

Safety of Railway Transport Facilities Operating in Extreme Climatic Conditions

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Abstract- Railway facilities in the Northern territories of Russia are built and operated in the areas of the cryolithozone and low climatic temperatures. Railway transport in the Republic has been operating since 1979. In 2004, a 360 km long highway to Tommot was built. Passenger and cargo transportation to Tommot station has been carried out since 2006. In 2014, the Tommot - Nizhny Bestyakh section was built with a length of more than 400 km. Currently, intensive preparation of the construction of the Berkakit-Yakutsk-Magadan railway is underway in Yakutia. However, railway transport is one of the potential sources of emergency situations with a large number of victims, significant material damage and adverse environmental consequences. Accidents and emergencies at railway transport facilities are caused by the complex natural and climatic conditions of the region, violation of technical and technological regulations during construction and operation, factory defects of structures and materials, dangerous natural and climatic phenomena, degradation of the cryolithozone and interaction of technological elements and objects with the natural environment, human factor. This article presents an analysis of the main risk factors of railway transport facilities under construction and operating in the extreme conditions of the North. To ensure the the necessary indicators of reliability and durability of components and assemblies of railway equipment operating in cold climates, a regional technical regulation is developed for the operation of railway rolling stock, traction, track facilities and lifting mechanisms. The procedure used for risk analysis is focused on the consideration of emergency situations in which damage and losses may be caused.

Key words- railway transport; risk factors; accidents and failures; difficult climatic conditions; cryolithozone

I. INTRODUCTION

For Yakutia, the commissioning of the Tommot – Nizhny Bestyakh railway into continuous operation is of great economic importance, primarily for the delivery of goods to the Arctic zone [1]. At the end of this project, a large transport

and logistics center will be created on the basis of the Yakut transport hub with the organization of a year-round scheme of rail-road and rail-river communication for the delivery of cargo in most parts of the Republic.

Currently, a number of scientific papers are devoted to the problems of reliability and safety in operation of railway lines built in the cryolithozone [2-11, 18]. In work [2] the results of the study of permafrost regimes of the railway route on the Tommot section are presented – Kerdem from 688 to 734 km. At the same time, they showed that deposits of the ice complex with a maximum volumetric ice content (0,6 – 0,8) exposed to the greatest heat lees after man-made impacts are unsustainable grounds of railroad. Icy horizons located at a depth of 2-3 m are very dangerous in case of mounds and recesses.

The main types of deformations of the roadbed on the studied section of the railway identified in the course of route studies are wave-like deformation, subsidence of the main site of the embankment, as well as the sedimentation and erosion of the embankment slopes, fig.1. [9]. Deformations of the subgrade formation of railways in the cryolithozone are primarily associated with the degradation of permafrost in their base, therefore on the railway line Tommot-Kerdem builders use structures against deformation (rip rap, sun and shrinkage screening shelter, vertical device for accumulation of cold, the transverse cooling pipe). State analysis of Tommot-Kerdem railway line [10] revealed the problem of cryogenic weathering of the material and its influence on the stability of railway.

The operational reliability of railway route in the field of distribution of permafrost soils is determined not only by the correct choice and construction of structures against deformation. It is also determined by the permanent engineering of geocryological monitoring of the road providing systematic control, analysis, assessment and

prediction of changes in permafrost conditions on the road route for timely detection, attenuation or suppression of undesirable development of cryogenic processes and phenomena.



Figure 1. Wave-like deformations [9].

The aim of this work is to analyze the main risk factors of railway transport facilities constructed and operated in the extreme conditions of the North. The order used in risk analysis is focused on the consideration of uncertain situations of the state of objects, productions and project processes in which there is a possibility of damage and loss.

II. METHODS AND MATERIALS

Major railway junctions are critical [12] and potentially hazardous [13]. Potentially dangerous objects include facilities which use, produce, process, store or transport radioactive, flammable, explosive, dangerous chemical and biological substances creating real threat of occurrence of emergency situations source [14]. The technical condition of locomotives at low temperatures deteriorates: the number of failures of systems and units on locomotives increases significantly.

Risks of emergency situations with severe consequences for the railway service staff, the population, the objects of territories and the environment during transportation of dangerous goods cannot be completely excluded, and in certain cases they are very significant [15-17]. Since undesirable events occur both during construction and operation, it is necessary to take into account the entire life cycle of the railway. Therefore, risk management should start with the system design phase taking into account both the normal mode and the mode of aging and degradation of this system to take full account of all risks. Then, the results of the risk analysis system on the design stage are transferred to organizations at the stage of construction and operation, and at the same time there should be feedback between these steps. Hazard analysis and risk assessment procedure are shown in fig. 2

One of the main approaches for improving the efficiency of management in the event of emergency situations, the

minimization of economic damage from the consequences of accidents and catastrophes, their possible prevention is the introduction of information technology, modeling of natural and technological processes, risk assessment using GIS technologies.

