Determination of the technical condition of the metal bridge with wood covering

M O Karpushko¹, I L Bartolomei², E N Karpushko³, A V Zhidelev⁴

¹, ²Perm National Research Polytechnic University, 29, Komsomolsky prospekt, Perm, 614990, Russia
³Volgograd State Technical University, Institute of Architecture and Civil Engineering (IACE of VSTU), 1, Akademicheskaya st., Volgograd, 400074, Russia
⁴Branch «Vzlet» of Moscow Aviation Institute (National Research University), 5, Dobroljubova st., Akhtubinsk, 125993, Russia

E-mail: mkarpushko@gmail.com

Abstract. At present, the age of most transport facilities in the Russian Federation estimated by many decades, and most require reconstruction or repair. Consequently, there is an urgent need for periodic surveys and monitoring of the condition of such facilities. The main goal of these measures is to maintain high rates of transport infrastructure efficiency, the achievement of which is impossible without examining, analyzing and evaluating parts of the structure in the aquatic environment, and, as a result, the occurrence and development of various defects and damage. The most important conditions for ensuring uninterrupted and safe traffic on the bridges of vehicles and pedestrians are the regulatory bearing capacity of the structure and cleaning of the roadway and sidewalks. Then compliance with traffic safety requirements on decks and observing the characteristics and maintaining the function of the bridge for the period of ice drift and flooding. Timely execution of works for the care, maintenance, and repair of bridge elements. Technically stable structures and their reliability can be ensured by observing all the parameters of the structure of the road category and the requirements of regulatory documents. The paper presents the materials of the inspection of the bridge after repair — defect classification by groups and hazard classes — the results of determining the carrying capacity of the survey materials given.

Introduction
The problem of the technical condition of road bridges in the Perm Krai, as well as in the whole territory of the Russian Federation, is very relevant. According to statistics, there are about 300 bridges in the region [23, 24]. More than ten from the total number are in disrepair, travel on which is unsafe. Increasing the durability of bridges requires regular ongoing, periodic, and special inspections, which will contribute to a significant reduction in the number of bridges that need rebuilding, reconstruction, and repair.

Problem statement
On 5 + 650 km of the highway "Bashino-Biktulka" of the Oktyabrsky District of the Perm Krai, there is a bridge over the river Iren. At this picket the complex of repairs was carried out in accordance with the following list: dismantling of one-sided barrier fencing, removal of wooden floor coverings,
takedown of welded steel railings, dismantling wooden spans, installing metal beams, installing wooden spans, wooden planks and unilateral barrier fencing, and device of the coatings of the plank (Fig. 1).

The location of October district is in the south-east of the Perm Krai region with an area of 3 444.4 square kilometers or 2.15% of the whole province. The most of the Oktyabrsky district belongs to the subzone of the Volga-Kama transient broad-leaved taiga forests. The relief is predominantly hillside - the hills and ridges reach a height of 200-300 m, karst forms of landform developed. The climate of the territory is moderately continental with a cold long and snowy winter, warm and short summer, and frequent spring frosts. The average monthly temperature in January is -14.9 °C, July + 18.7 °C. The annual precipitation is 450-600 mm. The average duration of snow cover is 170-180 days. The yearly average wind speed 3-6 m/s.

Irene is a river in the Perm Krai region. It is the left tributary of the Sylva river [4, 5, 18, 19, 22], which starts in the south-east of the region to the south-west of the village of Verkh-Iren in the Oktyabrsky district. It flows through the territory of not only Oktyabrsky district but also Uinsky, Ordinsky and Kungur districts. Iren river falls into Sylva river within the city of Kungur. The length of the river is 214 km, and the area of the basin is 6110 square kilometers. The average catchment height is 232 m. The average slope is 0.4 m/km. Main left tributaries are Uyas, Small Tart, Big Tart, Aspa, Syp, Small Ashap, Kaltagiz, Big Ashap, Turka, Bym. Right- Upper Bartym, Tyush, Ariy, Kuryas, Telles, Sudinka, Kungur. The shores of Irene are mostly low and covered with shrubs. On the banks, there are rocks up to 50 m high. The bottom of Irene is primarily sandy and pebble, and in some places - ordained and clay.

The length of the river is 214 km; the basin area is 6110 km². The average height of the catchment is 232 m. The average slope is 0.4 m / km. Main tributaries: left: Uyas, Small Tart, Big Tart, Aspa, Syp, Lesser Ashap, Kaltagiz, Big Ashap, Turka, Bym. Right: Upper Bartym, Tyush, Arius, Kuryas, Teles, Sudinka, Kungur. The banks of the Iren are mostly low and covered with shrubs. On the banks, there are cliffs up to 50 m high. Along the right bank of the river passes the Irenska Ridge, consisting of limestone, and therefore the water in the river has rather high rigidity. The bottom of Iren is mainly sandy and pebbled, and in some places silty and clayey.

