Scientific Journal of Silesian University of Technology. Series Transport
Zeszyty Naukowe Politechniki Śląskiej. Seria Transport

Volume 110 **2021**

p-ISSN: 0209-3324

e-ISSN: 2450-1549

DOI: https://doi.org/10.20858/sjsutst.2021.110.10

Journal homepage: http://sjsutst.polsl.pl

Article citation information:
Soatova, N. Calculation of flexible bending elements of a flight structure given their actual condition. *Scientific Journal of Silesian University of Technology. Series Transport*. 2021, **110**, 115-123. ISSN: 0209-3324.
DOI: https://doi.org/10.20858/sjsutst.2021.110.10.

Nodira SOATOVA[1]

CALCULATION OF FLEXIBLE BENDING ELEMENTS OF A FLIGHT STRUCTURE GIVEN THEIR ACTUAL CONDITION

Summary. This article presents the results of the analysis of experimental data on testing of reinforced concrete elements for multiple-repeated loads and field tests of operated span structures. This article proposes dependencies on the definition of deflections during the operation period. Based on the processing of the available experimental data, dependences are proposed for determining deflections under multiple repeated loads, and on this basis, dependences are obtained for predicting the residual life of span elements. The initial data for the calculations are the data on the accumulated residual deflections determined in the process of technical diagnostics.

Keywords: resource impact of corrosion, span structures, deflections, reinforced concrete elements, calculation method

---

[1] Faculty Roads and Man-Made Structures. Tashkent Institute for the Design, Construction and Operation of Roads. 20 Amir Timur Street, Tashkent, Uzbekistan. Email: nsoatova@bk.ru.
ORCID: https://orcid.org/ 0000-0002-0783-6914

1. INTRODUCTION

In many countries of the world, special importance is attached to scientific research in the field of studying the effect of corrosion of reinforcement and concrete. Improving both quality indicators and methods for calculating durability and strength, extending the service life of transport facilities. In this direction, in particular, improving the calculations of the resource impact of corrosion of concrete and reinforcement of bridge span structures, the development of calculation methods for using modern computer technologies in scientific research is considered one of the important tasks [1,3-5,12,13].

With the acquisition of independence of the Republic of Uzbekistan, great importance was attached to the development of transport communications structures, the design of ground structures, and the improvement of their construction and operation.

Currently, more than 7000 bridges are operated in the Republic. To increase their reliability and calculate their strength, several tasks were performed. Along with this, it is necessary to improve the methods of calculation and increase the resource of artificial structures in the structure of transport communications. The Strategy for Action for the Further Development of the Republic of Uzbekistan, included the following objectives, "... the implementation of targeted programs for the development and modernisation of road transport, engineering, communication and social infrastructures". In a broad sense, the importance of a research and development approach to calculating the life of road bridges in this respect, increasing operational reliability and ensuring the reliability of newly erected and operated bridges grows.

2. FORECASTING RESIDUAL RESOURCE BY DEFLECTION

When assessing the load capacity and predicting the residual life of reinforced concrete spans, residual deflection (sagging) must be considered, and in many cases, this factor may be decisive.

As a result of the analysis of experimental data on tests of reinforced concrete elements for repeated loads and field tests of operated span structures, dependencies are proposed for defining deflections during operation. The results of the survey of reinforced concrete spans showed that the actual accumulated deflections (sagging) differ from the calculated. The calculation was according to the design standards of the year of construction of the objects under consideration. The use of existing standards has however not led to satisfactory results. This is clearly observed when calculating the deflections of the console of the plates of the extreme beams of the road bridges and the external console of the ballast trough plates in the railway bridges. Here, the difference between the actual and calculated deflections reaches 4-5 times [6,7]. In connection with the foregoing, an attempt was made to improve the existing methodology for calculating deflections.

