UDC 624.275

V.K. Shinder, V.V. Volotsiuga, Yu.V. Shinder
Lviv Polytechnic National University
Bridges and Structural Mechanics Department

RECOMMENDATIONS TO THE PROBABILISTIC STRENGTH ESTIMATION OF NORMAL SECTIONS OF THE ROADWAY BRIDGE PLATE-GILLED SYSTEM

In this article are presented the basic general approach principles to the development of the technique for deformation resistance calculation of the defective span bridge construction in a probabilistic formulation, based on the method of statistical testing operations.

Key words: probabilistic estimation, plate-gilled system, roadway bridge, normal distribution law.

Подано основні положення загального підходу до побудови методики деформаційного розрахунку міцності дефектної прогонової мостової споруди в ймовірнісній постановці, яка базується на методі статистичних випробувань.

Ключові слова: ймовірнісна оцінка, плитно-ребриста система, автодорожній міст, нормальний закон розподілу.

Introduction

The current condition of the construction industry requires research and improvement in theories and methods of reinforced bridge concrete structures calculation, including those of the plate-gilled ones, which allow reasonable and adequate use of the load-carrying reserves capacity; realistic estimation of the materials characteristics; considering the real state of structures and their elements at most. The need for more accurate calculations is caused by many factors, such as materials and labor costs savings, constant lack of funding, continuous rapid development of infrastructure, and as a consequence, the constant raising requirements for strength and durability of roads, bridges and overpasses.

Problem definition

The modern methods of bridge systems calculation, including plate-gilled ones, are deterministic, i.e. bridge structure calculations are performed using fixed load values based on the fixed parameters of materials strength and degrees of construction damage. In the existing regulations random real values of permanent and temporary loads, the magnitude and location of defects, spans geometric characteristics, physical and mechanical properties of materials are replaced by the calculated and standard values in such a way as to ensure the durability and reliability of spans and bridge constructions in whole.

Analysis of recent research and publications

The previous analysis of the literature revealed that the given topic was studied poorly, and it turns to be currently a pressing problem in the modern construction industry and therefore has prospects for the development. Among some other, this subject was under consideration in [6, 8, 9, 10].

The basic material statement

The algorithm for probabilistic calculating of the span highway bridge structures strength can be developed on the basis of statistical testing operations method, which is based on the multiple calculation of vehicles passage, not considering the dynamic effects of the traffic load action.

For the description of variations in the strength characteristics it is appropriate to use the normal distribution law, which is described by the formula:

$$p_R(R)=\frac{1}{\sqrt{2\pi\sigma_R}}e^{-\frac{(R-\bar{R})^2}{2\bar{R}}},\;\; P_R(R)=\frac{1}{\sqrt{2\pi\sigma_R}}\int_{-\infty}^{\infty}e^{-\frac{(R-\bar{R})^2}{2\bar{R}}}dR, \tag{1}$$

where $\bar{R}$ and σ_R are the center and the dispersion of the normal distribution respectively.

According to the results of testing of standard samples there was recorded a number of random R values of a definite parameter, for instance ultimate stress limit, and there were built the corresponding histograms. The average value of the distribution is determined by the formula:

$$\bar{R}=\frac{\sum_{k=1}^{m}R_k n_k}{\sum_{k=1}^{m}n_k}, \tag{2}$$

where $n_k(k=\overline{1,m})$ is a number of samples, the strength of which corresponds to R_k, and the strength standard (standard deviation) equals:

$$\sigma_R=\sqrt{\sum(R-\bar{R})^2}, \tag{3}$$

Normal material resistance is defined with the correlation:

$$R_k=\bar{R}(1-\alpha\nu), \tag{4}$$

where α is a ratio, which is calculated from the condition of a given strength provision and according to the current regulations equals 1.64. The coefficient of variation $\nu=\sigma_R/\bar{R}$ is set to $\nu=0{,}165$ for the concrete under tension, and $\nu=0{,}135$ for concrete under compression, due to the fact that the range of distribution of the concrete strength under compression is less than of that under tension. For the steel it is set to $\nu=0{,}008-0{,}10$.

The obtained coefficient values for reinforcement and concrete variations do not include collaboration of investigated concrete prisms and reinforcing rods. Theoretical calculations and experimental tests [1,2] allowed to estimate the collaboration of concrete and steel that is determined by the increasing displacement of the average strength values in 1,25-1,40 times and by the significant change of the statistical distributions mode, i.e. the range of strength significantly decreases which is reflected in the coefficient of variation, which is $\nu=0{,}03-0{,}05$ for concrete.

Estimated resistance is determined by the relation:

$$R=\frac{R_n}{\gamma_m}, \tag{5}$$

where γ_m is a ratio for material reliability that is set in such a way that the probability of compression resistance development or steel and concrete strain is close to zero.

Thus, the following approach can be used to design new constructions with the required reliability. And in such a probabilistic case of reliability calculation there should be used random values of strength and materials, and not the normative or calculated ones. Although in practice it is often quite impossible to obtain reliable data on the materials strength distribution, but the use of actual values of strength and load allows estimating more reliably the durability, reliability and loading capacity reserve. Variability of materials mechanical properties was examined in many researches, including [3, 4, 5, 6, 7].

