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PROBLEMS OF ENVIRONMENTAL INTERFERENCE IN EMERGENCY REPAIRS OF RAILWAY SECTIONS – A CASE STUDY

PROBLEMY INGERENCJI W ŚRODOWISKO PRZYRODNICZE PRZY NAPRAWIE AWARYJNYCH ODCINKÓW LINII KOLEJOWYCH – STUDIUM PRZYPADKU

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Abstract

This article presents the history of identifying the causes of emergency threats and the repair of a section of the railway line within the Wolin National Park. The author focuses on issues related to the legal aspects of environmental protection in a specially protected area that arose during the design and execution of repair works on the railway infrastructure.

Numerous meetings between the Management of the Railway Line Department in Szczecin and the Management of the Wolin National Park, with both sides fully understanding the essence of technical and environmental problems of the project, led to a consensus. The scope and method of repair were established, allowing the minimization of the negative impact of the investment process on the park's natural and environmental values while ensuring the safety of train traffic.

Despite the typical and straightforward nature of the repair task, due to environmental protection constraints, non-standard construction problems were encountered, which consequently increased costs and extended the construction time.

Keywords: slope, erosion, emergency threat, railway line, environmental protection, train traffic safety, landslide

Streszczenie

W artykule przedstawiono historię ustalenia przyczyn zagrożenia awaryjnego i naprawy odcinka linii kolejowej w obrębie Wolińskiego Parku Narodowego. Autor skoncentrował się na problemach związanych z prawnymi aspektami ochrony środowiska przyrodniczego na terenie obszaru szczególnie chronionego, które wystąpiły w trakcie projektowania, jak i wykonywania budowanych robót naprawczych kolejowej infrastruktury komunikacyjnej.

Liczne spotkania pomiędzy Dyrekcją Zakładu Linii Kolejowych w Szczecinie a Dyrekcją Wolińskiego Parku Narodowego, przy pełnym zrozumieniu przez obie strony istoty problemów technicznych i środowiskowych przedsięwzięcia, doprowadziły do uzyskania konsensusu. Ustalono zakres i sposób naprawy, który pozwolił na zminimalizowanie negatywnego oddziaływania procesu inwestycyjnego na walory przyrodnicze i środowiskowe parku przy zapewnieniu bezpieczeństwa ruchu pociągów.

Mimo typowego i prostego w realizacji zadania przy wykonaniu naprawy, ze względu na obostrzenia wynikające z ochrony środowiska przyrodniczego, natrafiono na niestandardowe problemy budowlane. W konsekwencji wpłynęło to na wzrost kosztów oraz wydłużenie czasu realizacji robót budowlanych.

Słowa kluczowe: skarpa, erozja, zagrożenie awaryjne, linia kolejowa, ochrona środowiska przyrodniczego, bezpieczeństwo ruchu pociągów, osuwisko

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1. INTRODUCTION

A long-standing and seemingly insolvable conflict exists between the broadly understood development of industrial production facilities or technical infrastructure and the preservation of the natural environment's conditions in an untouched state. While obtaining a consensus is less problematic during the design phase of new investments, it becomes a challenging issue for existing investments that have suffered failures and disrupted the environmental equilibrium.

The importance of the problem is linked to the legal protection category of the natural environment on one side and the significance of the constructed facility for the state on the other (e.g., inclusion of the investment in critical infrastructure).

These problems frequently arise in the context of communication infrastructure, particularly railway lines, due to the extensive national railway network, its construction history, the pace of industrialization and development of specific regions, and primarily local geo-environmental conditions. Additionally, the situation is complicated by the fact that railway lines are a crucial element of Poland's critical infrastructure.

2. REQUIREMENTS FOR RAILWAY STRUCTURES

Railway regulations, consistent with the Construction Law Act [9], the Railway Transport Act [10], and industry regulations such as the MTiGM on technical conditions for railway structures and their location [7], as well as instructions [8, 12, 13], mandate the durability of the railway line structure.

The railway line's reliability must be ensured regardless of operational impacts and destructive factors and processes under all geo-environmental conditions. The subgrade is designed for a durability of 100 years, while the track (the upper part of the subgrade on which the track is laid) should be designed for a durability of 20 to 50 years, depending on the category of the railway line.

A crucial requirement for railway lines is forecasting changes in the subgrade and ground base for the broader safety of train traffic. Meeting these requirements is an engineering necessity for maintaining the natural environment's equilibrium.

Any failure or catastrophe of a railway line section disrupts the environmental balance and requires repairs to the level prescribed by the durability regulations of the building structure.