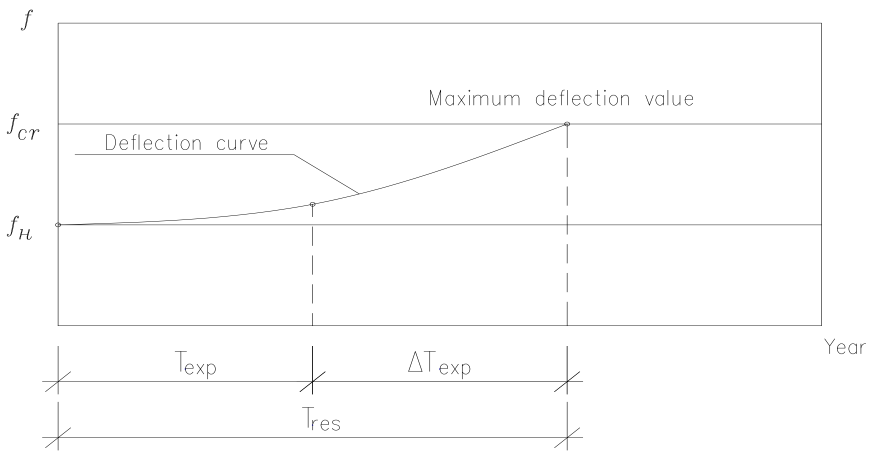

Fig. 1. Prediction of residual resource on the criterion of limiting deflection T_{exp} - time from the start of operation until the time of the survey; T_{res} is a complete resource; ΔT_{res} - residual resource

Simultaneously, the total value of the deformation of the residual deflections of bending reinforced concrete elements, considering long-term constant and frequently repeated loads, is presented in the form:

$$f = fg + f_N \tag{1}$$

where:
fg - deflection from the effects of permanent long-acting loads;
f_N - deflection from repeated exposure to temporary loads.

The value of f_g is determined by known methods [6] considering the creep of concrete under the action of a constant load. Moreover, as shown in [11], for bending reinforced concrete beams under constant long-acting loads, in natural climatic conditions, formulas of normative documents, considering creep deformation of concrete according to recommendations [14], give satisfactory results.

The deflections of reinforced concrete beams due to the long action of multiple-repeated loads are manifested due to the deformation of the vibro-creeping concrete. According to V.M. Bondarenko [2], the additional increment of the deflection in dynamically loaded structures due to the vibrocreep of concrete can reach significant values.

Below, an attempt is made to develop a practical method for determining the deflection of the dynamic component of the load based on the available experimental data [15]. This paper uses the results of experimental studies performed in TashIIT laboratory [15]. The test results of beams for multiple loadings are shown in Fig. 2. As can be seen in Fig. 2, a clear pattern of changes in deflections during repeated loads depends on the voltage level. Beams loaded with a high level of stress have high values of relative deflection at repeated loads.

The determination of the expected limit values of residual deflections during repeated loads is carried out by constructing diagrams according to the procedure [6] (Fig. 3). To do this, we calculate the increment *N/f*, where N is the number of loading cycles; f is the value of residual deflection corresponding to this magnitude of loading cycles. On the diagram, we plot *N/f* along the ordinate axis and *N* values along the abscissa axis. From the obtained points, a regression line is plotted graphically or analytically, the cotangent of which angle is taken as the limiting deformation value of the residual deflection *fcr, N*, and the section cut off by this straight line at abscissa axis, for the parameter of the rate of increase in the deflection deformation.

The limiting values f_{g-} of curvature from constantly repeated loading can be determined by the dependence:

$$\frac{1}{\rho_{N_{cr}}} = \frac{\varepsilon_{bN_{cr}}}{x} = \frac{l\sigma_b C_{fN_{cr}}}{x} \tag{2}$$

where:

ε_{bNcr} - limit values of deformation from constantly repeated loading; l is the length of the span;

C_{fNcr} - limiting values of a measure of a vibrocreep of concrete;

x - height of the compressed zone of concrete.

