. 3). This state is also supported by noticeable deflection generated by the structure's dead load. The opening of joints between segments accelerates local corrosion of prestressing tendons. Due to the facts mentioned above, the pedestrian bridge was immediately closed to pedestrian traffic.

Fig. 3. Corroded prestressing reinforcement

Pedestrian bridges over the railway line in the direction of Rusínska - Lesík Delostrelcov. The load-bearing structure of both bridges consists of two prefabricated I–shaped concrete beams

fastened together with prestressing tendons. The length of the beams is 37 m. Their lower and upper flanges are not concreted and thus not connected. Other than lowered cooperation of beams, limited within thin concrete slab constructed above the upper flange, corrosion of stirrups sticking out of beams occurs. These stirrups were to bind a reinforcement of a prefabricated beam with concreting between beams. There are visible cracks parallel to prestressing tendons on the walls of the beams. Non-grouted prestressed reinforcement with advanced corrosion was discovered after removing the delaminating concrete cover layer (Fig. 4). There is a high probability of water leaking into non-grouted ducts, which subsequently freeze in winter. Consequently, the water expands in a narrow duct space and generates cracks parallel to prestressing reinforcement. This phenomenon indicates a problem with the waterproofing of the bridge. The leaking water transports chloride ions from deicing salts along cable ducts.

For both bridges, the permissible chloride levels in the concrete for prestressed structures were exceeded several times according to EN 206 [7]. The permeated chlorides act as a corrosive catalyst, making corrosion progress more rapid due to the lack of diffusive protection around the prestressing tendon. This protection usually consists of a highly alkaline grouting compound. It is assumed that most cable ducts are not grouted or are grouted with poor quality grouting compound, which significantly increases the risk of corrosion of the prestressing reinforcement and thus increases the likelihood of a possible sudden collapse of the structure. Due to advanced corrosion of the exposed prestressing cables, both bridges were immediately closed. They will have to be rebuilt, as they threaten train traffic passing under the bridges.

Fig. 4. Non-grouted cable ducts with corroding prestressing reinforcement

*Pedestrian bridge over the Torysa river on Mukačevska street***.** The pedestrian bridge made of an atypical, prestressed concrete beam with a total length of 39.25 m and a height of 1.0 m indicates excessive cracks with a width of 2 mm at the working joints, approximately 3 m from the piers. The anchors of the prestressing reinforcement and the anchored prestressing cables are visible in the joints, insufficiently grouted and partially corroded (Fig. 5). However, the bridge slab does not show excessive deflections. The approach ramps with stairs have deteriorated significantly, and their reinforcement is massively corroded due to inadequate concrete cover, probably also due to manufacturing defects. The abutments show significant concrete deterioration and corrosion of the steel reinforcement due to leakage. The bearings on the abutments corrode. The bridge has been closed to the public due to non–grouted prestressing tendons and the disrepair of the access stairways.

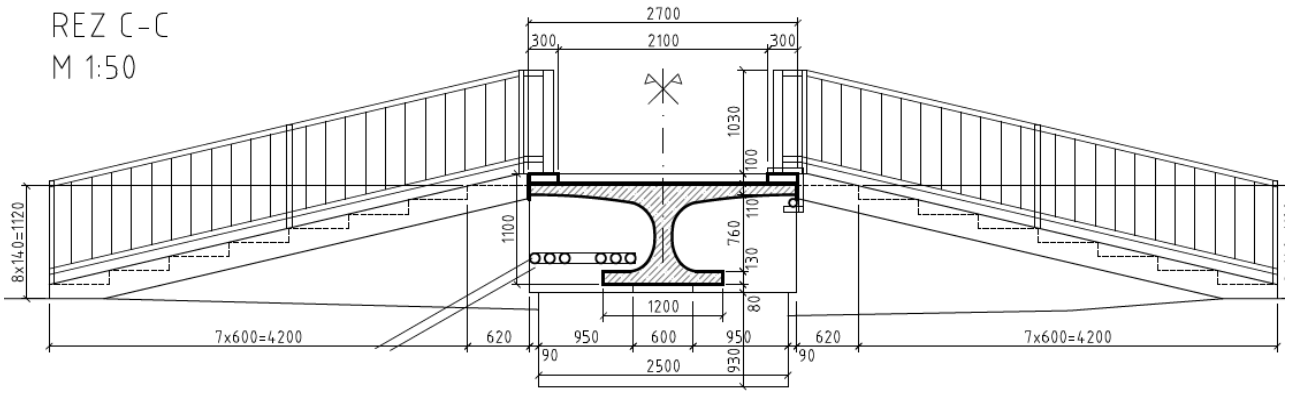

Fig. 5. Schematic cross-section by abutment

Concrete samples taken from the ledges, under the asphalt and from the bottom slab did not confirm excessive chloride content in the concrete, probably due to the lower intensity of winter maintenance. Prestressing tendons corrode significantly slower, although they are not grouted with cement (Fig. 6). The low chloride contamination of the concrete creates good preconditions for the reconstruction and further functioning of the bridge. The bridge has already been reconstructed and reinforced with free-running external prestressing cables.

