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A quick method of improving the load-bearing capacity of natural airport pavements

Abstract: The load-bearing capacity of natural airport surfaces directly affects the safety of air operations. Natural airport surfaces at military airports are front seat belts, work belts and side seat belts. The load-bearing capacity of the natural airport pavements must be high enough to prevent damage to the aircraft from the runway, damage to the underground infrastructure of the airport, and to enable quick restoration of the airport's operational capacity by efficient removal of the aircraft from the natural surface by airport services. That is why it is so important to have a quick and effective method of strengthening natural surfaces. The article proposes to improve the load-bearing capacity of natural airport pavements by using geogrids (airport gratings) pressed into the existing pavement.

Keywords: Carrying capacity; Natural airport pavement; Safety Conducting air operations

Introduction

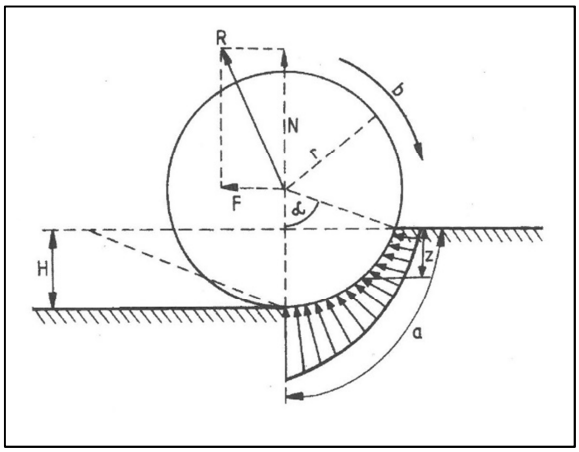
The load-bearing capacity of natural airfield pavements plays a very important role in the safety of air operations. Tests of the load capacity of natural airport pavements on civil and military airport facilities show that, in most cases, the load capacity does not meet the specified requirements. Therefore, these surfaces should be treated to improve the load capacity parameter. The process of strengthening the natural pavements must allow for the airport's operational capacity to be restored as soon as possible.

The load capacity of natural airfield pavements

According to [10], a "natural airfield pavement" is an airfield pavement created by appropriate ground preparation to ensure the safe movement of military and civil aircraft on it. Natural airfield pavements are responsible for ensuring safety in relation to the aborted take-off maneuver, delayed landing, and possible taxiing from the runway [13]. Fig. **1** shows a photo of an aircraft that skidded and left the runway shortly after touchdown.

1. Aircraft running off the runway [17]

When dealing with low-bearing soils, the application of an external load, which may be the wheel of an aircraft leg, will cause deformation of the soil. Vehicular traffic on unreinforced natural surfaces creates ever-increasing ruts. The vertical force acting from the wheel load causes shearing or displacement of the soil, which in turn causes displacement of the soil [14]. The rut depth of the natural pavement can be calculated according to the formula: $H = \frac{q_k^2 \cdot D}{\sigma_d^2 \cdot k_h}$, in which H – rut depth [mm], q_k – ground pressure of one wheel of the undercarriage [MPa], D – aircraft wheel diameter [cm], σ_d – ground resistance [MPa], k_h – $k_h = m \cdot \xi$, m – coefficient depending on soil plasticity, ξ – tire stiffness [5]. The diagram of stresses in the ground during the movement of the aircraft is shown in Fig. **2**, where N - vertical reaction of the ground to the wheel load, F - friction force, and R - resultant of forces F and N, H - rut depth, a - length of the segment of contact between the wheel and the ground surface, α - angle corresponding to the length of the segment a, r - radius of the circle, b - direction of rotation of the circle, z - depth of the considered soil layer [8].

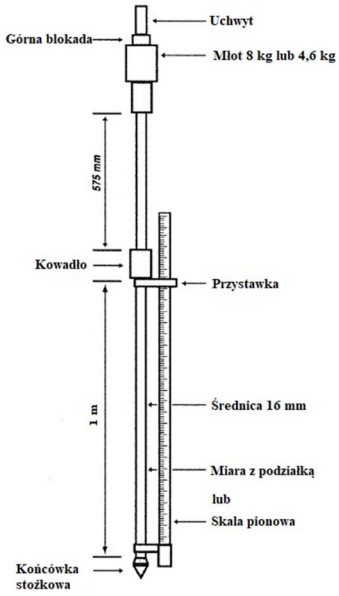


2. Scheme of distribution of stresses and strains arising in the ground during taxiing of the aircraft on the ground surface [8]

The load capacity of natural airport pavements, according to [10], is the ability of the pavement to carry a specific load from a military aircraft without the risk of damaging it, expressed by the California bearing ratio (CBR). The CBR load index is calculated according

to the formula: $CBR = \frac{292}{DCP^{1,12}}$, in which CBR – California bearing ratio [%], DCP – penetration of the probe's cone per stroke [mm] [10].