The problem highlighted in the article title will be illustrated with the case study of the post-emergency repair of the railway line section No. 401 Szczecin Dąbie – Świnoujście Port at km 84.800÷84.860 near the Międzyzdroje railway station (West Pomeranian Voivodeship, Kamień County, Międzyzdroje Municipality).

3. SHORT CASE DESCRIPTION

3.1. Location and Construction History of the Railway Line

Railway line No. 401 Szczecin Dąbie – Świnoujście Port was initially built as a single-track line, with sections gradually opened to traffic, and the entire line was operational by June 1, 1901. Between 1975 and 1980, the line was expanded to a double track. During the modernization, curve radii were changed, embankments were extended, and electrification was carried out.

The railway line on the discussed section is constructed in a cut, with a depth reaching approximately 10.0 meters [1-3].

3.2. Geological structure and terrain morphology

The discussed area is within the physiographic unit of the Uznam and Wolin Islands (313.21). The landscape of the discussed sheets has its unique features, marked by the contrast between low, expansive, and flat areas of the Świna Gate and the varied surface of the Uznam and Wolin highlands. These two sets of landforms are of different ages. The depression is entirely young Holocene, while the highland areas' relief was finally shaped during the last ice sheet's retreat [4, 5].

Both have a varied relief and structure. The western part of the area features fluvial and coastal accumulation plains, while the eastern part consists of hilly highlands. These are made of deposits from the Pomeranian phase of the North Polish Glaciation, in the form of stacked moraines and forms of aeolian and marine accumulation [5].

3.3. Existing condition at the time of research

Research work began on the emergency section when its condition threatened the safety of train traffic. The technical condition resulted from years of progressive slope degradation and occasional temporary repairs. The problem arose from the construction of two tracks with a significant correction of alignment and profile. The modernization resulted in a cut with a depth reaching 10.0 meters in homogeneous sands of a stabilized dune formed by aeolian processes.

To determine the technical condition of the ground base necessary for identifying the causes of the failure and designing repair works, appropriate

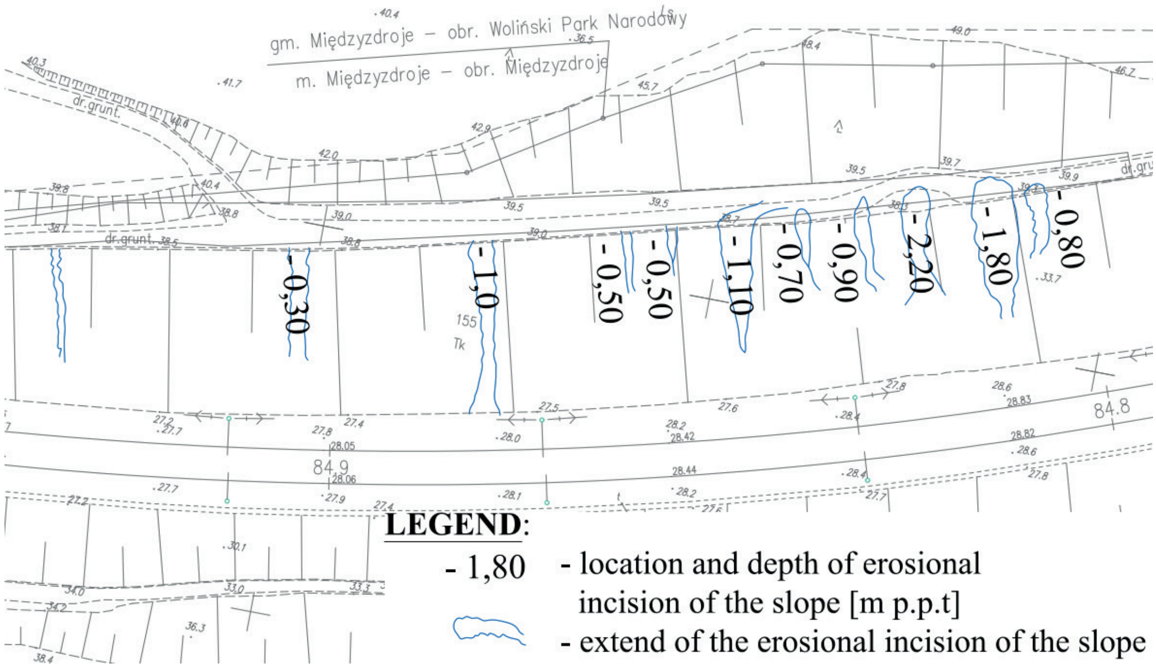

Fig. 1. Map of the railway line section with marked locations, depths, and extents of the erosive cuts on the slope

Phot. 1. Erosive funnel with washed-out fine sandy material. Photo by Tomasz Sobkowiak

geotechnical surveys were conducted, including 25 test holes, 15 light dynamic penetration tests (DPL), 10 heavy dynamic penetration tests (DPH), geodetic measurements, and laboratory tests. Additionally, the drainage condition within the railway line and adjacent area was analyzed, along with a review of construction and operation history and testimonies from individuals diagnosing the technical condition of the railway section.

