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THE IMPACT OF A GEOGRID SYSTEM ON LOAD-BEARING CAPACITY OF NATURAL AIRFIELD PAVEMENTS

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Natural airfield pavements divide into soil and turf pavements. Turf pavement is a soil pavement covered with a developed grass layer that reduce soil moisture level, thus increasing its' resistance and extending exploitation period. Natural airfield pavements are formed through appropriate ground preparation. This pavement should be constructed in such a way as to have sufficient load-bearing capacity, which directly affects the safety of flight operations by aircraft. The current research indicates that a significant part of natural airfield pavements in Poland does not meet the requirements for load bearing capacity and require reinforcing. The article provides an example of reinforcing the natural airfield pavement with a system of geogrids. The paper describes what research was performed in order to measure the load-bearing capacity of natural airfield pavements and analyses the obtained results.

*Keywords***:** Natural airfield pavement, reinforcement, geogrid system, geocells, load-bearing capacity, California Bearing Ratio

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1. INTRODUCTION

Airfield pavements, both artificial and natural ones, are intended for aircraft parking and movement. The natural sod and dirt airfield pavements are formed through appropriate ground preparation. The natural airfield pavements constitute the basic pavement at lower-class airfields, i.e. sports, flying club, and personal use airfields. However, at higher-class airfields, they occur within runway object free areas (ROFA), runway end safety areas (RESA) and runway strips (RS). A runway shoulder should be prepared in a manner, so that in the event of the aircraft running-off, it would not lead to damaging its structure and that it is able to transfer the weight of ground vehicles moving along the shoulders [4].

The load bearing capacity of airfield pavements is the main factor determining the ability to conduct flight operations. Studies show that a significant part of natural airfield pavements in Poland does not meet the requirements in terms of their load bearing capacity. The article describes methods for measuring the load bearing capacity of natural airfield pavements and presents the possibility of reinforcing the subsoil with the use of geosynthetics, and more precisely, with the use of a geogrid. The results of the carried out studies were also analysed.

2. NATURAL AIRFIELD PAVEMENTS

The natural airfield pavements, according to the defence standard NO-17-A503:2017 [3], constitute airfield pavements formed by appropriate ground preparation in order to ensure the possibilities of safe movement on them by military aircraft.

There are two types of natural airfield pavements: dirt and sod ones. A driving layer of the dirt pavement is made of soil, without a layer of sod. However, the sod pavement is a dirt pavement additionally covered with a layer of sod which usually has a thickness of 10-18 cm. According to [1], sod is a dense plant cover, usually grassy, with a well-developed root system.

The sod pavement is subjected to regular agrotechnical and reinforcing treatments in order to maintain and meet the increasingly greater operation and maintenance requirements. These treatments include regular mowing of natural airfield pavements, pavement rolling, replenishing areas with reduced sodding with a mixture of grasses, levelling ruts, fertilisation and chemical spraying.

The natural airfield pavements most often constitute a basic type of the field pavement of the ground air traffic in the flying club, sports and private facilities which are exposed to lower loads. It is assumed that the load on the main strut of an aircraft should not exceed 100.00 kN for this pavement [10]. On higher-class airfields, the natural pavements have a supporting role associated with securing: emergency take-offs and landings, periodic maintenance in training conditions and in the event of aircraft running-off of the artificial pavement [13].

3. THE IMPACT OF A SOIL MEDIUM WHEEL

During the movement of the vehicle on the natural pavement (sod and dirt ones), its impact on the soil changes with a change in velocity [10]. According to the literature data and experience associated with work on stresses formed in the soil at various depths depending on the vehicle movement speed, the data included in Table 1 was developed [10].

Table 1. The relationship between the aircraft speed and the stress value in the soil [10]

Movement speed [km/h]	Stresses at a depth of 25 cm [MPa]
0	0.24
15	0.09
30	0.05
45	0.02

The aircraft-related pavement static loads cause greater pavement deformations than short-term dynamic loads of the same value. It is worth noting that the airfield pavements adopt heavy, repetitive loads on a small contact surface, which means that the loads reaching design values adopt small pavement areas, however, other areas adopt such loads occasionally. Fig. 1 shows a diagram of stresses formed in the soil during the aircraft taxiing on the dirt pavement.