Load capacity tests of natural airfield pavements are performed in accordance with [9] and [10] using the SDS (Dynamic Cone Penetrometer) probe - Fig. **3**.



3. Scheme of the SDS probe [9]

According to the requirements described by the International Civil Aviation Organization ICAO [15] and the European Union Aviation Safety Agency EASA [19], the CBR indicator should be at a level of 15÷20% at a depth of 15 cm below ground level. The defense standard [18] specifies the requirements of the CBR load capacity index for a layer up to a depth of 15 cm - 15% and a layer from a depth of 15 cm to 85 cm - 8%.

Treatments reinforcing natural surfaces

In the event of insufficient load-bearing capacity, and to maintain the appropriate load-bearing capacity of natural pavements, they should be subjected to ongoing maintenance and maintenance procedures. Proper maintenance of natural airfield pavements has a direct impact on the safety of air operations. The basic measures aimed at improving the load-bearing capacity of natural surfaces include: - systematic mowing of natural surfaces, rolling surfaces, supplementing areas with reduced turf with a mixture of grasses, fertilizing turf, and performing chemical spraying. In order to improve the load capacity parameter, strengthening measures should be applied.

The most commonly used are mechanical and chemical stabilization. Mechanical stabilization consists of performing activities leading to the appropriate compaction of the soil, which will ensure a permanent increase in the mechanical strength of the soil [7]. This method includes the addition of native soil to obtain the appropriate granulometric composition of the soil (the so-called optimal mix), mixing, and compacting - Fig. **4**.

4. Mechanical compaction of the subsoil

Chemical stabilization consists of mixing the native soil with appropriately selected chemicals - Fig. **5**, such as cement, lime, fly ash, and slag. The composition of the mixtures is adapted to the type of stabilized soil and its intended use. Each of the above chemical agents is designed to improve the load-bearing capacity of the reinforced structural layers by reducing the sensitivity to atmospheric influences, as well as by reducing humidity.

5. The process of mixing native soil with a chemical agent

The polymer fiber reinforcement system consists of creating a flexible turf surface - Fig. **6**, which is a mixture of sand, native soil, and polymer fibers [15]. Polymer fibers interlock, ensuring high tensile and shear strength of the soil, while properly selected soil ensures adequate compaction of the surface and its stability in wet conditions.

6. Rooted layer with the use of polymer fibers [1]

Soil replacement - Fig. **7** is another method of strengthening natural pavements. It is used when there are weak soils in the subgrade, such as cohesive soils in plastic, soft plastic, or liquid state, organic soils, e.g., peat, silt, gyttja, and uncontrolled landfills of weak materials or waste. This method consists in selecting soils with insufficient bearing capacity, and then backfilling the excavation with soils suitable for earthworks.

7. Replacement of low bearing soils [16]

The discussed methods of subsoil strengthening are effective but time-consuming, and in the case of strengthening with polymers and soil replacement, also expensive. In the case of improving the load-bearing capacity of natural airport pavements, it is very important to restore the operational capacity of the airport as soon as possible. Therefore, research was carried out on the use of airport gratings to reinforce natural airport pavements. This procedure consists in pressing the airport gratings into the existing subsoil, which effectively improves the load-bearing capacity of the natural surface.

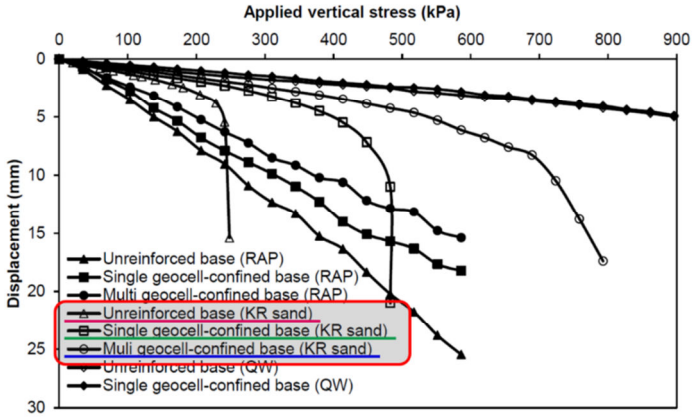
Airport grating is an effective and quick treatment for strengthening natural airport surfaces

Currently, airport grating is used to strengthen natural airport surfaces both in the country and abroad. In accordance with the PN-EN 13249:2016-11 standard "Geotextiles and Related Products, Properties are required for products used in the construction of roads and other traffic-loaded surfaces, excluding railways and asphalt pavements." The airport grating is classified as cellular geosynthetic. In the world literature, e.g., in the article [2], in which the authors describe the possibilities of reinforcing ground trails in wet conditions, geocells (such as those in this article) have been classified into the Geo-Others group - Turf Reinforcement - Fig. **8**. The Geo-Others group is described in [2] as reinforcement made of recycled plastics and designed to protect the sod from rutting, against soil erosion, and to support the compaction of the sod. In the book [4], the author, describing the types of geosynthetics, mentions Geo-Others as one of the groups, to which he qualifies e.g. geocells.

