

PAPER • OPEN ACCESS

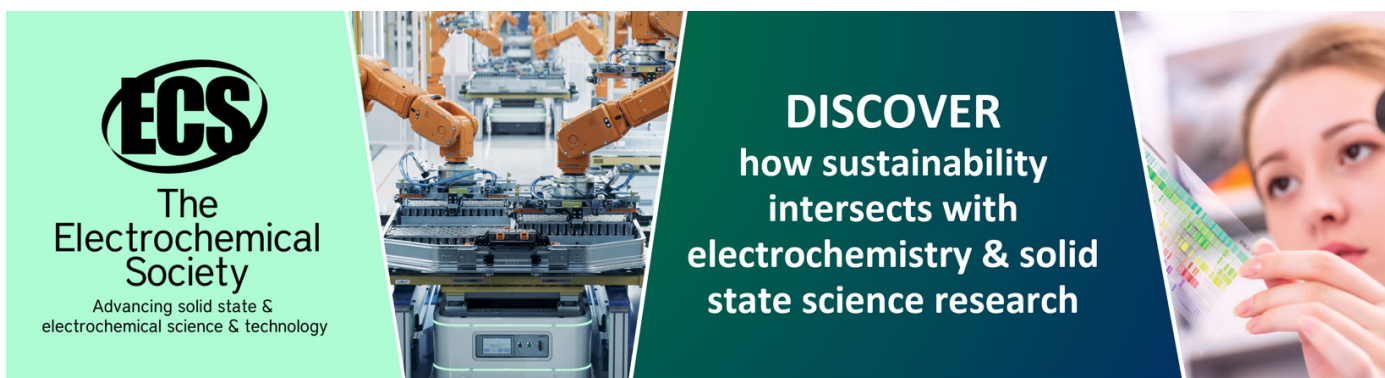
Case Study: Road Embankment Foundation on Weak Organic Soils

To cite this article: Stanisław Majer 2021 *IOP Conf. Ser.: Mater. Sci. Eng.* **1203** 032092

View the [article online](#) for updates and enhancements.

You may also like

- [Vacuum consolidation for construction of motor road embankments in peat soil](#)
A Nikitin
- [Preliminary Study on Ultrasonic Method in Cement Concrete Detection of Road Top of Embankment](#)
Aoyun Xiong, Zhen Li and Zhengjun Wang
- [EPS-Geofoam as Lightweight material for Replacement of Embankment Fill to Overcome Landslide Problems at STA 40+200 of Cisumdawu Toll Road, West Java](#)
P P Rahardjo, B W Anggoro, M Wijaya et al.



ECS
The
Electrochemical
Society
Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Case Study: Road Embankment Foundation on Weak Organic Soils

Stanislaw Majer ¹

¹ West Pomeranian University of Technology in Szczecin, Poland

majer@zut.edu.pl

The paper presents the problem of embankment foundation during reconstruction and extension of regional road 110 on the section Witomierz - Grądy. On this section the road crosses the valley of meltwater formed during the last Weichselian glaciation. It is a watershed area between the streams Stuchowska Struga and Otoczka Reska. In the Holocene a 961 ha fen peat called Wielki Smogorze has been formed. There are favorable conditions in the area for the formation of fen peats. The thickness of the peats is over 4 m, reaching almost 8.0 m in its peak. Since 1964 the Przybiernówko-Grądy II deposit (402 ha) is continuously exploited. Currently, the deposit is being used by a company called "Lasland". Extraction is conducted on the basis of a relevant concession within a designated mining area of 242.9 ha. The mining concession is valid until the end of 2030. The pits are deep and are located on both sides of the regional road no. 110. Peat is transported by narrow-gauge railroad to the nearby processing plant, where it is sieved, sorted and packed. Based on the analysis of available archival materials, the road as found today was functioning already in the middle of the 19th century. In the 1970s the road was widened to 6.0m. In 2003 due to the bad condition of the surface the asphalt layer was renovated by applying a grid and new asphalt layers. During the renovation longitudinal cracks have been reported and there were problems with the compaction of the mix. The direct cause was the shallow layer of peat located just 1.1 - 1.3 m under the road. Conducted renovation did not bring expected results, so in 2019 the documentation for the reconstruction of the road was prepared. Different methods of road foundation were analyzed, from soil replacement through the use of piles. In the end the decision was made to directly settle the embankment with the use of geosynthetics. This study presents a selected solution and shows the results of calculations. Changes during the execution of the reconstruction were discussed. The applied solution allowed for simultaneous functioning of the mining plant and reconstruction of the regional road on the section of 1.2 km.