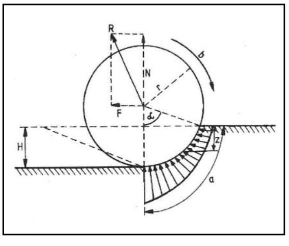

Fig. 1. Model of the soil medium wheel impact [10]

where:

N – soil vertical reaction to the wheel load; F – friction force R – resultant of N and F forces; H – rut depth; a – distance length of the wheel contact point with the dirt pavement; α – angle corresponding to the length of the section a; r – wheel radius; b – wheel rotation direction; z – depth of the considered soil layer.

The factor determining the soil deformation size is its durability σ, which depends on the following factors: load P_k attributable to the aircraft wheel, aircraft wheel diameter D (D = 2r), aircraft wheel width B, tyre spring rate ξ, m rate, depending on the soil plasticity degree. The soil strength is calculated using the following formula [10]:

$$\sigma = \frac{q_k^2 \cdot D}{H \cdot k_H} \tag{3.1}$$

where:

$q_k = P_k/D \cdot B$ – pressure of one wheel of the landing gear on the soil, for the main landing gear =0.43 MPa, for the nose landing gear =0.44 MPa; kh= m·ξ; ξ– tyre stiffness; H– rut depth.

In order to determine the suitability of a given dirt pavement for use by aircraft, the rut depth H [5] is essential, and it is calculated in accordance with the following formula:

$$H = \frac{q_k^2 \cdot D}{\sigma^2 \cdot k_h} \tag{3.2}$$

4. COMPUTATIONAL MODEL OF THE GEOGRID AND SUBSOIL

For the structural system composed of a geogrid being part of the subsoil, it is possible to adopt the following computational model (Fig. 2). The composite layer, which is a geogrid with sod filling, has the h_k thickness and it is described by the E_k elasticity modulus and Poisson's ratio ν_k. Whereas the subsoil is a laminated elastic half space, which consists of elastic layers unlimited in the plane, described by three quantities: thickness $h_1 \to \infty$, modulus of elasticity E_1 and Poisson's ratio ν_1.

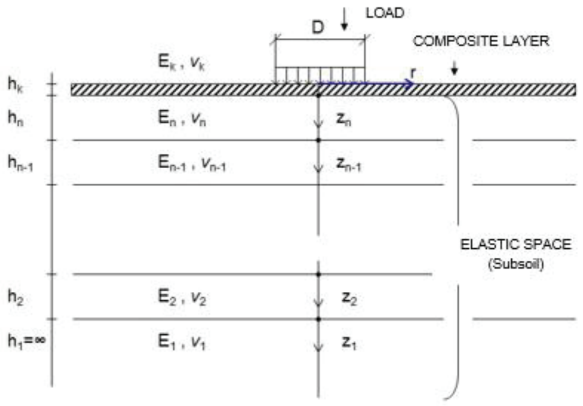

Fig. 2. Computational model of the geogrid and subsoil system

The developed computational model is based on a model of Winkler's elastic foundation which implies that it consists of a system of unconnected springs on a non-deformable foundation, Fig. 3. The foundation deflection occurs at the load application point, Fig. 4.

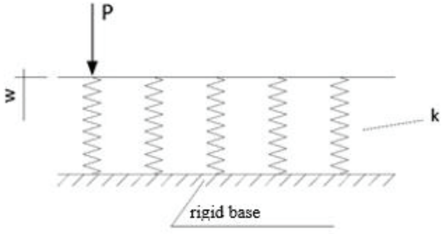

Fig. 3. Winkler's elastic foundation model

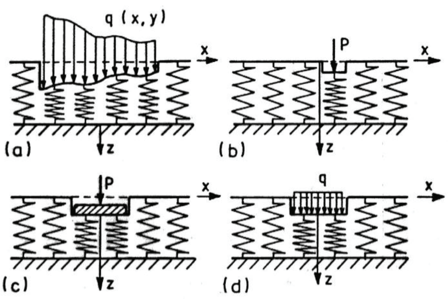

Fig. 4. Winkler's foundation deflection

The load-bearing capacity of a presented structural system at a given point and in its immediate surroundings can be determined, if the solution to the theory of elasticity issue for the adopted computational model, taking into account the forecast load structure, is known. The basic physico-mechanical properties of the materials of the aforementioned structural system, i.e., composite layer and the subsoil, can be determined during laboratory and field tests. The tests in field conditions are conducted with static and dynamic methods. On the basis of the obtained results, it will be possible to conduct a bearing load capacity analysis of the natural airfield pavements reinforced with a system of geogrids.