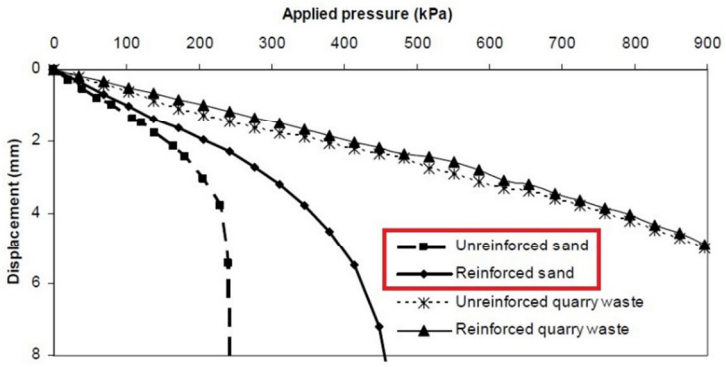
8. Geocell - GOBLOCK® Grass Pavers from the Geo-Others group [12]

In the domestic and foreign literature, you can find many studies that describe laboratory experiments involving the use of cellular geogrid in structural layers subjected to loads. The article [3] describes a series of static and cyclic load tests of slabs on geocell-reinforced substrates with various filler materials, i.e., poorly sorted sand from the Kansas River, quarry waste, and recycled asphalt pavement. The tests carried out showed that the geocell filled with poorly sorted sand used to strengthen the subsoil reduced the deformation of the subgrade (displacement under the load) and thus increased the subgrade load capacity (Fig. **9**). Deflection (displacement) equal to 10 mm arose for the subgrade: unreinforced with a tension of approximately 248 kPa; reinforced with a single geocell at a stress of approximately 477 kPa; reinforced with multiple cells at a tension of approximately 720 kPa. The use of cellular geogrid has also influenced the possibility of reducing the required thickness of the foundation to achieve the same parameters as a road on a weak subsoil [3].

The article [11] presents the results of experimental work carried out to examine the impact of the use of geocells as soil reinforcement. The geocell filled with river sand was subjected to static loads. Based on the tests performed, it was found that the applied limiting cell system improved the load-bearing capacity of the assessed layer by a factor of 1.75 in relation to the unreinforced subgrade - Fig. **10**.

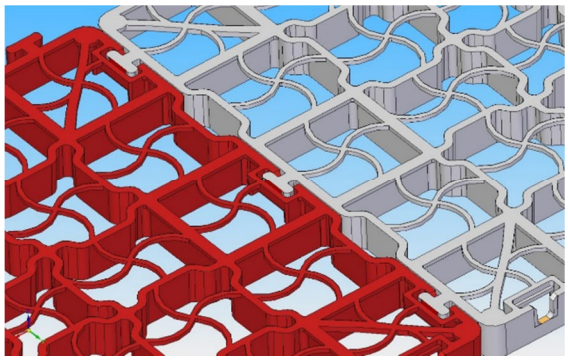


9. Stress curves as a function of displacement for the static slab load tests [3]



10. Stress-displacement plot for geocell-reinforced and unreinforced soil under static load [11]

The airport grille, which was used for the experimental tests, was made of recycled plastic materials, and the individual elements were connected using a lock that allowed disassembly but did not unfasten in operating conditions - Fig. **11**. The technical data of the airport grille used for experimental tests are presented in Tab. **1**.



