



THE MOST COMMON CAUSES FOR FASTER DETERIORATION OF BRIDGES

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Abstract

During past ten years a condition survey of reinforcement concrete bridges in Croatia has been frequently undertaken due to the fact that durability, bearing capacity and stability of structures was impaired what led to a reduced traffic safety. During these condition surveys, which are performed to establish current state of a structure, structural elements and built-in materials, it is often established that deteriorations that have taken place are much more extensive than it would be expected. According to the authors experience reasons for this are the following: wrong design solutions and construction details, use of wrong or poor quality materials and faults during construction period. These mistakes can be and often are a cause why structures and their constituent elements have exponential growth curve of degradation and deterioration processes during exploitation period according to conditions they are exposed to. This paper will present some of the most commonly found reasons why structures deteriorate much faster and why degradations are more extensive and severe on a number of examples and case studies that have been inspected in the last decade. Bridges and overpasses presented on a number of case studies, divided in groups according to type of structure most commonly found in continental part of Croatia: monolithic, two types of overpasses with prefabricated girders containing circular shaped voids, bridges with a deck slab placed on a grid like structure made of longitudinal and lateral girders and bridges with deck slabs alleviated by containing circular shaped voids. Also some commonly found mistakes regardless of structural system and problems due to lack of maintenance will be analyzed.

Keywords: bridge, overpass, deterioration, reinforced concrete

1 Introduction

A series of condition surveys was performed to assess condition of reinforced concrete bridges in Croatia in the last decade. The assessed bridges were built in late 1970's and early 1980's. Extensive investigation works included visual inspection, in-situ and laboratory testing and they revealed some defects that are characteristic for a number of bridges. These defects are the main reason why deterioration of concerned structures was so extensive and rapid, more than it would be expected. In this paper bridges and overpasses are divided regarding their structural system and also some commonly found problems regardless of a bridge/overpass type are presented. [1]

2 Case studies regarding type of a structure

2.1 Monolithic bridges

Highway bridges with monolithic deck slabs with cantilevers were often used for over passing smaller spacing (spans up to 25 m). The most obvious mistake which was made during the construction period was that deck slab with cantilevers was concreted in two phases. First deck slab was concreted and then later cantilevers were ‘pasted’ on. This caused a working joint where water very soon finds a way to the bottom parts of the structure. This is a very often found mistake which is evidenced by traces of water leaking on the bottom parts. It looks like water is coming from nowhere because cornices on cantilever edges is dry and has no damage while leaking of precipitation water appears on sides of deck slab. When the area is inspected closer a longitudinal crack is noticed directly in the corner between vertical surface of deck slab and horizontal bottom surface of cantilever. On some bridges cracks extend through the whole length and there is intensive leaking of precipitation water saturated with deicing salts through a thick layer of concrete together with incrustation, efflorescence, calcification products, large areas of moistening and corrosion of reinforcement. Last mentioned factor is most dangerous because it is very often found that, after removal of cantilever concrete, reinforcement bars are almost completely cut off.

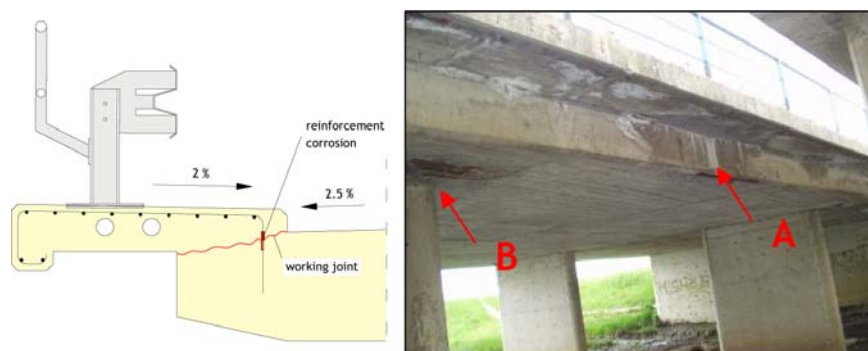


Figure 1 Cross section of the cantilever and deck slab edge with marked working joint and location of reinforcement corrosion; Photograph: A-water penetration through working joint, B-leaking underneath gully [1]

These overpasses were constructed with a type of box girders containing circular shaped voids that was widely used in Croatian bridge construction. Usually bridges or overpasses with this type of structure were constructed in a way that adjacent girders were connected only with tricosal mortar which was poured between them. Above the head beams, prestressed continuity slabs were carried out to connect girders in the lateral direction. Waterproofing was placed directly on the girders despite the fact that design predicted a layer of mortar (4-5cm) with inclination on both sides. Even if this layer was placed cracks would turn up very soon so it would have not made much difference. Numerous overpasses were derived like this on Zagreb-Lipovac highway, and they are today app. 25-30 years old.

