tation in the FRP composite will be subject of future analyze.

Analytical models based on bond mechanism better represent the real behaviour of the RC beams strengthened with externally boned FRP sheet than the approaches based on FRP fracture mechanism.

In spite of the lower values of the strengthened RC beams obtained from the test compared to calculated values, the strengthening concrete constructions with externally bonded FRP composites may by used to increase shear capacity of the concrete members.

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REFERENCES

[1] TRIANTAFILLOU, T.C.: Shear Strengthening of Concrete Members Using Composites, *Non-Metallic (FRP) Reinforcement for Concrete Structures, Proceedings of the Third Symposium*, Vol. 1, Japan, Oct 1997, p. 523-530.

[2] MAEDA, T – ASANO, Y. – SATO, Y. – UEDA, T. – KAKUTA, Y: A Study on Bond Mechanism of Carbon Fiber Sheet, *Non-Metallic (FRP) Reinforcement for Concrete Structures, Proceedings of the Third Symposium*, Vol. 1, Japan, Oct 1997, p. 279-286.

[3] KHALIFA, A. – GOLD, W.J. – NANNI, A. – AND ABDEL AZIZ, M.I.: Contribution of Externally Bonded FRP to Shear Capacity of Flexural Members, *ASCE-Journal of Composites for Construction*, Vol. 2, No.4, Nov. 1998, p. 195- 203.

[4] Design guide FRP, Fibre reinforcement polymer for S&P Products, June 2000, 70 p.

[5] STN P ENV 1992–1–1: Design of concrete structures, Part 1: General rules and rules for buildings, Bratislava, May 1999

[6] HORIGUCHI, T. – SAEKI, N: Effect of Test Methods and Quality of Concrete on Bond Strength of CFRP Sheet. *Non-Metallic (FRP) Reinforcement for Concrete Structures, Proceedings of the Third Symposium*, Vol. 1, Japan, Oct 1997, p. 265-270.

NEW CONCEPT OF RAILWAY BRIDGE MANAGEMENT IN SLOVAKIA

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1. Introduction

The modernization of the transportation infrastructure, which consists of the highway and the railway network, has the significant sense for economic of every country. On this account, the phase of the infrastructure rehabilitation of existing railways has begun. The part of the railways is rebuilt to the high-speed railways and the rest one is rehabilitated.

In term of transformation and restructuralization of the Slovak Railways infrastructure [1], the computer-aided Bridge management system was created by the Department of Structures and Bridges in Žilina. The methodology of existing bridge diagnostic and evaluation has been presented in this computer-aided system without subjective decision-making process.

In season, the computer-aided Bridge management system should replace the actual out of date Bridge management system of railway bridges, which is based on the guideline ČSD S5 „Administration of bridges", [2]. The code takes into account the level of knowledge in the area of bridge engineering from the beginning of 80's years. On this account, the old system is based on empirical approaches using information obtained from regular inspections with its processing based on experience of responsible workers. In such a case the decision-making processes are subjective due to significant influence of the bridge evaluator's knowledge and his experiences.

The main aim of the new computer-aided Bridge management system is to reach objective model of funds planning on the basis of diagnostic information concerning to actual bridge condition, to process this information, to calculate loading capacity and to determine the passage of actual traffic railway load. Obtained results processed by criterion aspects enable to define priorities and to determine the objective

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model of limited funds distribution in conjunction with maintenance, repair and reconstruction planning.

2. New concept of Bridge management system

In the concept proposed in [1], the computer-aided Bridge management system of Slovak Railways is considered to be a part of the global Information system of Slovak Railways infrastructure (ISI) [3], which has been developed since 1995. The created Bridge passport is involved in the system ISI. The Bridge passport containing basic bridge registration data as are invariable bridge parameters (project documentation and photo gallery in electronic form) and variable bridge parameters (diagnostic data and the results of the regular inspections, data about maintenance, repair and reconstruction of bridges), is the first part of the Bridge database.

The bridge database is considered as a basic member of the Bridge management system and consists of three following modules:

- information and registration module
- bridge evaluation module
- decision-making module

The bridge passport is the core of the information and registration module. Information and registration module will be completed with the catalogue of failures. The catalogue of failures is considered to be worked up as a part of the information and registration module to enable determining bridge defect character from the viewpoint of its influence on bridge reliability. Signification of the catalogue of failures is to eliminate different and subjective approach to classification of diagnosed failures and to evaluation of actual bridges condition.

