**Mariusz Wesołowski**
Ppłk dr inż.
Instytut Techniczny Wojsk Lotniczych, Warszawa, Zakład Lotniskowy
mariusz.wesolowski@itwl.pl

**Krzysztof Blacha**
Mjr mgr inż.
Instytut Techniczny Wojsk Lotniczych, Warszawa, Zakład Lotniskowy
krzysztof.blacha@itwl.pl

**Paweł Iwanowski**
Mgr inż.
Instytut Techniczny Wojsk Lotniczych, Warszawa, Zakład Lotniskowy
pawel.iwanowski@itwl.pl

**Paweł Pietruszewski**
Mjr mgr inż.
Instytut Techniczny Wojsk Lotniczych, Warszawa, Zakład Lotniskowy
pawel.pietruszewski@itwl.pl

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# Role and function of natural airfield pavements in the system ensuring air operation safety

**Abstract:** An important factor impacting the safety of conducted air operations is the appropriate load-bearing condition of natural airfield pavements. The article contains information on the role and functions to be fulfilled by natural airfield pavements in various facilities designed for air operations, as well as within individual airfield functional elements. It touches upon the common issue of insufficient load-bearing capacity of natural pavements, which directly impacts the safety and effectiveness of air operations conducted by military and civilian aircraft. The approach of the authors towards assessing natural airfield pavements was presented, along with a sample analysis of obtained field test results, as well as the manner of their presentation. Moreover, sample technologies of strengthening in the case of insufficient load-bearing capacity of natural pavements and seasonal agrotechnical and biological treatments necessary to maintain an appropriate load-bearing capacity of natural airfield pavements, thus, maintaining their continuous operating readiness were presented.

**Keywords:** Natural airfield pavements; Load capacity; Flight safety

## Introduction

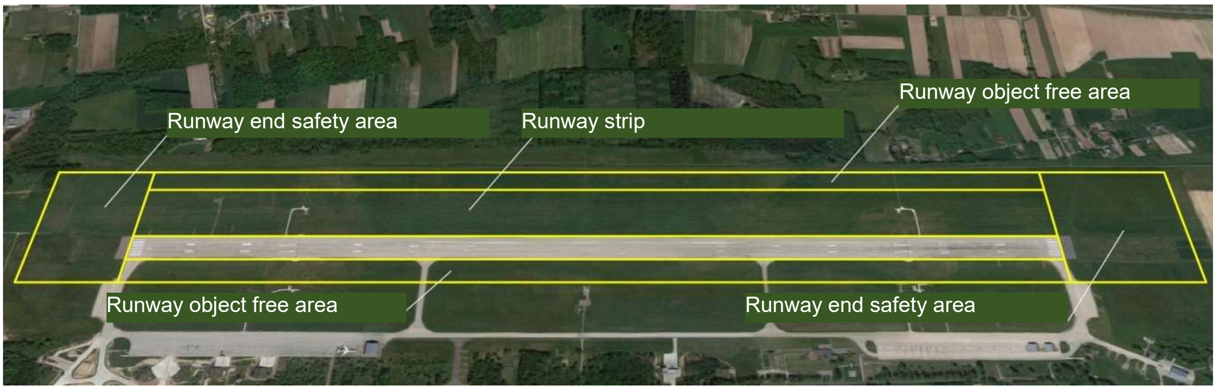
Over the last decade, air transport recorded a several-fold increase of air operations worldwide. This was caused, among others, by a significant increase of low-cost commercial carriers and the development of new technologies. However, the dynamic and vibrant development of aviation has also resulted in numerous issues, particularly associated with ensuring air operation safety. One of the most dangerous events when conducting air operations is the manoeuvre of aborted take-off or delayed landing and potential taxiing out of the runway, emergency leave of a paved runway and running off to the side of the runway. Many accidents associated with the a/m situation were recorded in the international plane crash database, sometimes with disastrous consequences [7]. An example can be the event of

17 July 2007, when an Airbus A320-233 rolled off the end of the runway at Congonhas Airport (Brazil) and hit a petrol station and a building. The crash resulted in the death of 187 people, including the crew. Another incident was recorded on 22 May 2010, when a Boeing 737-800 crashed during a landing attempt in adverse weather conditions. The aircraft did not stop on the runway, slid down into a valley and burst into flames. 158 people died that day. Examples of the consequences of insufficient specific load-bearing capacity of an airfield pavement are shown in figure 1.


