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Application of geogrids to ensure the load-bearing capacity of natural airfield pavements

Abstract: The article describes natural airport pavements in the aspect of performing air operations. Due to the fact that airfield functional elements are not always located on ground of sufficient bearing capacity, it is necessary to use treatments that increase the strength of weak soils. Various reinforcement technologies are available on today's market, and choosing the right method is not simple and depends on many factors, including the final effect we want to achieve after improvement, availability of technology or economic reasons.
The article presents a proposal to strengthen the natural airfield pavements using geogrids (cellular geosynthetics). The influence of the applied technology on the improvement of the natural airfield pavemen at one of the airport facilities is described. The results of field tests including geotechnical wells, DPL and DCP probing as well as static plate load tests (VSS and load tests performed with high weight deflectometer (HWD), were analyzed.

Keywords: Natural airfield pavements; Reinforcement with geogrids Load bearing capacity

Introduction

Natural airport pavements are surfaces created by proper preparation of the ground in order to ensure the possibility of safe movement after them [7]. Natural airport surfaces are divided into turf and ground. The ground surface layer is made of soil, it does not have a turf layer. On the other hand, the turf surface is a ground surface, which is covered with soil with developed grass vegetation and is adapted to perform aerial operations thereon.

Natural airport surfaces dominate at sports airports with less traffic and loads, i.e. at airports of a lower class. For turf surfaces, the load on the main landing plane should not exceed 100.00 kN [14]. In airports of higher technical classes, a natural airport surface appears on the runway strip in the area of the working runway, side safety belts, and front seat belts. These runway sections should be adapted or constructed in such a way as to minimize the risk to aircraft, for which the given runway is designated, resulting from the difference in the load capacity of the surface, in the event that the airplane would run off the runway [15].

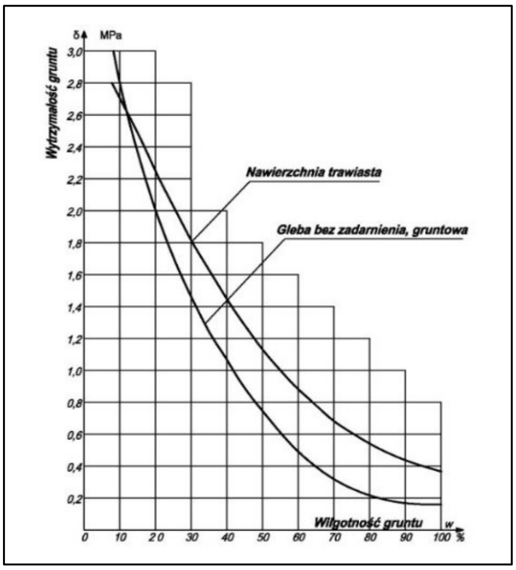
According to [12], the runway strip on both sides should be strengthened so that the threat is reduced an aircraft that accidentally left the runway. The runway strip on both sides should be leveled and covered with at least the width determined depending on the airport code digit. In the case of the flight field (part of the ground traffic field, consisting of one or several runways [7]) from the surface the natural, natural surface of the runway should be free from unevenness and allow: maintaining the direction of the aircraft's movement, its braking and run-off, drainage of rainwater roads, maintaining the required wet load capacity. The height of the grass in the take-off area should not exceed 10 cm, while in the area of the protection of runway ends (RESA) the grass can have a height of up to 20 cm. At a distance of up to 3 m from the edge of artificial turf, the grass should be mowed low to ensure the visibility of navigational aids.

Rainfall is a major contributor to the condition of airport pavements. Long-lasting rains and rapid snow melting cause the airport area to be slimy and pose a threat to air traffic. It can be predicted that precipitation has a decisive impact on the condition of the flight field, which determines the safety and regularity of air traffic [4].