Information collected in the first database module is processed in the second module - bridge evaluation module. The actual loading capacities of bridges taking into account their technical condition are considered to be the major outputs of this module. The bridge evaluation module is the key module of the whole system due to giving the important information for choice of maintenance and rehabilitation strategy in decision-making process.

From the viewpoint of decision-making process, the bridge maintenance planning is only considered on the regional level. The passage of actual railway traffic load, which is a basis for bridge classification, should be determined. Based on the bridge classification and in conjunction with financial calculations of economic effects, the bridge order for repair and rehabilitation should be determined taking into account the financial possibilities of the owner.

3. Methodology of existing railway bridge evaluation

The bridge evaluation module has pivotal position in the bridge management system. The main aim of the bridge evaluation module is to carry out complex bridge assessment on the basis of the actual bridge loading capacity and passage of traffic load taking into account actual bridge condition obtained by regular inspections or technical diagnostics.

The reliability is considered as the basic qualitative factor of evaluation. The methodology of reliability-based evaluation was elaborated in [1] considering traditional approach to the railway bridge evaluation and allowing for modern trends in that problem. The bridge reliability is the basic parameter of evaluation in this approach. In this concept, the evaluation represents the reliability verification of existing bridge taking into account the actual bridge technical condition with all relevant failures, which were found by diagnostics, design model of resistance and loading. As the relevant failures should be considered such defects affecting the bridge reliability that cannot be eliminated by bridge regular maintenance.

The bridge loading capacity is the basic quantitative factor of bridge reliability and evaluation due to taking into account the actual technical bridge condition. Within the second phase of project solution [1], the new guideline for determining loading capacity of railway bridges [4] was worked out. The methodology presented in [4] is fully in accordance with European design standards for structures and bridges and respects modern approaches into existing bridge evaluation.

The input parameters entering loading capacity calculation are considered as design values, which take into account the reliability level determined by appropriate standards. The reliability level is able to describe by failure probability P_{fd} and by reliability index β_d. The failure probability of newly designed bridges is $P_{fd}= 7.24 \cdot 10^{-5}$ (β_d=3.80). This reliability level can be increased for existing bridges due to regular inspections, which reduce the uncertainties of input data for loading capacity calculating. The mathematical model [5] used for specifying existing bridge reliability levels compatible to newly designed bridges reliability level was observed in the framework of research activities of the Department of Structures and Bridges.

The reliability levels were determined depending on time of the bridge evaluation and its planned remaining lifetime. The planned remaining lifetime is the difference between designed overall lifetime and time its evaluation or can be shorted due to required loading capacity.

The bridge reliability level is time dependent and it is influenced by many factors, as are degradation of materials, change of loading, fatigue of materials, rehabilitation of bridge, repair of bridge etc. There is shown the example of decreasing reliability level due to degradation of materials, increase of loads or fatigue of materials in Fig. 1. The effect of repair and reconstruction of bridge on increasing of reliability level and lifetime lengthening are shown in Fig. 1 with assumption of taking into account the social requirements growth.