**1.** Consequences of insufficient specific load-bearing capacity of an airfield pavement [5].

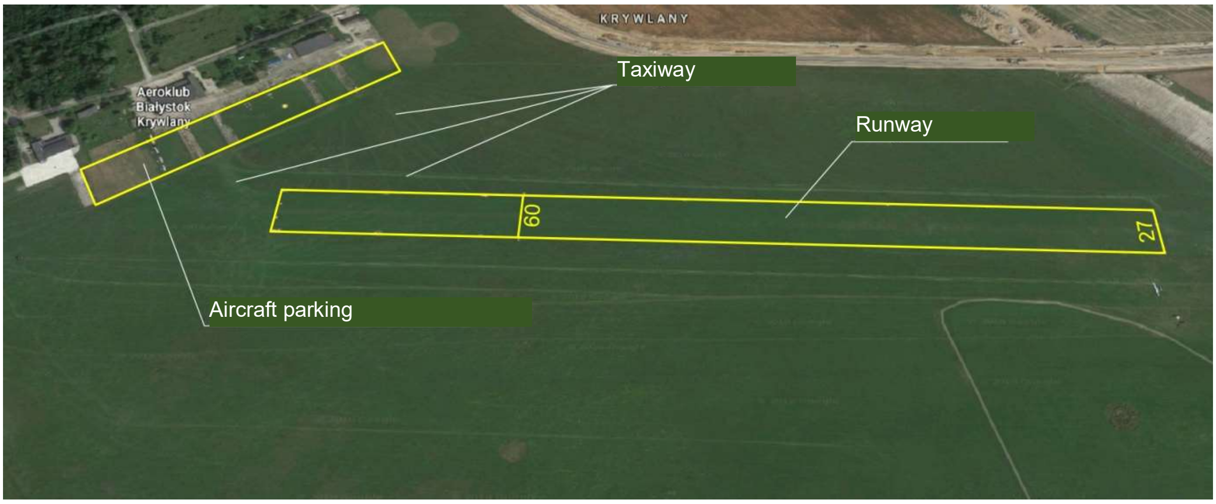
**Location**

Natural airfield pavements are airfield functional elements (AFE) created by an appropriately prepared subsoil, enabling safe movements of an aircraft, without damaging its structure. Currently, natural airfield pavements are divided into dirt and sod. Dirt pavements are made from appropriately prepared and compacted soil (without a sod-grass layer). Whereas sod pavements are dirt pavements, covered with a layer of appropriately selected grassy vegetation. On airfields with artificial pavement for air operations, the natural pavements are present on the runway strip (RS), runway object free areas (ROFA) and runway end safety areas (RESA). A sample diagram presenting the arrangement of individual functional elements of an airfield with a natural airfield pavement subject to assessment is shown in figure 2.




**2.** Arrangement of natural airfield pavements on a sample airfield facility

In the case of facilities used by flying clubs; no matter if they are private or sports purpose ones, the arrangement of individual AFE is slightly different. Quite often, the number of elements is limited only to a runway. Aircraft move in the manoeuvre area over makeshift taxiways, which are not set out in the ground. The figure shows a Białystok-Krywlany flying club airfield layout example with AFE description. The taxiways not listed in the aviation information set (Aeronautical Information Publication - AIP), which aircraft move on are marked.




**3.** Flying club, private and sports airfields on the example of the Białystok-Krywalny facility


**4.** Helicopter landing site

**Role and functions**

Air incidents and accidents caused by an emergency situation of leaving a runway are associated with inadequate load-bearing capacity of natural airfield pavements within a runway. Depending on the airfield type and its functions, natural airfield pavements must play specific roles during air operations. Currently, natural airfield pavements are present on airfield functional elements, such as:

- Runway object free area (ROFA) - spread along the entire runway and the runway strip. Their task is to protect an aircraft against possible damage in an emergency situation of leaving the runway. The load-bearing capacity of natural pavements must be high enough, so that any such potential event did not result in any damage to the aircraft or the underground airfield infrastructure. Moreover, its condition should enable quick restoration of operating capability of the airfield through effective removal of an aircraft from the natural airfield pavement by airfield services.
- Runway end safety areas (RESAs) - located beyond the runway threshold (on both its sides) with a task to protect an aircraft, so that an aborted take-off or delay take-off manoeuvres and the potential leaving the runway could be executed without any damage to the aircraft.
- Non-compacted runways on smaller airfield or the runway strip (AFE on military airfields) - a part of the runway strip intended for aircraft take-off run and take-off when starting, and touchdown and landing run during landing.