In this case, the risk analysis should include:

- hazard identification;
- identification of the causes that can lead to dangerous situations;
- development of possible scenarios for the development of undesirable situations;
- drawing up a list of security measures that can prevent the occurrence of such events;
- drawing up a list of measures to reduce the damage of a potential accident;
- description of the consequences of events, the occurrence of which may have a negative impact on people and the environment (the construction of fields of affecting factors; selection of damage criteria; assessment of the impact of damage effects);
- calculation of risk indicators (analysis of the frequency of scenarios based on the actual data for the past period);
- recording of any additional measures or actions that may be considered for the purpose of further reduce of a risk associated with the intended scenario.

The scenarios of railway accident and the scenarios of development of railway accident consequences are drawn up. Both groups of scenarios are divided according to the initiating dangerous events. The scenarios of railway accidents are identified by the causes of these accidents occurrence. In these scenarios the estimation models of railway accidents frequency are often used. The second group of scenarios of railway accidents consequences development (consequences) is used to estimate severe and serious consequences [15, 16, 17].

When analyzing risk factors it is necessary to take into account not only the problems of diagnostics and control of technical condition of railway transport objects but also the influence of natural and geological environment on them. Causes and factors of occurrence and development of accidents related to external natural and geological impacts inherent in the territory of Yakutia are as follows: - natural phenomena - floods, seismic activity, forest fires; hazardous geological processes – thermal erosion; thermokarst phenomena; water logging of track route.

Causes of dangerous geological processes occurrence – violations in the construction process of surface conditions of vegetation cover removal with violation of the soil-turf horizon; water logging associated with conditions of passage of a line through marshes, *alaases*, valleys of rivers and streams characterized by a weak capacity of soils. Water logging is caused, as a rule, by violations in technology of construction of a railway; overlapping of natural ways of surface water runoff.

Sites with permafrost soils are the most difficult to assess hazards for railway facilities due to high dynamics and variability of geocryological processes that are caused by external climatic conditions and the impact of railway facilities on the environment. The main reasons listed above which cause the possibility of emergency situations are the following factors of influence on the technical condition of railway facilities: the creation of stresses in the structure associated with mechanical movement, sagging, twisting of the rail bed due to the changes in surface topography (thawing and erosion of soils); cyclic seasonal permafrost processes causing soil heaving during freezing and settlements during thawing that leads to the creation of a complex-deformed condition of the structure and is the cause of its possible destruction.

To assess the operational reliability of the modernized locomotives the statistical information on the performance of modernized locomotives during 2008-2014 has been collected and generalized [18]. From 2008 to 2014, total of 172 failures of modernized diesel locomotives of Aldan depot were recorded. Distribution of the number of failures of systems and units of modernized locomotives depending on a season showed that in winter months the number of refusals increases [18].

The causes of accidents are diverse and develop as technology improves, but there are the basic factors inherent in the specifics of rail transport:

- high speed of a train;
- long safe stopping distance;
- existence of high voltage electric current (up to 30 kV);
- the variety of striking factors and the possibility of their binary combinations;
 - transportation of people or dangerous goods;
 - the necessity to trip through areas of dense urban development;
 - lack of technical requirements for the operation of locomotives and heat engines under conditions below -40°C ;
 - a small amount of data on the performance of railway equipment under extreme conditions of the Far North;
 - external influences, natural factors

The consequences of accidents on railway transport facilities can be very severe concerning damage and loss of life:

- death and harm to human health;
- damage to the environment;
- damage to rolling stock;
- damage and loss of cargo;
- delays in the progress of cargo traffic due to repair work on the destroyed areas of railway

The damaging factors of the considered accidents are:

- shock wave;
- heat radiation and hot combustion products;
- toxic products of combustion;
- fragments of destroyed equipment, tanks;
- pollution of water, air, soil and grounds by spills of toxic products.

III. RESULTS AND CONCLUSIONS

The main method of adaptation is thermal stabilization of permafrost using various methods of engineering protection. Operational reliability of railway route in areas of distribution of permafrost soils is determined not only by the correctness of choice and construction of anti-deformation structures.