5. LOAD BEARING CAPACITY OF NATURAL AIRFIELD PAVEMENTS

5.1. GENERAL INFORMATION

Both the natural and artificial airfield pavements must meet the requirements in terms of their load bearing capacity. The load bearing capacity is one of the main operational features of the airfield pavement and it is its ability to transfer loads from the aircraft to the subsoil. In case of the sod pavements, it is resistance that is put up by a well-developed root system and the soil particles contained in it against the loads from the weight of the aircraft moving or being parked.

The load bearing capacity criteria of the sod pavements should be strictly associated with a type of the reference aircraft, to be operated in a given airfield facility.

The tests regarding the load bearing capacity of the natural airfield pavements are performed on all airfield functional elements, which have such a pavement. The diagram of arrangement of the airfield functional elements was presented in Fig. 5.

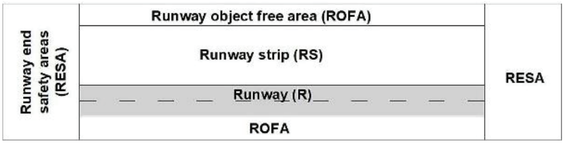

Fig. 5. Arrangement diagram of AFEs subject to load bearing capacity assessment [3]

5.2. LOAD BEARING CAPACITY ASSESSMENT METHODOLOGY

The load bearing capacity tests of the natural airfield pavement are carried out at points, according to ASTM D6951M-09, with the use of a DCP (Dynamic Cone Penetrometer) probe. The number of measurement points is determined depending on the type and area of the tested AFE [3]. This test involves measuring the probe tip penetration per one impact of a weight falling from a specified height. The load bearing capacity of the natural airfield pavement is expressed by the California bearing ratio (CBR). In the world literature, it is possible to find many formulas for calculating the CBR, however, according to [3] and ASTM D6951M-09, this ratio should be determined according to the following formula:

$$CBR = \frac{292}{DCP^{1,12}} \tag{5.1}$$

where:

CBR – California bearing ratio, [%]; DCP – DCP probe cone penetration per one impact, [mm].

The test is carried out to a depth of 0.85 bgl for three separated layers: to a depth of 0.15 m, in a depth from 0.15 m to 0.50 m and in a depth from 0.50 m to 0.85 m. The averaged result for a layer up to 0.15 m, the required value is CBR=15%, and the averaged result for a layer formed as a result of combination of the second and third layers, that is in a depth from 0.15 m to 0.85 m, the required value is CBR=8%, are assessed.

6. CHARACTERISTICS OF CELLULAR GEOSYNTHETICS

Cellular geosynthetics (geogrids) are regular cellular structures, the so-called honeycomb structure, made of plastic, usually HDPE. These systems have a variety of uses, e.g. protection of slopes and embankments against erosion, and reinforcement of temporary road pavements. The cellular geosynthetics were used for the first time by the US Army in 1979 for quick reinforcement of sandy soil [11], i.e. to build tactical roads on infirm ground with unfavourable water conditions [9].

While selecting the appropriate geosynthetic, it is important to take into account the factors resulting from its durability, resistance to external factors and its intended function [6]. The materials used in order to reinforce a subsoil should have defined material parameters, such as: tensile strength, elongation under maximum load, CBR static puncture resistance, dynamic puncture and durability.