Turf surfaces

The turf surface is a natural airport surface, adapted to perform aerial operations. It is a ground surface, additionally covered with soil with developed grass vegetation and with a strongly developed root system, adapted thanks to technical and agrotechnical measures for take-offs and landings [14]. The thickness of this layer is usually from 10 cm to 18 cm. It is believed that the load on the main shaving plane should not exceed 100.00 kN [14].

The turf surface is a better version of the ground surface because thanks to its properties it reduces the soil moistening and thus increases its durability. The turf surface gives the possibility to multiply the wheel loads by 3-5 times compared to the ground without turf [11]. Figure 1 shows the relationship between soil moisture and its strength for ground and grass surfaces.



1. The relationship between the strength σ of the ground surface, turf, and humidity [5]

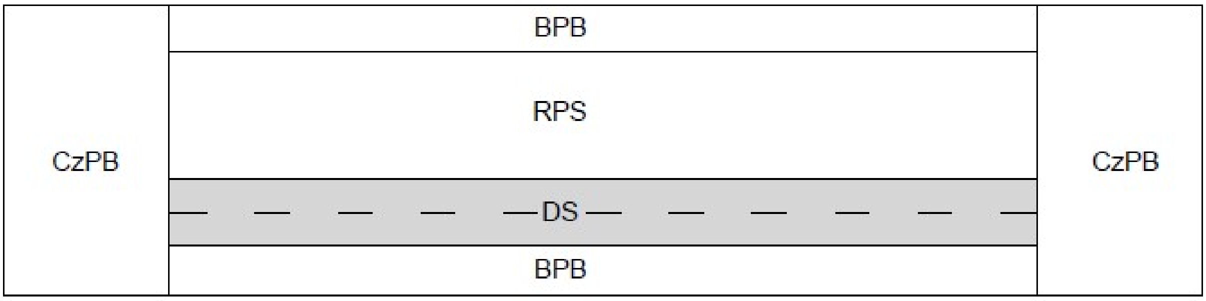
Load capacity of turf surfaces

The load-bearing capacity of a natural airport pavement is its ability to take over and carry a specific load from aircraft, without the risk of damage. Specifically, the load-bearing capacity of the turf surface is the resistance that the strongly developed root system and the soil particles contained in it have on the loads that derive from the weight of the aircraft being in a state of rest or movement. The bog turf of the take-off area has the same load-bearing capacity on the whole surface and the even grass growth [11]. The load-bearing capacity of natural airport surfaces is expressed by the California CBR load capacity index.

Loads of airport pavements are different from those on roads. The main difference is the size of the surface, which has to accept these loads because in the case of airport pavements it is a small contact area that has to absorb large, repetitive loads. Typically, the situation is such that a small surface area takes overloads that reach design values, and significant areas of airport pavements occasionally assume computational load. It should be noted that static loadings of pavements originating from airplanes cause greater deformations of the surface than short-term dynamic loads of the same value.

The criteria for the load-bearing capacity of turf surfaces should be related to the type of calculation aircraft that will be operated at the given airport [5].

The tests of the load-bearing capacity of natural airport pavements should be performed on all functional elements of the airport, which have a natural surface. The layout of the individual functional elements of the airport is shown in Figure 2.



