

Maintenance particulars of bridges and pipe culverts on major traffic arteries located in the North climatic zone of the Asia Pacific region

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Abstract. The research data of the technical state of bridges that are built and maintained in the North climatic zone of the APR is set forth in the article. The impact of climatic, environmental, and geotechnical aspects, as well as engineering and maintenance procedures on the technical state of artificial structures is analyzed. To ensure health and serviceability of artificial structures, monitoring of their state and temperature survey of permafrost subgrade soils along with predicted heat engineering calculations during maintenance term are to be carried out.

1 Introduction

A great number of long-distance stretches of traffic arteries located in the Asia Pacific Region of Russia are maintained in severe climatic conditions, including areas of permafrost. They encompass railway lines built in the Far East and Trans-Baikal– the Chita and Amur Regions, the Khabarovsk Territory, and the Republic of Sakha Yakutia.

Such artificial structures as bridges, tunnels, pipe culverts, supporting walls, foundation galleries, etc., – are known to take up a significant position in the arrangement and development of main traffic arteries. The technical state and maintenance reliability of engineering structures are to a considerable extent responsible for the normal working operation of communication routes, i.e. providing the required carrying capacity and optimum vehicle speeds. It should be noted that the most numerous artificial structures built on main traffic arteries are small and midsized bridges, as well as pipe culverts.

2 Target and results of research

Based on long-term experience (from 1900 to 2000) of using and maintaining artificial structures on the Far East, Trans-Baikal, and Baikal-Amur Railway Lines located in the areas of severe climate we can state that numerous cases of their technical failure are caused by rapidly developed deformations and structural deterioration [1,2].

According to the data obtained due to on-site inspections and surveying of structures by bridge testing laboratories and FESTU engineers, the amount of damaged small and midsized bridges accounts for 14 – 16 %, and the amount of unhealthy pipe culverts accounts for 35 –

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40 % of the total number, respectively. It is 1.5 or even twice as much as compared to the number of similar structures on traffic arteries located in the areas of moderate climate.

The analysis and evaluation of deformations in small and mid-sized structures located on the Far Eastern Railway have revealed the main types of damages affecting the technical state of artificial structures:

1. in conditions of the northern construction-climatic zone:

- subsidence of supports, longitudinal and transverse rolls of the bridge axis, support rolls combined with pinching of bridge spans;
- displacement of bridge spans along the bridge axis aggravated by jamming;
- insufficient expansion joints of bridge spans, abutment of bridge spans to backwalls and to each other;
- jacking and tilting of the abutment backwalls that result in crack formation;
- frost deterioration of concrete masonry of bridge spans and supports;
- deviation from specified arrangement and configuration of the upper and lower slabs of the bridge bearing supports.

2) in moderate climatic conditions:

- jacking of the abutment backwalls that result in crack formation;
- frost deterioration of concrete masonry of bridge spans and supports;

The following major reasons account for the development of various deformations and damages of bridges maintained on the Far Eastern Railway:

- degradation of permafrost subgrade soils;
- processes of frost boil of the ground soils;
- extremely low temperatures and frost deterioration of concrete and reinforced concrete structures;
- violation of standard building procedures and job practices.

As can be seen from the above, the technical state of artificial structures in field conditions has revealed a strong momentum to buildup of destructive processes [1 – 6]. This tendency is most typical of extreme maintenance conditions in the areas of severe climatic conditions (table 1).

Table 1. Proportioning of unhealthy and damaged artificial structures according to the climatic zones of the Asia Pacific Region.

Climatic Zone	Types of Structures	The Total Number of Surveyed Structures	Unhealthy or damaged Structures (%)	Technical, Natural, And Climatic Particulars according to Climatic Zones
Severe Climate	bridges	821	41.0	PSS; DSF; FH; GIM; LT; AAT T lower than 1°C soil freezing more than 3.0 m deep
	culverts	1,071	57.0	
Cold Climate	bridges	2000	33.0	DSF; FH; AAT T lower than 0°C soil freezing more than 3.0 m deep
	culverts	320	38.0	
Moderate Climate	bridges	398	18.2	AAT T higher than 0°C soil freezing less than 3.0 m deep
	culverts	221	22.0	

Notes: 1. The following abbreviations are used in the Database Table: PSS – permafrost subgrade soils; DSF – deep seasonal freezing of subgrade soils; FH – frost heave of subgrade soils; GIM – ground ice mound in the area of construction; LT – low temperatures of external air (–30°C and lower) during the coldest five-day period; AAT – average annual temperature of external air. 2. The number of unhealthy and damaged structures is established for the average maintenance period of 45 years.