In order to determine the operational effectiveness of the geosynthetic, which is to function as the subsoil reinforcement, it is possible to specify the load capacity ratio (LCR) or the bearing capacity ratio (BCR) [7]:

$$LCR = \frac{q_r}{q} \tag{6.1}$$

where:

q_r and q – are the values of loads that should be applied respectively to the pavement structure surface, in which the subsoil was reinforced with the use of the geosynthetic and the same structure, in which the reinforcement was not applied, in order to induce a specific deformation of the subsoil.

$$BCR = \frac{q_{(u)R}}{q_u} \tag{6.2}$$

where:

$q_{(u)R}$ / q_u – respectively determine the load bearing capacity of the dirt pavement reinforced with the use of the geosynthetic reinforcement and the load bearing capacity of the subsoil, in which the reinforcement was not applied.

Substrate reinforcement with cellular geosynthetics consisting of load bearing capacity and sittness increase according to [8] depends on (Fig. 6): increase of geogrid filling materials' shearing resistance as a result of its' closure and compression inside geocells; decrease of subsidence caused by natural compression and reduction of cellular geogrid filling material's lateral displacements; decrease of tensions transmitted to the subsoil from bearing load on surface with distribution of concentrated loads on the adjacent geogrid's cells.

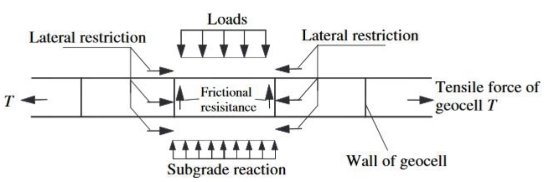

Fig. 6. Lateral restriction of cellular geogrid reinforcement [8]

Within the framework of experience at one of the flying club airfields, the geogrid, presented in Fig. 7, was applied in order to reinforce the natural pavement.

Fig. 7. Geogrid used to reinforce the natural airfield pavement

The geogrid applied in order to reinforce the pavement is harmless to the environment and neutral for groundwater. The biologically active area of the geogrid is 85%, hence, the plastic amounts to 15%. The geogrid technical data was presented below: dimensions of a single element: 50 x 50 cm; wall height: 4 cm; wall thickness: 3-4 mm; mesh size: 49 mesh, 7 x 7 cm (in one grid); number of elements per m2: 4 pieces; material: PP PE 100% recycled; weight: 1.40 kg/piece, 5.60 kg/m2; dimensional stability: ±3% (-30ºC to +50ºC).

The geogrid characteristic properties declared by the manufacturer were presented in Table 2.

Table 2. Geogrid characteristic properties

Assessed essential characteristics		Performance properties
Tensile strength	–	66.7 [kN/m] ± 15%
Elongation under maximum load	–	11±5 [%]
Expected durability in pH>4 and pH<9 conditions	–	at least 12 years
Permissible axle pressure	–	200 [kN]

7. DESCRIPTION OF CARRIED OUT TESTS

In order to determine the impact of using the geogrid system on the load bearing capacity of the natural airfield pavements, a series of field tests on the natural pavement without reinforcement and on the pavement made in accordance with the designed reinforcement technology was designed and carried out. The tests were performed on the natural pavement runway with a length of 500 m and a width of 36 m.

7.1. TESTS OF THE NATURAL PAVEMENT WITHOUT THE APPLIED REINFORCEMENT

Lithology of the tested subsoil was identified to a depth of 2.0 bgl. During the geotechnical drilling, at a depth of 1.30 m bgl, a groundwater table, which stabilised after one hour at a depth of 1.00 m bgl, was found. The grounds occurring in the subsoil were classified in the G4 load bearing capacity group – largely swelling grounds. The lithological profile of the tested subsoil is shown in Table 3.

Table 3. Lithological profile of the natural airfield pavement

Depth [m]	Soil type	Macroscopic description (colour, moisture)
0.0 - 0.3	Humus	black, little moist
0.3 - 0.8	Fine sand with stone admixture	grey-yellow, moist
0.8 - 1.3	Loamy sand	dark grey, wet
1.3 - 1.7	Loamy sand with sandy loam interbedding	dark grey, hydrated
1.7 - 2.0	Medium sand	dark grey, hydrated

The results obtained during the load bearing capacity testing of the pavement without reinforcement with the use of the DCP probe were shown in Fig. 8.