The slope of the cut on the side of track No. 1 clearly showed signs of deformation in the form of erosive cuts with depths of up to 2.0 meters, and in some sections, the slope geometry was completely destroyed. This condition was a permanent state of the slope, which repeatedly underwent local landslide processes, directly threatening the safety of train traffic on this line [2].

3.4. Development mechanisms of destructive processes

Technical destruction of the slope results from the sum of exogenous phenomena and processes occurring within the ground base, construction, modernization, and maintenance history of the line, as well as zoogenic processes involving mechanical trampling of the slope within animal migration paths. The destruction zone is within the Wolin National Park. The phenomena and processes within this structure are objective.

The cut on the examined railway line section, as mentioned, was made within fine dune sands. These sediments are characterised by a very low value of the coefficient of differential grain size Cu, which for these soils is in the range of approx. Cu = 2.0. This value of the coefficient of differential grain size Cu indicates that the soil from which the excavation is built belongs to homogeneous, poorly compactible and easily loosened soils. Uniformly graded soils are easily loosened by external impulses such as vibrations and dynamic impacts, and surface water erosion is very intense on the slope surface. Dynamic probing results showed moderately compacted states bordering on loose states to significant depths below the surface.

The near-surface zone of the slope undergoes permanent, significant loosening (granular

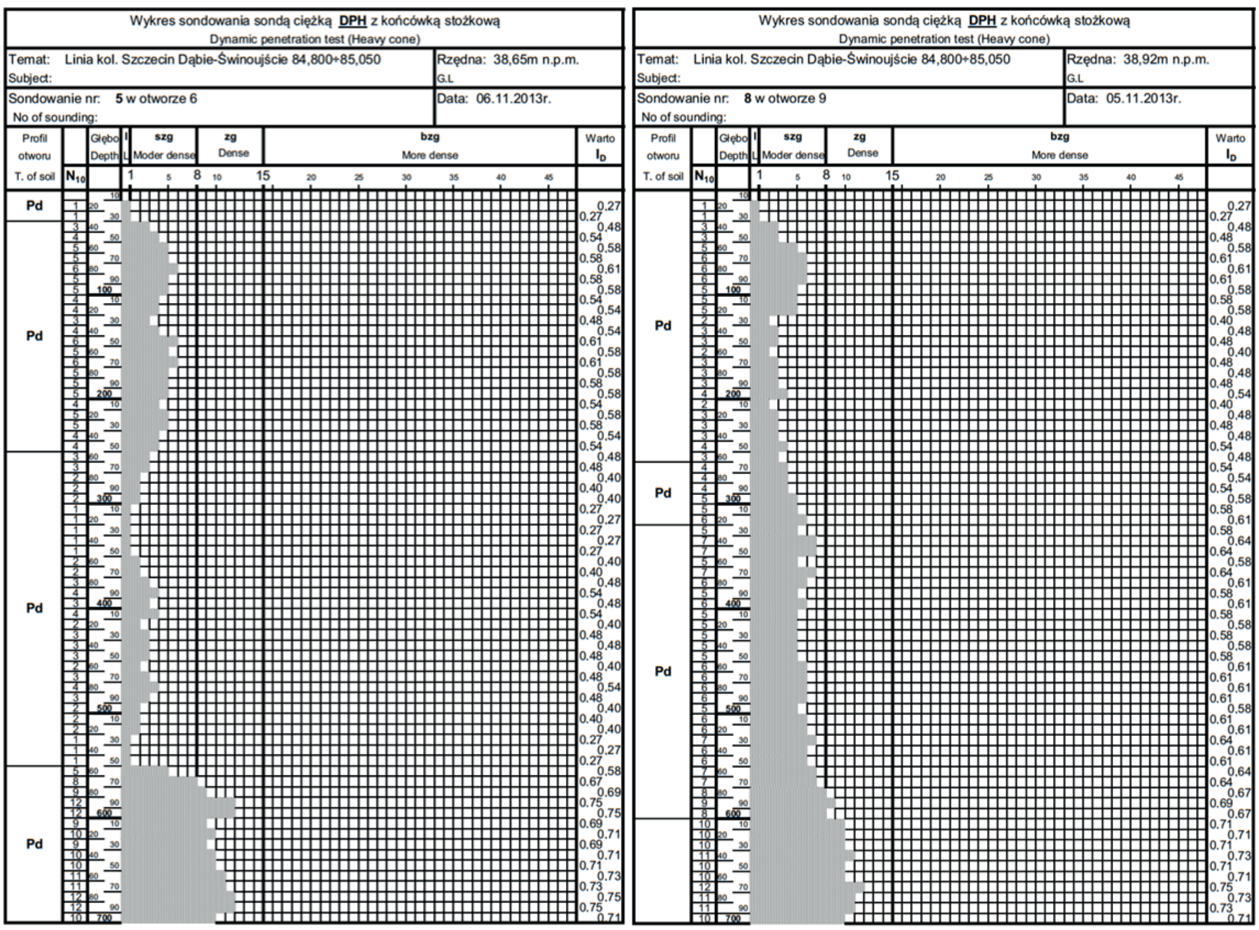

Fig. 2. Dynamic probing (DPH) test charts

disintegration) due to surface freezing and thawing, lack of vegetation (southern exposure with intense sunlight, especially in summer), runoff of rainwater, and significantly due to the movement of wild animals on the slope surface. The contribution of wild animals to the destruction of the slope also involved the construction of a system of underground burrows within it. The "channeled" runoff of rainwater in one place and the movement of wild animals specifically in the erosive cuts are the primary causes of slope instability.

The slope of the cut on the side of track No. 1, despite its depth exceeding 10.0 meters, has an almost uniform inclination. According to engineering standards, a slope with a height exceeding 6.0 meters must have a berm with a width of 1.0-2.0 meters with an outward slope or a variable inclination, starting with a smaller inclination at the base and increasing toward the upper part of the slope.

3.5. Wolin National Park directorate's position

The discussed section of the railway line is located within the Wolin National Park (abbreviated as WPN), therefore, the Investor - PKP Polskie Linie Kolejowe S.A., before commencing work, had to obtain approval for the design solutions, methods of conducting repair works, approval of materials anticipated for use during repair works, logistics arrangements within WPN, consent regarding the extent of territorial interference within WPN, and approval and conditions for the location of construction facilities.

