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Autor: Radi, Jure

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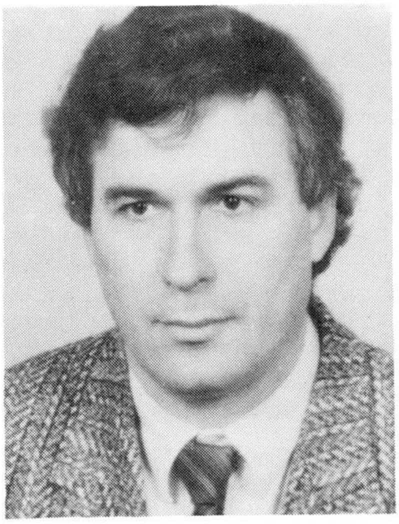
Bridge Durability Parameters

Paramètres de durabilité de ponts

Brücken-Dauerhaftigkeitsparameter

Jure RADIĆ
Assist. Professor
University of Zagreb
Zagreb, Yugoslavia



Jure Radić, born 1953, graduated at the Civil Eng. Faculty at the University of Zagreb, and received his doctor's degree 1987. His special research interests are dynamics and bridge durability. He is now Assist. Prof. for Bridges at the Civil Eng. Faculty in Zagreb.

SUMMARY

Throughout history a great many bridges have been built on Yugoslavian soil, among them many being exceptional structural and traffic achievements. Detailed data on their present state are presented in the paper, from which follows the need for regular maintenance, but also for the definition of guidelines for design and construction in especially aggressive environments.

RÉSUMÉ

A travers toute l'histoire, une multitude de ponts a été construite sur sol yougoslave. Plusieurs de ces ouvrages sont des réalisations remarquables. Dans l'article, des données précises sur leur état actuel sont présentées. Il en ressort la nécessité d'un entretien permanent ainsi que le besoin d'élaboration de directives relatives à la conception et à la construction dans un environnement agressif.

ZUSAMMENFASSUNG

Zahlreiche Brücken, davon einige mit aussergewöhnlichen konstruktiven Leistungen, wurden in der Geschichte Jugoslawiens gebaut. Daten über ihren heutigen Zustand und die Notwendigkeit der regelmässigen Unterhaltung, sowie Richtlinien für Entwurf und Ausführung für besonders aggressive Umweltbedingungen sind ausführlich dargestellt.

1. INTRODUCTION

Throughout history, paramount accomplishments in bridge construction have often been achieved on the territory of Yugoslavia. Terrain characteristics, main European traffic routes, the presence of superior builders, from Apolodoros and Mimar Sinan to contemporary ones, as well as contacts between prevailing cultures and civilizations influenced the creation of numerous bridges of great value, many of which still endure today. Particularly strong impetus in bridge construction took place during the three decades after World War II. In this period, several thousands of interesting bridges have been constructed, among them a number with exceptional dimensions and accomplishments, as is, for instance, the Tito's Bridge between land and the Krk island with the largest, 390 m span, reinforced concrete arch in the world.

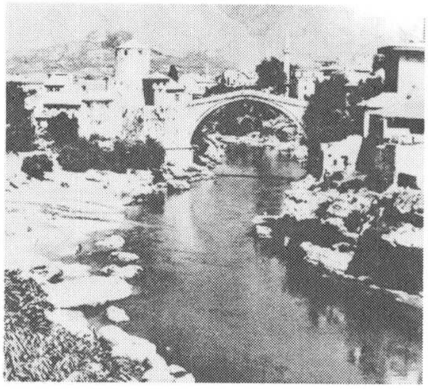


Fig 1. View of Mostar Bridge, built in XVI century

In the last several years, particular significance is being given to the bridge durability parameters analysis, by studying existing structures to determine optimal measures for enhancing their usability and durability. Also the necessary parametrical studies are carried out to investigate general data relevant for assessing the design life of structures to be designed or constructed in the future.

The first comprehensive inspection of 2210 bridges on main roads in Croatia has just been completeed. Thus, a very detailed and complex data base comprising the basic characteristics of such a large number of bridges and their present condition is being formed, on the basis of which parameters of their durability and main causes of damage are being analysed and urgent and long-term maintenance works planned.

2. DATA BASE ON BRIDGES

Modern bridge management services and the planing of all the pertaining activities calls for a comprehensive and well developed data base and an efficient working system with a prompt and regular inspection service. [1]

By the term "data base" we understand a set of all meaningful data on the initial and present properties of any particular bridge, with the programme of planned works, inspections and regular maintenance, as well as traffic and other loads imposed upon the bridge. Such a set, managed by experts and backed up by a contemporary information system and computer techniques, may at all times yield the information on:

-the levels of bearing capacity and serviceability, i.e. degree of degradation,
-the possibilities of allowing the passage of actual extraordinary loads,
-the plan, the schedule and instructions for regular maintenance work,
-specific elements associated with each particular bridge in the system,but also for groups of structures, as are data related to the planning of equipmentand means for regular and irregular works on bridges.