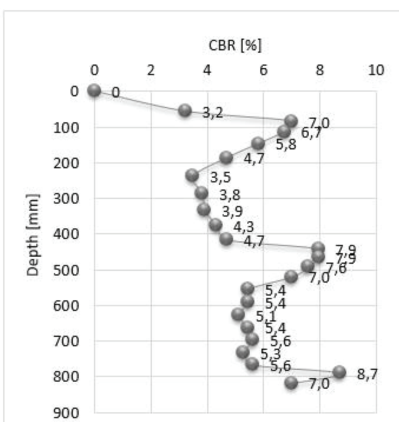

Fig. 8. Diagram of the obtained values of CBR

The CBR = 5.7% was obtained from the carried-out test for the layer I and CBR = 5.7% for the layer II, calculated according to the formula (5.1).

In order to further analyse the obtained results, the CBR ratio was converted to the deformation modulus value for the tested pavement. The relationship determined in Powell's formula, which is the most frequently applied formula for this purpose in Poland, was used [2]:

$$E = 17{,}6 \cdot CBR^{0{,}64} \tag{7.1}$$

where:

E – modulus of elasticity [MPa], CBR – California Bearing Ratio [%].

Formulas elaborated by other authors (Table 4) may be used for the Modulus of Elasticity derived from CBR ratio tests calculation.

Table 4. Relationship between the Modulus of Elasticity and the CBR ratio according to various authors [12]

Author	Equation
AASHTO	$E = 10{,}34 * CBR$ [MPa]
US Army Corps of Engineers	$E = 37{,}3 * CBR^{0{,}711}$ [MPa]
Danish Road Laboratory	$E = 10 * CBR^{0{,}73}$ [MPa]

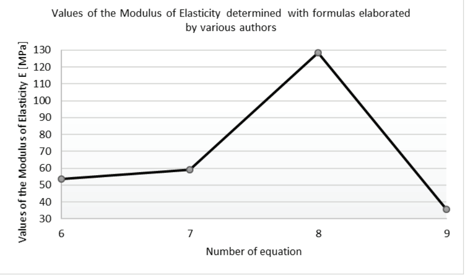

Fig. 9. Values of the Modulus of Elasticity determined with formulas elaborated by various authors

After applying the formula (7.1), the modulus of elasticity for the natural pavement equal to 54 MPa was obtained.

7.2. TESTS OF THE NATURAL PAVEMENT REINFORCED WITH THE GEOGRID SYSTEM

In order to reinforce the natural airfield pavement, a system of the runway structure, which was presented below, was designed and implemented: filling the geogrid with humus and sowing airfield grass; geogrid with PEHD, dimensions 500 x 500 x 40 mm; sand bed for 2cm geogrid arrangement; the upper crushed stone bedding layer of hard breakstone 0/31.5 (melaphyre, gabbro, granite, etc.) for mechanical stabilisation, 10 cm thick and compacted; the bottom crushed stone bedding layer of hard breakstone 0/63 mm (melaphyre, gabbro, granite), 15 cm thick layer; sand bed with a thickness of 10 cm; aligned and levelled subsoil; runway shoulder with a grass non-reinforced 2 x 7 m pavement; soil shoulder drop 3%.

Within the framework of the load bearing capacity assessment of the reinforced natural pavement, the tests with a static VSS plate, Fig. 10 (two measurement points) and a HWD airfield deflectometer, Fig. 11 (two measurement points), were performed.

Fig. 10. Static VSS plate measurement

Fig. 11. HWD airfield deflectometer measurement

In order to calculate the Modulus of Elasticity derived from VSS testing, the following formula shall be used:

$$E = \frac{3\Delta p}{4\Delta s} \cdot D \tag{7.2}$$

where :

Δp – pressure difference, [MPa]; Δs – differential settlement equal to the pressure difference, [mm] ; D – plate diameter, [mm].

Modulus of Elasticity derived from HWD airport deflectometer measurements was calculated with the following formula:

$$E_o(0) = \frac{2\cdot(1-v^2)\cdot q\cdot a}{u(0)} \tag{7.3}$$

where :

$E_0(0)$ – surface modulus beneath the loading plate ; v – Poisson's ratio, q – strain beneath the loading plate ; a – plate radius ; u – deflection in analyzed point (0 – beneath the loading plate).