However, regardless of the airfield functional element (AFE), all-natural airfield pavements have one common, most important objective, i.e., to mitigate negative impacts when a given AFE is utilized by an aircraft. Natural airfield pavements, with the exception of small airfield with non-compacted runway for air operations, are not airfield functional elements, which are continuously used by aircraft, but their proper maintenance is a very important aspect of an airfield's operating ability.

**Requirements and test results**

Airfield pavements are periodically subjected to comprehensive load-bearing capacity assessment, whose scope has been presented in table 1. It involves evaluating the load-bearing capacity on all AFEs with a natural airfield pavement, i.e., RS, RESA and ROFA. In addition, periodic inspection tests are conducted, which involve testing the strength of the sod surface down to a depth of 0.3m below ground level and testing the load-bearing capacity of the natural pavement down to a depth of 0.85m below ground level. The periodic tests should be conducted every 3 years.

In addition, tests of the load-bearing capacity on military airfield and landing fields shall be conducted every time prior to commencing air training. Such tests cover only AFE included in the air training schedule, and the sole measurements are taken during initial preparation for the flights, prior to commencing air operations.

The following stages shall be taken into account during a comprehensive evaluation of natural airfield pavements:

- Testing the load-bearing capacity of the sod surface down to a depth of 0.3m below ground level,
- testing the load-bearing capacity of the natural pavement down to a depth of 0.15 m below ground level,
- testing the load-bearing capacity of the natural pavement from a depth of 0.15m to a depth of 0.50 m below ground level,

- testing the load-bearing capacity of the natural pavement from a depth of 0.50 m to a depth of 0.85 m below ground level,
- investigating the subsoil to a depth of 2.0m below ground level,
- determination of the California bearing ration (CBR) for each AFE.

The mitigation of negative consequences of leaving compacted airfields in an emergency situation is the basic task of natural airfield pavements. Flight safety must be ensured in any conditions and at any time, particularly in adverse conditions, in which the probability of an emergency situation is the highest. For this reason, the field measurements shall be conducted in the least favourable ground-aquatic conditions. In Poland, this period falls in the Spring and Autumn, where thaw and long-term precipitation occurs.

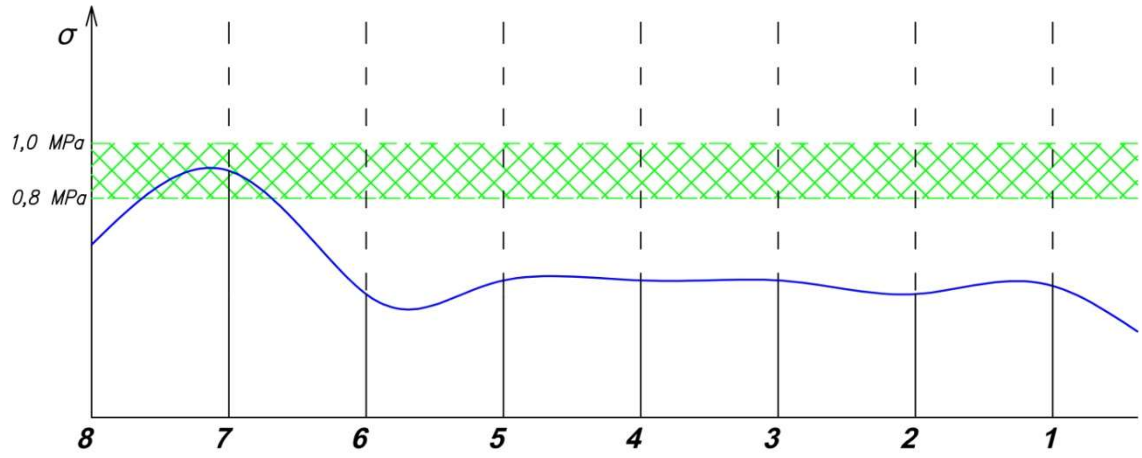
Pursuant to the defence standard NO-17-A503:2017 [6], field tests shall be conducted on all evaluated AFEs with a natural airfield pavement. The location of individual measuring points on natural airfield pavements is determined by the AFE, which is subject to the measurements. However, regardless of the test location, all measurements have to be conducted while maintaining a safe distance from the underground infrastructure and between individual types of tests in a given location. Should the main (primary) runway (DS) have a natural airfield pavement, its measurements shall be taken as in the case of a RS.

