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Improving the Durability of Precast Concrete Bridges

Amélioration de la durabilité des ponts en béton préfabriqués

Verbesserung der Dauerhaftigkeit von vorfabrizierten Betonbrücken

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SUMMARY

Prefabricated road bridges have been constructed in Poland for over 35 years. During this long period about 20 various types of precast concrete bridge beams have been designed and implemented. The experience gained from inspection and maintenance indicates that this kind of structure has very low durability. The paper presents some general methods of repair and rehabilitation of prefabricated bridges. In addition a case study on the rehabilitation of a typical precast structure in Poland is described..

RÉSUMÉ

Les ponts-routes préfabriqués sont construits en Pologne depuis 35 ans. Plus de vingt différents types de poutres préfabriquées ont été développés durant cette période. Les résultats d'inspection et de contrôle des ponts préfabriqués indiquent que ces types de construction sont peu résistants. Cet exposé présente les principes de réparation et de consolidation des ponts préfabriqués. Un exemple typique de reconstruction est présenté.

ZUSAMMENFASSUNG

Die vorfabrizierten Brücken werden in Polen seit über 35 Jahren gebaut. In diesem Zeitraum waren im Brückenbau über 20 verschiedene Typen von vorfabrizierten Balken projektiert und eingeführt worden. Die bei den Brückenüberwachungen gesammelten Erfahrungen zeigen aber, dass die Bauwerke sehr niedrige Festigkeiten haben. In dem Artikel werden ein paar allgemeine Reparatur- und Sanierungweisen der vorfabrizierten Brücken dargestellt und ein Beispiel der Instandsetzung einer in Polen typischen vorfabrizierten Brücke beschrieben.

1. INTRODUCTION

The construction of fully prefabricated bridges has been the predominant technology of concrete road bridge building in Poland. Bridges with precast concrete beams constitute 18% the whole number of all polish bridges and 67% the number of concrete ones, constructed in 1956 - 1990. Generally, in polish public road network there are about 5300 precast concrete bridges [1].
A general tendency to industrialize bridge construction led to working out and practical application of over 20 different systems of precast bridges. Regarding to the span length there have been constructed bridges with following types of precast beams:
- reinforced - up to 15 m,
- prestressed pre-tensioned - up to 24 m,
- prestressed post-tensioned - up to 36 m.

Most of the above-mentioned bridge systems are fully prefabricated with minimum of cast-in-place concrete. Multispan structures have been constructed as a row of simply supported beams with many expansion joints. Analysis of the precast bridges deteriorations showed, that the bad state of their repair results from unsatisfactory construction, poor quality of used materials and faulty design solutions. Due to low durability of precast spans these bridges need now urgent rehabilitation.
The paper presents the most typical damages of polish prefabricated bridges and some basic ways of their rehabilitation with a case study of the typical reconstruction.

2. TYPICAL DAMAGES OF PRECAST CONCRETE BRIDGES

The basic reasons of precast bridge damages are mainly:
- inadequate transverse stiffness of the span, causing destruction of longitudinal joints between precast beams,
- poor quality of the superstructure fitting, i.e., waterproofing, expansion joints, gulleys, sidewalks,
- poor quality of both precast and cast-in-place concrete, causing not adequate rebars protection from aggressive environment.

The superstructures built of the precast beams are very leaky. Most of the longitudinal cast-in-place joints between beams, poor quality transverse expansion joints, too thin deck slabs and the sidewalks made of loose, separate elements provide good conditions for seepage through the deck causing their corrosion.
Unsatisfactory transverse stiffness is usually responsible for damaging the joints between the prefabricated elements. Due to service load the deflection of the beams is so extensive that the poor quality cast-in-place concrete in the joints gets damaged and the waterproofing ripped. Longitudinal joints became loose due to vibrations caused by dynamic load. The water gets through and causes extensive corrosion of the beams.
Widely used domestic expansion joints are leak and not satisfactorily anchored in the structure. The parts of the structure next to expansion joints and those under them become affected. The effect of leaking expansion joints is also corrosion of the areas where cables are anchored and destruction of the area round the span supports as well as extensive damage of the supports.
The low quality of waterproofing and its damage due to beam fluctuation caused insufficient protection for the concrete of the deck slab and the beams against the aggressive influence of water with deicing salt. The chloride attack took usually place.
Other fitting of prefabricated spans was also bad quality. For example gulleys with pipes of too small diameter were installed in the holes, either left or hammered in the concrete deck slab, when it has been precast. Such installation is not watertight and water does not flow through the gulley but through the adjacent area.