The limiting values of the vibro-creep measure are recommended to be determined by the expression [6]:

$$C_{fN_{cr}} = \frac{\varphi_{cr}(t,\tau_0)}{E_b}\left[\rho + \frac{1{,}11\, lgN_{cr}(1-\rho^2)}{6{,}3}\right] \tag{3}$$

where:

$\varphi_{cr}(t,\tau_0)$ - the limiting values of the characteristic of simple creep of concrete;

ρ - asymmetry of loading cycles;

N_{cr} - the limit number of cycles until the deflection of permissible values is reached.

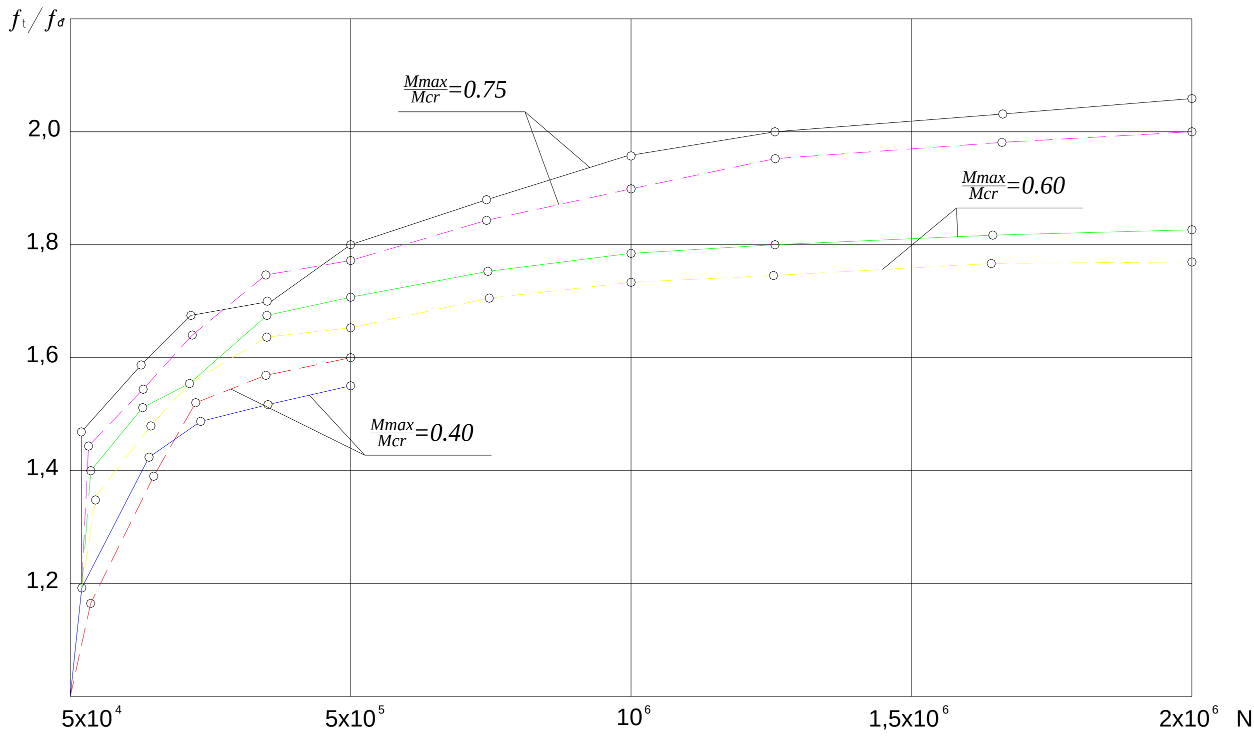

Fig. 2. The increase in the relative deflection of beams with multiple repeated loads