A comprehensive assessment of natural airfield pavements includes, apart from field tests, also in-house studies. Having measured the geotechnical ground parameters and with information about the subsoil, they involve a geotechnical analysis providing derived values, which are a base for appropriate assessment and classification of a natural airfield pavement load-bearing capacity. Table 1 shows an example of a geotechnical analysis outcome in the form of an assessment of individual subsoil layers. The test results and corresponding requirements are shown.

**Tab. 1:** Example result statement

| Test scope | Test type | Parameter | Result | Requirement | Assessment |
|---|---|---|---|---|---|
| surface layer | sod probe | soil strength σ [MPa] | 0.5 | 0.8 - 1.0 MPa | negative |
| | SDS probe | CBR [%] | 1.7 | ≥15 | negative |
| intermediate layer | SDS probe | CBR [%] | 7.6 | ≥8 | negative |
| subsoil | DPL | $I_D$[-] | 0.60 | ≥64 | negative |
| comprehensive assessment | | | | | negative |

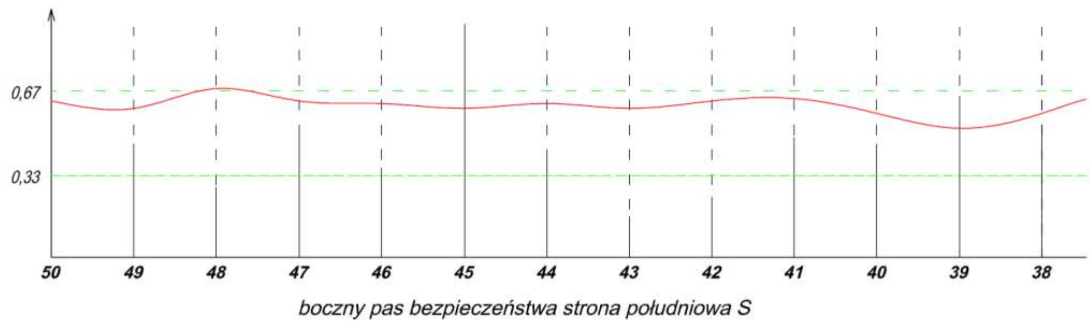
The results obtained for each point are presented graphically on profiles depicting a natural airfield condition on the day of the test. The very profiles include a level of minimum statutory requirements ensuring safe AFE operation by aircraft. Figures 5-8 show example profiles of ground strength determined with SD, SDS and DPL probes.




*The graphs contain:*

*Averaged, measured sod surface load-bearing capacity value (to z=0.3m)*
*Sod surface recommended load-bearing capacity value (σ=1.0 MPa)*
*Sod surface minimum load-bearing capacity value (σ=0.8 MPa)*