For a number of specific aspects regarding the possibility, or rather the necessity, of repairing the railway line within WPN, approval had to be obtained from the Minister of Environment.

Consequently, on April 23, 2014, the Directorate of the Wolin National Park requested the Minister of Environment to issue a decision allowing deviations from the prohibitions in force within the Wolin National Park as specified in Article 15, paragraph 1, points 1, 3, 5, 9, 15, 18, 19, and 20 of the Nature Conservation Act [11] for the project *"Emergency repair of the cut slope of the railway line Szczecin Dąbie-Świnoujście"*, on the section passing through part of the Wolin National Park [6].

The WPN Directorate attached an opinion to the letter, explaining the essence of the project, describing the natural habitat, and addressing the repair method that allowed minimizing the negative impact of the investment process on the park's natural and environmental values.

3.5.1. Conditions for emergency repair - WPN's position

Despite challenging negotiations between the Investor and the WPN Directorate, both parties reached a consensus, fully understanding the technical and environmental problems. The following WPN opinion (in brief) was presented and accepted by the Ministry of Environment:

"The investment will be carried out entirely in the National Park area where semi-natural plant formations occur, partly natural habitat patches. These are xerothermic grasslands maintained by human activity limiting natural succession processes. In this context, the investment, with planned reclamation activities using only local materials and re-spreading the collected topsoil after the investment, ensures both their durability and local improvement of the state. The slope repair location and technology were designed to exclude interference with natural habitats and species habitats protected in the Natura 2000 area" [6].

The designer and contractor were obliged to:

1. Inform WPN about the actual implementation dates of active protection measures at least 7 days in advance and ensure the possibility of control during their execution.
2. Agreement with WPN on the methods and execution of land reclamation after the completion of the project within plot 42/7, including particularly the used access road, to enable the spontaneous restoration of forest plant communities.
3. Reclaim the repair site by restoring the topsoil layer using the collected topsoil with plant and fungal survival forms for profiling and filling geocells.
4. Prohibit the use of foreign materials like rubble and fertile soil for slope stabilization, geocell filling, or road adaptation.
5. Temporarily strengthen the access road surface in a fully removable manner after work completion using environmentally neutral materials [6].