Figure 1. General view of the bridge

The top cover of the deck is in the form of double plank flooring on the crossbars. Drainage from the road and sidewalks is carried out by gravity due to the slopes to the edges of the bridge. The roadway is separated from the paths by a metal barrier fence — railing on the sides of the bridge - metal. Adapter plates are made to connect the bridge ride track with the roadway.

Following [1, 2, 3, 6, 9, 11], when accepting for commissioning, all bridges should be inspected. The main task of examining bridges before putting them into operation is to establish the conformity of the structures with the approved project and the requirements of the current regulatory documents.
By decision of the operating organization, it was justified to survey to eliminate concerns for the reliability of the structures put into operation after bridge repair.

**Theoretical part**

Survey results determined that the bridge in the longitudinal direction was made 5-span with a pitch of 8.70 + 6.48 + 7.68 + 7.78 + 10.60 m, a transverse scheme of six beams at a distance of 1.42 * 5 m. Steel pipes with a diameter of 530 mm and a wall thickness of 8 mm, combined into a continuous system, form the span structures.

In the spans No. 1 and No. 2, the pipe joint made with a one-sided seam. In the spans No. 3 and No. 5, the docking of the pipes was made by welding with a 30 cm wide lining. The static system of spans is beam-continuous. Bearing beams on supports - articulated. The main parts of the beams on the abutments are pipes, which stand from 10.00 cm to 33.00 cm. Double plank flooring on the crossbars serves as upper pavement.

Defects identified in the span structures. The height of the railing is 1.00 m. Following paragraph 5.62 [10], on the outside of the superstructure, sidewalks and service aisles are fenced with a railing at least 1.1 m high. The identified safety malfunctions can attribute to the first category, S1.

Bridge supports single-row metal piles. The abutment made in the form of log support.

The number of racks in the support - five pieces. The size of the extreme frames - diameter 320 mm. Internal shelves are 170 mm in diameter. Bolt's diameter is 170 mm and a length of 9.61 m. The abutment made in the form of bed support, the size across the bridge is 10.10 m, along 0.67 m. Defects identified in the supports and recommendations for eliminating them shown in Table 1.

| Location                  | Description of the defect or damage                                      | Method to eliminate the fault or damage                              | Defect category |
|---------------------------|--------------------------------------------------------------------------|---------------------------------------------------------------------|-----------------|
| Bridge footing №1, №6    | Concrete surface damage, bare reinforcement. Cracks                       | Remove loose areas of concrete. Clean the reinforcement elements from corrosion products. Fill the defective places with repair compound | D2, CC1         |
| Bridge footing №2, №3, №4, №5 | Various deviations of the piles from the vertical in the pile supports (Piling without the conductor and guiding devices) | Pose no hazard to life, repair not required                         | D1              |

By durability, according to [1, 21], the construction of bridge footings can be attributed to the second group. The category of detected defects relates mainly to CC1, D2.

Type of regulatory structures is embankment cone made of sand-and-gravel.

The survey established that a part of the cone of the dam had been washed out and the shores were overgrown with vegetation.

By durability, according to [1, 21], design approaches, cones, regulatory structures can be attributed to the first group. The category of detected defects relates to D1.

**Calculation results**

Determination of the actual load capacity of the span structures of road bridges is performed using the recalculation method using the normative method described in ODN 218.0.032–2003 “Interim Guidelines for Determining the Load Capacity of Bridge Structures on Highways” and includes four stages [7, 8, 12-17].

1° stage. The definition of the limiting bending moment $M_{ult}$, taking into account the actual state of the main carrier element of the superstructure, according to the following formula:
\[ M_{\text{ULT}} = W_f \cdot R_\gamma \cdot m = 1686 \cdot 10^{-6} \cdot 372,8 \cdot 0,9 \cdot 1 = 565,6 \text{ kN m} \]  

where \( W_f \) is the actual moment of resistance of the main bearing element of the pipe 530x8; \( R_\gamma \) is the calculated resistance to bending of the material, 38 kg / mm\(^2\); \( m \) - reducing factor taking into account the defects that reduce the load capacity equal to 1.

The actual state of the bearing element determined by the actual geometrical parameters of the cross section and the actual strength of the material.