1. Introduction

The Central European Lowland is located in north of the Ardennes, the German Mid Foothills, the Czech Massif and the Polish Highlands and on south of the North and Baltic Seas. The relief of the majority of the Lowlands was shaped during the Pleistocene glaciation by the Scandinavian glacier. Several terminal moraines run latitudinally through the Lowland, reflecting the different stages of glaciation. On the inner sides of the terminal moraines stretch the hilly areas of the ground moraines. Near the outer sides of the terminal moraines lies the great outwash, in front of which run the glacier valleys. The valleys are filled with grid of rivers, although smaller than the once existing in the past. Therefore, in the bottoms of these



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

valleys there are favourable conditions for accumulation of organic soils and formation of peat bogs. Hence, a fairly typical problem in this part of Europe occurs when designed road crosses those lands. It is one of the basic geotechnical problems - foundation of embankments on weak soils. One of the solutions is to use piled embankments. This type of embankment was often used in the 19th century during the construction of roads and railroads, where wooden logs were fixed at the base.



Figure 1. Peat deposit Przybiernówko-Grądy II.

A special type of a peat bogs are fen peats, developing in drainless depressions or on a watershed. An example of a bog on a watershed is the Great Smogorze Bog with an area of 961 ha (Fig 1.). It was created in a wide valley of meltwater in the watershed zone between Stuchowska Struga and Otoka Reska. In the western part of the peatland there is sedges-sphagnum and sphagnum peats, and in the eastern part - sphagnum, sedge and pine peats. The average thickness of the peats is over 4 m, and the maximum thickness of the deposit is 7.6 m. In the western part of the peatland the sphagnum fens and sphagnum peat occurs, and in the eastern part - the sphagnum fens, sphagnum and pine peats.

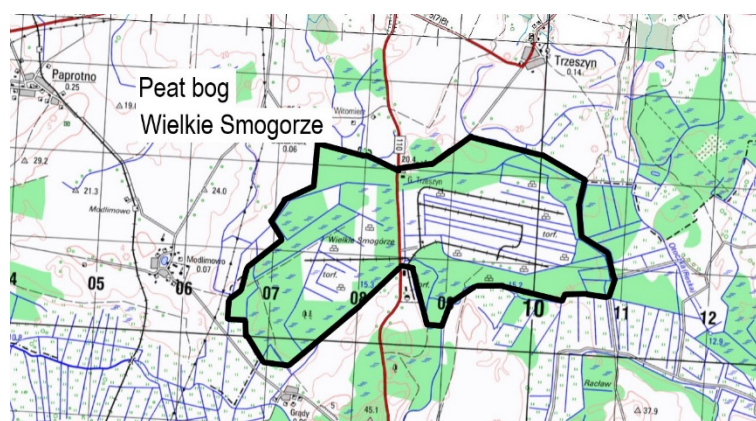


Figure 2. Location of the regional road no. 110.

The deposit is being exploited since 1964. The current user of the deposit is the company "Lasland". Mining is conducted on the basis of a concession granted by the West Pomeranian Voivode, within a designated mining area of 242.9 ha. The surface area of the mining site is 274.6 ha (the mining area and the mining site are divided into 3 fields). Extraction is conducted on the basis of a relevant concession within a designated mining area of 242.9 ha. The mining concession is valid until the end of 2030. The pits are deep and are located on both sides of the regional road no. 110 (Fig. 2). Peat is transported by narrow-gauge railroad to the nearby processing plant, where it is sieved, sorted and packed. The characteristics of the peat are as follows: degree of decomposition - from 16.0 to 44.0 (average 24.0%),

ash content - from 0.9 to 8.6 (average 3.1%), moisture content - from 75.9 to 97.7 (average 90.6%), pH - from 2.9 to 4.9 (average 4.0) [1].

2. Segment characteristics, initial geotechnical data

On the basis of available archival topographic maps [2], the road in question connecting Gryfice (German: Greifenberg in Pommern) with Cerkwica (Zirkwitz) was built in the middle of the 19th century (Fig. 3). The construction were made for the loads occurring at that time, i.e. horse traffic. Such traffic was characterized by high loads (2-5 MPa) exerted by steel cart rims and horse hooves on a relatively small area of 5 to 25 cm² [3]. Those loads required the use of paving blocks, cobblestones, and gravel surfaces on a not very thick substructure; the thickness of the surface did not exceed 20-40 cm. In the region of Pomerania at the end of the 19th century it was typical to build a 9 m wide roads with a 4 m wide gravel road and a 2.5 m wide unpaved part planted with trees on both sides [4].



