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Airport grating as a fast and effective method of improving the load-bearing capacity of natural airport pavements

Abstract: Natural airport surfaces, which are functional elements of airports, such as: runway shoulders, frontal lanes, emergency runway, or working runway, play an important role in the safety of air operations. Both the International Civil Aviation Organization (ICAO) and the European Union Aviation Safety Agency (EASA) define the load-bearing capacity requirements that natural airport pavements should meet. These documents specify the required California Bearing Ratio (CBR) of 15-20% at a depth of 15 cm below ground level. The previous field tests in civil and military airports have shown that the load-bearing capacity of natural airport pavements sometimes does not meet certain requirements. Due to the fact that airports cannot afford to shut down the airport for a long time, it is reasonable to search for innovative methods of improving the load-bearing capacity of natural airport pavements, which will be effective and quick to implement. Such a method may be the use of an airport grating pressed directly into the natural airport pavement.

Keywords: Load capacity; CBR; Natural airport pavement; Safety of air operations

Introduction

Natural airport pavements acting as a runway for, among others, aeroclub aerodromes, shoulders of runways, frontal safety lanes, emergency runways, working runways, must meet certain load capacity requirements. Airport infrastructure services are looking for effective and fast methods to improve the load-bearing capacity of natural airport pavements because it is very important to restore the airport's operational capacity as soon as possible.
One of such methods is the use of an airport grating made of plastic.

Natural airfield pavements

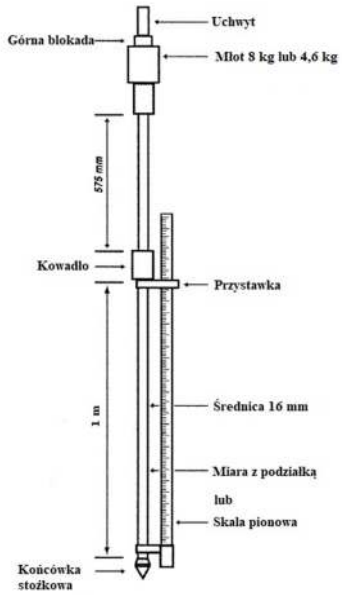
There are natural ground surfaces (the driving layer of the surface is made of soil) and turf surfaces (soil surface, additionally covered with a layer of turf with a thickness of 10-18 cm). According to the description in [14], the turf is a dense plant cover, usually grassy, with a very strongly developed root system. According to the defense standard NO-17-A503: 2017 [5], natural surfaces are airfield surfaces created by appropriate soil preparation in order to ensure the safe movement of military aircraft on them.

The load-bearing capacity of natural airport pavements is the basic parameter influencing the safety of air operations. It is determined on the basis of the Californian load capacity index CBR, which is calculated on the basis of measurements made with the dynamic cone probe DCP - Fig. **1** (DCP Dynamic Cone Penetrometer), according to the formula: $CBR = \frac{292}{DCP^{1,12}}$, in which CBR - Californian load index [%], DCP - probe cone depth per one stroke [mm] [4]. This formula, according to [10], is the best correlation between the DCP index and the CBR index - Fig. **2**.

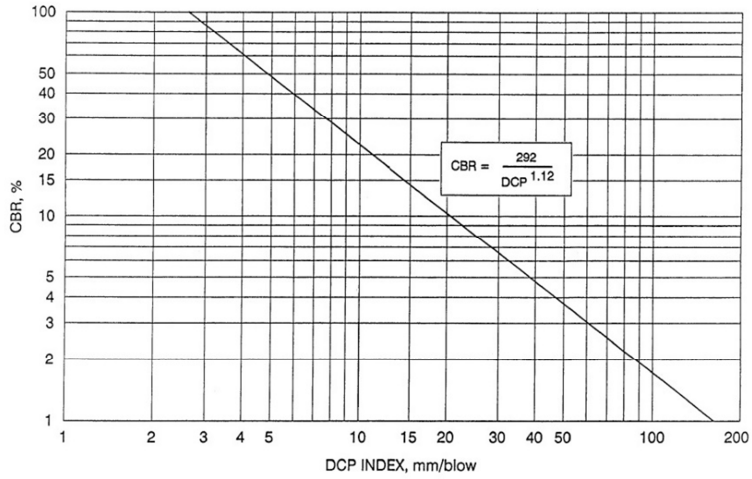
The insufficient load-bearing capacity of natural airport pavements may pose a threat to the safety of air operations. Figure **3** shows a photo of the aircraft skidding shortly after touchdown and over-starting the runway. This resulted in both sides of the main landing gear collapsing, causing wing damage and fuel leakage [8].