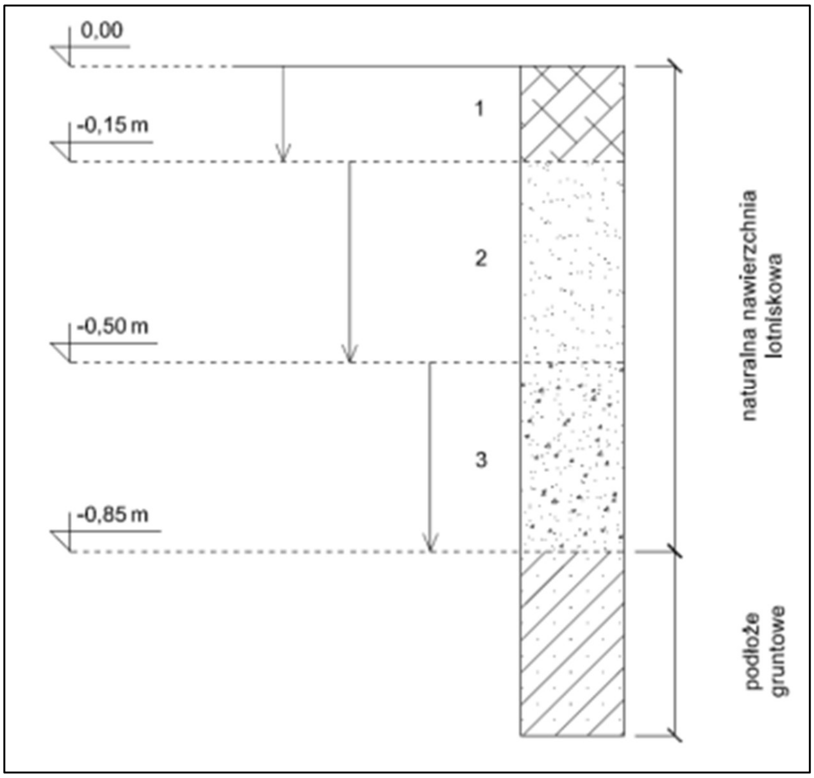
2. The EFL distribution scheme is subject to load capacity assessment [7]

where:

CzPB - front seat belt;
BPB - side safety belt;
DS - runway;
RPS - working runway.

Tests of the capacity of natural airport pavements are carried out to a depth of 0.85 m below the surface area. They are made for three separate layers, drawing **3**:

- up to a depth of 0.15 m - first layer,
- from a depth of 0.15 m to a depth of 0.50 m - the second layer,
- from a depth of 0.50 m to a depth of 0.85 m - third layer.



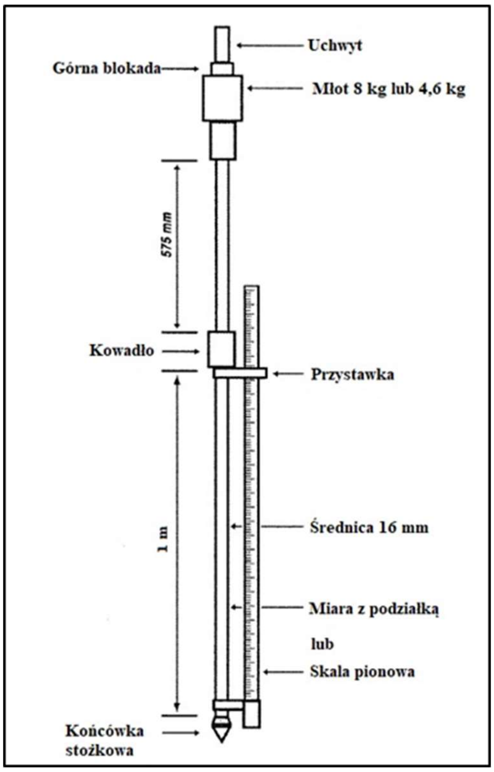
3. Layout of separated layers of natural airport pavement [7]

In order to determine the California CBR index of natural airport pavements, it is necessary to perform tests with the DCP probe (Figure 4), which should be in accordance with ASTM D6951M-09 [1]. These tests, according to ASTM D6951M-09, consist in measuring the depth of the probe tip to one impact of the weight falling from a certain height.
Californian CBR load index is calculated separately for each separated layer, according to the formula [7]:

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

where:
CBR - Californian load index [%];
DCP - probe cone recess per one stroke [mm].

The minimum CBR value for the tested EFL should be 15% for the first layer, up to a depth of 0.15 m and 8% for the layer formed from the combination of the second and third layers, i.e. from a depth of 0.15 m to a depth of 0.85 m below the ground surface [7].