The load bearing capacity results obtained during the tests with the static VSS plate were presented in Table 5, however, the values of deformation moduli estimated based on elastic deflection measurements using the HWD airfield deflectometer measurement were shown in Table 6.

Table 5. Load bearing capacity results of the reinforced natural pavement obtained through static VSS plate tests

Measurement point No.	Primary deformation module E_1 [MPa]	Secondary deformation module E_2 [MPa]	Deformation index I_0 [-]
1	47	82	1.8
2	43	80	1.9

Table 6. Values of the moduli of deformation estimated based on elastic deflection measurements using a HWD

Measurement point No.	Pavement type	Deformation module E [MPa]
1	Natural reinforced	134
2		121

8. DESCRIPTION OF CARRIED OUT TESTS

Fig. 12 presents the test results of the load bearing capacity of the natural airfield pavement, which were performed within the layer without reinforcement and within the layer with reinforcement with the use of the geogrid system.

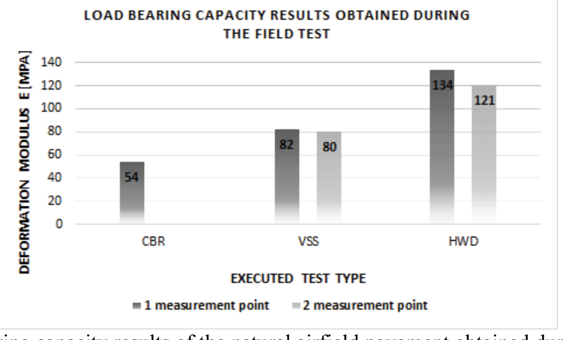

Fig. 12. Load bearing capacity results of the natural airfield pavement obtained during the field tests

The analysis of the obtained results showed that, according to the diagram in Fig. 12, the load bearing capacity of the natural airfield pavement reinforced with the geogrid system improved by approx. 30%. When assessing the obtained results, it is important to take into account the fact that the structure specially designed for this purpose was applied in reinforcing the pavement. Therefore, in the entire process, the mechanically stabilised aggregate upper and bottom bedding layers also had an impact on the load bearing capacity improvement.

The tests with the use of an HWD airfield deflectometer and a static VSS plate were performed on the same pavement, however, the value of the moduli of elasticity obtained from these tests differ. The test with the use of a VSS plate involves measuring ground settling under the plate, under its constant loading with the use of a counterweight. This test characterises the subsoil zone (deformation and strength) properties to a depth of approximately 30-50 cm, however, the test with the use of an airfield deflectometer has a greater range.

9. CONCLUSION

The article presents the concept of natural airfield pavements that are dominant in the area of flying club, sports and personal-use airfields, but they also occur at higher technical class airfields. Both at the lower-class and higher-class airfields, a well-prepared natural pavement is a basis for safe performance of flight operations.

As it results from the current test results, the state of natural airfield pavements in Poland does not largely meet the requirements in terms of load bearing capacity and requires reinforcement.

The paper proposes to reinforce the natural pavement by using the geogrid system, that is cellular geosynthetics. For this purpose, a series of field tests aimed at determination of the load bearing capacity of the natural airfield pavements was performed before the use of reinforcement and after its application.

The analysis of the conducted test results provided information that the load bearing capacity of the tested natural pavement after the geogrid system reinforcement increased by approx. 30%. The value of the elasticity modulus for the unreinforced natural pavement was 54 MPa, however, the deformation moduli of the improved layers were, on average, 81 MPa of the test with the use of a VSS plate and 128 MPa of the test with an HWD airfield deflectometer. In the discussed case, in addition to cellular geosynthetics applied to reinforce the natural pavement, the subsoil reinforcement technology, which also had an impact on improving the load bearing capacity of the pavement, was designed and executed. Accordingly, the next stage of work will be to perform the field tests involving the measurement of the load bearing capacity of the natural pavements reinforced with the geogrid system, but without applying the improvement of the soil layers that are below the sod layer. The tests will involve the use of the geogrid in the actual soil conditions.

