Monitoring of bridge conditions for durability evaluation in Poland

Monitoring of Bridge Conditions for Durability Evaluation in Poland

Inventaire de l'état des ponts en Pologne et estimation de leur durabilité

Überwachung des Brückenzustandes zur Bewertung der Dauerhaftigkeit

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SUMMARY

This paper describes how the durability of bridges is taken into account in the Polish Bridge Management System on the basis of data acquired by systematically monitoring the technical condition of over 18'000 bridge structures through annual inspections . The construction of an optimum model for the Polish conditions of degradation will allow to determine the real life for each of the bridges in service. This is also important for long-term planning, because it creates the basis for optimising the allocation of funds for the maintenance and rehabilitation of these bridges.

RÉSUMÉ

L'article décrit comment la durabilité des ponts est prise en compte dans les normes polo-naises sur la base de données acquises chaque année par surveillance et évaluation systématiques de l'état des structures de plus de 18'000 ponts en Pologne. La construc-tion d'un modèle optimal pour les conditions de dégradation en Pologne permettra de déterminer la vie réelle de chacun des ponts en service. Cela a également de l'impor-tance pour la planification à long terme, car il créera une base pour l'optimisation des fonds alloués à la maintenance et à la réhabilitations des ponts.

ZUSAMMENFASSUNG

Dieser Vortrag beschreibt wie im polnischen Brückenwirtschaftssystem auf der Grundlage von Daten aus systematischer Überwachung ihres technischen Zustandes bei den jähr-lichen Revisionen von über 18'000 Konstruktionen die Dauerhaftigkeit berücksichtigt wird. Der Aufbau eines für polnische Verhältnisse optimalen Degradationsmodells wird die Be-stimmung der tatsächlichen Lebensdauer jeder der betriebenen Brücken erlauben. Dies ist auch wesentlich angesichts der langfristigen Prognostizierung ihres technischen Zu-standes, da es die Grundlage zur Optimierung der für die Erhaltung und Modernisierung dieser Brücken im Haushalt vorgesehenen Mittelaufteilung darstellt.

1. INTRODUCTION

An extensive knowledge on the technical and service condition of the bridges, bearing on the estimation of their real life, is of essential importance for the process of the management of bridges. The term real life commonly refers to the serviceability of a bridge structure which agrees with the requirements of the design. The knowledge on this subject forms the basis for the optimization of bridge work which in Poland is closely connected with a computer system that aids the management of bridges, further referred to as the Bridge Management System - BMS.

This system is made up of the main Inventory module (EGM) and some programs which by collaborating with one another carry out the selected reporting and service options of the planning function. The Polish BMS has some procedures which make the system of bridge inspection more efficient. By means of the functioning KPP (Basic Inspection Data Form Editor) program all damage to bridge components, including its frequency, can be described and their technical condition can be assessed [1, 2].

At the moment, the Polish BMS monitors the following parameters which are taken into consideration when the durability of bridges is estimated: the technical condition of the bridges, the amount and the structure of the traffic, the frequency and the quality of the maintenance work, and the effect of the environment. In this paper, the authors would like to focus on the estimation of the technical condition of bridges combined with the recording of damage, which will constitute the basis for the evaluation of durability in the Polish BMS.

2. DIVISION OF BRIDGES INTO COMPONENTS FOR MONITORING THEIR TECHNICAL CONDITION IN POLISH BMS

The developed and implemented version of the KPP program, which describes in computer terms the basic inspection, divides each of the monitored structures of the bridge into eleven basic components that occur in each case (see Fig. 1) that are complemented, depending on the need, by eight additional components (piers and their foundation, river-bed, foreign equipment, mechanisms of span movement, articulated joints, retaining walls, pylons, external tension members).