4. Diagram of the DCP probe

Strengthening of soil surfaces

When choosing the area for an airport with turf surface, it is necessary to have all the rules and arrangements as for aerodromes with artificial surfaces [5]. In the case of turf surfaces, the additional requirement is the type of soil. The type and properties of the soil may determine the negative nature of the selected area for the future airport. According to [8] turf surface is assumed on the ground with such strength that the vertical deformation of the surface during the passage of the wheel of the aircraft with the largest dimensions, the largest weight and unit pressure on the tested surface of about 0.6 MPa was not more than 2 cm.

In order to increase the strength of natural airport pavements, you can apply various types of reinforcements and improvements. There are many technologies for ground reinforcement, it is difficult to clearly classify these methods. The following criteria are accepted as a criterion for the division: reinforcement technology, depth of interference in the substrate, applied materials, final reinforcement effect [3].

The following technology groups can be distinguished:

- strengthening the substrate by improving its properties and / or parameters, without using additives of other materials;
- replacement of low-bearing soils with the use of qualified aggregates;
- reinforcement of the substrate with the use of admixtures, e.g. by surface or depth stabilization or column forming;
- strengthening the substrate using geosynthetics [3].

Geosynthetics, as reported [10], are products whose at least one component was made of synthetic or natural polymer, in the form of a sheet, strip or spatial form, used in contact with soil and/or other materials in geotechnics and construction. Geosynthetics have multiple applications, including drainage, filtering, separation, reinforcement or protection, eg against surface erosion. Geosynthetics division, based on [10] presented in table 1.

Tab. 1: Types of geosynthetics in accordance with PN-EN ISO 10318-1: 2015-12 [10]

GEOSYNTHETICS (GSY)			
GEOTEXTILES (GTX)	**GEOTEXTUAL RELATED GOODS (GTP)**	**GEOSYNTHETIC BARRIERS (GBR)**	**GEOCOMPOSITES (GCO)**
• Woven (GTX-W)	• Geotextiles (geogrids) (GGR)	• Polymer (GBR-P)	
• Nonwoven (GTX-N)	• Drainage geogrids (GNT)	• Loamy (GBR-C)	
• Knitted (GTX-K)	• Cellular geosynthetics (GCE)	• Bituminous (GBR-B)	
	• Geotapes (GST)		
	• Geomats (GMA)		
	• Distancing geosynthetics (GSP)		

The selection of the right type of geosynthetic is not easy, taking into account various factors resulting from its durability, resistance to external factors and the function to be used [2].

Application of geogrids for reinforcing ground surfaces

Geogrids are cellular geosynthetics that are used to reinforce ground, anti-erosion or construction of retaining structures. According to [10], cellular geosynthetics are polymeric (synthetic or natural) products with a spatial, permeable honeycomb structure or similar cell structure, made from geosynthetics tapes connected together.

When assessing the correctness of choosing a geosynthetic to perform a particular function, you can use different coefficients. And so, when the geosynthetic is to act as ground reinforcement, coefficients can be analyzed [2]:

$$\mathrm{LCR} = \frac{q_r}{q}$$

where:

LCR - gain factor (Load Capacity Ratio);

q_r - load that should be applied to the surface of the pavement structure to induce a given amount of deformation of the substrate reinforced with a geosynthetic;

q - load that should be applied to the surface of the pavement structure to cause the same amount of deformation of the substrate not reinforced with a geosynthetic.

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

where:

BCR - load factor (Bearing Capacity Ratio);

$q_{u(R)}$ - bearing capacity of a geosynthetic reinforced substrate;

