ORIGINAL ARTICLE
DOI: https://doi.org/10.30932/1992-3252-2023-21-3-3

World of Transport and Transportation, 2023,
Vol. 21, Iss. 3 (106), pp. 189–196



# Assessment of the Technical Condition of Spur Dikes

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## ABSTRACT

*Spur dikes are one of the types of structures for engineering protection of the roadbed, which, in combination with a wave-damping beach, are used to protect the railway track from wave action.*

*The objective of this work is to improve safety of coast railway track operation in areas subject to wave action. The author used the methods of experimental research and survey for obtaining the criteria for assessing the technical condition of spur dikes.*

*Based on the results of the survey of spur dikes, conclusions were drawn about low quality of construction, and the main types of defects were identified both in entire structures and in their elements. Experimental studies on hydrowave models were carried out to assess the beach-holding capacity of the spur dikes and their resistance to wave action in the wave basin. It was proposed to divide the spur dikes into separate elements according to the degree of their significance, and the criteria for the technical condition by types of defects for each element of the structure under consideration were obtained.*

*The technical condition criteria obtained from the results of surveys and experimental studies make it possible to assess the technical condition of spur dikes, which will increase railway operation safety.*

*<u>Keywords:</u> shore protection structures, wave basin, railway track, roadbed, engineering protection, survey, spur dike, technical condition criteria, experimental studies.*

*<u>For citation:</u> Tlyavlin, R. M. Assessment of the Technical Condition of Spur Dikes. World of Transport and Transportation, 2023, Vol. 21, Iss. 3 (106), pp. 189–196. DOI: https://doi.org/10.30932/1992-3252-2023-21-3-3.*

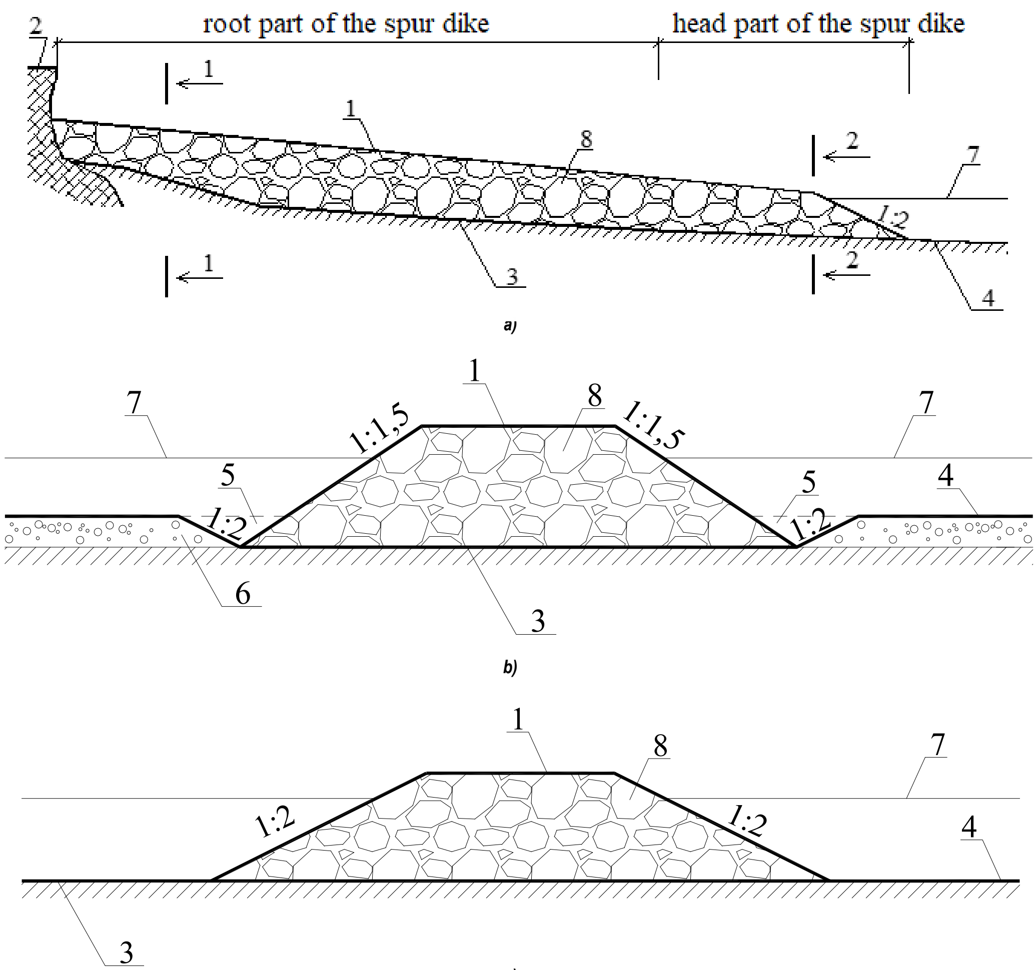
***The text of the article originally written in Russian is published in the first part of the issue.***
***Текст статьи на русском языке публикуется в первой части данного выпуска.***