Figure 3. Topographic map of the area (1888) [1]

In the 1970s, the road was widened to 6.0 m with bituminous layers. The current truck traffic is characterized by axle loads up to 115 kN, with wheel contact area of 700 cm² and pressure up to 0.9 MPa. This requires to use much thicker surface layers. The total thickness of the road reaches even up to 80 cm. Based on the traffic count which is being carried out every 5 years on the public road network in Poland, average daily traffic expressed as number of axes of 100 kN on the considered section of the regional road no. 110 (DW110) is about 100, which corresponds to the KR3 traffic category. Due to the fact that the technical condition of the DW 110 section running through the peat bog significantly differed from the remaining part of the road (deep ruts, unevenness), the road administrator decided to renovate the road surface in this section. The repair consisted in milling the existing irregularities, reinforcing the old layers with geocomposite, and then making a new binder and wear layers of asphalt concrete (AC) 4 cm thick. The works were done in 2003. Control tests ordered by the investor showed that appropriate compaction of mineral-asphalt mixtures < 98.0 was not achieved. Measurements of cross fall showed that the permissible tolerance of $\pm 0.5\%$ was exceeded on almost the entire length of the renovated road. Additionally, the occurrence of longitudinal cracks was observed on the newly made road (Fig. 4). The direct cause of this situation were peats located closely underneath the road, and lack of proper road design that considered their occurrence [5]. The problem of wrong survey at the stage of designing the road was discussed in the work [6], where the conclusion was made that there is a problem with moisture of the subgrade and loss of bearing capacity of the road. In order to recognize the subsoil, a series of small borings were made using a manual drill. The boreholes were made in the roadside at a distance of 0.3-0.5 m from the edge of the road. Geotechnical cross-section through the valley along the road is presented in Fig. 5.



Figure 4. Cracks on the renovated road (2003).

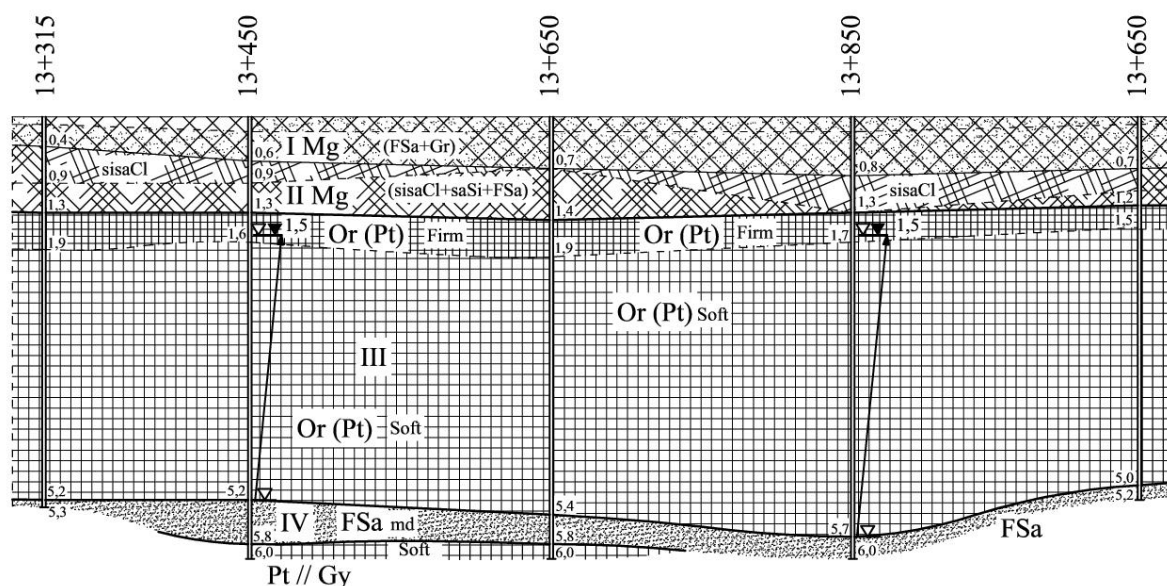


Figure 5. Geotechnical cross-section of the segment of DW 110.