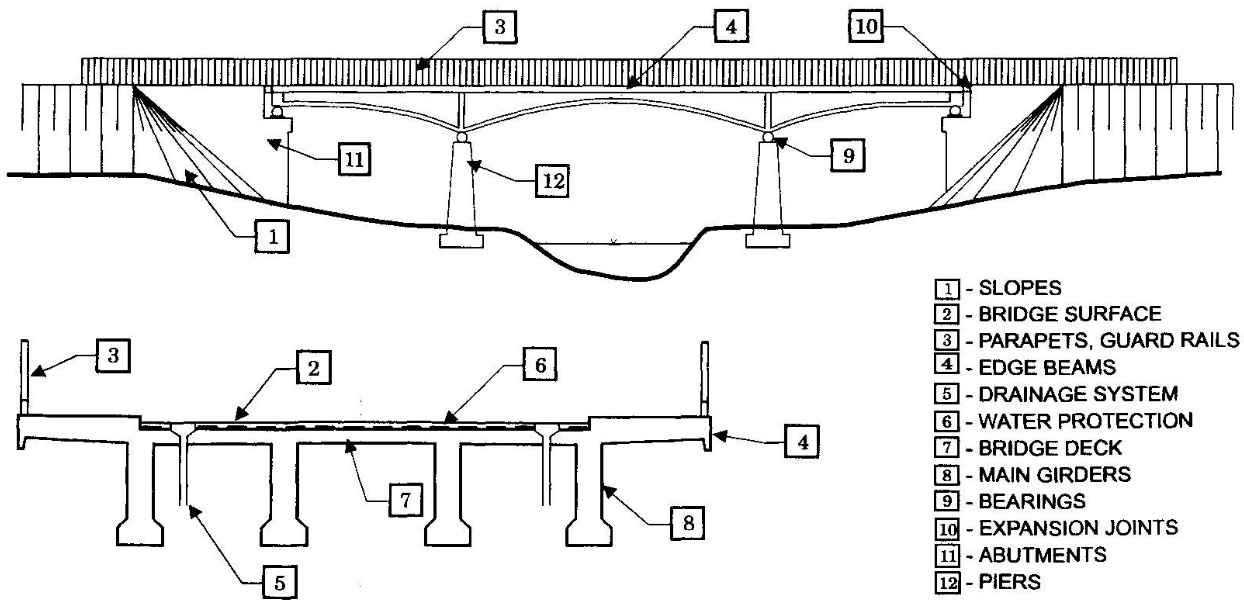

Fig. 1 The bridge components for which damage was monitored

Considering the size and the typical character of the bridge structures in Poland, one can say that in most cases, the technical condition is monitored for 12 bridge components (11 basic ones plus piers) which perform specifically defined functions when the bridge is in service.

In the years 1990-1994, the authors of this paper together with their team carried out inspection, within the framework of the work on the CEDOM (Central Inventory of Great Bridges) program, of over 300 bridges situated on bigger rivers in Poland, in which, among other things, the damage to the particular components of the bridges was monitored. In our considerations, we have limited ourselves to the analysis of the results for 100 selected types of bridge structures situated on the Warta, the Pilica and the San and on the southern Polish border.

No.	OBSTACLE (river)	NUMBER of BRIDGES			TOTAL
		CONCRETE	STEEL	STEEL WITH TIMBER DECK	
1	THE SAN	4	13	3	20
2	THE WARTA	34	17	4	55
3	THE PILICA	16	2	1	19
4	S. BORDER	3	3	0	6
	TOTAL	57	35	8	100

Table 1 The number of bridges for which the rates register was kept (bridges divided according to the span structure material)

A sketch of the typical bridge structure with the superimposed division into the 12 components that the KPP program calls for, for which the damage and the technical condition was monitored in accordance with the principles of conducting the basic inspection being in force in Poland, is shown in Fig. 1.

One hundred selected types of the bridge structures registered in the CEDOM program, for which rates were recorded have been compiled in Table 1.

3. MONITORING OF CONDITION OF BRIDGES IN POLISH BMS

The monitoring of the technical condition of bridges is one of the primary tasks of the basic inspection. According to the regulations that apply, basic inspections are conducted once a year by trained bridge inspectors in all the 171 Road Management Units on the whole territory of Poland. Over 18 thousand of bridge structures of different types and with different static schemes are inspected regularly. During the inspection all the damage to the structure sustained in service is monitored and the current technical condition of the particular bridge components are evaluated. The data are entered directly from the field into the KPP program installed on the bridge inspector's notebook.

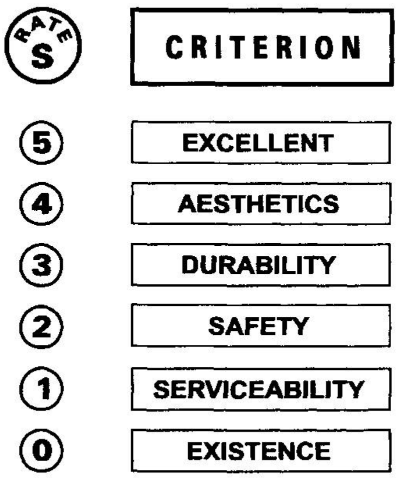

Fig. 2 The condition rating scale in Polish BMS

To standardize the description of different kinds of damage a catalog of damage of bridge components [3] was worked out for the further processing of the information. Each of the detected damage is described by a code consisting of two letters which stand for the kind of damage and the material. Each of the evaluated components is rated using a six-grade scale from 0 to 5. The adopted rating scale is presented graphically in Fig. 2.

The results obtained from basic inspections are stored in BMS in the base of rates which is serviced by the KPP program. The overall rate for each bridge is computed as the lowest from the mean rates of all the components, the girders, the deck and the supports [4].