2.2 Overpasses constructed with box girders

This type of constructive system is functional for some time if waterproofing was laid properly and if it has good quality. The first problem are vertical joints on the edge girders (near pedestrian ways), because none or insufficient waterproofing underneath pedestrian ways causes that the first leaking starts on these joints. After a period of time when waterproofing

is not functional anymore leaking starts through all vertical joints between girders. Lingering leaking causes severe reinforcement corrosion on all structural elements and very dangerous corrosion of groups of prestressed cables.[4]



Figure 2 Overpass junction 'Ivanič Grad' on highway Zagreb-Lipovac: severe reinforcement corrosion and leaking [2]

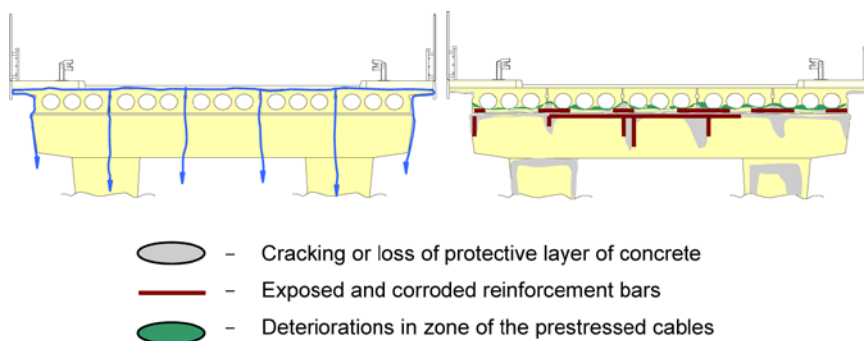


Figure 3 Cross-section of overpass with marked ways of water penetration on girders, head beams and all elements of the substructure(left) and areas with characteristic deteriorations(right) [3]

2.3 Overpass constructed with rectangular girders with oval recesses

Same problems as in the previous chapter will be analyzed. This structure is app. 30 years old. Constructive system is a little different, as well as girders and joints, but the results are very similar. In this case girders are with a rectangular cross section and they contain oval recesses and cantilevers on both sides. Joints between them are app. 20 cm wide and they were concreted on site. Girders are free supported on cantilever head beams and there are no rail expansion joints above the support area (only on abutments).[3]

Design solution is not satisfactory regarding durability because on almost all locations where expansion joint or sealing were not installed above bearings and supporting areas, there is heavy and long-term leaking of precipitation water saturated with deicing salts on all elements below. This has caused significant damage of concrete and corrosion of reinforcement in the supporting area (edges of longitudinal girders, edges of cantilever head beams...) and bearings. This situation is also very unfavourable because potential repair of the structure is not possible due to the fact that girders are transversely solidified what disables them to be lifted and also the area of prestressed cables anchoring is attacked what makes structural stability and safety of girders very doubtful.[4]

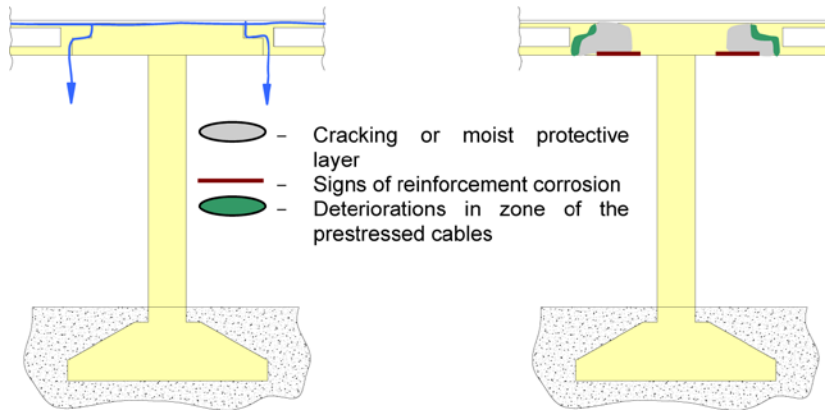


Figure 4 Marked ways of water penetration on the support areas, and deteriorations on these locations[3]

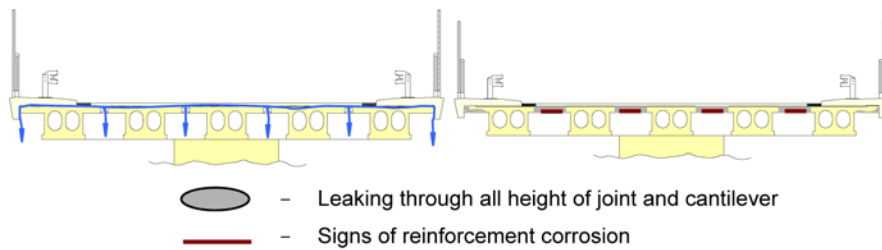


Figure 5 Cross- section with marked ways of water penetration (left) and deteriorations due to water ingress through joints (right)[3]



Figure 6 Leaking through longitudinal joints; signs of ongoing corrosion on cantilever head beams and heads of girders; heavy leaking through transverse joints on the support area on Overpass in junction Lučko[2]

2.4 Bridges with a deck slab placed on a grid like structure made of longitudinal and lateral girders

Analyzed structure is Bridge over Sava on Zagreb bypass near Ivanja Reka. Design solution was deck slab made out of prefabricated slabs connected with transversal and longitudinal joints (20cm) concreted on site. Slab is placed on longitudinal prefabricated girders connected with transversal girders.