In order to provide the necessary indicators of reliability and durability of components and assemblies of railway equipment operating in a cold climate, the regional technical regulations for the operation of railway rolling stock, traction, track facilities and load-lifting mechanisms are developed; the database on failures of equipment on railway transport in the conditions of low climatic temperatures, with the release of units limiting reliability is created; scenarios of railway accident occurrence and scenarios of development (consequences) are developed, there is calculation of risk indicators (analysis of the frequency of scenarios implementation based on the actual data for the previous period). Various dangerous events that could potentially lead to accidents have been identified by collecting of various accident reports and conducting of conferences and seminars with transport safety experts. The developed models will be used to assess the risk of accidents on road and railway systems.

The reliability evaluation of steel structures is based on models of growth and development of cracks and aging of the material, taking into account:

- climatic conditions;
- mode of operation;
- defects and deviations from the project;
- and also taking into account all the causes of failure and destruction.

In general, to ensure reliable operation of railway transport in conditions of low climatic temperatures it should be maintained:

- permanent engineering geocryological monitoring of a road, providing systematic control, analysis, evaluation and prediction of changes in permafrost conditions on roads for timely detection, attenuation or suppression of unwanted

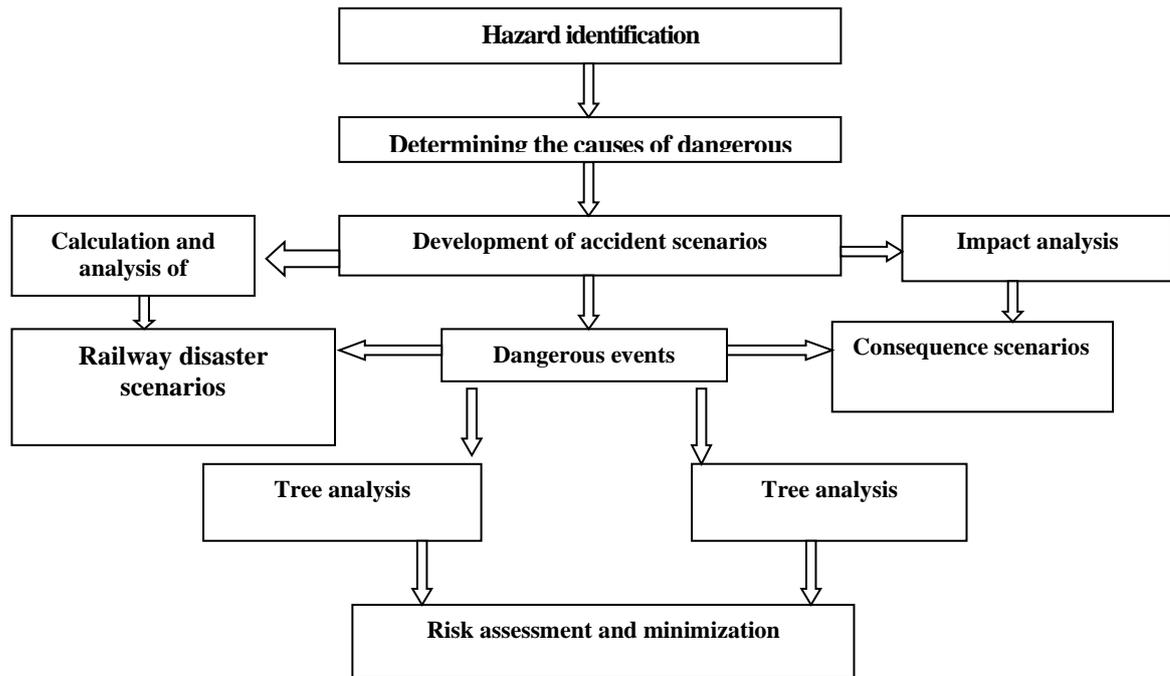


Figure 2. Main stages of railway risk assessment

cryogenic development processes and phenomena, control of their dynamics and impact on the elements of road structures;

- to make diagnostics and the prognosis of operational durability and durability of knots and welded joints of bearing elements on metal structures;

- establishment of the causes of destruction, conducting studies of the defective state, the stress-deformed state of equipment elements of a railway train, including by x-ray methods of nondestructive testing;

- to ensure the safe condition of the linear system, it is necessary to organize the system of geotechnical monitoring in the first place to solve a complex attracting of space-aerial filming and GIS technologies materials [19,20].

The organization of spatial information in geoinformational systems significantly increases the validity and quality of control engineering solutions for the protection of railway network objects from the impact of dangerous natural and man-made processes, eliminates errors in the assessment of the state of natural and man-made systems associated with the lack of information on the degree of danger of natural and man-made processes.

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