2\(^{nd}\) stage. Determination of the bending moment from the constant load \( M_{\text{const}} \), which is determined by its weight of the elements of the superstructure per one main bearing element, according to the formula:

\[ M_{\text{const}} = \frac{q_{dl} \cdot L_p^2}{8} = \frac{3,68 \cdot 10,6^2}{8} = 51,6 \text{ kN m} \]  

Where \( q_{dl} \) is the intensity of the dead load of the elements of the superstructure - both the most important carrier element and its dead weight from the elements of the bridge bed and the coating layers. The dead weight of the elements falls on one main supporting element of the superstructure.

3\(^{rd}\) stage. The limiting value of the bending moment from the live load is determined by the following formula:

\[ M_{\text{LL}} = M_{\text{ULT}} - M_{\text{const}} = 565,6 - 51,6 = 514,0 \text{ kN m} \]  

4\(^{th}\) stage. The value of class \( K \) is determined when the span structure loaded with the standard vehicular load (VL) or the \( R_{\text{NV}} \) value per axis is determined when the span structure loaded with a single normative vehicular (NV) load. Regulatory loading schemes along and across the superstructure must fully comply with the requirements [10]. The following formula determines the value of class \( K \):

\[ K = \frac{M_{\text{LL}}}{(1+\mu)_{\text{VL}}\left[\text{TSR}_{\text{AT}} \cdot \gamma_f^T \cdot 2 \cdot Y^A + \text{TSR}_{\text{NV}} \cdot \gamma_f^T \cdot 0,1\gamma\right]} = \frac{514,0}{533,65} \cdot 11 = 10,6 \text{ (t)} \]  

The formula determines the amount of \( R_{\text{NV}} \) per single load axis:

\[ R_{\text{NV}} = \frac{M_{\text{LL}}}{(1+\mu)_{\text{NV}} \cdot \text{TSR}_{\text{NV}} \cdot \gamma_f^N \cdot \sum^i Y_i^N} = \frac{514,0}{3,42} = 150 \text{ kN} \]  

Where \((1+\mu)_{\text{NV}}\) is the dynamic coefficient, according to the requirements of [10], is assumed to be 1.1. \( \text{TSR}_{\text{NV}} \) is the coefficient of transverse installation of a single load, which is determined by the line of influence of the most loaded carrier element constructed using a lever or an eccentric compression [10]. \( \gamma_f^N \) - the reliability coefficient for a single load, according to the requirements of [23], is assumed to be 1.0. \( Y_i^N \) - ordinates under the wheels of a four-axle bogie on the curve of the bending moment. The value of a single load is:

\[ NV=4\cdot R_{\text{NV}}= 600 \text{ kN} \]  

Thus, the bearing capacity of the beams, taking into account the actual condition of the bridge structure, allows the passage of an automobile load according to the VL circuit with the load class \( V = 10 \), a single wheel building according to the NV scheme with the class \( V = 8 \).

LOADING CAPACITY (permissible total and axial mass of the vehicle):

In the stream - total: 20 tons, axial: 10 ton.
In single order - total: 60 tons; axial: 15 ton.

Inspection of structures showed that the category of faults could be attributed mainly to S1, CC1, D1, D2.

Evaluation of the technical condition was carried out following the requirements [10, 20] taking into account the actual state of the building structures, the parameters of the detected defects and damage, their effect on the reduction of the carrying capacity and reliability.

Table 2 gave the results of the evaluation of the technical condition of the building structures.
Table 2. Evaluation of the technical condition of building structures

| №  | State assessment       | Characteristic       |
|----|------------------------|----------------------|
| 1  | Durability             | Four category        |
| 2  | Safety                 | Four grade           |
| 3  | Overall score according to VSN 4-81 | 4 points |

A survey of building structures revealed omissions that require correction. Elimination of these drawbacks will ensure the regular operation of the surveyed object. If you do not eliminate the observations identified during the survey, then the combination of adverse factors may lead to loss of the bearing capacity of the structures.

For structures with malfunctions belonging to the second category, the repair and restoration work is possible with the restriction of their operation. The organization operating the facility should provide the following activities.

- Outline an action plan to correct the comments indicated in the report.
- Carry out work to eliminate defects and damages revealed during the examinations following the recommendations given in this report.
- Confirm the quality of the work performed to remove errors and damages by appropriate acts.

The maintainability category of most of the identified defects is not lower than R2.

Summary

With the timely conduct of inspections of facilities and the organization of repair work, it is possible to avoid the development of a significant number of defects and damages in the construction elements of bridges, many of which can later lead to accidents and catastrophes [25]. To date, there are still a lot of unlit and undeveloped issues in the field of monitoring the safe operation of bridges, which is impossible without periodic surveys and monitoring of their condition.