The evidence presented on the amount and proportioning of unhealthy and damaged artificial structures located on the traffic arteries in severe climatic regions indicates the dominant influence of specific climatic, environmental, and geotechnical aspects on the technical state of engineering structures.

The following geotechnical and climatic aspects exercise the decisive and lasting influence on the service ability of such structures as bridges and pipe culverts [2, 4]:

- permafrost soils;
- deep seasonal soil freezing;
- low annual temperatures of external air;
- meteorological precipitation and drain;
- water stagnation;
- snow deposition;
- ground ice mound;
- solar radiation and wind.

Actually, permafrost soils hold a unique position among the aspects mentioned above, since they form foundation beds for artificial structures [7]. Temperature conditions of permafrost soils determine in a great measure the stability of artificial structures. Therefore, while designing, building, and maintaining bridges and pipe culverts it is necessary to evaluate, anticipate, and forecast the thermal stability of permafrost subgrade soils in respect to the influence of climatic, environmental, and geotechnical aspects, as well as structural engineering particulars and building production techniques (figure 1).

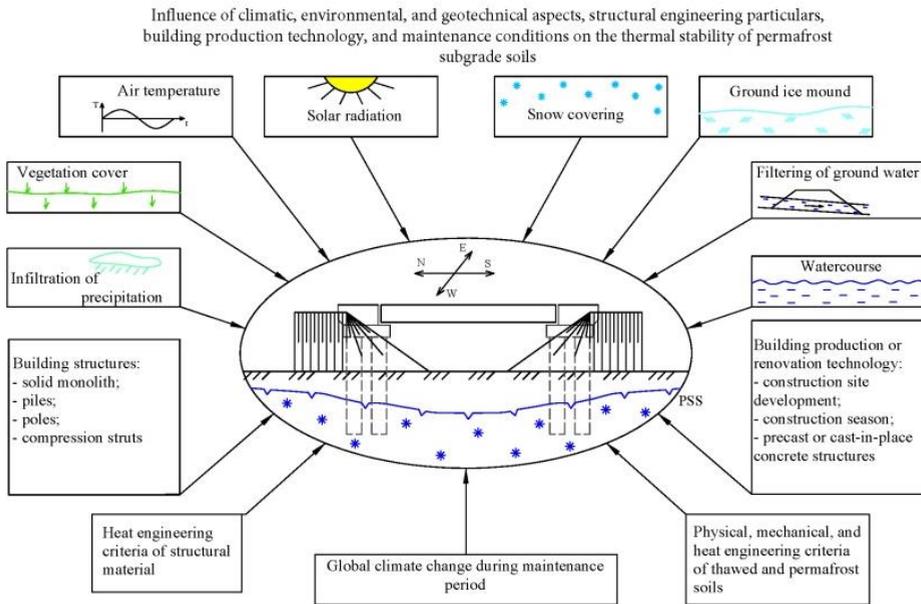


Fig. 1. Influence of climatic, environmental, and geotechnical aspects, structural engineering particulars, building production technology, and maintenance conditions on the thermal stability of permafrost subgrade soils.

A number of researchers are sure that the most important characteristic determining the normal behavior and operation of bridges, which are maintained in the Northern climatic zone, is the interaction of bridge foundations with permafrost soils. Temperature fluctuations of permafrost soils determine, to a great extent, the stability or susceptibility of artificial

structures to deformations and, in the long run, to massive fracture or irreparable deterioration.

To substantiate this thesis, a comparative analysis of the technical state of small and mid-sized bridges maintained on the Far Eastern Railway lines has been performed. To this aim, the following materials of full-scale bridge surveys have been used:

- Records on periodic inspections of artificial structures carried out by bridge testing laboratories of the “Center for Diagnostics and Monitoring of Far Eastern Railway Infrastructure” in 2004-2016;
- Surveys performed by the staff of the “Bridges, Tunnels, and Underground Structures” Department of the FESTU in 2007-2013;
- Reports on scientific research work for monitoring artificial structure conditions carried out by the employees of the Tynda Permafrost Station in 1989-2009.