3. Survey of subsurface and groundwater conditions during design of the road

As predicted in [5], the works performed in 2003 did not significantly delay the process of degradation of the DW 110 surface. The degradation occurred at the edges and shoulders of the road only few years later. The condition deteriorated to such an extent that before starting the reconstruction of the section running through the peat bog (approx. 1.2 km), the road had to be narrowed with introduction of the shuttle traffic (Fig 6). In 2018, a design documentation was commissioned for the reconstruction of DW 110 along the section of the peat bog, i.e. from km 13+100 to km 14+300. For the design, geological and engineering documentation was prepared, which included:

- 16 boreholes from 5.0 m to 10.0 m; total length 133.0 lm;
- SLVT sounding - 3 locations, total depth of 15.0 lm, number of shears - 21;
- CPTu static soundings - 6 soundings from: 4.0 m to 12.0 m; total of 62.0 lm;

- Laboratory tests including soil grading - 17, natural moisture content - 25, organic matter content - 20.



Figure 6. Narrowing of the DW 110 (2020).

Performed tests confirmed the results presented in the study [5]. The height of the embankment on weak soils ranged from 1.1 m to 1.7 m, with an average of 1.4 m. Organic soils were classified into 2 layers, the thickness of the weak layer ranged from 4.0 to 6.2 m. Peats under the embankment were characterized by moisture content ranging from 300% to 600% average 485% and ignition losses ranging from 61% to 93% average 75% (tests were performed on 9 samples). Laboratory tests of the samples taken from the embankment allowed to determine that they are made of doubtful and swelling soils with the sand index $SE = 23 - 13\%$ and the CBR index value from 8.2 to 13. Thus, they confirmed the cross-section of the embankment established in 2003 (Fig. 7).

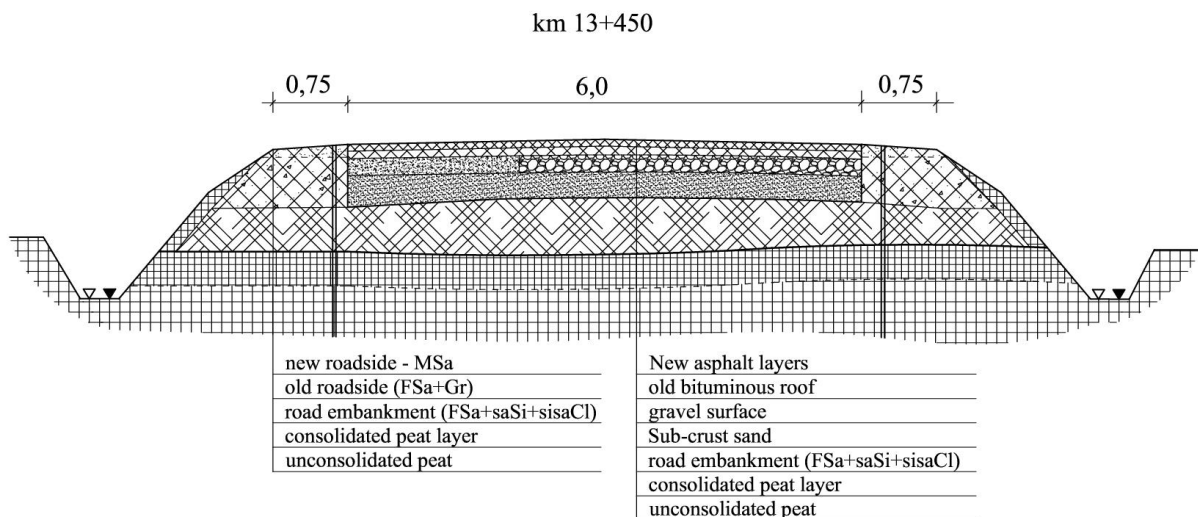


Figure 7. Cross section of the embankment DW 110.