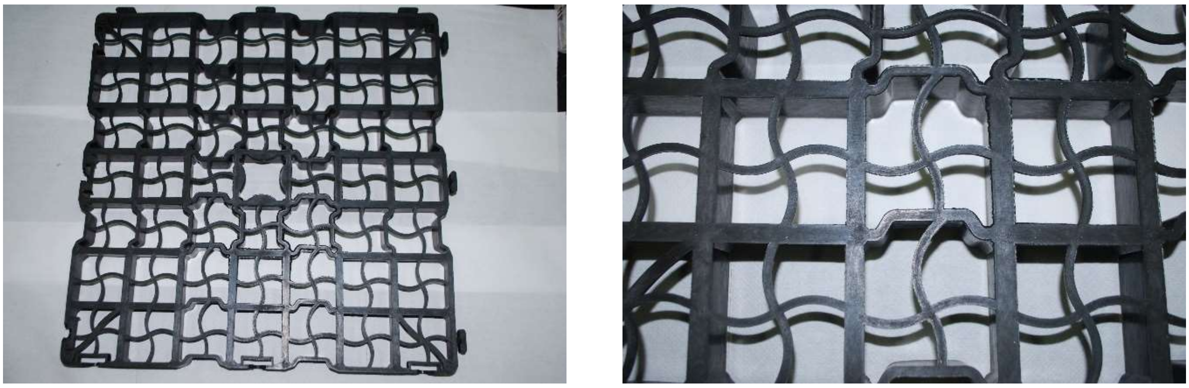
q_u - bearing capacity of the substrate not reinforced with a geosynthetic.

The standard PN-EN 13249 [9] specifies the requirements for properties that should be met by geosynthetics, depending on the function performed. The materials used to reinforce the subsoil should have the following parameters defined:

- tensile strength;
- elongation at maximum load;
- CBR static breakdown resistance;
- dynamic puncture;

- durability.

Properties of the geogrid used to strengthen the natural surface
To strengthen the grass surface at one of the aerodrome airports, a geogrid was used, which was previously used to modernize the runway of a forest landing pad, used for takeoffs and landings of light fire and agricultural aircraft.The geocard's appearance is shown in the photograph 5.



5. The geogrid used to strengthen the natural airport surfaces

The biologically active surface of the discussed geogrid is 85% and thus the material is 15%. Technical data is shown below [13]:

Dimensions	-	50 x 50 cm
Wall height	-	4 cm
Thickness of walls	-	3 – 4 mm
Mesh size	-	49 meshes; 7 x 7 cm (one grid)
The number of elements per m^2	-	4 szt.
Stuff	-	PP PE 100% recycled
Weight	-	1,40 kg/piece; 5,60 kg/1 m^2
Dimensional stability	-	± 3% (-30˚C do +50˚C)
Material durability	-	minimum 10 years
Permissible axle load	-	200kN/oś

Geogrid has a certificate of conformity of factory production control issued by an accredited body certifying products and declaration of the performance of CE. Declared usable properties are shown in table 2.

Tab. 2: Characteristic properties of geogrids

Essential characteristics assessed in the 2+ system		**Useful properties**
Tensile strength	-	66,7 [kN/m] ± 15%
Elongation at maximum load	-	(11 ± 5)%
Predicted durability at pH> 4 and pH <9	-	at least 12 years

The results of field tests of a natural airport pavement without reinforcement and reinforced with a geogrid
The designed construction of the natural surface of the runway had the following layout:
- filling the geogrid with humus with sowing of airport grass,
- HDHD geogrid 500 x 500 x 40 mm,
- ballast made of sand for 2 cm geogrid arrangement,
- upper layer of crushed stone foundation from hard breakstone for mechanical stabilization 0 / 31.5 (melaphyre, gabbro, granite, etc.), 10 cm thick with compaction,

- bottom layer of crushed stone foundation made of hard crushed rock from igneous rocks e.g. melaphyre, gabbro, granite, 0/63 mm, layer thickness 15 cm,
- sand bedding with a thickness of 10 cm,
- contoured and leveled floor,
- roadside of the runway with 2 x 7 m unbroken grass surface,
- fall of the ground shoulder 3%.

The process of laying the geogrid is shown in photograph 6.


6. The process of laying a geogrid on a properly prepared structure

The area covered by the study included a non-reinforced natural surface, a grassy surface and a surface with complete reinforcement technology, including a sodden geogrid (photo 7).