According to the requirements described in the International Civil Aviation Organization ICAO [15] and the European Union Aviation Safety Agency EASA [16], the CBR index should be at the level of 15 ÷ 20% at a depth of 15 cm below the ground level. The defense standard [15] specifies the requirements of the CBR load-bearing capacity index for a layer up to a depth of 15 cm - 15% and for a layer from a depth of 15 cm to 85 cm - 8%.

Numerous field tests of the load-bearing capacity of natural airport pavements, which were carried out on civil and military airport facilities in the Republic of Poland, have shown that most of the natural pavements do not meet the requirements. Fig. **4** shows the load-bearing capacity profile of the natural airport pavement, which does not fully meet the specified requirements. This applies in particular to a layer up to a depth of 15 cm. On the other hand, Fig. **5** shows the load-bearing capacity profile of a natural pavement that meets certain requirements.

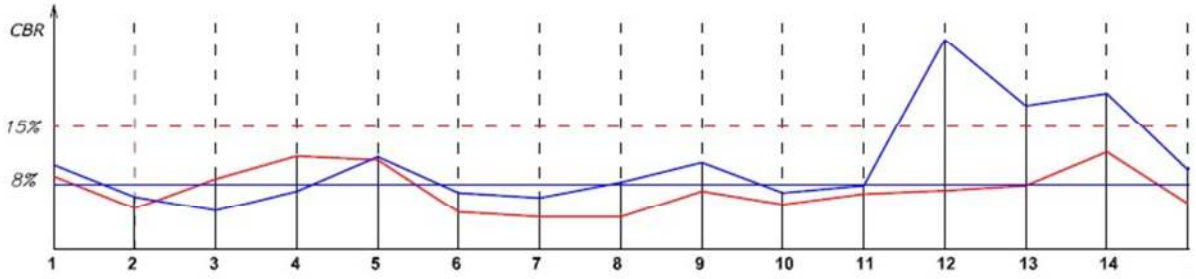


1. SDS probe scheme [14]

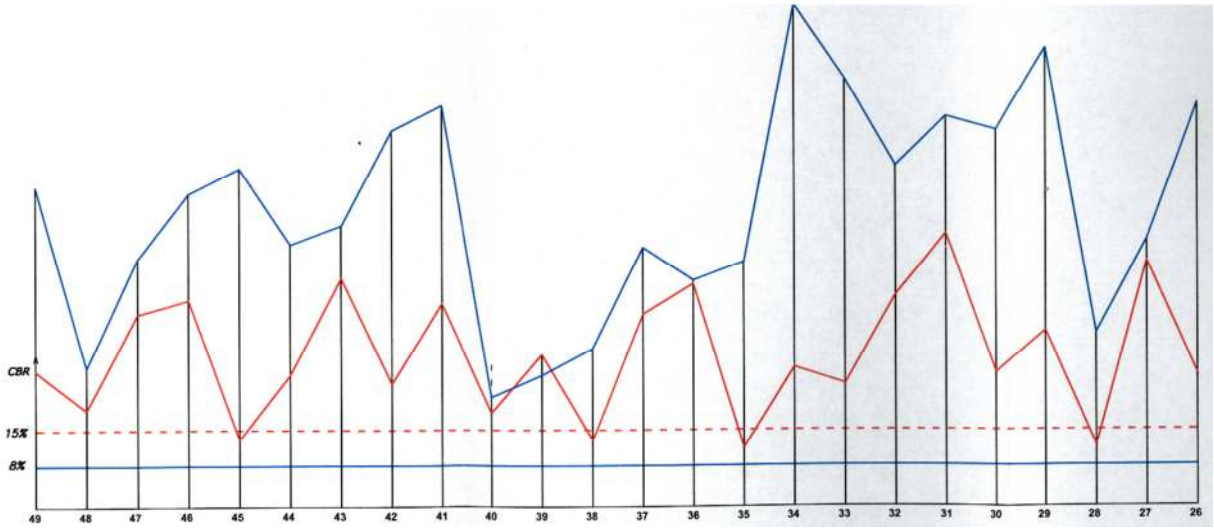


2. Correlation between the CBR index and the DCP index [10]

3. Aircraft overrun of a runway [8]



4. The load-bearing capacity of natural airport pavements not fully meeting the requirements



5. Load-bearing profile of natural airport pavements meeting the requirements

Methods of improving the load-bearing capacity of natural airport pavements

In order to improve and maintain the appropriate load-bearing capacity of natural airport pavements, they should be subjected to repair and maintenance treatments.

Maintenance procedures consist in carrying out planned and ongoing agrotechnical and mechanical treatments, which contribute to increasing the level of soil fertility and the operational value of turf-forming vegetation [9].

