Causes of Damages and Rehabilitation of the Pancevo Bridge

Causes des dommages et restauration du pont de Pancevo

Schadenursachen und Sanierung der Pancevo-Brücke

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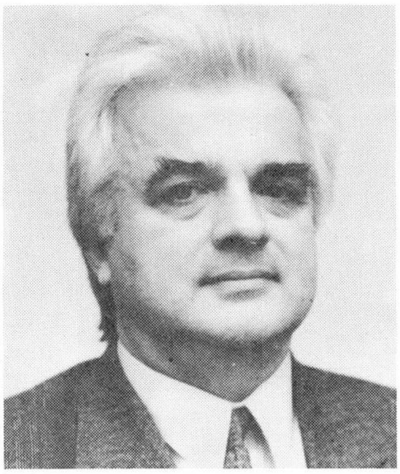

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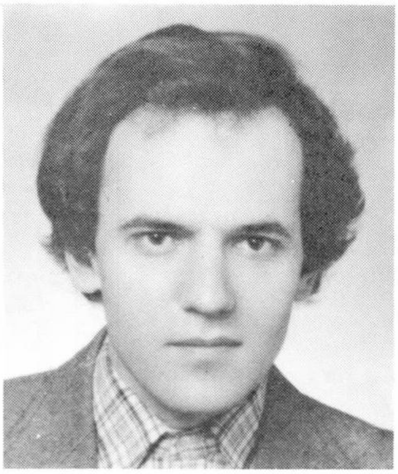

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SUMMARY

Access parts of the Pancevo bridge across the river Danube in Belgrade were built at the beginning of 1960s among the first prestressed concrete bridges in Yugoslavia. Numerous cracks in the concrete and in places very corroded prestressing wires have resulted from insufficient prestressing force, poor corrosion protection, poor drainage and by other failures in design, execution operation and maintenance. The rehabilitation covered injecting of the cracks, installation of new prestressing tendons inside the box cross-section, improvement of drainage and removal of other failures.

RÉSUMÉ

Les structures d'accès du pont de Pancevo sur le Danube à Belgrade ont été construites au début des années soixante parmi les premiers ponts en béton précontraint en Yugoslavie. De nombreuses fissures dans le béton et à certain endroits une corrosion très avancée des fils de précontrainte sont apparus à cause d'une force de précontrainte insuffisante, d'un mauvais enrobage des fils de précontrainte, d'une mauvaise évacuation des eaux de pluie et d'autres défauts dans les phases de projet, d'exécution, d'exploitation et de maintenance. La restauration comprend l'injection des fissures, la mise en place de nouveaux câbles de précontrainte à l'intérieur de la section en caisson, la réparation des systèmes d'évacuation d'eau et l'élimination d'autres défauts.

ZUSAMMENFASSUNG

Die Zugangsbrücken der Pancevo-Donaubrücke in Belgrad sind Anfang der sechziger Jahre als erste Spannbetonbrücken Jugoslawiens gebaut worden. Zahlreiche Betonrisse und stellenweise stark korrodierte Spannstähle sind die Folgen ungenügender Spannkraft, schwachen Korrosionsschutzes, schlechter Entwässerung und anderer Entwurfs-, Ausführungs-, Anwendungs- und Unterhaltungsfehler. Die Sanierung bestand aus einer Rissinjektion, dem Einbau neuer Spannstähle innerhalb des Hohlquerschnitts, der Instandstellung der Entwässerung sowie der Behebung von anderen Mängel.

1. GENERAL

Access parts of the Pancevo bridge across the river Danube in Belgrade had been made at the beginning of 1960s. They were among the first prestressed concrete bridge structures in Yugoslavia. The total length of 1.269 m is divided to 16 independent bridge structures interconnected by expansion joints, Fig. 1. The structures are continuous frames with two, three of five fields, of the span ranging between 20 and 40 m, with slender posts. The width of the bridges is (1.50+7.00+0.80) m with two carriageways to the same direction. The cross section is the constant height box of 1.45 m, Fig. 2.