This type of deck slab was probably very geometrically uneven when finished so levelling course concrete was placed on it before installing waterproofing and asphalt layers. This layer of concrete had no special characteristics for higher durability, and it is spread on the deck edges also so it is a layer on which pedestrian ways are placed.

Concrete layer under asphalt and waterproofing was completely destroyed during exploitation, in conditions of intensive traffic and intensive use of deicing salts, together with freeze/thaw cycles, what as a consequence had two processes of degradation:

- Leaking of water saturated with deicing salts through transversal joints
- Especially intensive leaking over the edges of deck slab in the zone beneath curb

Consequence of this degradation is that structural stability and safety of supporting of pedestrian ways and middle slab is endangered even without lateral impact of a vehicle.[4]



Figure 7 Disintegration of levelling course concrete which is seen on asphalt surfacing, leaking through transversal joints of deck slab and over edges, and leaking on main longitudinal girders[4]

2.5 Bridges with deck slab alleviated by containing circular shaped voids

During 1970's and 1980's often used constructive system for bridges with smaller spans on highways was a deck slab alleviated with circular shaped voids. These slabs were concreted on site and circular pipes (cardboard or metal $\phi 60-90\text{cm}$) were placed before concrete was poured so circular voids would be left inside deck slab. Problem with this type of structure is that it was often the case that when concreting took place buoyancy would lift or deform these pipes. Due to slipping of formwork often afterwards cracks would turn up on the up or bottom side of deck slab what caused entrance of water in the voids. Consequence is transport of water from pavement and destruction of concrete and corrosion of reinforcement. It is also possible that when water freezes in voids it can cause destruction of overlays and lifting of concrete.[4]



Figure 8 Visible wholes after removing asphalt surfacing and waterproofing, leaking on abutments through all 12 deck slab voids, after removal of levelling course concrete is sipping into voids[4]

3 Commonly found mistakes or problems due to lack of maintenance

There are some mistakes that can appear on bridges and overpasses regardless of their structure that at first seem small but can in time cause significant damage and at the same time considerable costs. These are for example related to equipment of a bridge which when looking at the cost of construction works constitute a smaller amount of the whole financial structure but if quality is not satisfactory durability of all structural elements can become impaired. Also consequences of lack of maintenance will be presented in the following items.



Figure 9 Leaking around whole left from formwork, degradation of concrete curb, leaking around drainage system on head beam

3.1 Concrete elements on highways

Concrete elements that constitute equipment of highway structures such as curbs (Fig. 9.), pedestrian ways and cornices are exposed to severe exploitation conditions, freeze/thaw cycles and deicing salts. This can cause significant deterioration in a very short period of time. Deteriorations are not exclusively associated to concrete but can also include elements such as traffic barrier or pedestrian guard rail. A specific example is rising of traffic barrier columns caused by freezing when water has access to column base which is sealed by concrete. The main cause for this kind of degradation is inadequate quality of concrete or concrete that has no special characteristics – as is sufficient resistance to freeze/thaw cycles (Fig. 9.).[4]

3.2 Deteriorations of deck slab due to freeze/thaw cycles together with deicing salts around formwork holes

Special problem are holes from formwork left from construction period which are later sealed with mortar. These are almost always locations on which the first leaking from pavement starts and from which degradation processes spread until the whole area of deck slab is contaminated (Fig. 9.).[4]

3.3 Adverse drainage from the pavement

When drainage is not properly designed (pipelines are led through body of longitudinal or transversal girders, head beams Fig. 9.) and access and maintenance are not possible, or sealing around gullies and entrance to pipelines is not properly installed, it can severely damage areas around drainage system where heavy leaking occurs even in conditions without freezing. Also a very common problem is open drainage systems when pipes are not elongated enough underneath deck slab.

3.4 Rail expansion joints and lack of maintenance

Insufficient maintenance and tolerance of damaged sealing in rail expansion joints (REJ) causes endangerment of traffic and significant degradations on the substructure elements (Fig. 10.).



Figure 10 REJ without sealing filled with debris, denivelation of asphalt, severe leaking on abutments and cantilever soffit underneath REJ

4 Conclusion

Deteriorations with common characteristics and which had predictable outcome appear on highway bridges and overpasses due to recurrence of some typical mistakes during construction. Leaking of precipitation waters saturated with deicing salts can in some circumstances cause significant and serious damage. This can in time lead to a situation where structural stability and safety becomes questionable or even collapse of parts or the whole structure. It is very important for these mistakes and problems to be identified and recognized because of their immense impact on durability characteristics. Life cycle of a structure can be significantly prolonged by a careful and responsible design, construction and maintenance thus considerably lowering costs and use of resources.

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