## INTRODUCTION

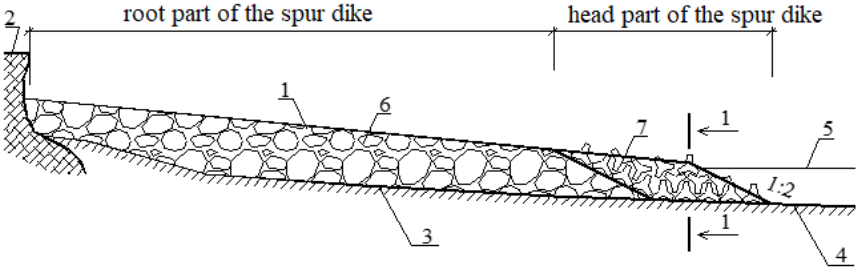
Abrasion processes on seacoasts lead to significant material consequences and reduce safety of railway roadbed operation. Railways in the Russian Federation have been built and operated under the conditions of wave abrasion on the coastal sections along the shores of the Black Sea, Lake Baikal, and Sakhalin Island. To protect the coastal sections of railways from wave action, engineering protection structures (shore protection structures) are used, which also include gravel-and-stone (or stone, or rock-fill) dike spurs. Rock-fill spur dikes are classified as active coastal protection structures designed to retain beach material. An artificial beach is an «ideal» wave-damping structure, but in some parts of the coast it cannot exist without beach-retaining structures (spur dikes), as it is intensively eroded, being drawn into the alongshore sediment flow.

In accordance with SP [Construction rules] 277.1325800.2016[1], dikes are subdivided by permeability, by design, by the materials from which they are built, and by the method of sediment passage. By design, stone spur dikes can be built of dimension stone (Pic. 1) or with a core consisting of smaller stones. In this case, the core must be protected from erosion by a larger homogeneous dimension stones with a protective layer thickness of at least three stone diameters. The angles of the slopes of the side faces of stone spur dikes should not be steeper than 1:1,5, and the head section should not be steeper than 1:2. The root part of the spur dike, as a rule, adjoins the sea wall.

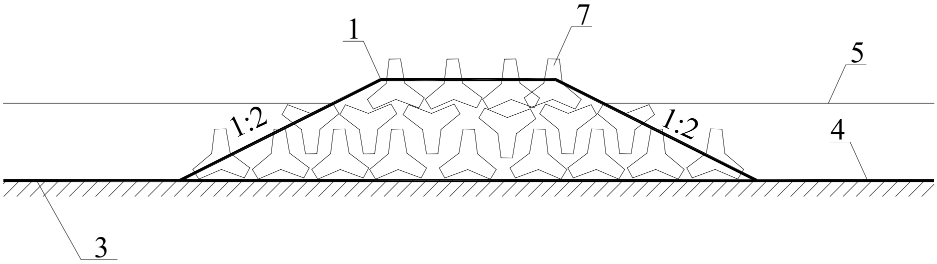
[1] SP 277.1325800.2016 Coastal protection structures. Design rules. App. by the Order of the Ministry of Construction and Housing and Communal Services of the Russian Federation, No. 963/pr, dated December 16, 2016. Moscow, Tekhnorma publ., 2017, 58 p. [Electronic resource]: https://standartgost.ru/g/%D0%A1%D0%9F_277.1325800.2016. Last accessed 24.05.2023.