The greatest corrosion damage usually occurs along the sidewalks, exactly in the slab under them and on external beams. This results from placing water-collecting elements inside the sidewalks. There are various chambers, empty spaces for telecommunication cables and water or gas pipes, lean concrete and other porous materials as filler, which not only let water through but also hold some of it for a long time.
Another cause of the fast deterioration of the structure is poor concrete quality in both precast and cast-in-place elements. The strength grade of the concrete is usually too low. It is badly compacted, has numerous voids and losses and low corrosion resistance. This resistance is considerably reduced due to the content of fly ash commonly used in the seventies as concrete admixture. The poor quality of the concrete makes it insufficient protection for the reinforcement against the chloride attack, more so as the thickness of the concrete cover was often too small.

3. METHODS OF IMPROVING PRECAST BRIDGES DURABILITY

These defects of prefabricated bridges required, after a relatively short period (5-10 years), a major repair. Initially, the repair consisted in a reconstruction of the original state, i.e., damaged elements were removed and replaced by new ones of the same kind. However, this procedure was not effective as it only temporarily eliminated the effects, but not the main causes of the damage.
In the end of the eighties, the way of modernization of the precast bridges underwent considerable change consisting in the elimination of the faults pointed out in until now applied solutions. The main changes were the following:
- making the structure continuous - eliminating of expansion joints and changing the statical scheme greatly enhance the durability of the object,
- increasing the stiffness of spans and supports - making the structure dynamic and fatigue resistant,
- good waterproofing of the superstructure - stopping water penetration through the concrete.

Making the structure continuous aimed mainly at getting rid of faulty expansion joints as the main factor of prefabricated bridge destruction (fig.1). The first way was to join the spans in a chain by means of a flexible slab, covering a gap, shaped in the thickened deck slab of a bridge. It formed a continuous beam scheme regarding horizontal forces and thermal influence, but it was still a chain of simple - supported beams regarding live load. However, this method did not work properly. Theoretical assumption concerning the behavior of a flexible slab allowed its cracking, which really occurred. Consequently, they underwent very fast damage. Thus, they stopped being used.
Another method of eliminating expansion joints was performing full continuity of the deck slab without changing existing system of bearings. The static scheme of the structure was changed from a chain of simple - supported spans into a row of quasi - frame segments of several spans.
The technologically most complicated solution necessitating use of assembly supports was obtaining a full continuity of all spans in a continuous beam system or a frame system. A monolithic joint, shaped above the pier, made it possible to place some extra reinforcement on negative moments as well as protect and strengthen the ends of precast RC beams. The change of the static scheme enabled to upgrade the load carrying capacity of the whole structure and to achieve its considerable stiffening.
Except monolithic joints, the upgrading of span stiffness was achieved by casting, on the whole deck, a new reinforced concrete about 12 cm thick deck slab. The slab was made as composite with the existing precast elements or, possibly, with the old deck slab. It ensured the cooperation of two slabs in carrying live load, which often increased the load capacity of the bridge. In the new slab extra reinforcement was embedded, transverse and longitudinal falls were shaped and new gulleys fastened. Over the gap between the span and the abutment, the new deck slab was lengthened behind the back wall using brackets, thus eliminating expansion joints.