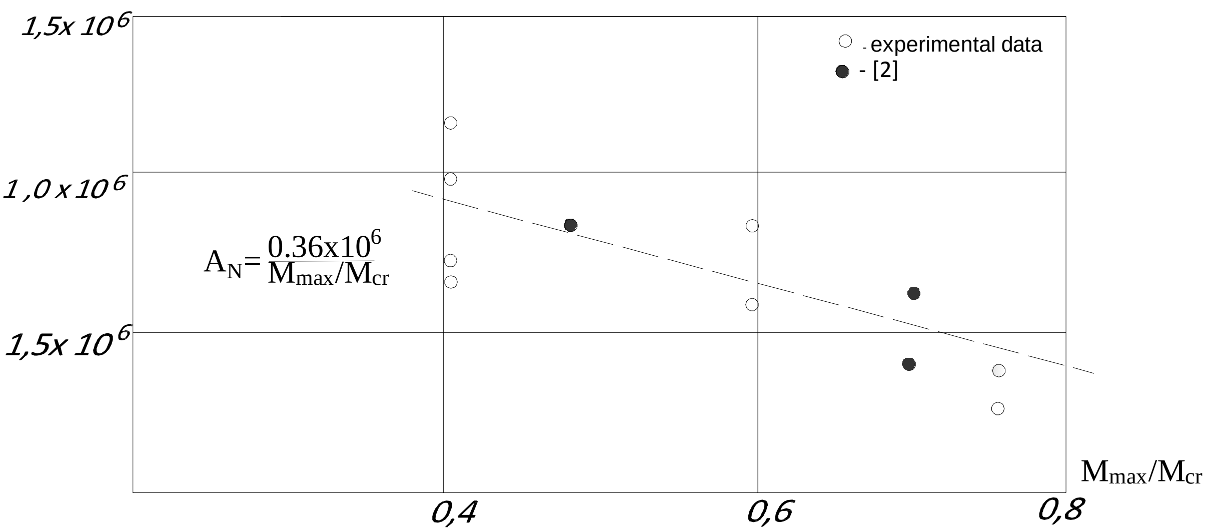

Fig. 3. The change in a_f depending on the level of loading M_{max}/M_{Cr}

The limiting deflection from constantly repeated loading is determined by the known formula:

$$f_{N_{cr}} = \frac{1}{\rho_{N_{cr}}} M_{max} \tag{4}$$

According to the parameters obtained above, it is possible to determine the value of the deflection f_N for any number of loading cycles N by the formula:

$$f_N = f_{cr} \frac{N}{a_f + N} \tag{5}$$

In the formula, the parameter a_f characterises the rate of accumulation of residual deflection under repeated loading and depends on many factors. The change in a_N determined from the results of processing the experimental data shown in Fig. 3, depending on the loading level of the beam M_{max}/M_{cr}. The change in the a_f parameter from M_{max}/M_{cr} is satisfactorily described by the expression:

$$a_f = \frac{0{,}36 \cdot 10^6}{M_{max}/M_{cr}} \tag{6}$$

Perhaps there is a connection from the asymmetry of the loading cycle, the mechanical characteristics of concrete and other factors. However, according to the available experimental data, such a link cannot be established. In the calculations, the number of loading cycles according to the actual throughput of the overpass is determined by this method [6]. For practical calculations, the increase in deflections over time can be established using the relationship:

$$\frac{t}{T_{res}} = \frac{N}{N_{cr}} \tag{7}$$

From here:

$$N = t \frac{N_{cr}}{T_{res}} \tag{8}$$

Combining formulas, we get:

$$f_N = f_{cr} \frac{tN_{cr}}{T_{res} a_N + tN_{cr}} \tag{9}$$

where:
N_{cr} - the number of loading cycles until the deflection of f_{cr} is reached;
T_{res} - the service life of the superstructure.