If the experimental data is absent, random values can be obtained with the help of standard ones, one can use for that purpose pseudorandom numbers generator. And the standard resistance can be obtained from the project concrete and steel classes, or with the help of non-destructive methods of control strength. Next it is necessary to determine the center and distribution standard according to the received formulas (4), whereas the coefficient of variation is set to ν. After setting the required number of random values, center and standard of distribution, a range of pseudorandom numbers for the normal distribution law is obtained.

The normal distribution law can be applied as well in order to describe the variability of the geometrical characteristics of cross sections. From the analysis of numerical measurements of full-scale structures it appears to be a small statistical range. Furthermore, the same law can be applied for the empty weight load description. In this case the distribution center is considered to be the value of the specified characteristic load $(N_n = \overline{N})$ and the distribution standard is determined by the formula:

$$\sigma_n = \frac{N_n(\gamma_f - 1)}{\alpha}, \tag{6}$$

where γ_f is a partial safety factor for material strength according to the Ukrainian national construction regulation; and α is a factor that depends on the provision of the value N_n; $(\gamma_f - 1)$ is the coefficient of variation ν. The coefficient of empty weight variation for the reinforced-concrete bridges (acc. [8]) is accepted as 0,033.

The vertical load from traffic stream action can be described with the actual motion parameters or standard loads.

The laws of intensity distribution u, velocity υ, distance between cars $l_{\min}$, i.e. the nature of the load can be established observing the span of a bridge or road segment l, through regular photoengraving with parallel measurement of flexure angle dimension, which will help to establish the law of mass distribution of vehicles. Having installed the inspection stations for the vehicles weight control, can be used to receive the percentage of vehicles based on their weight. But such process is time-consuming and costly, even though the received data can be directly used for statistical estimation of the bridge. Therefore, for practical calculations it is proposed in [9] to subdue the probability of finding $\overline{P}_i^l$, the number of cars *i* on the segment *l* to the Poisson's law:

$$\overline{P}_i^l = c \cdot \frac{m^i \cdot e^{-m}}{i!}; \tag{7}$$

$$c = \frac{e^m}{\sum_{i=0}^{n} \frac{m^i}{i!}}, \tag{8}$$

where c is a section constant, that is determined by the maximum possible number of vehicles $n = l/l_{\min}$ that can simultaneously be within the interval *l* accepting that $m = lu/3600\nu$; *i=0,1,2,…,n.*

The probability P_i^l of vehicles *i* $(i \neq 0)$ being on the road segment *l* with allowance for the correction of compression is defined with the formula:

$$P_i^l = \overline{P}_i^l + \overline{P}_i^l \frac{u - \sum_{i=1}^{n} i \cdot \overline{P}_i^l \frac{3600}{l}\nu}{\frac{3600}{l}\nu \sum_{i=1}^{n} i \cdot \overline{P}_i^l}, \tag{9}$$

A certain set of data on the intensity and nature of traffic stream, that was obtained with the observation, among some other data, are given in [10]. Note that in the case of dynamic analysis, or in order to determine the dynamic coefficient on the basis of static calculations there should be given data on the state of the road segment topping under research. For that purpose the uneven coverage profile is represented as a two-dimensional random variable, namely, length and depth of inequalities. To approximate conditional density of the distribution of inequalities length and depth Rayleigh distribution can be used.

Thus, using formulae (7.9) and taking into account the probability of presence of vehicles of certain weight the random load situations can be generated in order to use the received data for static calculation.

Summary

The article contains recommendations to the probabilistic strength estimation of normal sections of the roadway bridge plate-gilled system. It is proposed to build a probabilistic algorithm for calculating the strength of a roadway span bridge on the basis of statistical testing operations, this algorithm is based on the multiple calculations of vehicles passage situations with the use of the normal distribution law.

1. Iosilevskiy L.P., Rudenko M.S Ways to improve the design of reinforced concrete bridges. – "Transport Construction", 2001, №5,pp. 21-25. 2. Sizov V.P. Comparison of the variation coefficients on the basis of the average concrete strength and private results in the series. // Concrete and reinforced concrete № 1,1999. pp. 29-30. 3. Madatyan S.A. Reinforcement of concrete structures. – M., 2000. 4. Madatyan S.A. Standard and calculated resistance of the steel. Concrete and reinforced concrete in №3 2005 pp. 2-5. 5. Degtyarev V.V. The variability of the mechanical properties and the area of cross-sectional reinforcement of class A500S. // Concrete and reinforced concrete № 1,2005, pp. 2-7. 6. Mirza S.A., McGregor J.G. Variability of mechanical properties of reinforcing bars // Journal of the Structural Division / 1979 / – № ST5. – pp. 921-937. 7. Gamble W. L. Thermo-processed reinforcing bars // Concrete International/-2OO3.-V.25.- № 7.pp. 85-88.8. Chirkov V.P. Probabilistic methods for calculating the reinforced concrete structure bridges. M., "Transport", 1980. pp.134. 9. Barchenkov A.G. Dynamic calculation of road bridges. M., "Transport", 1976. pp.199. 10. Kossenko M.V. The calculations of non-linear deformation of strength and survivability used in bridge construction of girder concrete bridge systems with defects and damages [internet resource]: Diss. Doctor of Engineering: 05.23.17 / Mikhail Kosenko. – Voronezh State Library, 2007. – pp.142. 11. Ukrainian national construction regulation B.1.2-15: 2009 Transport facilities. Bridges and pipes. Pressures and impacts. – In effect from 2010-03-01. – Kyiv: Ukraine Ministry of Regional Development, 2009. – pp.83.