For comparative analysis of the technical state of bridges, the structures with bridges support deformations have been selected. These damaged structures have defects of second and third categories. In accordance with the RZD Instruction, artificial structures of the categories mentioned above must undergo either a massive building renovation or a total reconstruction. As a rule, those are bridges that have subsidence, jacking and tilting of supports, longitudinal and transverse rolls of the bridge axis line, horizontal shear of spans, and zero expansion gaps.

The data on the technical condition of small and medium-sized bridges maintained in severe and moderate climatic conditions are presented in the diagram below.

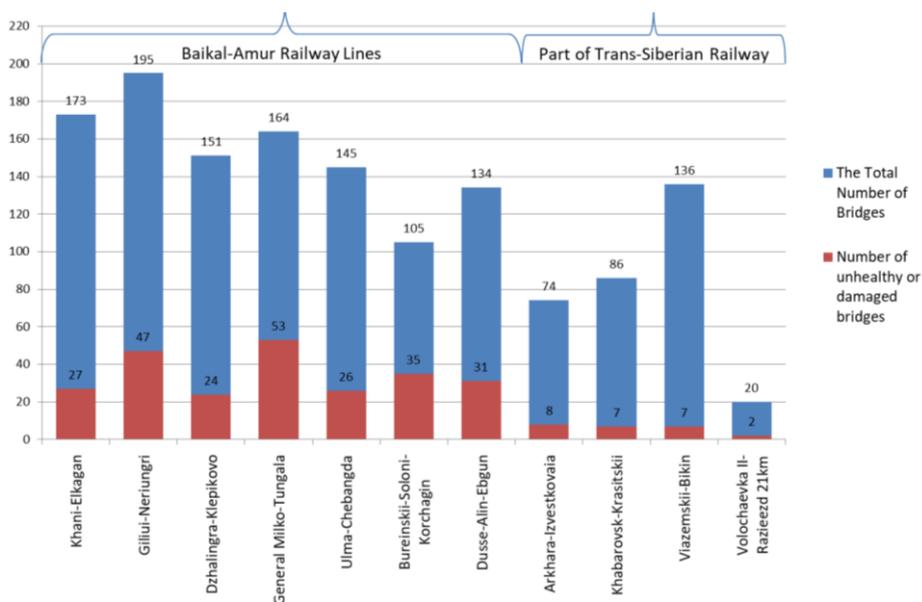


Fig. 2. Summary data on the comparative analysis of the technical condition of small and medium-sized bridges maintained on the Far Eastern Railway.

Based on the analysis of the tabulated data, we can come to the following conclusions:

1. The number of damaged bridges located in the northern construction and climatic zone is 2-4 times higher than that in moderate climatic conditions;
2. The main reason for the intensive development of bridge deformations in areas of severe climate is temperature variance of the permafrost soils of support foundations;

3. During the recent 70 or 90 years, there has been observed a strong tendency towards global warming. This phenomenon can lead to the persistent increase of temperature and, as a result, to the degradation of permafrost soils;

4. With that knowledge in mind, there is a high probability of increasing imperfection of artificial structures. Therefore it is necessary to predict this process and plan in advance efficient and anticipating measures that allow stabilizing temperature regime of permafrost foundation soils of bridge supports.

It has been established by observation and experience that the most widely used railway artificial structures – bridges and pipe culverts – refer to the most complicated and expensive track facilities. Their reliability and failure-free operation contribute much to positive maintenance and economic criteria of railways and highways.

The ever-increasing deterioration and failure of engineering structures maintained in severe climatic condition have always been and still remain issues of immediate significance. Unfortunately, short age of financial and human resources prevents performing in full measure major repairs or partial renovation of artificial structures.

3 Conclusions

To provide adequate long-term serviceability of artificial structures, the following procedures are of vital necessity:

- monitoring and controlling the technical state of engineering structures, updating the data on bridge and pipe culvert carrying capacities, especially with allowance for the development of faults and troubles;

- applying mathematical modeling techniques to the heat exchange process in the system “artificial structure – permafrost foundation bed”, considering the most significant environmental, climatic, structural, and technological aspects, as well as man-made impacts.

These data will open up opportunities for performing timely analysis and long-range forecast concerning the technical state of such engineering structures as bridges and pipe culverts. In addition, it will ensure optimum scheduling of maintenance, repair, refurbishment work, and volume of expenditures intended for short-term (3 – 5 years), medium (7 – 10 years), and long-term (15 – 20 years) perspectives.

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