4. Embankment foundation

Since DW 110 is loaded with heavy traffic, it was decided to widen the roadway to the width of 7.0 m and to install a 1.5 m wide dirt shoulders. As part of the geotechnical design, 3 foundation alternatives were analyzed. All three solutions required demolition of the existing road and construct a new one in its place. Option I proposed a standard construction for a KR3 traffic with an additional layer of

substructure made of aggregate 0/31.5, application of 2 layers of hexagonal geo-grid under the aggregate layers, and a 25 cm thick embankment reinforced with PES 150/50kN/m geotextile. Option II in terms of the arrangement of construction layers was identical to Option I, the difference was in execution of the surcharge embankment with a height of 2.0 m over the reinforced embankment. The value of the load from the embankment was 36 kPa and was executed to even out the loads from the construction layers and traffic. The surcharge embankment was to be maintained until stabilization of settlements - an estimated period of 2 - 3 months. Option III required to execute the foundation of the embankment on 40 x 40 cm prefabricated piles with a square spacing of 1.9 x 1.9 m and with the use of 80 x 80 x 25 cm prefabricated topping slabs. The layout of the remaining layers remained unchanged, the only difference to Option I was the replacement of the geotextile with PVA 250 kN/m. For Option I calculations were performed to ensure that weak soils would not be displaced from under the embankment. According to EC-7 in relation to vertical load and embankment ($B/L \approx 0$) the limit resistance of weak soil (≈ 0) was determined from relation (1).

$$q_f = (2 + \pi)c_u + D\gamma_D \quad (1)$$

Based on the CPT soundings following values were assumed for the weakest organic soil layer in the calculation: $c_u = 13\text{ kPa}$, embankment compaction - 0.6 m, soil weight - 16.0 kN/m^3 . The calculated value of the boundary resistance taking into account the partial coefficient $R=1.4$ was equal to 57.0 kPa, while the loads from the reinforced embankment and substructure layers as well as from the technological traffic was $V_d=44.4\text{ kPa}$. Calculations of settlements were performed by FEM using GEO5 program, maximum settlement of embankment in variant I is 56.4 mm (Fig 8).

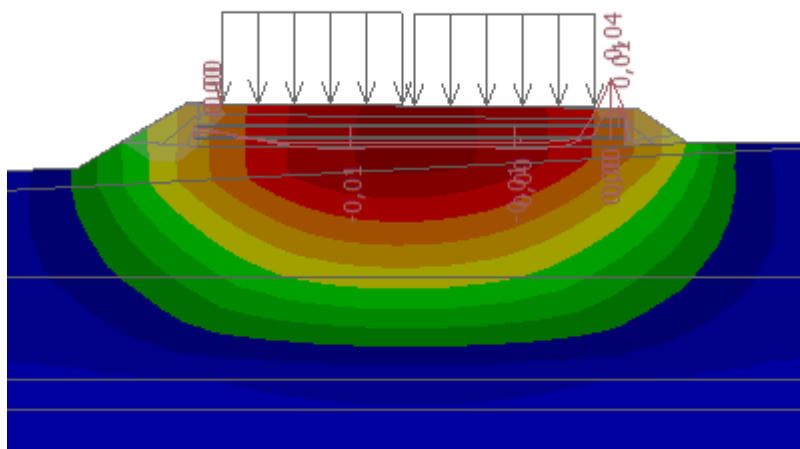


Figure 8. Wizualizacja osiadań nasypu w wariantcie I

After consultations with road administrator, based on the costs and execution time, the Option I was chosen.

5. Execution of the road

Execution of works on DW 110 commenced after the end of August 2020 and was completed in December 2020. The works were carried out with the road completely closed for traffic, while maintaining the production at the peat processing plant. A test section was first executed to verify the design assumptions. The design solution did not present any requirements to levels of compaction and bearing capacity on the geotextile-reinforced embankment layers, but static plate load tests was applied to test the effectiveness of the solution. The required value of the secondary modulus E_2 was at least 140 MPa with ratio of moduli $E_2/E_1 < 2.2$.



Figure 9. Execution of the new road

Tests performed after execution of the road showed that the recommended values were not achieved, as the value of E2 was below 100 MPa. As part of the project supervision, it was decided to modify the design. Two solutions were proposed: the first one with a sand layer of 25 cm to 40 cm and the second with a sand layer and an subbase made of CBGM cement-bound mix with a strength up to 5.0 MPa (Fig. 9). Re-examinations showed that the solution no. 2 meets the design requirements and a bearing capacity of E2=200MPa was obtained. The final layout of layers applied is presented in Fig. 10. Laying of asphalt layers was finished in November, control of mineral-asphalt mixes showed positive results. The road was opened to traffic in December 2020, the reconstruction lasted 4 months.