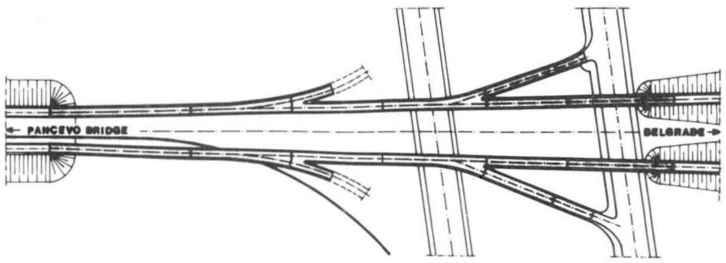

Fig. 1 - The lay-out of the access bridges

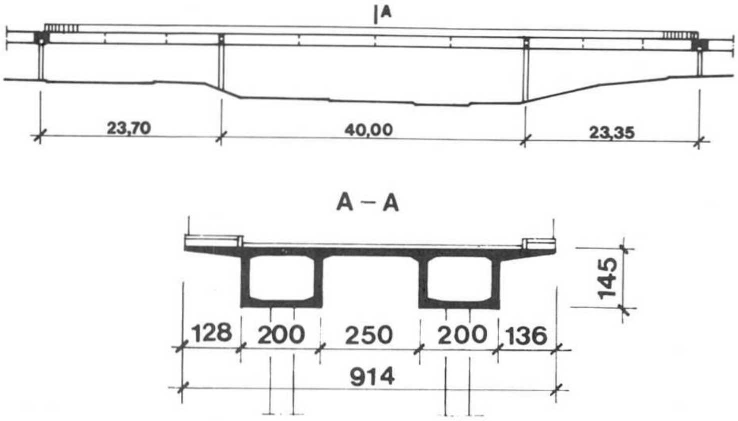

Fig. 2 - Disposition of a bridge

The prestressing of the main girders was made according to the Yugoslav IMS system. The tendons of 6Ø7 mm were conducted through steel tubes placed in the webs and the upper and lower chords. The deck of the bridge was partly prestressed in the lateral direction, too.

The medium posts are of circular cross section and have monolith connection with the main girder. The girders are supported at the ends, by sleeper beams where expansion steel bearings are placed via short elements of the reduced height.

Waterproofing of the structures has, unfortunately, not been either designed or erected.

2. CAUSES OF DAMAGES

Already during the test examination of the structures, before it was used for traffic, cracks were noticed on some of the structures and remained after the test loading was removed. That was why the majority of 40 m span structures were immediately subjected to interventions by adding a certain number of new tendons inside the box of the main girder.

During the subsequent inspections, a large number of cracks was noticed on the majority of structures. The cracks were mainly perpendicular to the main girders direction and distributed in the zones around the medium supports and about the middle of the span, Fig. 3. A detailed inspection of the structures has been made including the "survey" of cracks, both from the outside