*Pic. 1. Stone spur dike on rocky soils: a – longitudinal section; b – cross section 1–1; c – cross section 2–2; 1 – spur dike profile; 2 – wave wall; 3 – rocky bed; 4 – existing bed; 5 – backfill; 6 – beach material; 7 – water level; 8 – dimension stone [performed by the author].*




a)




b)

*Pic. 2. Combined spur dike: a – longitudinal section; b – cross section 1–1; 1 – spur dike profile; 2 – wave wall; 3 – rocky bed; 4 – existing bed; 5 – water level; 6 – dimension stone; shaped arrays (tetrapods) [performed by the author].*

The author, based on the results of experimental studies in the wave basin at the testing facilities of the branch of Sea Coasts Scientific Research Centre of the JSC Central Research Institute of Transport Construction and of the field survey on the section of Tuapse – Adler railway [1], repeatedly recorded the destruction of the head parts of rock-fill spur dikes.

In [2], it is noted that one of the main reasons for destruction of rock-fill spur dikes is their construction quality, this is also confirmed in [3, 4].

To strengthen the head parts of spur dikes, they can be filled with tetrapods, as a rule, weighing 5,0 tons. Such spur dikes can be called combined spur dikes. A typical solution for construction of combined spur dikes is shown in Pic. 2.

A combined design of a spur dike is known, when shaped concrete blocks, for example, tetrapods, strengthen not only the head part of the spur dike, but also the side surfaces along the contour of the structure [5]. In this paper, for additional stability, it is proposed to connect concrete blocks with ropes if necessary.

The works [6, 7] describe the methods of scientific substantiation of regulatory requirements and substantiate the need to develop a regulatory document on the use of natural stone in hydraulic engineering. They also offer the description of the world experience in construction of hydraulic structures made of stone and confirm the expediency of its application.

*The objective* of the research described in the paper was to improve safety of railway track operation at coastal sections subject to wave action. The article considers issues of developing criteria for assessing the technical condition of structures. The main methods that allowed drawing the conclusions when obtaining criteria for assessment of the technical condition of spur dikes, should include: experimental studies in wave basins carried out at the testing facilities Sea Coasts Scientific Research Centre, as well as survey and field observations on Tuapse – Adler railway section. The method of physical modelling of interaction of waves with hydraulic structures is the most reliable in terms of obtaining not only qualitative, but also quantitative results [8–12].

When developing GOST [State Standard] R 59241-2020, the author proposed and published a methodology for assessing the technical condition of engineering protection structures under wave action conditions [13–15], that considered in detail concrete spur dikes and wave-damping structures, such as protective wave-damping screens made of concrete blocks

*Pic. 3. View of deformed stone spur dikes [photo by the author, 07.02.2008].*

or natural stone, wave damping beach and fill berms. Though, the issues of assessing the technical condition of spur dikes were not considered in [13–15].

## RESULTS

The first stone spur dikes were built in 2005 at the 1933rd km of the section of Tuapse – Adler railway between Chemitokvadzhe and Yakornaya Shchel stations in Osokha River area according to the project carried out by CJSC Kavgiprotrans. To create a wave-damping pebble beach, capable of neutralise the energy of storm waves, the project provided for the dumping of pebble material with an average size of 40–70 mm in front of the wave-break wall. As beach-retaining structures, spur dikes were used made of dimension stone. The length of the spur dikes was of 45 m along the ridge. The freeboard at the root parts of spur dikes should have been +2,6 m relative to the Baltic height system, and +0,8 m for head parts. The side faces of the spur dikes were built as slopes with gradient 1:1,5 in the root part smoothly passing to the gradient of 1:2 in the head part. The head parts of the rock-fill spur dikes attained with their slopes the depths exceeding 3,5 m, where waves over 3 m high fell on them. To ensure stability of stone spur dikes to wave action, dimension stones weighing from 3 to 5 tons each were to be used in construction.

During the first three years after the construction, the stone spur dikes had been significantly deformed by storms (Pic. 3).

Based on the results of examination of the deformed structures, it was concluded that the cause of destruction was poor-quality construction. The main deviations should include discrepancy between the geometry of the constructed stone spur dikes and the project, the gradients of the slopes were not respected, the marks in the root and head parts of the spur dikes were lower than designed, the width of the spur dikes along the ridge was less than six meters, the size of the stone was much lower than that provided for in the project.

In total, 153 stone spur dikes were built on the section of Tuapse – Adler railway during the period from 2005 to 2017, and by the end of 2017, 62,7 % needed repair [1, 16, 17].