11. A view of the two airport gratings connections [5]

Tab. 1. Airport grating technical data

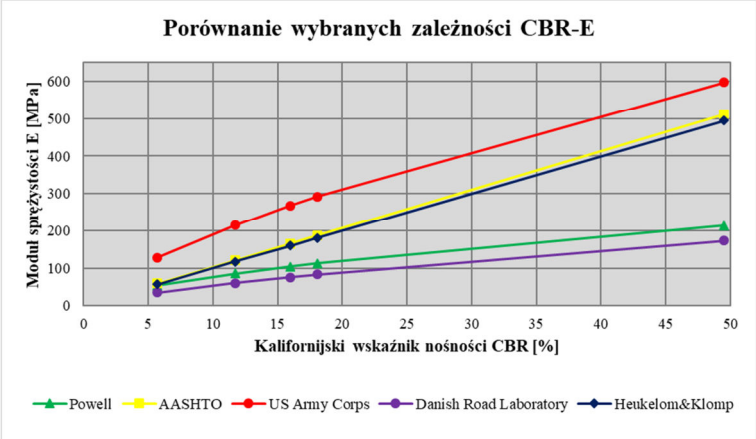
Characteristics	Declared values
Dimensions: ± 3%	490 x 490 mm
Wall height:	40 mm
Wall thickness:	the walls have a conical structure from the top 5 mm from the bottom 3,5 mm
Number of gratings per m ^{2}:	~ 4,2 pcs
Mesh size:	24 empty meshes - 63 mm x 63 mm 25 built-in meshes - 63 mm x 63 mm 36 full squares - 23 mm x 23 mm
Weight: ± 4%	1,65 kg/ piece 6,93 kg/m^2
Biologically active surface:	53% free area 47% raw material

In order to determine the impact of the use of airport gratings on the improvement of the load-bearing capacity of natural airport pavements, tests were carried out using a dynamic-conical probe and an HWD airport deflectometer on three experimental plots. The measurements were carried out before and after the application of the airport gratings.

To analyze the results obtained from field tests, the obtained value of the Californian load capacity index CBR [%] of the pavement was converted to the value of the deformation modulus E [MPa] of the pavement. In the international and domestic literature, various relationships are proposed that allow estimating the value of the modulus of elasticity E based on the CBR index. In Poland, the most frequently used relationship is the Powell formula Powella [6]: $E = 17{,}6 \cdot CBR^{0{,}64}$. Typical relationships used around the world to calculate the deformation modulus E based on the CBR index are shown in Fig. **12**.

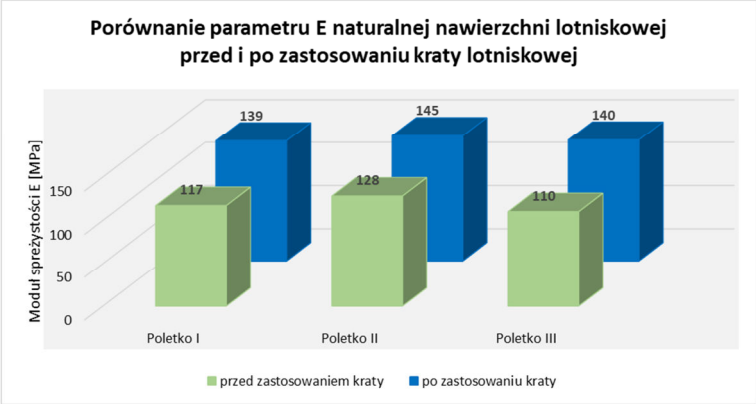
The tests of the load capacity of the natural pavement structure and the airport grating were carried out using the HWD airport deflectometer - Fig. **13**.

Graph - Fig. **14** shows a comparison of the elastic modulus values obtained before and after pressing the airport grating into the natural pavement. The obtained results confirmed the effectiveness of using this method to strengthen natural pavements. The increase in modulus of elasticity ranged from 13% to 27%, depending on the experimental plot.



12. Comparison of CBR-E dependencies estimated on the basis of selected formulas

13. Measurement of bearing capacity with the HWD airport deflectometer



14. Comparison of the natural pavement modulus of elasticity before and after the application of the airport grating

Summary

The airport grille has been designed in such a way that its strength parameters are matched to the loads it must carry from the aircraft.

The use of an airport grating improves the load-bearing capacity of natural pavements by: increasing the resistance of the grating filling materials to shear as a result of their closure and compaction inside the cells, reducing settlement caused by natural compaction and limiting the lateral movements of the material filling the cells, reducing the stresses transferred to the subsoil from the load acting on the pavement in as a result of distributing concentrated loads to adjacent lattice cells.

The airport cards in question are made of recycled plastic, which in financial terms is a more advantageous solution compared to, for example, a rigid pavement made of cement concrete.

Experimental tests have shown that the use of airport gratings by pressing them into the natural pavement improves its load-bearing parameters. On three experimental plots, the increase in modulus of elasticity ranged from 13% to 27%.

The use of airport gratings to reinforce the natural surfaces of military and civil airports is a new approach to increasing the level of safety for aircraft during air operations. The unprecedented advantage of using geogrids to strengthen natural pavements over other methods is the time regime for restoring the operational capacity of the airport.

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