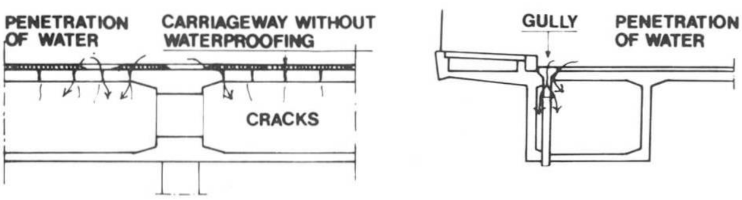

Fig. 3 - The penetration of water to the inside of the box

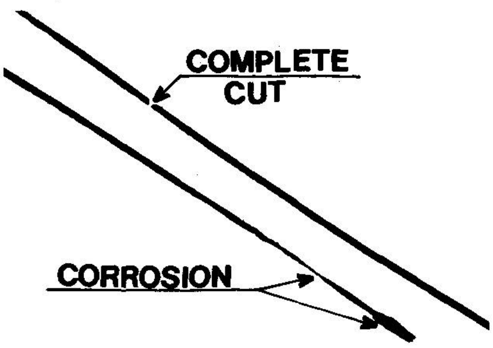

Fig. 4 - Corroded tendon

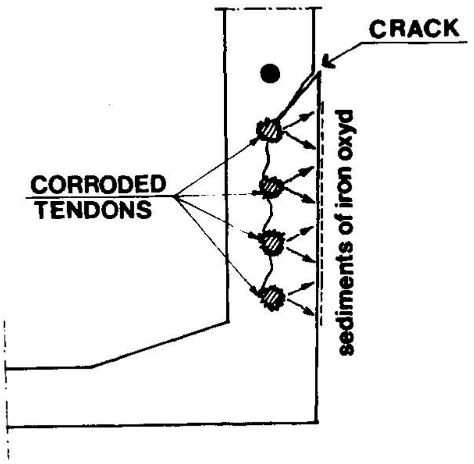

Fig. 5 - Irregular injected tendons

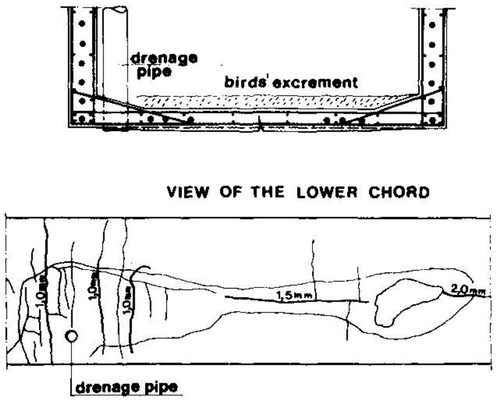

Fig. 6 - Damaged lower chord

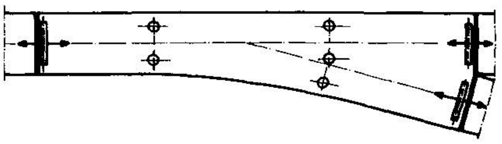

Fig. 7 - Irregular disposition of expansion bearings

and the inside, after washing the inside of the box. All the cracks have been registered, classified and inserted into the corresponding plans. All weak and suspected spots on the surface of the structures have been registered, too. The areas with a large number of cracks, with the sediments of iron oxide or lime and the areas which, under the blows of the hammer, demonstrated the existance of bubbles or sepatation of the concrete cover, had been opened in order to establish the level of the damage.

It has been found out that prestressing tendons were corroded on some of the places, from slight corrosion to complete cut, Fig. 4. Cement grout for injecting tendons was not of the required quality and on some of the places it did not exist, at all, Fig. 5. By measuring the existing force in the tendons, it was established that on a number of wires the designed prestressing force was not achieved. The results of measuring their own free oscillations and damping pointed to the decrease of general rigidity of the main girders.

Large damage and concrete deterioration zones have been tested and checked by ultrasonic, Fig. 6. The quality of the built in concrete and of the prestressing wires was examined, too.

Beside the structures, the other elements of the bridges have also been examined: bearings, expansion joints, gullies, drainage system, carriageway, fense and the like. The expansion joints were incorrect and broken, Fig. 7, the bearings contained empurities and were corroded, some of them outside the bearing slab or turned out and the gullies were either blocked or out of operation due to some other reasons. The carriageway was unsmooth and wavy with a large number of impact holes, Fig. 3. The posts and the foundations were in a good state.

On the basis of the results of the detailed inspection and examination as well as of the analysis of the complete design and technical documentation, the causes and the level of damages have been established together with the required rehabilitation measures.

The damages of the structure came as a result of various failures in designing, execution, exploitation and maintenance.

One of important design and execution failures is that waterproofing has not been planned. That has caused penetration of water and salt used for rubbing the bridge deck during the winter time. The penetration was to the inside of the box, through the bridge deck, and especially through cracks appearing in the upper zone, above the medium supports, Fig. 3. Incorrect and damaged gullies were another way of water penetration to the inside of the main girder box. Their designed position in the middle of the span is very inconvenient as that is the place where the tendons are concentrated in the lower zone and the lower chord through which the drainage tubes penetrate, Fig. 6.

The possibility of subsequent intervention in case that due to any reason, the designed prestressing force is not acquired, has not been anticipated by the design.

A certain number of crackes has appeared in the zones around 1/4 of the span due to incorrect anchoring of the tendons in the lower chord and webs as no care was taken of the necessary overlapping of the tendons at the places of anchorage, Fig. 8.