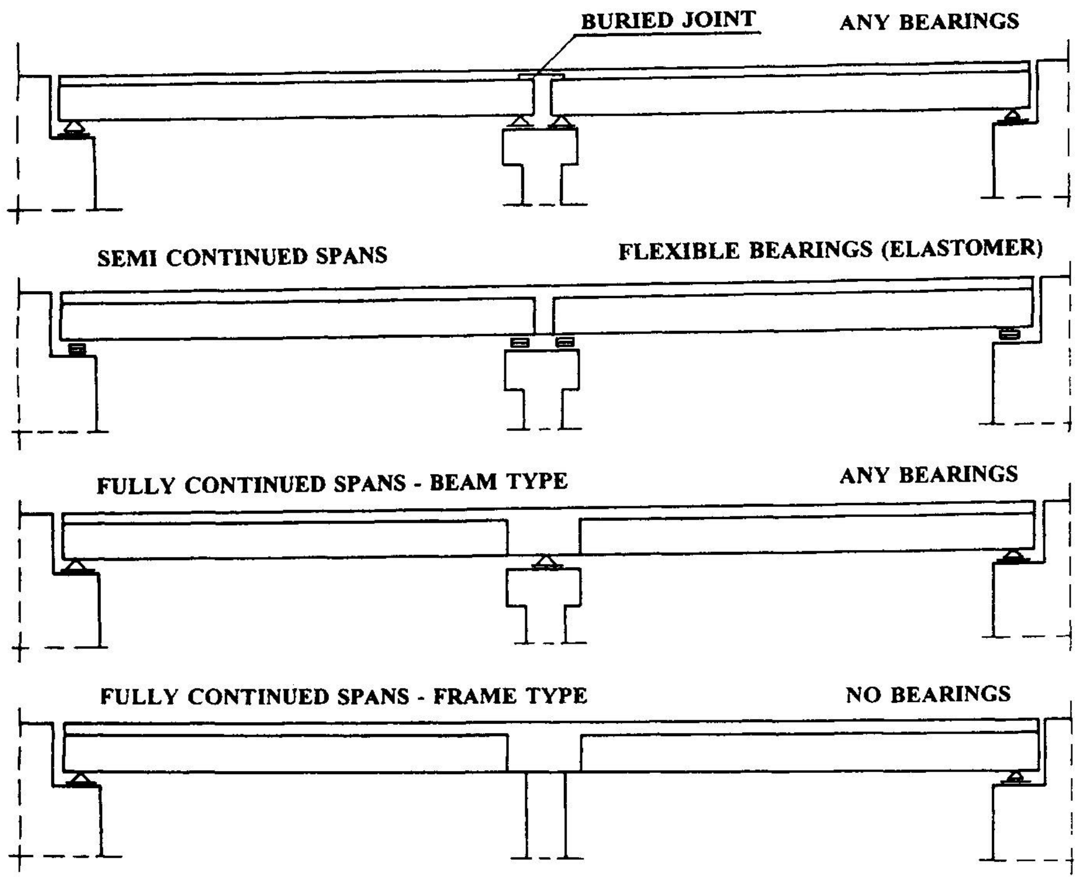

Fig.1. Methods of making continous of simply supported precast spans

The complex updating of the decks included also additional sealing of the structure. Additional waterproofing layers were put on, particularly in the curb area. The sidewalk was modernized by shaping reinforced concrete put-on slabs while all hollow bricks, openings and extra installations were removed. Besides, leakproof pavement both on the carriageway and sidewalk was laid. Described above rehabilitation steps executed on a broad basis and up to proper quality standard restored the right condition of the structure and often upgraded its load capacity.

4. CASE STUDY OF PRECAST BRIDGE REHABILITATION

The rehabilitated bridge is a four-span structure with axially spaced supports of 16.3 m and a total length of 68.6 m, with a curbless deck of 11.0 m service width. Each span contains six beams, spaced axially at any 2.0 m. The beams support precast deck slabs of 2.0 x 3.0 x 0.12 m. The whole deck has a one sided 1.5% crossfall and a 4.0% longitudinal fall. The bridge had no draining gulleys.

The faulty structure of the spans and severe service conditions caused considerable damage of deck elements, fittings and supports. The condition of the main beams varied regarding the span and the cross-section of the beams. The areas near the supports were the most deteriorated because of the leaky expansion joints. Corrosion of the main reinforcement caused cover destruction and occurrence of considerable concrete loss and delamination. As in the beams, corrosion affected areas of the precast deck slabs were near the leaky expansion joints. The blooms, decolorization, scalling and small concrete losses were observed. The other parts of slabs were in good repair and showed no corrosion.

The caps of piers were the most damaged elements of the bridge structure. Leaky expansion joints and also lack of efficient drainage of the pavement caused extensive and deep losses in the concrete, loosening of the cover to the level of the reinforcement, exposure of the corroding rebars, scalling on the whole surface, etc. Besides, hammerhead piers with such a wide cap form too flexible support for bridge structures. The flexibility could easily be felt when heavy lorries were crossing the bridge.

The main rehabilitation stages were the following:

- making continuity of spans by joining them with piers in a frame,
- introduction of changes in the cross-section of the bridge,
- covering of the whole superstructure with a reinforced concrete slab,
- extending the deck slab beyond the back walls of the abutments.

The main goal of making continuity of spans was the upgrading the longitudinal and transverse rigidity of the structure and the elimination of expansion joints, which meant sealing the structure. Concrete cast-in-place joints over the piers create a frame structure. A strongly reinforced joint of considerable size stiffens also the cap of the pier (fig.2).