Pic. 4 shows the process of measuring the size of the stone used in construction of stone spur dikes. According to the results of measurements, it was found that the average size of a stone in the body of a spur dike is from 0,5 to 1 m, and the weight, respectively, from 150 to 1300 kg, while the project provided for that spur dikes will be built of stones with a size of about 1,5 m and a weight of 3 to 5 tons.

It should also be noted that the quality of the stone itself does not correspond to the project specifications, a stone of low strength and with an aspect ratio of more than three is often used. In accordance with GOST [State Standard] R 70021-2022, in construction of shore protection structures, it is necessary to use rock that is homogeneous in composition and not subject to

*Pic. 4. Assessment of stone size in stone spur dikes [photo by the author, 20.07.2007].*

flakiness. The ratio of the maximum size of each stone to the minimum one should not exceed 3. This requirement is due to the need for stability of the stone on the slope under wave action. There are cases when a structure built of slab-shaped stones was destroyed, although the size of the stones corresponded to the calculations.

To test the effect of stone flakiness on resistance of spur dikes to wave action, a series of experiments was carried out in the middle wave basin at the testing facilities of Sea Coasts Scientific Research Centre.

Experimental studies were carried out in accordance with the well-known methodology described in [8, 18–20], which is based on the theory of similarity. When reducing the modelling object, geometric similarity, similarity of the wave regime, of surface and volumetric forces must be ensured. Meanwhile when the same liquid (water) is present in the model and in reality, it is impossible to simultaneously ensure similarity according to Reynolds and Froude numbers. However, solving many problems does not require simultaneous similarity according to both parameters [21].

Experimental studies were carried out on a scale of 1:30. The location of the head parts of the spur dikes, subject to the greatest wave action, coincided with the line of the last wave breaking. The wave height was 3,6 m and the average period was 10,2 s. The interaction of the initial wave with the stone spur dike is shown in Pic. 5.

As a result of the experiment, it was found that a slab-shaped stone, placed in the head part of a spur dike, is less resistant to wave action compared to a stone shaped rather like a ball, and a structure built from such stones is destroyed. Pic. 6 shows the model without water at the end of the experiment. The head part of the stone spur dike with the length of 22 m was destroyed. This resulted in deterioration of the beach-holding capacity of the spur dike, and the width of the beach decreased from the designed 35 m to 15 m. Thus, the main function of the spur dike to hold the beach material was not fulfilled.

Considering the experience of monitoring the constructed spur dikes and the experimental studies on stability of rock-fill structures to wave action, it was concluded that the main group of elements is a rock-fill or bulk concrete structure since the loss of stability of individual elements of that structure affects the beach-holding capacity of the entire spur dike.

It is proposed to divide the spur dikes into separate elements according to the degree of their significance. Spur dikes comprise two main groups of elements with the corresponding significance rate $b_i$: the rock-fill or bulk concrete structure with $b_i = 80\ \%$ and the bed in front of the structure with $b_i = 20\ \%$. Depression, including local one, can lead to an increase in the wave action on the structure and to the loss of stability of individual elements of the structure.

To assess the technical condition of rock-fill structures according to the method described in [13–15], it is necessary not only to divide the rock-fill spur dikes into separate elements