According to the obtained dependence, it is possible to determine the amount of deflection from the impact of a long-term load during operation. Full deflection for bending beams:

$$f = \frac{5ql^4}{384B} + f_{cr} \frac{tN_{cr}}{T_{res} a_N + tN_{cr}} \tag{10}$$

For the outer console slab:

$$f = \frac{ql^4}{3B} + f_{cr} \frac{tN_{cr}}{T_{res} a_N + tN_{cr}} \tag{11}$$

3. CONCLUSIONS

Thus, based on the processing of the available experimental data, dependencies are proposed for determining deflections under multiple-repeated loading and are obtained on this basis for predicting the residual life of elements of span structures [15]. The initial data for the calculations are the data on the accumulated residual deflections determined in the process of technical diagnostics.

Furthermore, it was established that one of the main factors that reduce the carrying capacity and residual life of elements of the superstructures is the accumulation of residual sags (sagging). It is shown that the main reason for the development of unacceptable deflections is the constant build-up of the carriageway with asphalt concrete pavement and salt corrosion of concrete and reinforcement.

References

1. Balevičius R. 2005. “Semi analytical modelling of reinforced concrete members in bending”.*Mechnika* 5(55): 32-40.
2. Bondarenko V.M., L.I. Iosilevsky, V.P. Chirkov. 1996. *Reliability of building structures and bridges*. Moscov: Publishing House of the Academy of Architecture and Construction.
3. Dell'Acqua, Gianluca, Mario De Luca, Carlo Giacomo Prato, Olegas Prentkovskis, Raimundas Junevicius. 2016. „The impact of vehicle movement on exploitation parameters of roads and runways: a short review of the special issue”. *Transport* 31(2) Special Issue: 127-132.
4. Kliukas R., R. Kačianauskas. 2005. “Comparison of global and local damage in reinforced concrete columns specimens”. *Mechnika* 4(54): 30-37.

5. Krayushkina Kateryna, Olegas Prentkovskis, Andrii Bieliatynskyi, Raimundas Junevičius. 2012. “Use of steel slags in automobile road construction”. *Transport* 27(2): 129-137.
6. Mamazhanov R. 1989. “Prediction of the process of damage accumulation in elements subject to regime loads”. *Bulletin of the Academy of Sciences of Uzbekistan. Series of technical sciences* 2: 22-25.
7. Mamazhanov R.K., R.Z. Nizamutdinova, O.I. Kildeva. 1996. “Results of inspection of railway reinforced concrete bridges”. *Materials of the International Scientific and Technical Conference*. Tashkent Automobile and Road Institute. P. 102-105.
8. Mazurkiewicz D. 2010. „Tests of extendability and strength of adhesive-sealed joints in the context of developing a computer system for monitoring the condition of belt joints during conveyor operation”. *Eksploatacja i Niezawodnosc – Maintenance and Reliability* 3: 34-39.
9. Mazurkiewicz D. 2014. „Computer-aided maintenance and reliability management systems for conveyor belts”. *Eksploatacja i Niezawodnosc – Maintenance and Reliability* 16(3): 377-382.
10. Michalski R., S. Wierzbicki. 2008. „An analysis of degradation of vehicles in operation”. *Eksploatacja i Niezawodnosc – Maintenance and Reliability* 1: 30-32.
11. Nizamutdinova R.Z. 1994. “Resource of reinforced concrete bridge spans on the railways of an industrial enterprise”. Tashkent Institute of Railway Engineers. *Thesis for the degree of candidate of technical sciences 05.23.15*. Tashkent.
12. Pokorny P., D. Dobias, M. Vokac. 2016. “Bond strength of hot - dip galvanized reinforcement (B500B) with concrete”. *Metalurgija* 55(3): 337-340.
13. Pokorny P., P. Tej, P. Szelag. 2016. “Chromate conversion coatings and their current application”. *Metalurgija* 55(2): 253-256.
14. *Recommendation for evaluating and ensuring the reliability of vehicles*. Moscov: TSNISK. 1989.
15. Saatova N.Z. 2019. “The method of calculating the deflections of the bent elements of the superstructure taking into account the actual state at the time of technical diagnostics”. *XXXXIII International Scientific And Practical Conference*. St. Petersburg. P. 89-96.

Received 01.08.2020; accepted in revised form 30.10.2020