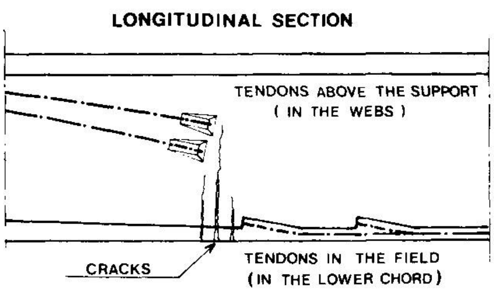

Fig. 8 - Irregular end of tendons

Long presence of water in the inside of the box has also contributed to the corrosion of tendons as no openings on the lower chord for drainage of possibly penetrated water have been designed. No wire net was placed at the openings for entering the inside of the main girders and for aeration so the inside of the box made a good "home" for birds. In time, a thick layer (10 cm and more) of birds'excrement, eggs and similar impurities was formed which had extensively increased aggressivity of the environment, Fig. 6.

The incorrect position and undesigned moving possibilities of expansion bearings have contributed to incorrect operation and undesigned stressing on some of the structures, Fig. 7.

The increase of weight and spead of vehicles in exploitation, frequently above the permitted limits, together with undesigned dynamic action due to driving of vehicles along the unsmooth and damaged carriageway and inadequate and damaged expansion joints have significantly contributed to the appearance of cracks and to further progressive increase of the level of damage suffered by the structures of this traffic route whose frequency is very high.

Incorrect and irregular maintenance of the pavement, of the gullies and expansion joints together with the application of salt for rubbing the carriageway have also considerably contributed to the appearance of the described damages. Incorrect expansion joints made the penetration of water and mud from the carriageway to the expansion steel bearings possible, which caused their damages and the cessation of the correct function.

3. REHABILITATION

On the basis of the detailed inspection, examination and establishment of the level of the damages, the rehabilitation designs for each separate structure have been made according to which the works were started with.

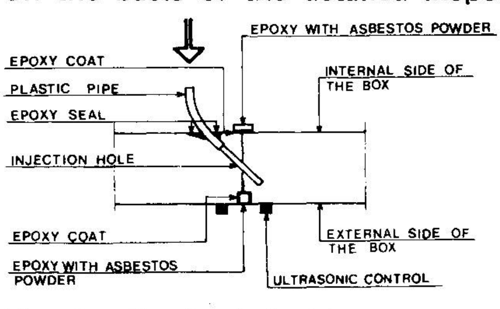

Fig. 9 - Cracks injecting

Within the rehabilitation of the structures, injecting of all cracks over 0.1 mm wide, by the application of special procedure, using low viscosity epoxy resin under pressure has been done. There was ultrasonic control of injecting, Fig. 9. During the execution of those works, the traffic on the bridge was completely stopped.

On one of the structures on which greater deterioration of the concrete, due to permanent wetting, and action of frost and salt took place, the whole damaged zone of the lower plate was replaced - several square metres, Fig. 6.

For improving the state of stress and in order to achieve the required prestressing force, supplementary prestressing has been performed using new tendons of the IMS system. The tendons 4Ø15.2 mm in polyethylene tubes are placed in the inside of the main girder boxes, Fig. 10. On the places on which the tendons

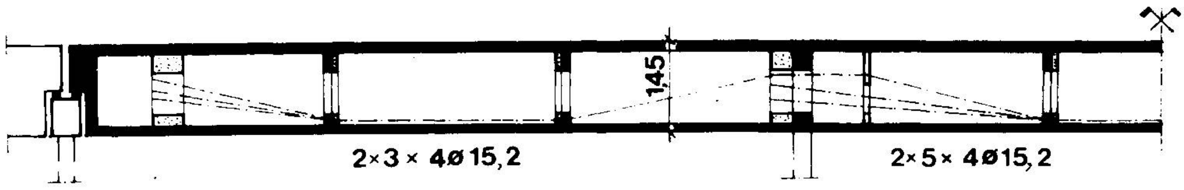

Fig. 10 - Disposition of additional tendons

are curved, correspondingly curved steel tubes have been placed instead of polyethylene tubes, Fig. 11. Such turnoff of the tendons has been executed on the places of the existing internal diaphragms whereat those diaphragms have been reinforced. On the places on which the tendons should be turned off but on which there have been no diaphragms, the new ones are made. The tendons are anchored into the newly built anchor blocks positioned in the inside of the box at the ends of the structure, as the access from the front of the structure was not possible, Fig. 11.