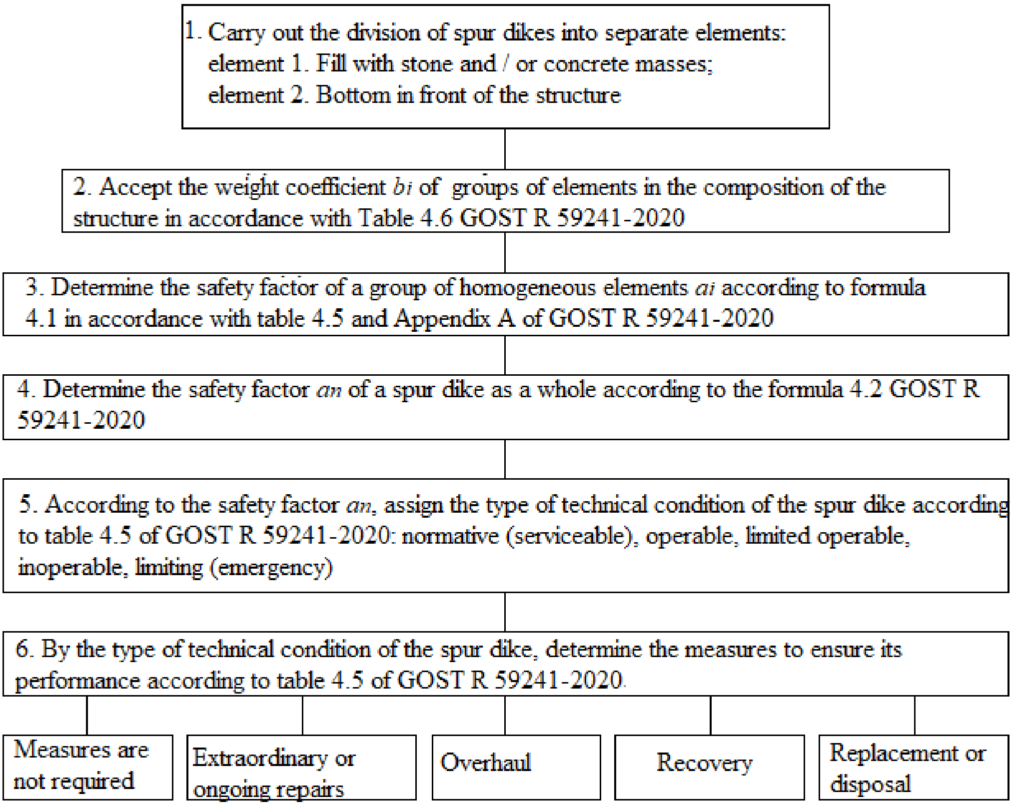
Pic. 5. Interaction of waves with the stone spur dike [photo by the author].

Pic. 6. View of the rock-fill spur dike at the end of the experiment [photo by the author].

according to their significance rate, but also to obtain criteria of technical condition by types of defects for each element of the structure under consideration. In accordance with [15], the technical condition of the structure is divided into five groups from the condition compliant with standards (operable) to the limiting (emergency) condition. The safety factor of the structure, determined by formula 4.2[2] for the standard (serviceable) state is $a_n = 1$, and for the limiting (emergency) – $a_n = 0$.

To determine the safety factor of a group of homogeneous elements $a_i$ according to formula 4.1[2], when performing a comprehensive survey by means of an expert assessment, it is necessary to assign a special value of the safety factor of an individual element $a_j$. In case of fixing a local depression of the bed in front of construction by not more than 0,2 m in depth and within a section with a length of not more than 0,25 of the diameter of the stone or the height of the concrete unit, the operable state of the element with $a_j = 1,0–0,8$ is assigned. The limit (emergency) state with $a_j = 0,2–0$ is assigned when fixing a local depression of more than 0,5 m in depth and on a bed section with a length of more than 0,25 of the stone diameter or the height of the concrete unit.

The safety factor of individual elements of a rock-fill or bulk concrete structures must be assigned according to the types of defects: erosion and landslides of slopes, mass deviation and deviation of the strength of stones or concrete units to a smaller side. It is necessary to refer to




*Pic. 7. Block diagram for determining the technical condition and the required measures to ensure operability of the spur dikes [performed by the author].*

the operable state with $a_j = 1,0–0,8$ the elements of the structure, in which there are no erosion and landslides of the slopes of the structure, the mass of the elements of the structure differs from the design one by no more than 5 % and the deviation of the strength of the element differs to the smaller side from the design value by no more than 7 %. The limiting (emergency) state with $a_j = 0,2–0$, respectively, includes elements of the structure with a deviation in the mass of elements by more than 10 %, and with a deviation in strength by more than 20 % down from the design values. The safety factor in case of erosion and landslides of the slope is determined by an expert, depending on their respective magnitude.

## CONCLUSIONS

Based on the proposed criteria, a block diagram was constructed to determine the technical condition and the required measures to ensure operability of the rock-fill or bulk concrete spur dikes (Pic. 7).

The criteria proposed by the author for assessing the technical condition of the spur dikes are included in the GOST R 59241–2020[2] developed by Sea Coasts Scientific Research Centre, allowing further improvements in the safety of railway operation in areas subject to wave action.

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*Article received 03.03.2023, approved after reviewing 25.06.2023, accepted 28.06.2023.*