3.5.2. Adopted repair assumptions

A compromise was negotiated, obliging the designer and contractor to undertake a challenging task, using innovative and rare (forgotten) construction technologies.

The following method was adopted for repairing the railway cut slope:

1. Reconstructed embankment geometry by filling erosion cuts with soil collected from slope profiling, binding new material with existing embankment through slope benching, and reinforcing the upper slope edge with geocell layers.

2. Implemented soak wells to manage runoff from the highland surface towards the cut.
3. To protect the slope surface from exogenous processes and the destructive impact of migrating animals, a flat geogrid and a cellular geogrid with a height of 100 mm were selected, fastened to the slope surface using a polymer rope system with polymer pins. This solution did not guarantee mechanical reinforcement of the slope.
4. Used CHANCE screw anchors without injection for mechanical reinforcement, marking a first in Poland's railway lines.
5. Completed the repair by restoring drainage along the tracks adjacent to the repaired slope.

3.6. Consequences of the agreement

The repair method presented in the previous chapter seems typical and straightforward in execution. However, upon examining the details, the repair turned out to be difficult and very challenging in terms of logistics and execution. Here are some of the problems that had to be faced:

1. **Selection of the slope reinforcement method – the use of screw-in nails.**

   Constraints resulting from the agreements between the investor and the WPN management obligated the contractor to use nails that do not introduce chemicals into the natural soil. The Polish construction market primarily offers injection nails and anchors proposed by various manufacturers. The essence of these reinforcement systems is the introduction of a chemical injection (mainly cement-based) into the natural soil to bind the soil with the drill rod, increasing friction, sealing, and thereby achieving the desired load-bearing capacity of the nail/anchor. To meet the environmental requirements imposed on the design solutions, it was decided to use, for the first time on railway lines in Poland, the American