The mean rates of the technical condition of the particular bride components for the monitored group of 100 bridges have been compiled in Fig. 3. A comparative analysis shows that expansion joints are rated decidedly lowes but these elements traditionally degrade fastest.

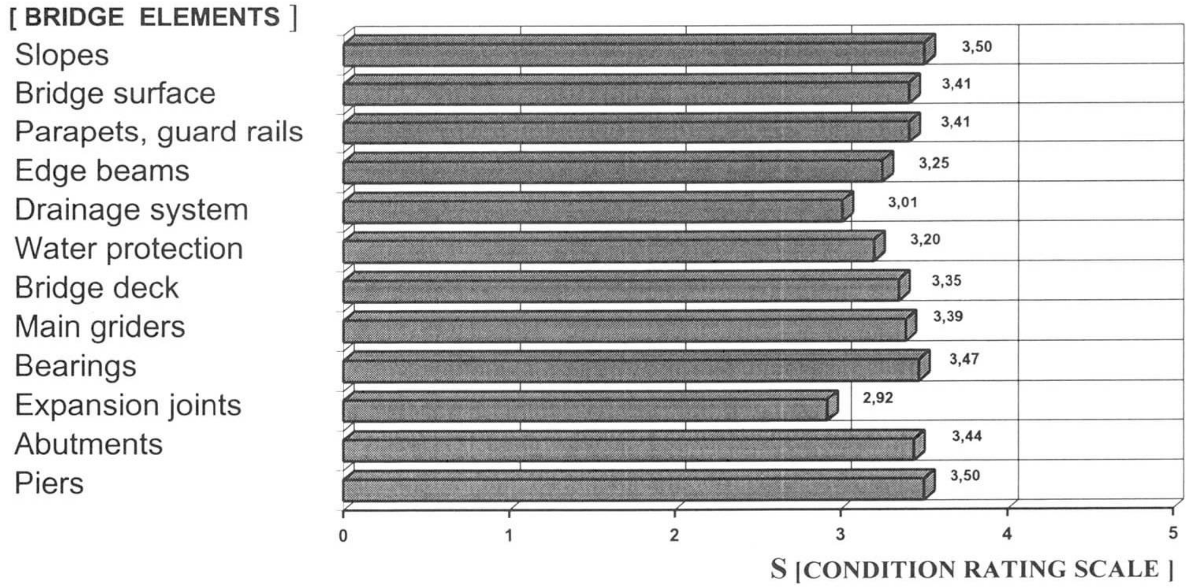

Fig. 3 Mean rates of the technical condition for the particular bridge components

4. HOW POLISH BMS EVALUATES DURABILITY

During the work on the Polish BMS it was assumed that the real life of bridges was affected by factors associated with the technical condition of the bridge structure itself, its service and the immediate environment. The total effect of all these factors on the durability of bridges can be estimated through their continual monitoring which provides the basis for the development of an appropriate model of degradation. It has also been taken into consideration that the future model of degradation should be maximally effective in the Polish bridge-work conditions.

This problem can be solved in two ways: through the theory (models of degradation) and through the practice (monitoring conducted for many years). At the moment the work aimed at this is at the conception stage.

4.1. Theoretical Model

Solutions based on the theory yield bridge structure degradation curves in the form of a function which, however, must be modified so that it would meet the practical requirements (empirical correction coefficients). In Poland, attempts are being made to derive theoretical relationships in order to construct degradation curves through computer analyses of different types of structural solutions taking into consideration the division of bridges into components. Bridge structures that include components that, for example, have not been repaired, been repaired, are damaged, were badly executed or have structural defects have been subjected to this analysis.

Various service parameters that characterize a particular bridge structure are associated with the real life of each of the analyzed components. The overall effect of these parameters resulting in a change of the technical condition of the bridge is represented by the level of its wear based on the relationship between the service life till now and the assumed durability of the bridge. The following coefficients that affect the level of wear of a bridge most strongly have been selected on the basis of the analyses: **a material coefficient**, **a fatigue coefficient**, **a load coefficient**, **a maintenance coefficient**, **an environment impact coefficient** and **a construction period coefficient**. [5].

The level of wear of a bridge can be described by this formula:

$$p = \frac{W x\, t_e}{M x\, T} \tag{1}$$

where: W - structural-service coefficients, t_e - the service life till now, T - the assumed service life of the bridge, M - a material coefficient.

At the moment the individual coefficients are being calibrated on the basis of the input data obtained from the inspections of the bridges and this work is in its final stage. Such calculations have been done for all types of bridges.