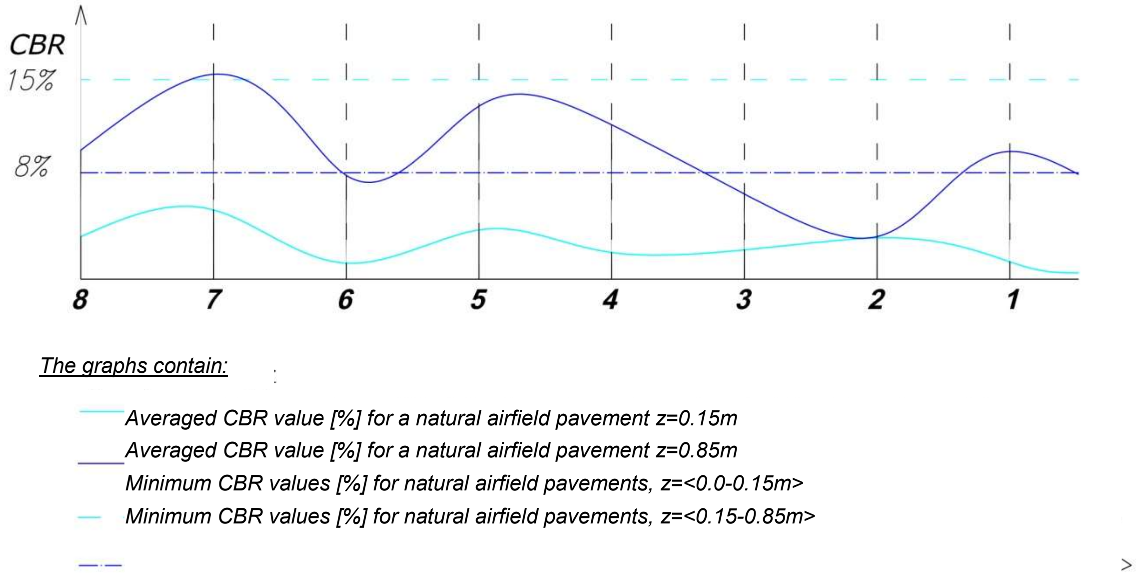
**5.** Sod surface strength profile (SD probe test)



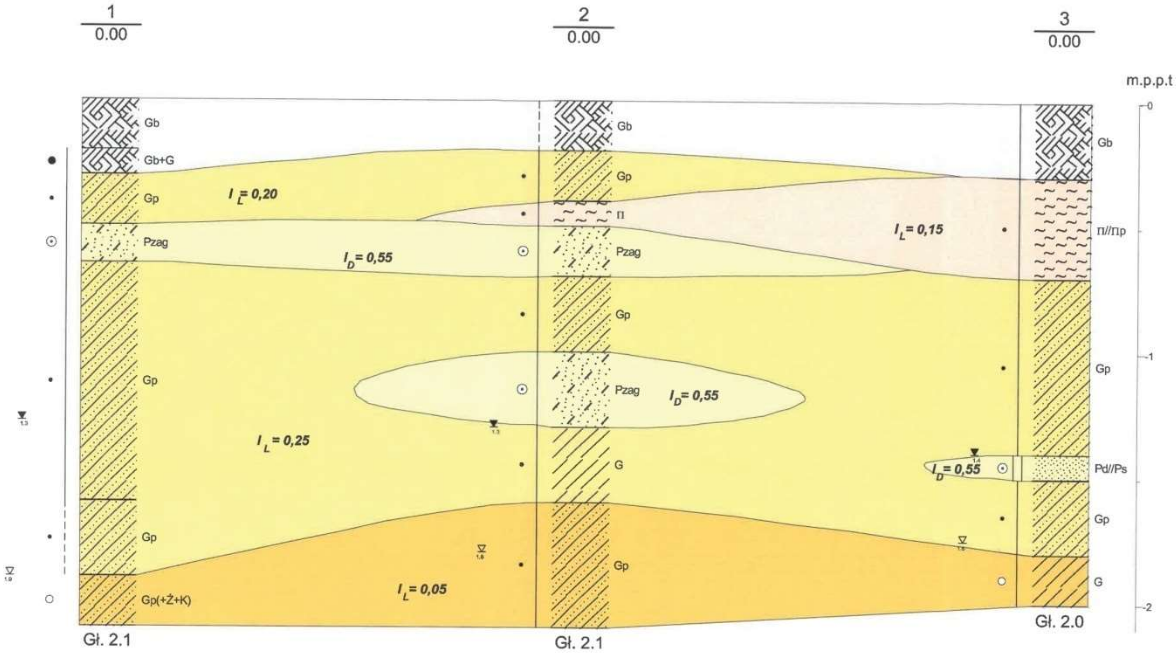

*The graphs contain:*

*averaged, measured subsoil compaction value (to z=0.3m)*
*boundary between compacted and loose soil condition (Id=0.33)*
*boundary between compacted and loose soil condition (Id=0.67)*

**6**. Subsoil compaction condition profile (DPL probe test)




**7.** Natural airfield pavement load-bearing capacity profile (SDS probe test)




**8.** Geotechnical cross-section

Thanks to the graphical presentation of the values derived from field tests, it is simple to determine the areas, which meet statutory requirements, and where reinforcing procedure shall be conducted. Figure 9 shows a natural airfield pavement ensuring safe execution of air operations.