REFERENCES

1. Airfield guidelines. Technical assessment of sod pavements on a sandy and sandy-loam subsoil, Air Force Institute of Technology, Warsaw, 1967.
2. C. Kraszewski, B. Gajewska, Methods for determining the load bearing capacity of the road subgrade - requirements and tests, Road Construction Vademecum, 2016.
3. Defence standard NO-17-A503:2017 Airfield pavements. Natural airfield pavements. Load bearing capacity tests.
4. Doc 9157 AN/901 Aerodrome Design Manual Part 1 Runways. ICAO, 2006.
5. J. Marszałek, Airports construction. Part II. Pavement calculation, Military University of Technology, Warsaw, 1984.
6. K. Łach, Review and systematics of geosynthetics, Highways Magazine, 3/2017.
7. K. Kazimierowicz-Frankowska, Principles of modelling the work of the geosynthetic reinforcement used for reinforcing the road construction, Maritime Engineering and Soil Technology, 1/2013.
8. L. Zhang, M. Zhao, C. Shi, H. Zhao, Bearing Capacity of geocell reinforcement in embankment engineering. Geotextiles and Geomembranes 28, 475-482, 2010
9. M. Wehbi, P. Musgrave, The use of Geocells reinforcement to improve the structural performance of the railway track bed in the UK. Permanent Way Institution, 2018.
10. P. Nita, Construction and maintenance of airfield pavements. Transport and Communication Publishers, Warsaw, 2008.
11. S.L. Webster, Investigation of beach sand trafficability enhancement using sand-grid confinement and membrane reinforcement concepts. Report 1 Sand Testing Sections 1 and 2. DTIC Document, 1979.
12. S. Wu, S. Sargand, Use of dynamic cone penetrometer in subgrade and base acceptance. Ohio University, April 2007.
13. Vademecum of the Airfield Service part I, Ministry of National Defence. Air Force Command. Poznań, 1974.

LIST OF FIGURES AND TABLES:

WPŁYW SYSTEMU GEOKRAT NA STAN NOŚNOŚCI NATURALNYCH NAWIERZCHNI LOTNISKOWYCH

Słowa kluczowe: *naturalne nawierzchnie lotniskowe, wzmocnienie, system geokrat, geokomórki, nośność, kalifornijski wskaźnik nośności*

STRESZCZENIE

W artykule przybliżono pojęcie naturalnych nawierzchni lotniskowych, które dominują na lotniskach aeroklubowych, sportowych i użytku wyłącznego, ale występują także na lotniskach wyższych klasach technicznych. Zarówno na lotniskach klas niższych, jak i na lotniskach klas wyższych dobrze przygotowana nawierzchnia naturalna jest podstawą do bezpiecznego wykonywania operacji lotniczych.

Jak wynika z dotychczasowych wyników badań, stan naturalnych nawierzchni lotniskowych w Polsce, w dużej części nie spełnia wymagań odnośnie nośności i wymaga wzmocnienia.

W pracy zaproponowano wzmocnienie nawierzchni naturalnej poprzez zastosowanie systemu geokrat, czyli geosyntetyków komórkowych. W tym celu wykonano szereg badań poligonowych mających na celu określenie nośności naturalnych nawierzchni lotniskowych przed zastosowaniem wzmocnienia oraz po jego zastosowaniu.

Analiza wyników z przeprowadzonych badań dostarczyła informacji, że nośność badanej nawierzchni naturalnej po wzmocnieniu systemem geokrat wzrosła o około 30%. Wartość modułu sprężystości dla niewzmocnionej nawierzchni naturalnej wyniosła 54 MPa, natomiast moduły odkształcenia warstw ulepszonych wyniosły średnio 81 MPa z badania płytą VSS oraz 128 MPa z badania ugięciomierzem lotniskowym HWD. W omawianym przypadku oprócz geosyntetyków komórkowych zastosowanych do wzmocnienia nawierzchni naturalnej, zaprojektowano i wykonano technologię wzmocnienia podłoża, która również miała wpływ na polepszenie nośności nawierzchni.

W związku z tym, kolejnym etapem prac będzie wykonanie badań poligonowych polegających na pomiarze nośności naturalnych nawierzchni wzmocnionych systemem geokrat, ale bez zastosowania ulepszenia warstw gruntu leżących poniżej warstwy darniowej. Badania będą polegały na użyciu geokraty w rzeczywistych warunkach gruntowych.

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