**Structural Analysis of Load-Bearing Capacity of Reinforced Concrete Bridges Containing Defects**

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**Abstract.** The article presents a calculation method for reinforced concrete bridge spans taking into account the changed rigidities of the constituent elements, since, as practice shows, during the operation of bridge structures, defects accumulate in the roadway slabs and beam ribs. The calculation algorithm uses the methods of elastic supports and determining the share of temporary transport load falling on each main beam of bridge span. The bearing capacity of a two-span bridge with precast T-shaped beams with a lower flange is calculated for the impact of excess heavy transport load.

**Keywords:** Bridge, transport load, span, T-shaped beam, calculation method, algorithm

# INTRODUCTION

The service life of bridge structures depends on many factors: the quality and installation of the structure, operating conditions, maintaining the structure in good condition and timely repair work. Analysis of the work performed shows that most existing reinforced concrete road bridges and overpasses have unsatisfactory load-bearing capacity for the following reasons [1, 2]: excessive corrosion of reinforcement; change in temporary loads; rapid development of defects.

Based on the analysis of the work, the following data can be provided, confirmed by experimental studies conducted to study the condition of beams of typical span structures [3, 4]:

1. Destruction of the protective layer along the entire height of the beam leads to a decrease in rigidity.

2. Vertical cracks with an expanded bottom, located in the lower part of the beams, negatively affect the bearing capacity and, consequently, the rigidity;

3. The destruction of concrete leads to a change in the cross-sectional area, moment of inertia, bearing capacity of the beam and, consequently, its rigidity.

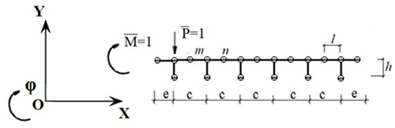
Currently, there is no unified approach to the methodology for taking into account the parameters of rigidity of reinforced concrete elements of bridges, since, as practice shows, during the operation of bridge structures, defects accumulate in the roadway slabs and ribs. Naturally, all this, as well as the variability of the rigidity of the ribs and slabs, affects the spatial behavior of span structures. The need to solve the problem is associated with the joint operation of the span beams and the roadway slabs as elements of a single spatial system subject to deformations under the action of a vehicle load.

**METHODS**

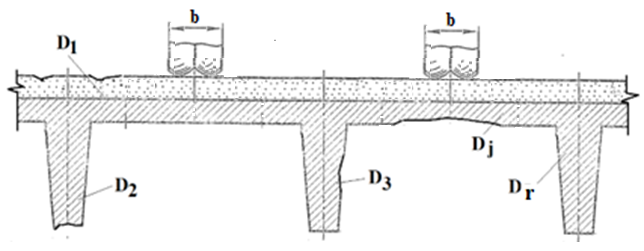
Let's consider the reinforced concrete span structure of the bridge, which can consist of various ribbed girders with the number r . To do this, we cut across the span a transverse strip of unit width 1m, and use the principle of the method of elastic load distribution between girders [5], where the span structure is considered as a slab supported on elastic longitudinal strip supports, which are girders. After obtaining a framed system, we further divide this system into n nodes and m beam elements (Figure 1).

Here the span structure may have certain defects and damages, which will be reflected in the rigidity indicators of its elements, for example, after several years of operation, the rigidity of the beams in different sections of the span structure has become different , i.e. and (Figure 2).

Where is the modulus of elasticity and the moment of inertia of a separate section of the roadway slab; is the stiffness of a separate section of the main beam. In the longitudinal direction, some individual main beams also have modified stiffness parameters, such as the cross-sectional area or the modulus of elasticity. To determine the internal forces, as well as the deflections in the main beams of the span structures, it is necessary to draw up calculation schemes for various options for supporting individual beams.



**FIGURE 1.** Continuous framed system of transverse strip



**FIGURE 2.** Various possible rigidities of elements of span structures due to defects and damages

The initial data for determining the forces are the prepared values of the Load distribution coefficients (LDC), while the share of the temporary transport load falling on each main beam of the span structure is determined using the given method [6]. In this case, the features of the distribution of loads between the beams depend on the transverse rigidity of the span structure. If we use the finite element method, the rigidity parameters are very easily specified within individual elements [7].