**9.** Natural airfield pavement ensuring safe execution of air operations

**Strengthening methods**

In the event of a failure to satisfy the requirements set out in the standard NO-17-A503:2017 *Airfield pavements. Natural airfield pavements. Load-bearing capacity tests*, conduct the following agrotechnical and biological operations, in the form of the following yearly activities:

regular moving of natural airfield pavements;

double rolling of the pavement - in the Spring and Autumn. Spring rolling can be conducted only after moderate drying of the soil. It is absolutely forbidden to roll wet soils, since air is squeezed out and the aquatic-air relations deteriorate. In such a situation, rolling can contribute to swamping, and in consequence, rush, horsetail and sedges growing over the sod pavement;

replenishing areas with reduced sodding with a mixture of low grasses intended for sodded airfield pavements. It is recommended to perform this procedure in early Spring (until May 15th) and late Summer (until 15th August), due to the abundance of moisture (in the late Summer period it results from the inflow of cooler and wetter air, as well as the presence of dew);

levelling ruts, molehills and surface unevenness;

fertilizing the sod by supplying the plants with nutrients of adequate quantity, expiry dates and in the right fertilizer form, after previously analysing the soil status in terms of absorbable nutrients;

chemical spraying limiting the growth of undesirable plants, i.e., weeds and broad-leaved plants, as well as the presence of insects, which could result in an increased presence of various species of birds on sodded airfield pavements.

After the a/m agrotechnical and biological operations are conducted, it is recommended to repeat the field tests, which check the load-bearing capacity status of natural airfield pavements on given AFEs. In the event of a failure to achieve required load-bearing parameters of natural airfield pavements, it is advisable to reinforce the natural airfield pavements depending on the prevailing ground-aquatic conditions, e.g. the use of geosynthetics, geo-grids or strengthening through replacing or compacting the subsoil.

**Conclusions**

Natural airfield pavements, contrary to appearances, play a very important role during air operation executed by aircraft. The issues presented in the publication indicated that the requirements set out for natural airfield pavements are and must be high, because it is about the safety of aircraft, and most of all, human life.

The experience of the authors gained over the previous years in the course of work aimed at determining the load-bearing capacity of natural airfield pavements indicates that a significant portion of natural pavement AFEs in Polish airfield facilities is neglected or suffers from insufficient maintenance, which is why it fails to satisfy the requirements.

Proper design and maintenance of natural airfield pavements has a significant impact on the effectiveness and safety of air operations. Load-bearing capacity tests involving these pavements is important, however, conducting field tests depends on the intensity of air operations, hence, is hindered and time-consuming. The authors point out to the need of developing a method, which would optimize the time of the tests and increase the natural airfield pavement load-bearing capacity assessment accuracy.

**Source materials**


[1] Annex to ED Decision 2017/021/R (CS-ADR-DSN Issue 4)

[2] ASTM D6951 / D6951M – 09 Standard test method for use of the dynamic cone penetrometer in shallow pavement applications

[3] Commission Regulation (EU) No 139/2014 of 12 February 2014, laying down requirements and administrative procedures related to aerodromes pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council

[4] Department of Army Waterways Equipment Station, GL-92-3,Ta7 W 34, May 1992

[5] http://www.latajznami.pl/aktualnosci,6367,lotnisko_katowice_wznowilo_normalna_pr ace _samolot_nie_blokuje_pasa.html, 11 September 2018

[6] NO-17-A503:2017 Nawierzchnie lotniskowe. Naturalne nawierzchnie lotniskowe. Badania nośności. [*Airfield pavements. Natural airfield pavements. Load-bearing capacity tests*]

[7] PlaneCrashInfo.com database, 2012

[8] Wytyczne Lotniskowe, Ocena techniczna lotniskowych nawierzchni darniowych na podłożu piaszczystym i piaszczysto-gliniastym. [*Airfield Guidelines. Technical assessment of sod pavements on a sandy and sandy-loam subsoil*]