Therefore, the data base should contain regularly updated data:

* Main initial data on a bridge: location, disposition, structure critical details, wearable elements, design loads, construction method, interruptions during construction, built-in materijals, achieved quality, results of carried out examinations and trial loadings.
* Planned programmes of regular inspections for every bridge with directions and manner of inspection depending on the level of investigation. It would be convenient that the inspectors, during lower level inspections, be provided with forms in which they answer prepared questions.
* The plan of regular maintenance works comprising the schedule for the replacement of wearable parts and equipment, surface protection, renewal of surfacing, as well as the maintenance of special parts and equipment (e.g. on movable bridges) etc.
* Return data determined during regular and extraordinary inspections, with detailed descriptions of all observed damages, their causes, state and progress, as well as changes in the materijal. This group also comprises data on works carried out on the bridge the actual traffic conditions and irregular incidents.
* Special data on structural specifics, e.g. conduits in it, special equipment, strategic importance for the economy and other activities etc.

Besides updating these data, the bridge management system should be programmed to automatically output data on the degree of degradation, or on the threatened bridge properties, comparing them with the initial data, the data during a previous period and the allowed ones.[2]
Thus formed and updated data base presents a basis for the workout of efficijent programmes and studious projects for the maintance and protection of structures, the achievement of the planed and

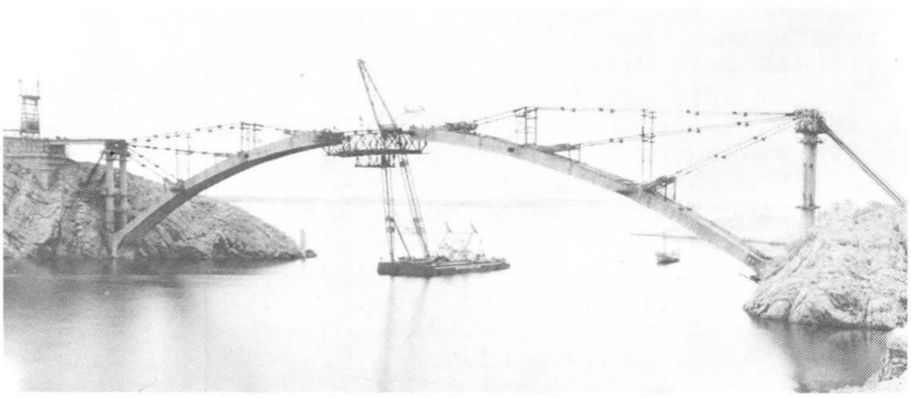


Fig 2. Reinforced concrete arch of Pag Island bridge during construction

designed durability, along with the compliance with bearability, safety and serviceability conditions.

3. INFLUENCES ON BRIDGE DURABILITY

On the basis of a comprehensive analysis and parametrical studies of safety and serviceability levels of a large number of bridges of different age the main factors of influence to the durability of bridges may be determined:

- general characteristics of traffic, particularly useful loads,
- influence of surrounding media, especially specific conditions caused by the action of sea and salt on great reinforced concrete bridges along the Adrtatic coast,
- influence of bridge characteristics (structure, materials, construction procedures, applied protection),
- influence of maintenance (from regular inspections to rehabilitation works).

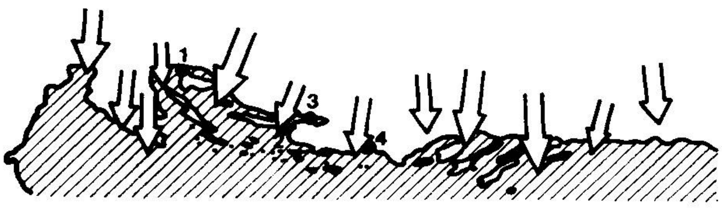


Fig 3. Locations of large arch bridges on the Adriatic coast and zones with particularly strong bura winds
Bridges: 1-Krk; 2-Pag; 3-Maslenica; 4-Sibenik

There are cases when certain, sometimes unexpected, factors lead to a significant durability decrease, and even a catastrophe, but conditions are not ancommon either when some of the mentioned factors take a dominant role and, if due measures for their neutralization are not undertaken, we may be witness unwanted consequences.

A good example of such a dominant influence on the decrease of the expected bridge durability is the aggresive action of sea water which has been observed and analysed on large Adriatic bridges for several decades already.

As known, along the coast and across channels and backwaters of the Adriatic Sea some ten very large bridges have been completed, and among them:

- the Sibenik Bridge (1966), with a 251 m span reinforced concrete arch,
- the Maslenica Bridge (1958), with a 155 m span steel arch,
- the Land-Pag Island Bridge (1968) 198 m span reinforced concrete arch,
- Tito's Bridge, between land and Krk Island (1980), with two reinforced concrete arches, the smaller a 250 m span, the larger a 390 m span.