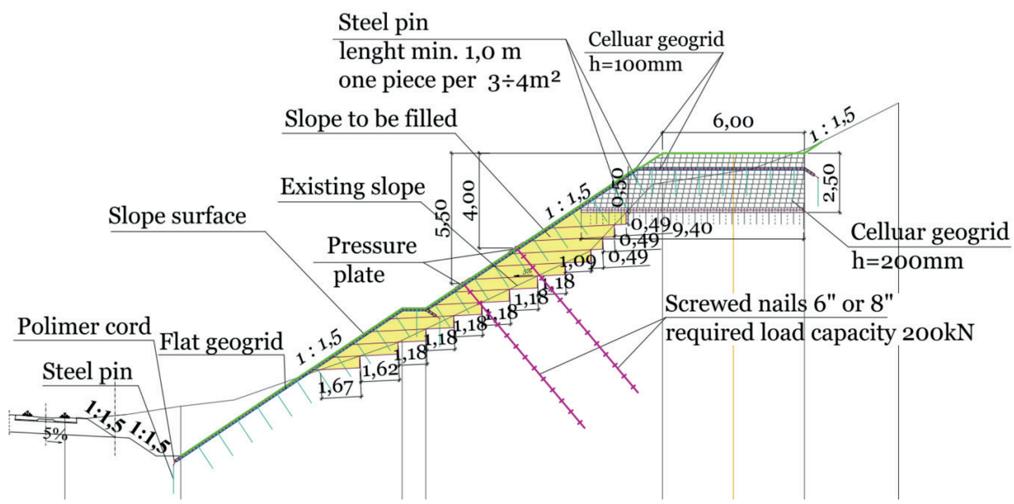

Fig. 3. Example cross-section from the construction project of the cut slope

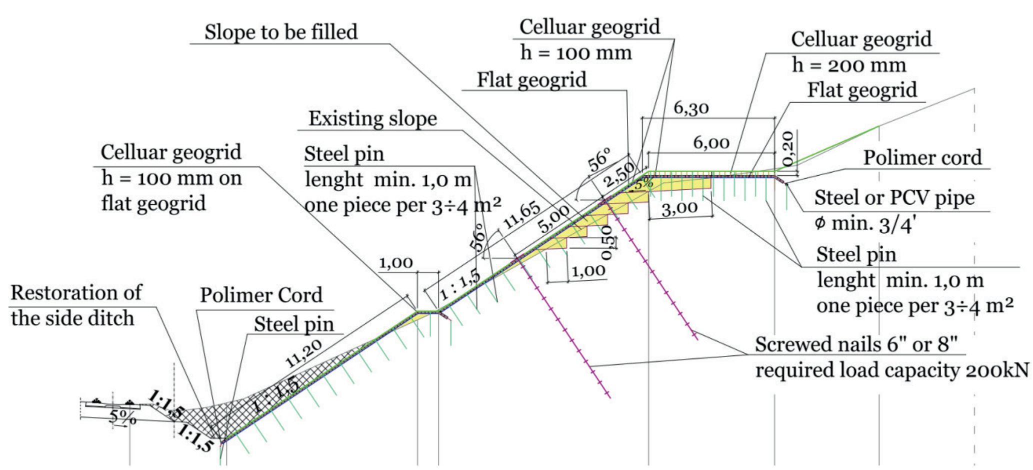

Fig. 4. Example cross-section from the construction project of the cut slope


Phot. 2. Installation of CHANCE non-injection nails. Photo by Tomasz Sobkowiak

technology of CHANCE screw-in nails. Organizing the entire screwing process required numerous procedures, as the selected technology mandated real-time control of the anchorage strength values. The screwing of the nails had to be conducted using factory-calibrated and equipped heads. The second significant problem that had to be addressed was the condition of obtaining a warranty for this technology from the producer of CHANCE screw-in nails. Supervision of the works had to be carried out by a person with credentials granted by the manufacturer. Due to the novelty and uniqueness of this technology in Poland, the author of this article, along with several other individuals, urgently attended the first appropriate course in Poland and obtained the manufacturer's certification for designing and supervising the installation of the CHANCE system.

2. **Logistical Problems**

According to the agreements, the park's internal roads could only serve as access routes for small construction equipment. Building materials, construction facilities, as well as large construction equipment, had to be delivered to the construction site by rail using railway platforms. Implementing the repair works according to the accepted project required the use of several crawler excavators, including the "Long" type, making logistics a significant challenge. For the entire duration of the works, the track adjacent to the damaged slope was taken out of service, along with the deactivation and partial dismantling of the electric traction. Temporary construction using geotextile and old wooden railway sleepers was necessary to protect the railway surface. On the adjacent track, the train speed was reduced along the length of the section where the construction works were being carried out. Preparing the working platform for the crawler excavator required building an additional earth buttress of appropriate width along the entire section of the works. Organizing the construction site and delivering equipment and materials was time-consuming, logistically challenging, and costly.

3. **Slope Seeding**

Seeding the slopes of embankments and cuts of earthworks for roads and railway lines is usually a standard part of construction completion and land reclamation. However, for the slope of the cut within Wolin National Park, this seemingly simple task became unfeasible. The condition set for the contractor regarding slope seeding was the prohibition of using any grasses other than those occurring naturally in the park – specifically, endemic grasses.

Providing seeds of grasses native to the park by Wolin National Park proved to be absolutely impossible, as the Park did not have such seeds, and selecting and purchasing the correct species composition and proportions of grasses was unfeasible. Despite the engineering awareness of an imperfectly completed repair, the requirements of the agreement between the investor and the park management were met by leaving the slope unseeded, hoping that nature would eventually replenish this deficiency on its own.

environment

Phot. 3. Transport of a crawler excavator on a track temporarily out of service. Photo by Tomasz Sobkowiak


Phot. 4. Section of the ditch slope after completion of repair works. Photo by Tomasz Sobkowiak

The above describes only three of the many problems encountered during the project process and repair execution. Other issues that could be described include: the method of constructing soak wells without the use of heavy equipment, tree cutting for the purpose of conducting works, and the restoration of firebreaks.

4. CONCLUSIONS

Undertaking repair activities for a section of the railway line within protected areas involves non-standard construction problems, which consequently leads to increased construction costs and extended construction timelines.

The case analyzed in this article involved eliminating the erosive incision of the cut slope and the runoff of eroded sandy material onto the railway line surface. The location of the investment in a valuable natural area within the boundaries of Wolin National Park necessitated close cooperation between the Investor and the Park Directorate at every stage of the repair work. A repair variant was chosen that allowed minimizing the negative impact of the investment process on the park's natural and environmental values. The slope repair technology was designed and executed in such a way that it excluded the possibility of interference with natural habitats and animal species sites, including those protected under the Natura 2000 area [6].

These actions primarily aimed to secure the operational parameters of the railway line in accordance with train traffic safety requirements. At the same time, the repair implementation did not conflict with the overarching goal of protecting the natural values of Wolin National Park [6].

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