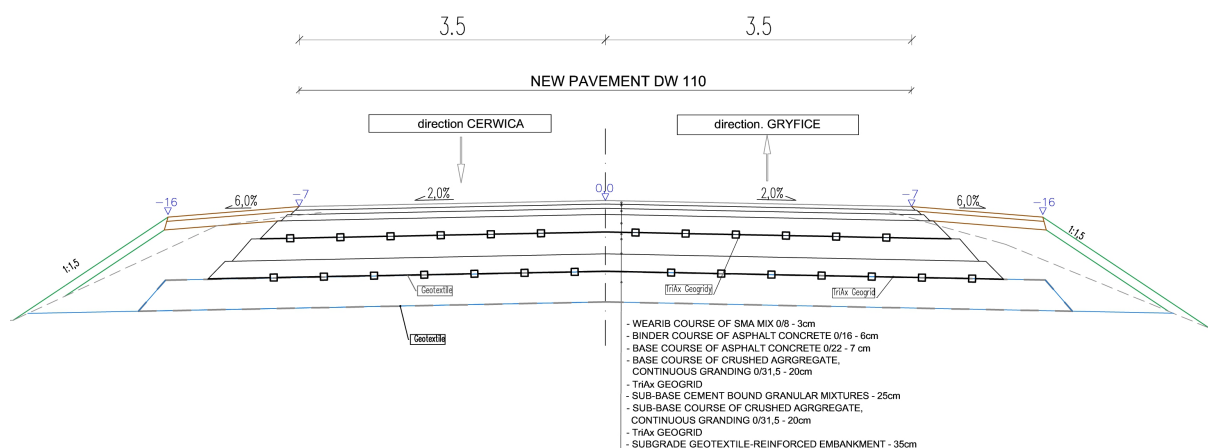


Figure 10. Final cross-section of the road DW 110

6. Conclusions

The paper presents a case study of a embankment foundation of a regional road no 110 that crosses a peat bog. The road was built in the middle of 19th century directly on the surface of peat bog using piled embankment. Increased traffic and exploitation of peat deposits resulted in road damages that required immediate considerations. Half-measured repairs consisting of replacing of asphalt layers were not sufficient. During the renovation works in 2003 the mineral-asphalt mixes were insufficiently compacted causing longitudinal cracks to appear on the new layers. Therefore, a decision was made to completely reconstruct the road on the length of 1.2 km. Three reconstruction options were proposed. It was decided to implement the option that incorporates the use of geosynthetics as a reinforcement. Both

geotextiles and geonets were used. The main argument for such solution was relatively low cost of reconstruction and time of execution. During construction there were problems with obtaining the parameters on the substructure for asphalt layers. Two alternative solutions were proposed, one of which required increasing the thickness of embankment reinforced with geo-mesh and an additional layer of CBGM mix substructure. The solution allowed to meet the design requirements and complete the reconstruction according to the plan without any problems.

References

- [1] “Objaśnienia do Mapy Geośrodowiskowej Polski 1:50 000. Arkusz Gryfice (116)“, PIG-PIB, Warszawa 2009
- [2] “Karte des Deutschen Reiches 1:100 000 – Generalstabskarte, blatt: Greifenberg i. Pomm.“, Königlich-Preussische Landesaufnahme, Berlin 1893.
- [3] A. Kaven, “Vorträge über Ingenieur-Wissenschaften an der polytechnischen Schule zu Aachen“, Hannover 1870.
- [4] O. Hübner, “Der Straßenbaum in der Stadt und auf dem Lande, seine Pflanzung und Pflege sowie die erforderlichen Maßnahmen zu seinem Schutz.“. Parey, Berlin 1914.
- [5] S. Majer, C. Seul, “Wpływ podłoża gruntowego na zagęszczenie mieszanki mineralno-asfaltowej na przykładzie drogi Cerkwica – Przybiernówko“, *XII Seminarium Naukowe z cyklu Regionalne problemy ochrony środowiska w ujściu Odry. Środowisko w świetle dyrektyw Unii Europejskiej, Kołobrzeg 4 - 6 czerwca 2004*, pp. 65-70, 2004.
- [6] Mieczkowski, P.; Budziński, B. Influence of Excessive Moisture in the Subgrade on the Durability and Load-Bearing Capacity of Road Pavements. IOP Conf. Ser.: Mater. Sci. Eng. 2018, 356, 012012, doi:10.1088/1757-899X/356/1/012012.