To determine the LDC, for each girder, it is necessary to determine influence line of the pressure (reactive force) R resulting from the unit combined vertical load and bending moment 1 applied to the continuous slab consoles (Figure 1). After dividing the beams of span into finite elements, it is necessary to form a vector of external vertical forces arising from transport and constant loads at each node of the system, taking into account the values of the corresponding LDC:

(1)

Each node can have three displacements in the vector:

(2)

The total displacements generated at **n** nodes can be expressed as**:**

(3)

According to the variation principle of Lagrange [8, 9, 10] it is possible to form a 3n system of linear algebraic equations:

=0 (4)

Then, the system of equilibrium equations (linear algebraic) of the problem can be expressed in the following form:

(5)

The matrix K in the system of equations is a quasi-diagonal matrix consisting of blocks of matrices of beam elements:

(6)

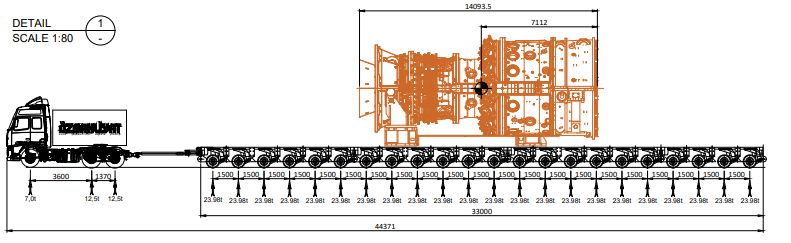
The proposed method of spatial calculation taking into account the probability of change in the rigidity of the elements of the beam span structure allows us to estimate the deformation of the span structure as a macrostructure both in the longitudinal and transverse directions when temporary transport loads are located in it in various ratios.

**NUMERICAL RESULTS AND ANALYSIS**

Let's calculate the load-bearing capacity of a two-span bridge for heavy loads. The bridge was built approximately in 1970-1973. In this case, in the cross-section, the span structure consists of six T-section beams with non-stressed reinforcement, with an estimated length of 8,4 m. The beams are connected to each other using reinforced concrete joints at the level of the roadway slabs with a thickness of 15 cm. The height of the beams in the spans is 70 cm. The distance between the beam ribs is within 165-168 cm. The material of the span structure is reinforced concrete with class B25. During the inspection of the bridge, the following defects were found: the surface of the roadway has potholes on the asphalt concrete pavement, and in areas of expansion joints. The waterproofing has lost its protective properties during operation. This is confirmed by the presence of concrete leaching on the supports and the joints of the beams of span. The handrails are loose; the edges of the sidewalks and curbs are half destroyed (Figure 3).

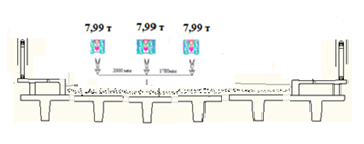


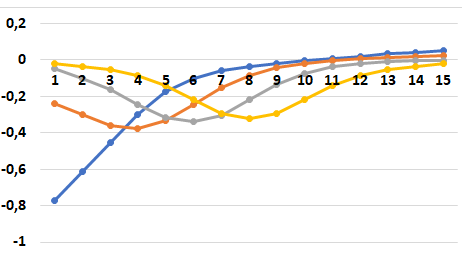
**FIGURE 3.** General view of the bridge with defects



**FIGURE 4**. The scheme of excess load from oversized vehicle

The temporary load is considered as the excess load from oversized vehicle (Figure 4). The total load equal to 527,5 t is distributed in the longitudinal direction through the axial lines with a quantity of 22 pieces at a distance of 1,5 m each. In this case, each axle bears a load of 23,98 t. In the cross section, the load is divided into three concentrated forces equal to 7,99 t (Figure 5).





**FIGURE 5.** The line of influence of pressure per unit length of the span structure, obtained using the elastic support method

The average value of load distribution coefficients from one load strip will be as for a three-axle bogie installed in the middle of the span structure is LDCAT = 0,321. Taking into account the pressure on the axle of oversized vehicle РАT = 23,98 t, the intensity of this load taking into account its distribution over the length between the axles of the trailer of 1,5 m is qAT = 15,99 tm. The calculated moment from the temporary load is determined by the formula:

- area of the line of influence.

Now we find the permissible axle load

The load passes, since 28,297 t>23,98 t, only if repair and strengthening work on the bridge is carried out.

**CONCLUSION**

The analysis of the condition of artificial structures shows that most existing reinforced concrete road bridges and overpasses have unsatisfactory load-bearing capacity due to excessive corrosion of reinforcement and destruction of concrete leading to a change in the cross-sectional area, moment of inertia, and therefore, rigidity. structures of beams of superstructures. To determine the possibility of distributing the impact of transport loads in the studied reinforced concrete superstructure of bridges, taking into account the existing defects, a mathematical model is proposed that describes the behavior of beams and decking as interconnected elements of a single common system subject to deformations under the action of transport loads. A calculation method has been developed for solving the problem associated with the joint work of span beams and roadway slabs as elements of a single spatial system subject to deformations under the action of a load from a vehicle.

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