References

[1] Inspection Guidelines to Road Overpasses and Underpasses (VSN 4-81), Ministerstvo avtomobil'nyh dorog, RSFSR, Transport, Moscow, 1990.
[2] Buildings and constructions. Rules of inspection and monitoring of the technical condition: internal standard GOST 31937-2011: ed. Official, Standardinform, Moscow, 2014.
[3] Automobile roads of the general use. Standard loads, loading systems, and access approach: national standard of the Russian Federation GOST R 52748-2007, Standardinform, Moscow, 2008.
[4] Town Planning Code of the Russian Federation. Dated December 29, 2004, N 190-FZ (as amended on December 31, 2017).
[5] Information on http://www.en.wikipedia.org/w/index.php?title=Iren_River&oldid=817922393.
[6] ODM 218.4.001-2008 Guidelines for the organization of the survey and testing of bridge structures on highways. Rosavtodor, Moscow, 2008.
[7] SP 22.13330.2011 Soil bases of buildings and structures. The updated version of SNiP 2.02.01-83 * "(approved by order of the Ministry of Regional Development of the Russian Federation dated 12.28.2010 N 823).
[8] SP 70.13330.2012 Load-bearing and separating constructions. The updated version of SNiP 3.03.01-87" (approved by order of Gosstroy of 12/25/2012 N 109 / ГС) (as amended on 26.12.2017).
[9] Requirements for Inspection of Load-Bearing Structural Elements of Buildings and Structures SP 13-102-2003, Publishing house Dean, (GPP Pech. Dvor), SPb, 2004.
[10] SP 35.13330.2011 Set of rules. Bridges and culverts. The updated version of SNiP 2.05.03-84*. Ministerstvo regional'no razvitiya Rossijskoj Federacii, Moscow, 2016.
[11] SP 79.13330.2012 Bridges and culverts. Rules of examination and test. The updated version of SNiP 3.06.07-86, Ministerstvo regional'no razvitiya Rossijskoj Federacii, Moscow, 2016.
[12] SP 14.13330.2014 Set of rules. Seismic Building Design Code. SNiP II-7-81* (approved by order of the Ministry of Construction of Russia dated 02/18/2014 N 60 / pr) (as amended on 11/23/2015).
[13] Loads and actions: rulebook: an updated version of SNiP 2.01.07-85. Standardinform, Moscow, 2017.
[14] Protection against corrosion of construction: rulebook, Standardinform, Moscow, 2017.
[15] ODM 218.4.025-2016. Industry road guidance document. Guidelines for determining the carrying capacity of operated bridge structures on public roads. General part (issued based on the Order of the Federal Road Agency of Ukraine on 09.11.2016 N 2322-p).
[16] ODM 218.4.027-2016. Industry road guidance document. Recommendations for determining the carrying capacity of operated bridges on public roads. Metal and steel-reinforced concrete structures (issued based on the Order of Rosavtodor of 09.11.2016 N 2326-p).
[17] ODN 218.017-2003. Industry road standards. Guidelines for assessing the transport and operational status of bridge structures (approved by order of the Ministry of Transport of Russia NOS-198-p dated March 26, 2003).
[18] Information on http://www.textual.ru/gvr/index.php?card=181023 (circulation date: 12/21/2018).
[19] Information on http://www.permkrai.ru/program/object/?id=563858&tab=description (appeal date: 12/21/2018).
[20] SP 16.13330.2011. Set of rules. Steel construction. The updated version of SNiP II-23-81 * (approved by Order of the Ministry of Regional Development of the Russian Federation dated 12/27/2010 N 791) (as amended on 12/30/2015).
[21] Reference aid to the road (pavement) master on the maintenance of bridge structures on highways, GP ROSDORNI FDS of Russia, Rosavtodor, 1999
[22] The national planning scheme of the October municipal district of the Perm region. 29 - 2007 – PZ, Perm, 2008.
[23] Federal law of 09.02.2007 N 16-FZ (as amended on 07.06.2016) "On transport security."
[24] Federal Law of 30.12.2009 N 384-FZ (as amended on 02.07.2013) "Technical Regulations on the Safety of Buildings and Structures."
[25] Karpushko M O, Bartolomei I L, Karpushko E N 2018 Determination of Technical Condition of a Bridge Structure Based on Survey Results (Materials Science Forum) 931 643-648. DOI: https://doi.org/10.4028/www.scientific.net/MSF.931.643