Repair and agrotechnical treatments consist of: systematic mowing of natural surfaces, rolling the surface, supplementing areas with reduced turf with a mixture of grasses, fertilizing the turf, and performing chemical spraying [9]. Fig. **6** shows the procedure of supplementing the areas with reduced turf cover with a mixture of grasses, while Fig. **7** shows the performance of chemical spraying [2].

Typical reinforcement treatments aimed at improving the load-bearing capacity of natural airport pavements are: mechanical and chemical stabilization, reinforcement with polymer fibers, and finally soil replacement.

Mechanical stabilization consists in carrying out activities aimed at obtaining appropriate soil compaction, which will ensure a permanent increase in the mechanical strength of the soil [3].

Chemical stabilization consists in mixing the native soil with properly selected chemicals, e.g. cement, lime, fly ash. The choice of chemical agent depends on the condition of the soil and what properties of the soil need to be improved. Fig. **8** shows the process of mixing native soil with a chemical agent.

Strengthening the natural pavement with polymer fibers consists in mixing a mixture of sand, native soil, and polymer fibers [13]. Polymer fibers interlock to ensure high tensile and shear strength, while a properly selected soil (sand) ensures adequate compaction of the pavement and its stability in wet conditions.

Replacing the soil is a very costly solution, it is used when there are low-bearing soils in the substrate, e.g. organic soils - peat, silt, gyttz, or fine-grained soils in a soft and liquid state.

6. Supplementing areas with reduced turf with a mixture of grasses [2]

7. Performing chemical spraying [2]

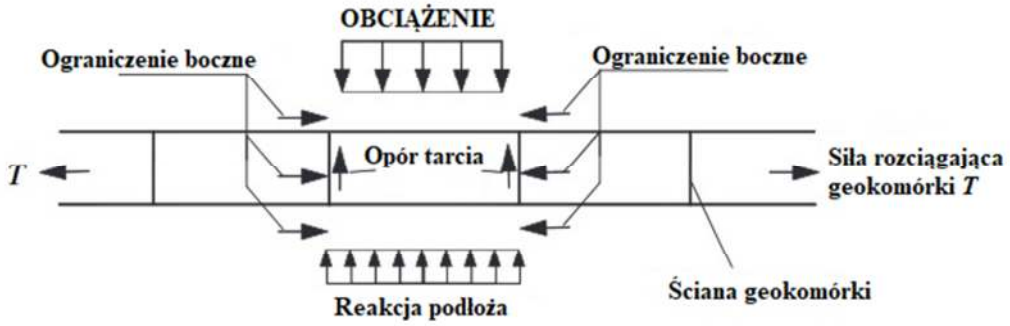
8. The process of mixing native soil with a chemical

The use of airport grating to strengthen natural airport pavements

The airport grating is a product identical to the road grating used, for example, in parking lots, with the difference that it has been designed in such a way that its strength parameters are adapted to the loads it has to carry from the aircraft.

The use of an airport grating improves the load-bearing capacity of natural pavements thanks to: increasing the shear resistance of the grate filling materials as a result of their closure and compaction inside the cells, reducing the settlement caused by natural compaction, and limiting the lateral displacement of the material filling the cells, reducing the stresses transmitted to the ground subsoil from the load acting on the pavement in as a result of distributing concentrated loads on adjacent lattice cells [11] - Fig. **9**.

Both in Poland and in the world, airport gratings made of recycled plastic materials are used to strengthen natural airport pavements. An example is the Narew 2 indoor airline, belonging to the company Pronar Sp. z o.o. It has a runway with a grass surface hardened with 1500 m long grates made of plastic. Among the runways built using this technology, the runway in Narew is the longest in the world [6]. Fig. **10** shows the process of placing the grate on a grassy starting surface, while Fig. **11** shows the final result.



9. Side limitation of the cell geogrid reinforcement [17]

10. Laying the grate on the grassy surface of the runway [7]

11. Finished grassy surface of the runway, paved with a grate [1]

Properties of the airport grating

The airport grating, which is the subject of the research (Fig. **12**), was made with the injection method made of high-density polyethylene - HDPE. Typical properties of this material are described in tab. **1**, while tab. **2** shows the technical data of the airport grating.