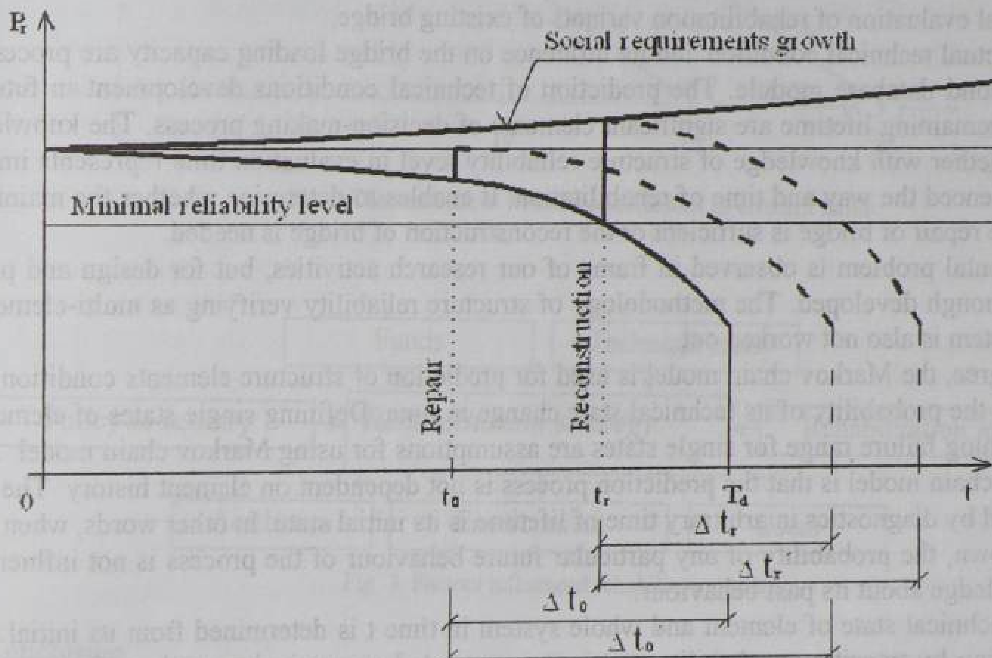

Fig. 1. Changing of bridge reliability in time

From the viewpoint of railway transport user, the bridge loading capacity is insignificant value. Therefore, the passage of actual railway traffic load through the bridge should be determined as the decisive parameter for transport user's satisfaction. The passage of actual railway traffic load is based on comparing bridge loading capacity to railway traffic load efficiency represented by loading models from A to D4 for goods trains.

Based on the actual loading capacity and the passage of actual traffic load, the observed bridge can be evaluated by means of the following bridge classification:

Classification	Evaluation	Criterion
1	Excellent	Bridge actual parameters correspond to actual design ones and its technical state is correct.
2	Good	The bridge has such defects and deterioration not affecting its actual loading capacity.
3	Satisfactory	The bridge has such defects and deterioration which influence the actual bridge loading capacity without any change related to passage of actual traffic load.
4	Poor	The bridge has such defects and deterioration affecting both the bridge loading capacity and the passage of actual traffic load so that its remaining lifetime t_r is within $3 \le t_r < 10$ year.
5	Critical	The bridge has significant failure affecting conclusively the bridge loading capacity and the passage of actual load so that its remaining lifetime is lower than 3 years.

4. Decision-making module

The decision-making module will be processed in the third phase of the project solution [1]. Following data is necessary to find out and should be available for correct and optimal decision about maintenance or rehabilitation of existing bridges:

- actual technical condition of whole structure,
- influence of actual condition on reliability of structure and its parts (defined loading capacities of bridge parts),
- prediction of technical conditions development and its remaining lifetime in future (failures, degradations, corrosion, fatigue),
- complex evaluation of existing bridge taking into account all known information about bridge,
- variant solutions of structure rehabilitation in accordance with found out information,
- economical evaluation of rehabilitation variants of existing bridge.

The bridge actual technical condition and its influence on the bridge loading capacity are processed by the first and second database module. The prediction of technical conditions development in future and determining its remaining lifetime are significant elements of decision-making process. The knowledge of these factors together with knowledge of structure reliability level in evaluation time represents important parameters influenced the way and time of rehabilitation. It enables to determine whether the maintenance or eventually the repair of bridge is sufficient or the reconstruction of bridge is needed.

The fundamental problem is observed in frame of our research activities, but for design and practical process is not enough developed. The methodology of structure reliability verifying as multi-element spatial structure system is also not worked out.

In a high degree, the Markov chain model is used for prediction of structure elements condition, which is able to define the probability of its technical state change in time. Defining single states of element failure and determining failure range for single states are assumptions for using Markov chain model. Advantage of Markov chain model is that the prediction process is not dependent on element history. The technical state detected by diagnostics in arbitrary time of lifetime is its initial state. In other words, when its present state is known, the probability of any particular future behaviour of the process is not influenced by additional knowledge about its past behaviour.

The future technical state of element and whole system in time t is determined from its initial state in time t_0 multiplying by transition probability matrix exponentiated on particular number of years $(t-t_0)$ for remaining lifetime

$$\{X_n\} = [P]^{(t-t_0)} \cdot \{X\} \tag{1}$$

where: $\{X\}$ is initial state of system in time t_0,

$\{X_n\}$ is state of system in time t,

$[P]$ is transition probability matrix contained the transition probability from one technical state to another technical state.