← natural surface without reinforcement

← reinforced surface

7. Areas of the surface covered by the tests

The measurements were carried out on the runway of the landing pad, 500 m long and 36 m wide.

As part of the study of the natural surface without reinforcement, the identification of the ground substrate was made, making a geotechnical well to the depth of 2.0 m (photo 8), giving an overview of the lithology of the research area. Dynamic probing was also carried out with a lightweight dynamic DPL probe (photo 9) and probing with a DCP conical dynamic probe (Figure 10). Probing with the DCP probe allowed to determine the density of non-cohesive layers, while by probing with the DCP probe the Californian index of CBR bearing capacity of the tested substrate was determined.

8. Geotechnical drilling

9. Probing with the DPL

10. Probing with the DCP

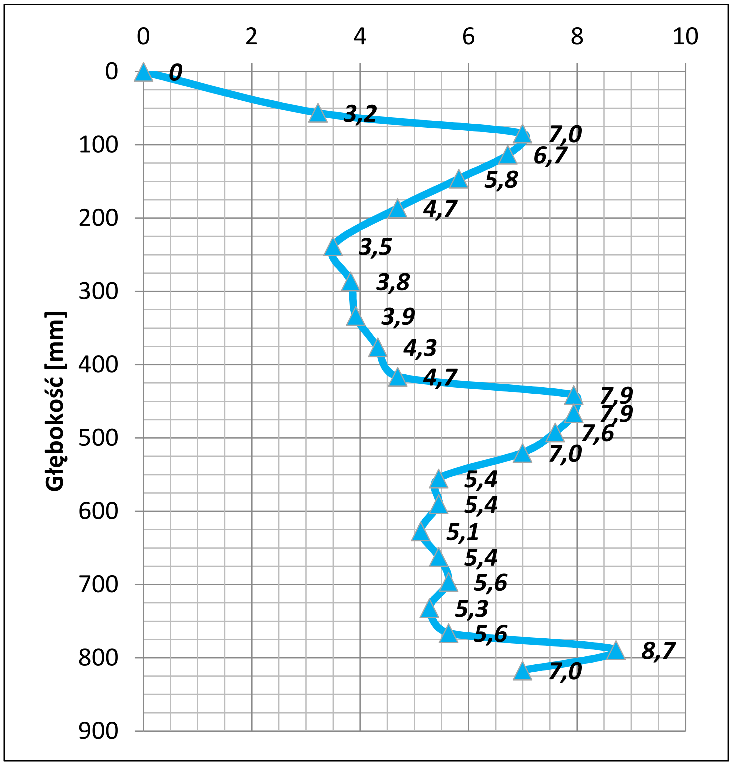
The system of lithological layers in the studied area is presented as in Table 3. The groundwater table was drilled at a depth of 1.30 m, after 1 hour it stabilized at a depth of 1.0 m in a d.b.g. The ground surface of the pavement in the depth range from 0.8 to 1.7 m d.b.g. qualified according to ground soil and water conditions, up to load group G4 (very loose soil).

Tab. 3: Lithium profile of the natural airport pavement

Depth [m]	**Type of soil**	**Macroscopic description (color, humidity)**
0,0 - 0,3	Hummus	black, dank
0,3 - 0,8	Fine sand with an admixture of stones	yellow-gray, dank
0,8 - 1,3	Clay sand	dark gray, wet
1,3 - 1,7	Clay sand laid over with sandy clay	dark gray, hydrated
1,7 - 2,0	Medium sand	dark gray, hydrated

The California CBR load test was conducted on a natural airport pavement without reinforcement (photo 7).

As can be seen from the diagram - figure 11 - the tested natural surface (without reinforcement) did not have the required values of CBR capacity index, the results were as follows: CBR (up to 0.15 m) = 5.7% (required at least 15%), CBR (from 0.15 to 0.85 m) = 5.7% (min. 8% required).