Fig. 6. Non-grouted prestressing tendons in the bottom slab of the precast concrete; left – anchorage point, right – approx. 0.5 m behind the anchor

Conclusion. Based on the executed main inspections of footbridges in the city of Prešov, where more than 30 bridges and pedestrian bridges have been inspected, we can sum up the following findings:

– the majority of primary and secondary faults discovered is the result of neglected maintenance not been executed properly due to missing structure inspections;

– the majority of primary faults on inspected bridges and pedestrian bridges could have been eliminated by prompt structural intervention;

– in the case of post-tensioned beams of I cross-section, the secondary manifestation of the not grouted, corroding prestressing reinforcement are cracks in the beam walls copying straight or polygonal prestressing reinforcement cables;

– secondary manifestation may occur before the prestressing reinforcement actually corrodes as the freezing water in the cable duct can expand the cable duct and create cracks on the wall surface;

– immediate grouting and repassivation of the prestressing reinforcement can prevent a significant shortening of the service life, despite substantial manufacturing error;

– in the case of segmental constructions, a detailed inspection of the interior of the chambers as well as the condition of the prestressing reinforcement located in cement mortar is needed on a

regular basis;

– to determine the condition of the mortar, the level of chloride content and depth of carbonation should at least be checked, best indicating its protective ability;

– it is considered an emergency when the joints open between segments and is an indication of advanced corrosion in the prestressing cables;

– if the chamber is not drained, it is advisable to intevene and drain the chamber so that any water entering will drain away quickly;

– for all types of structures, it is important to monitor the function of the bridge´s drainage system and any water penetration manifested by wet stains and efflorescence. Such problems must be solved immediately and will, in turn, significantly reduce the contamination of concrete with salts, greatly extending the service life of the bridge;

– all steel bridge accessories and drainage system must be maintained on a regular basis or replaced entirely.

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ДОСВІД, ОТРИМАНИЙ ПРИ ОБСТЕЖЕННІ ПІШОХОДНИХ МОСТІВ У ПРЕШОВІ

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Анотація. Технічне обслуговування та огляд мостів є необхідними складовими догляду за мостом, якими часто нехтують. Одним із факторів, що сприяють цьому, може бути

недостатність фінансових ресурсів для виконання ремонту в міській адміністрації, де фінансові ресурси зазвичай обмежені. Найбільш серйозною проблемою є недооцінка важливості інспекцій мостів. Профілактичні заходи у вигляді регулярних перевірок можуть виявити структурні проблеми, викликані конструктивними дефектами під час виробництва або зміною зовнішніх умов. Проте ми все ще можемо розставити пріоритети та ефективно використовувати фінансові ресурси для ремонту. Знання, отримані під час інспекцій, є важливою частиною процесу розробки нових мостів і уроків, отриманих щодо їх ефективного обслуговування. Це дослідження підсумовує найбільш серйозні несправності на вибраних конструкціях пішохідних мостів і надає висновки, отримані під час перевірок. У цій статті представлені результати перевірки пішохідних мостів у місті Прешов, Словацька Республіка: сегментний пішохідний міст біля Прешівського університету; пішохідні мости через залізничну колію в напрямку Русінська – Лесік Делострелков; пішохідний міст через річку Торису на вулиці Мукачевській. Технічні обстеження були проведені у першій половині 2021 року компанією ProPonti s.r.o. у співпраці з Кафедрою бетонних конструкцій та мостів STU у Братиславі.

Виходячи з проведених основних перевірок, ми можемо підсумувати такі основні висновки: негайне закриття та репасивація напруженої арматури може запобігти значному скороченню терміну служби, незважаючи на суттєву виробничу помилку; у разі сегментних конструкцій необхідний регулярний детальний огляд внутрішньої частини камер, а також стану напруженої арматури в цементному розчині. Стан розчину слід перевіряти хоча б на рівень вмісту хлоридів та глибину карбонізації, що найкраще свідчать про його захисну здатність; для всіх типів конструкцій важливо стежити за роботою водостічної системи мосту та будь-яким проникненням води, що проявляється мокрими плямами та висолами. Цю проблему необхідно вирішити негайно, що значно зменшить забруднення бетону солями та значно продовжить термін служби мосту.

Ключові слова: постнапружені балки, попередньо напружена арматура, несуча конструкція, пішохідний міст, канати.

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