An example of Markov chain model for technical state prediction in time period of 20 years is shown at Fig. 2

The numbers in the circles specify the probability of the state, which may be interpreted as the percentage of elements predicted in each state. The arrows represent the transition probability between states. More information about using the Markov chain model is presented in [6].

Based on information about actual technical state, its influence on bridge reliability and prediction of the reliability change in time using above-mentioned approach, the bridge structure can be complex evaluated. The complex evaluation is usually described by classification completed with verbal structure evaluation.

The rehabilitation strategy is needed to determine for structure that technical state demands the serious rehabilitation. It is influenced by many factors (see Fig. 3).

The required works on repair or reconstruction and time their realization is needed to define for every rehabilitation strategy. The economical evaluation and their comparison are decisive for selection of optimal rehabilitation strategy.

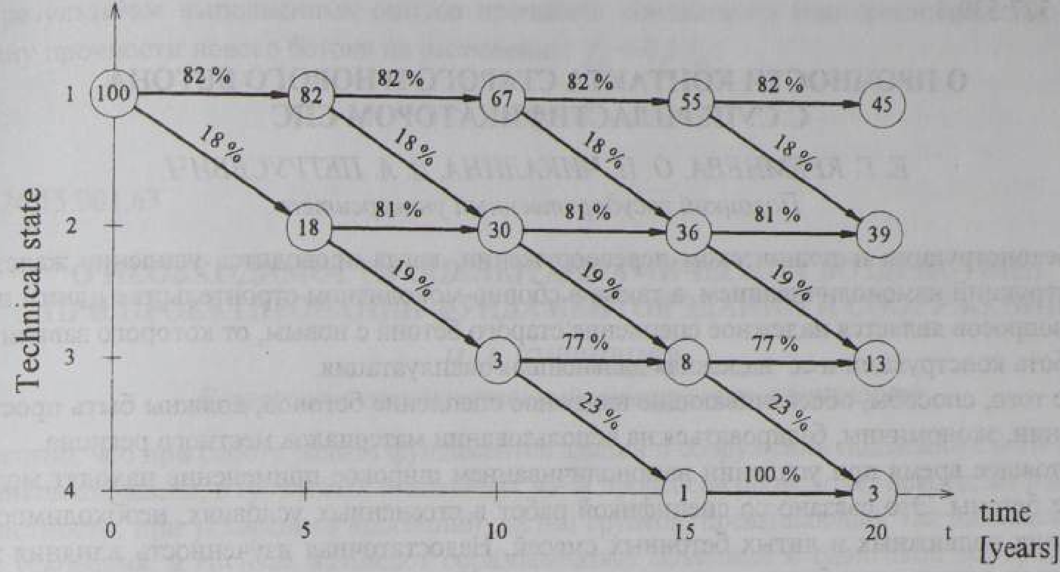

Fig. 2 The example of Markov chain model of element failure

Fig. 3. Factors influenced rehabilitation strategy

5. Conclusion

The paper describes the concept of computer-aided Bridge management system proposed for Slovak Railways in report [1]. Attention is paid to the decision-making processes based on existing bridge evaluation influencing the rehabilitation strategy very significantly.

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REFERENCES

[1] VIČAN,J. at all: PP 5.4 The program for maintenance planning and rehabilitation of infrastructure for project of transformation and restructuralization of the Slovak Railways. Part 1: Methodology of diagnostics and evaluation of Slovak Railways bridges and footbridges. University of Žilina, 12/2001, 81. p.

[2] ČSD S5: Administration of bridges. FMD, Nadas Praha, 1980

[3] CIHO,D.: Information system of Slovak Railways infrastructure. Seminar "From diagnostic to railway truck maintenance", Hradec Králové, 2001, p. 52-57

[4] VIČAN,J. at all: Methodology of railway bridge loading calculation. Final report, University of Žilina, 12/2002, 86. p.

[5] VIČAN,J.-SLAVÍK,J.-KOTEŠ,P.: Effect of regular inspections on the existing bridge reliability. 19. Czech and Slovak Conference „Steel structures and bridges 2000", Štrbské Pleso, 2000, p. 69-74

[6] KOTEŠ, P. - VIČAN, J. - SLAVÍK, J.: System reliability using Markov chain model. 5-th European Conference of Young Research and Science Workers "TRANSCOM 2003", Žilina, 2003, p. 79-82