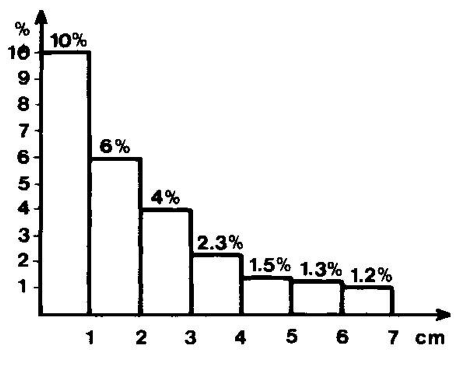


Fig 4. Diagram showing ion content compared with the quantity of cement from surface towards the interior of the Pag Bridge grider

They are exposed to an extremely aggresive action of sea water. The majority of them are located in zones with very strong bura winds, as is the Pag Bridge, where during its construction in 1967 builders recorded 241 day with force 6 winds or stronger, of which 138 days with force 8 winds or stronger. The bura is characterized by very cold winds which blow down the ridges of littoral mountains reaching greatest force along the sea surface, lifting sea drops and soaking the surroundings and these bridges above the sea.

The Adriatic Sea water has approximately the following content of aggresive ions:

SO_4^{2-}	2970 mg/l	Cl^-	21250 mg/l
Mg^{2+}	1420 mg/l	Na^+	11810 mg/l
Ca^{2+}	457 mg/l	K^+	390 mg/l

A detailed analysis and experimental investigation carried out on parts of Pag Bridge has shown that the cause of this aggresive action of the surrounding environment is best observed by the presence of free chlorides in the concrete of the bridge's pavement structure main girders. The amount of chlorides in the surface layer of concrete (up to a 1 cm depth).
In the surface layer (up to 1 cm thick) of concrete the quantity of chlorides compared to the quantity of built-in concrete is 10% and, as shown on Fig. 4., even at the depth of 7 cm (where cables are placed) the chloride content is 1.2% . All this Significantly exceeds allowed levels (e.g. according to Page [3]) even those classified as a great risk of reinforcement corrosion.[4]

The consequence of this is the significant reinforcement corrosion owing to which remedial works are carried out to upgrade the safety and serviceability of the bridge.
Sae water aggressiveness causes not only reinforcement corrosion but also concrete quality decrease, degradation of dilatations, bearings, fences etc and, in cases of metal bridges, the deterioration of every bridge part which is not maintained regularly.

The efects of these aggressive actions on durability have not been known completely and in all their manifestations during the construction of these bridges, but on the basis of actual data on their behaviour guidelines are being worked out as a foundation for the design and construction of structures along the future Adriatic Motorway and other structures in the region also

4. REWIEW OF CONDITION AND DAMAGE CLASSIFICATION OF BRIDGES IN YUGOSLAVIA

During the past five years all most important bridges in Yugoslavia have been inspected with the aim of forming a base of data and planning of the mcst urgent maintenance works on them. Data on the condition these structures are in are illustrated on the example of SR Croatia, where a total of 2210 bridges has been inspected:
- in good condition..........................25.16 %
- with minor deficiences.....................56.38 %
- with major deficiences.....................12.58 %
- worn out................................ 5.88 %

On the inspected bridges frequency of defects is different on various parts of structures. Namely, on the total number of inspected bridges defects have been observed in following percentages on:

- fences and bumpers............................59 %
- dilatations...................................50 %
- gutters.......................................47 %
- abutments.....................................35 %
- span structures...............................31 %

and on the remaining parts of the structures in lesser percentages.

This already points to the fact that defects are mostly a consequence of deficiencies in design, construction or maintenance and sometimes, inordinate traffic action. a precise analysis of all deficiencies has determined that they are a consequence of:

- design ....27 %
- construction ....41 %
- lack of maintenance...........................32 %
- other causes ....10 %

But this distribution should not be accepted anconditionally, as many deficiencies have such a character that, although they are a consequence of faulty design or construction, they can be eliminated or significantly reduced with adquate maintenance. Also a minor fault in the stage of design or during construction may acquire significant dimensions due to inadequate maintenance.

5. CONCLUSION

From the presented information on the relatively inferior condition and significantly reduced serviceability of a large number of anaysed data the following ensues:

- undelayable need for forming accurate data bases on bridge condition in every transportation system,
- timely and urgent maintenance and damage remedial works at the earliest stages of their manifestation,
- definition of criteria for the design and construction of structures in particularly aggresive environments or similar extraordinary conditions.

All these activities are currently being carried out on the system of bridges in the Yugoslav road network with the goal of regaining the high standard and exceptional accomplichments achieved by their construction.

References:

[1] Leonardt Fritz, Lippoth Walter: FOLGERUNGEN AUS SCHADEN AN SPANNBETONBRUKEN, Beton und Stahlbetonbau 10, 1970.

[2] DURABILITY OF CONCRETE STRUCTURES, State of the Art Report, Contribution a la 22 Session Pleniere du CEB, Munchen, 1982., CEB Bulletin d'Information, No 148, Paris, 1982.

[3] DURABILITY OF CONCRETE STRUCTURES, Workshop Report, CEB-RILEM International Workshop, Copenhagen, 1983., CEB Bulletin d'Information, No 152, Lausanne, 1984.

[4] STRUCTURAL REPAIR-CORROSION DAMAGE AND CONTROL, Seminar Course Manual, American Concrete Institute, Detroit, 1985.