11. CBR load capacity graph

On the natural airport pavement reinforced with the geogrid system, the load capacity was tested using the static VSS plate (photo 12) and capacity tests using the HWD air deflector (photo 13).

12. VSS exploration

13. Test with HWD deflectometer

As part of field tests carried out on a reinforced natural airport pavement (photograph 7), load tests were carried out using a static plate VSS in two points and near these points, using an HWD airport deflector.

The load test using the VSS plate consists in measuring the ground subsidence under the slab, with its gradual loading, using a counterweight and used to determine the deformation and strength properties of the substrate. This test characterizes the zone to a depth of about 30-50 cm.

Pavement load results obtained during the VSS plate tests are shown in Table 4.

Tab. 4: Results of the load-bearing capacity of the reinforced natural surface obtained during the VSS static plate test

Point number	E_1 [MPa]	E_2 [MPa]	I_0 [-]
1	47	83	1,8
2	43	80	1,9

where:
E_1 - primary deformation module;
E_2 - secondary deformation module (also called elastic deformation module);
I_0 - deformation index.

Analysis of the received data

To determine the deformation modulus for the unreinforced natural airport pavement for which the California CBR load index was determined, the Powell pattern was used [7]:

$$E = 17{,}6 \text{ x } CBR^{0{,}64}$$

where:
E - modulus of elasticity,[MPa];
CBR - Californium load index, [%].

When assessing the results of the tests carried out, it should be remembered that the load capacity assessment with the DCP probe was made in a natural, unreinforced surface. However, the design of the reinforcement, according to the design, is 41 cm thick, so during the load test with the static VSS plate of the reinforced natural surface, the load capacity of the reinforcement structure was tested above all.

A comparison of the results of deformation modules obtained as a result of the VSS plate test and the conversion of the CBR index is given in Table 5.

Tab. 5: The values of deformation modules obtained from the VSS plate test and the conversion of the CBR index

Point number	Surface type	E [MPa]
1	Natural unreinforced	64
2	Natural reinforced	83
3		80

Based on the obtained test results, it was found that the load-bearing capacity of the reinforced natural airport pavement increased by about 20%. The increase of the natural bearing capacity of the airport surface was certainly affected not only by the application of the geogrid, but also the foundation layer of mechanically stabilized aggregate (bottom foundation made of granulate with grain size 0 / 63 and the upper foundation, made of crushed stone with a particle size of 0 / 31.5 mm).

During the polygon tests, in the places where the VSS type plate was measured, the load capacity of the already improved EFL was also measured using an HWD type air deflector (photo 13). Based on the obtained results, the deformation modules for the entire structure were estimated, Table 6.

Tab. 6: The values of deformation modules estimated on the basis of elastic deflection tests with the HWD air deflector

Point number	Surface type	E [MPa]

1	Natural reinforced	134
2		121

The results obtained during measurements of elastic deflection of the pavement (HWD) are greater in comparison to the deformation modules obtained during the tests with the VSS plate. This may be due to the fact that the VSS plate testing is characterized by a zone of up to about 0.5 m deep into the test center, while the HWD by an airport deflector has a larger range.

Summary

The article discusses the concept of natural airport surfaces, dominating at sports airports, but also occurring in the runway strip at airports of higher technical classes. The most important feature of the surface is its carrying capacity, which is characterized as the ability of the surface to take over and transfer a specific load from the aircraft. When choosing a site for an airport with a natural surface, all the requirements and arrangements that apply to artificial surfaces are taken into account, moreover in the case of turf surfaces a very important factor, often deciding on the choice of area, is the type of soil.

The use of reinforcement of turf and ground surfaces to increase their load capacity is directly related to ensuring the safety of air operations. The article describes the strengthening of the surface of natural surfaces using cellular geosynthetics, such as geogrids.

The results of the preliminary tests confirmed that it is possible to improve the load-bearing capacity of natural surfaces, which is a summary effect resulting from the use of geogrids, but also from laying the foundation layers of mechanically stabilized aggregate.

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