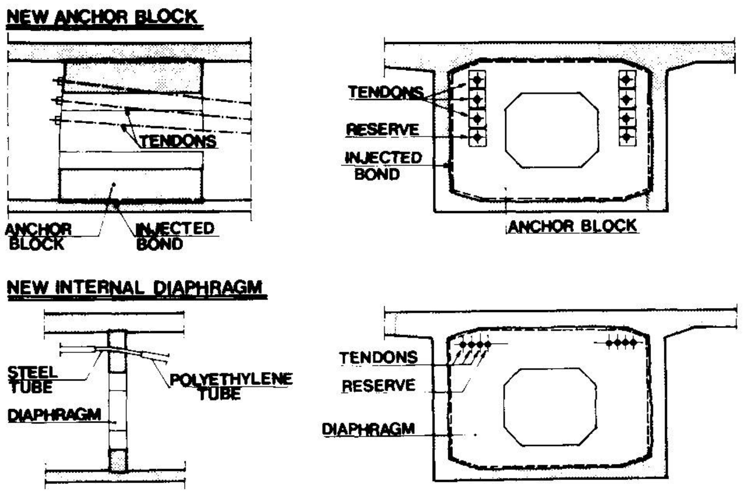

Fig.11-Details of the anchor block and diaphragm

Special attention has been paid to the bond between the old concrete of the existing structure and the new concrete of the erected anchor blocks. In order to improve those bonds and in order to eliminate negative effect of shrinkage and other factors, the existing contact concrete surfaces have been knocked off as deep as the protective layer and textured. Upon the concreting of anchor blocks and after the required strength has been acquired, the contact surfaces have been injected by low viscosity epoxy resin under pressure, with the ultrasonic control.

After tightening of tendons, injecting by cement grout has been performed in order to provide corrosion protection.

The magnitude of prestressing force has been determined for each structure separately, on the basis of the analysis and the assessment of the condition of the structure and of the existing tendons. Namely, in spite of the detailed examination, it was not possible to precisely establish the existing prestressing force in the tendons, along the whole route. In the conditions in which water penetrates to the cavities and cracks of the concrete section, when the corrosion of the tendons is very high, when on certain places the tendons are completely cut by the corrosion and only a small distance apart they are completely solid, the existing prestressing force, frequently lower then the designed one, significantly changes from section to section. That is why structural analysis has been made for ultimate cases of the lowest and the greatest prestressing force which, for the majority of structures, ranged between 60% and 90% of the designed force. Taking into consideration the most inconvenient combinations of those influences with maximum and minimum influences of loading in the sections, the possible ultimate states of stress have been obtained. According to the bearing capacity of the section and the minimum necessity to provide pressure in the cross sections, the prestressing force which can be safely subsequently introduced has been determined. For the majority of structures, by so determined subsequent prestressing force, the complete live load has been "covered" and about 10% of the dead load. For the structures in which the corrosion of tendons was much higher, the number of additional tendons was larger.

The possibility of subsequent intervention during the rehabilitation, or later on, during exploitation, has been also anticipated. The places for about 25% of additional tendons have been left prepared and can be used in case of the requirement.

In order to improve the traffic conditions on the bridges and in order to acquire protection and to increase durability of the structures, the following has been done beside the already mentioned works: waterproofing, replacement of the pavement and of gullies and expansion joints, repair or replacement of the bearings and of other damaged elements.

All the works have been executed without traffic brake only with its limitation on one side of the bridge. For only two of the structures, the condition of which required additional measures, temporary elastic support has been made during the execution of the works.

The structures have been examined by test loading whereat neither new cracks appeared nor the old injected cracks had opened.

During the stage of decision taking on the execution of the designed bridge rehabilitation works, technical and economic analysis has been made which has proved justifiability of investments to rehabilitation.

In order to achieve a more modern and a better approach to further regular maintenance of these bridges, which are located on a very important traffic route, all the information regarding the rehabilitation measures as well as the condition of all the elements and of the structure as a whole have been introduced to the computer "data bank" which enables regular follow-up of the condition and of the imperi for certain elements and the bridge as a whole, thus enabling due interventions.

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