12. View of the examined airport grating

Tab. 1: Typical properties of the material from which the airport grating is made

Common Properties	**Nominal value**	**Unit**	**Research method**
Melt flow rate (MFR) 190˚C / 2.16 kg 190˚C/5,0 kg	 4,0 11,0	 g/10 min g/10 min	 ISO 1133-1 ISO 1133-1
Density	0,955	g/cm^3	ISO 1183-1
Tensile modulus of stiffness	1200	MPa	ISO 527-1, -2
The yield stress	27	MPa	ISO 527-1, -2
Yield elongation	8	%	ISO 527-1, -2
FNCT (3,5 MPa, 2% Arkopal N100, 80˚C)	4,5	godz.	ISO 16770
Charpy notched impact strength 23˚C, Type 1, notch A -30˚C, Type 1, notch A	 4,0 4,5	 kJ/m^2 kJ/m^2	 ISO 179 ISO 179
hore hardness (Shore D)	60		ISO 868
Ball hardness (H 132/30)	52	MPa	ISO 2039-1
Vicat softening point (B/50 N)	73	˚C	ISO 306

Tab. 2: Technical data of the airport grating

Characteristics	Declared values
Dimensions: ± 3%	490 x 490 mm
Walls height:	40 mm
Walls thickness:	the walls have a conical structure from the top 5 mm from the bottom 3.5 mm
Number of bars per m ^{2}:	~ 4,2 szt.
Mesh size:	24 empty meshes – 63 mm x 63 mm 25 built-up 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% material

Field tests of the reinforcement of the natural airfield pavement with the use of an airport grating

The research on the impact of the use of the airport grating on the improvement of the load-bearing capacity of the natural pavement was carried out on two research plots. The airport grating was directly pressed into the existing natural pavement - Fig. **13**.

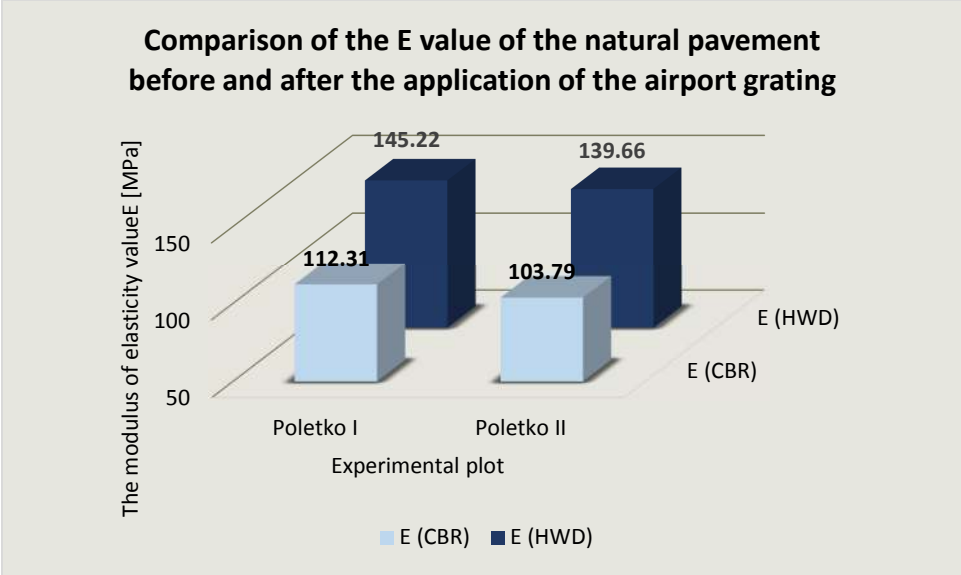
The load-bearing capacity of the natural pavement structure and the airport grating was tested with the HWD airport deflector - Fig. **14**.

In order to analyze the effectiveness of the use of the airport grating as a reinforcement of natural pavements, the results obtained from the CBR index study were converted into the E elastic modulus. In Poland, the most frequently used dependence for this purpose is the Powell formula [12]: $E = 17{,}6 \cdot CBR^{0{,}64}$.

The graph - Fig. **15** shows a comparison of the value of the elastic modulus obtained before and after the application of the airport grating on natural pavements. The obtained results confirm the effectiveness of using such a method to strengthen natural pavements, as the pavement load-bearing capacity increased by approx. 20-25%.

13. View of the airport grating right after pressing and after a month

14. Measurement of load capacity with the HWD airport deflection meter



15. Comparison of the value of the elastic modulus of natural pavement before and after the application of the airport grating

Summary

The use of an airport grating to improve the load-bearing capacity of natural airport pavements is justified for many reasons.

The main advantage of using airport gratings made of plastic is the ability to quickly restore the operational capacity of the airport.

The grating is made of recycled plastic, which is a more favorable solution in financial terms compared to the implementation of, for example, a rigid pavement made of cement concrete. Consequently, despite the fact that it is a plastic material, it has a lower negative impact on the environment as opposed to the production of cement concrete.

Experimental studies have shown that the load-bearing capacity of natural airport pavements reinforced with a press-fit plastic grating has improved by an average of about 20%.

In connection with the development of this method, as a reinforcement of natural surfaces, further work will be carried out on new shapes, properties, and methods of installing airport gratings on natural pavements.

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