4. 2. Practical Model

One can approach the problem of a model of degradation in a practical way using as the basis the data obtained from monitoring for many years the technical condition of bridges. The input data for the plotting of degradation curves are obtained from systematically conducted basic inspections. Naturally, the way in which the bridges are evaluated affects the shape of the degradation curve, where the measure of degradation are the rates the bridges received during inspections. Attempts are being made to plot degradation curves for the different types of bridges on the basis of the collected data. Further research in this area will allow us to obtain curves similar in their shape to the theoretical ones [6].

COMPONENT	NUMBER OF BRIDGES WITHIN RANGE OF RATES S		MEAN RATE S_m
	S≥3.0	S<3.0	
MEAN FOR ALL COMPONENTS	79	21	3.33
BRIDGE DECK	90	10	3.34
MAIN GIRDERS	93	7	3.38
SUPPORTS	89	11	3.39
MEAN RATE OF BRIDGES			3.04

Table 2 Compiled results of the technical condition monitoring for the group of 100 bridges

The results of the monitoring of the technical condition for the selected group of 100 bridges registered in the CEDOM program have been compiled in Table 2. On this basis, sample degradation curves have been plotted by the linear regression method and the curvilinear regression method.

5. SAMPLE DEGRADATION CURVES PLOTTED FROM DATA GATHERED IN BASE OF RATES

Having at their disposal the data collected during the work on the computer data base for the CEDOM program and using the derived theoretical relationships, the authors of this paper made an attempt to plot sample degradation curves for the selected group of bridges. The obtained degradation curves should be treated with caution since they pertain to a peculiar group of bridges whose transportation importance may lead to a quite different mechanism of degradation than in the case of small or less used bridges.

A sample diagram describing changes in the technical condition of the selected group of bridges as the function of time, obtained by the linear regression method is presented in Fig. 4. The visible distortion of the diagram was caused by the relatively low rates which some advanced in their age bridges received.

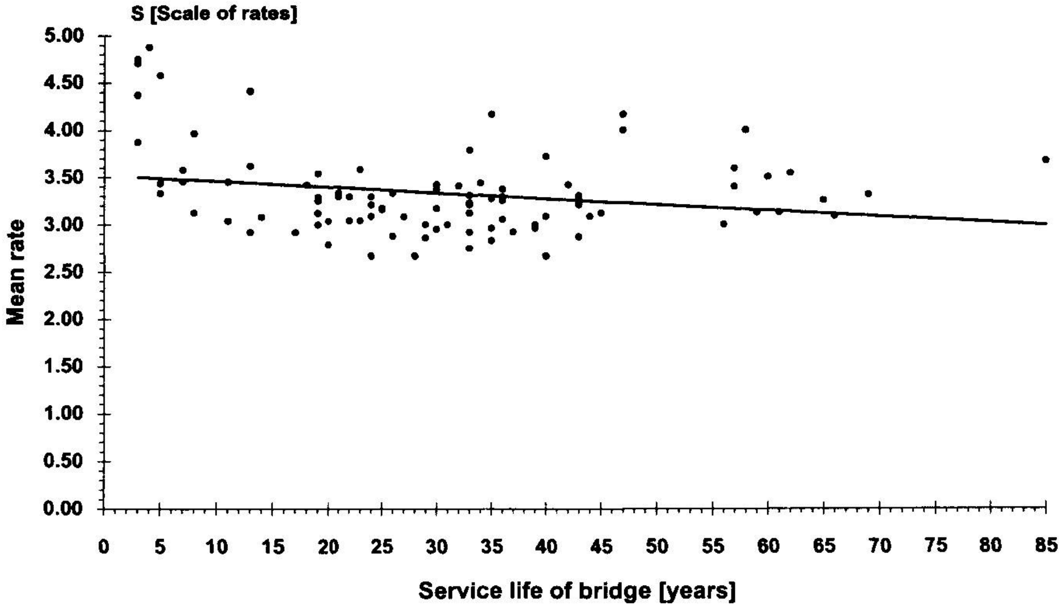

Fig. 4 A sample degradation curve for the selected group of bridges (including repaired bridge structures during their service)

6. RECAPITULATION

Models of the degradation of bridges allow one to plan long-term their technical condition which facilitates the optimization of the allocation of budget funds for their maintenance. This is why one finds so many solutions when systems that aid the management of bridges in different countries in the world are analyzed. In Poland, the foundation on which an optimum model of degradation is being built is the conducted since 1991 systematic monitoring of the condition of over 18 thousand of bridge structures of various types.

The methods of constructing degradation models presented in this paper should be treated as conceptual solutions since they are based on an analysis of technical condition rates for a selected group of 100 bridges. When these solutions are verified using the full data base, then one will be able to estimate more realistically the influence of the technical condition on the durability of structures of various types. These procedures will be included in the Polish BMS in the nearest future, which will make it possible to conduct rational policy in the domain of bridges maintenance and will result in the extension of the life of each of the bridges in service.

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