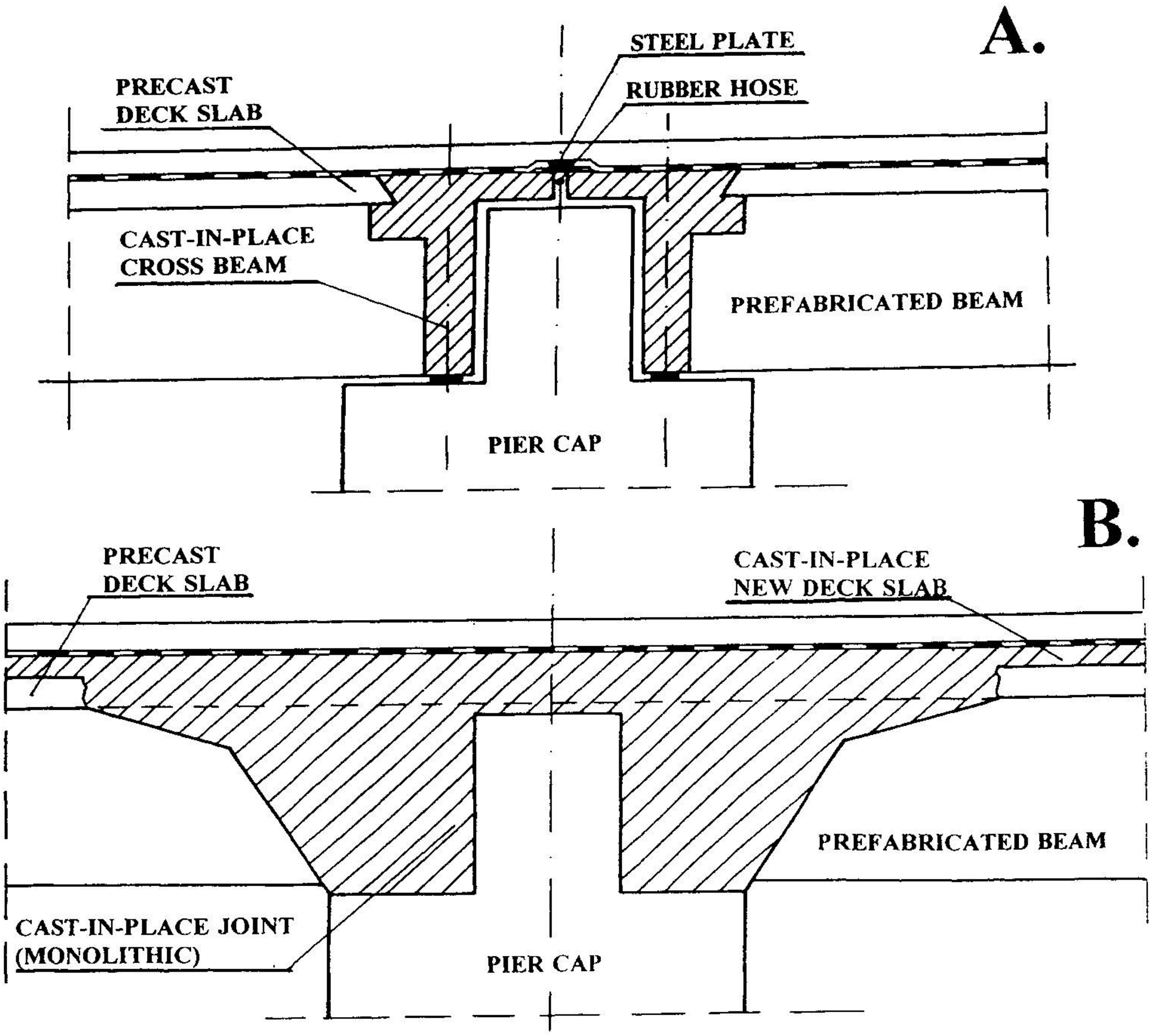

Fig.2. Modernization of the supporting area of piers:
a) before reconstruction; b) after reconstruction.

Curbless cross-section was replaced by new one with curbs separating pedestrian lanes from those for the traffic. Total structure and service width does not change. Sidewalk was designed as reinforced concrete put-on slab separated from the carriageway by stone curbs. All hollows, pipes and empty chambers were removed.
The new deck slab was composite with the hitherto existing one by means of special steel studs. The new slab sealed the deck, increased the load capacity of the span and enabled to properly anchor rebars of the joints over the piers.
To eliminate expansion joints over the abutments, the deck slab was extended beyond the back walls of the abutments. Besides, end cross beams were made which grasped the ends of the main beams over the bearing seat of the abutment.

5. CONCLUSIONS

The most important condition of long service life and high durability of concrete road bridges is the suitable protection of the structure from the influence of aggressive environment. For precast bridges it can be obtained by eliminating of expansion joints, applying of effective waterproofing and drainage and increasing the transverse stiffness of the span.
The unproven design of many prefabricated bridges, poor quality of construction and materials and mass construction of such objects caused the bad state of repair of many bridges in Poland. It is estimating, that more than 30% of the precast bridges require the fast repair or strengthening. To work out methods of their rehabilitation and restore their service value became an exigency. The presented method, which has been set up at several construction sites, seems to be the most effective.

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