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Technical diagnostics and reliability development of concrete airfield pavements in modernization and reconstruction progress

Abstract: The technical reliability of concrete airport pavements evolves mainly when the project and its technical and functional solutions in all types of industry works is being developed. In the operation process, the technical reliability of the pavement can be shaped as a result of its' modernization and reconstruction. The effect depends primarily on the quality of the works. Currently, the contractors have high-quality materials and specialized equipment minimising human factor in the process of preparing and placing the concrete mix. Potentially high qualifications of technical personnel and other members of the works crew should be a guarantee of high quality works. The operation process must be characterized by a high level of technical culture and rational maintenance procedures. The publication presents the theoretical model of modernized and reconstructed airport's reliability, paying particular attention to the accuracy and efficiency of its technological implementation.

Keywords: Pavement reliability; Quality of pavement works; Operational condition; AFE *(*airport functional elements)

Introduction

The purpose of the modernization and reconstruction of airport pavements or selected parts thereof (EFL) of the functional element of the airport is to increase the safety level related to the performance of air operations and to raise the technical standards of airport equipment, which this level ensures. This goal can be achieved through the high quality of technological processes during the modernization and the installation of effective technical devices that raise the safety of air operations to a higher level. The appropriate action in this respect is the use of mathematical relations resulting from the reliability theory, which mainly includes the assessment of statistical distributions and the determination of appropriate reliability indicators, which are usually related to the issues of the durability of these structures. The scope of reliability analysis includes, among others: collecting information about the structure and its features, including durability elements. In airport pavement structures, the reliability model of this system is most often the result of the ground condition and changes in its physical and mechanical parameters. Observations of numerous technological processes related to the

modernization of the pavement and their reconstruction, actual and computational stresses ($\sigma_{rzecz} \leq \sigma_{oblicz}$), and control tests carried out at individual stages of implementation show that in some cases the quality of the works performed is not satisfactory. The publication presents the importance of the technical reliability of these facilities and their impact on the safety of air operations.

Operational and technological process reliability

The reliability of the technological process T_i can be presented in the form of a dependency

$$T_i \in T_n \leftrightarrow [\, l_r \geq l_p \cap q_r \geq q_p \cap t_r - t_z] \quad (1)$$

in which:

- l_r - total number of works performed,
- l_p - planned number of works,
- q_r - quantified quality of works,
- q_p - required quality of works in accordance with applicable standards,
- t_r - the actual duration of works,
- t_z - time of decommissioning the object from use.

The comment on the total number of works should be understood as a synthesis of individual types of works, e.g. the total number of concrete works is influenced by the total number of works performed on a particular functional element of the pavement (foundation, construction layer, or possibly other layers). The degree of detail of such an analysis highlights the importance of such an assessment and its impact on the technological reliability of the modernization or pavement construction in a new facility. The column vector in the form of a relation should be considered a measure of a reliable technological process:

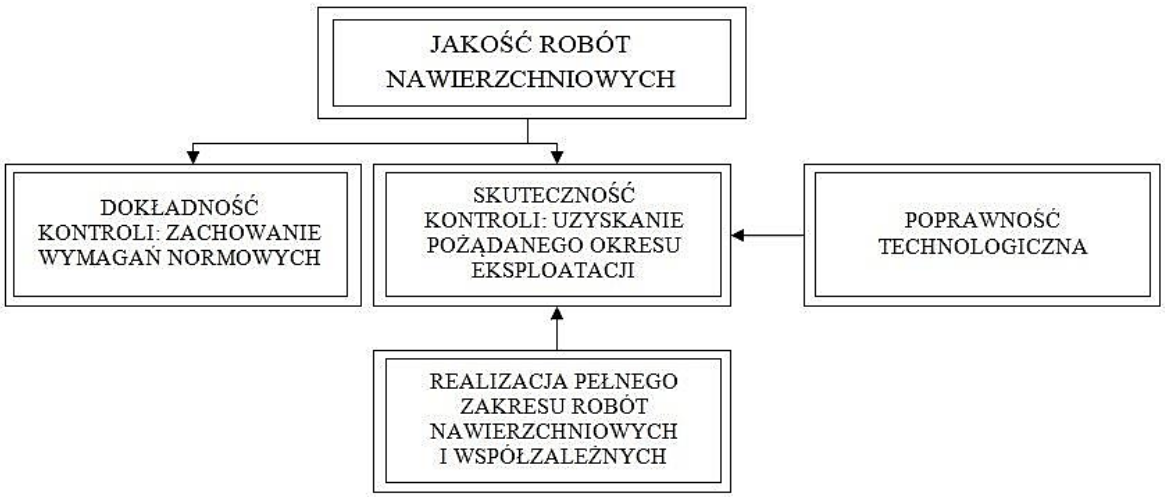
$$N = \begin{bmatrix} \frac{l_r}{l_p} \\ \frac{q_r}{q_p} \\ \frac{t_z}{t_r} \end{bmatrix} \quad (2)$$

The reliability of the airport pavement is a property understood as that it will correctly fulfill all functions in the assumed period of time, under specific operating conditions. With regard to the modernized concrete airfield pavement, the measure of its reliability is the total number of air operations and mass loads $\mathbb{Q}$ performed by the computational plane until the next repair or overhaul of several dozen percent of the actual *EFL* area is performed.

Other types of repairs may be the result of natural forces or forced actions. The mass load should not be less than $\mathbb{Q}_{min}$. This condition can be written as:

$$R(\mathbb{Q}) = P \{ \mathbb{Q}, \phi, \mathfrak{E}, \left| \mathbb{Q} \geq \mathbb{Q}_{min} \right| \} \quad (3)$$

The ϕ function means that the pavement condition ensures safe and regular movement of aircraft in the existing operational conditions $\mathfrak{E}$. The quantity that is able to meet this condition with the applied design, construction, and geometric solutions - is the quality of works q. The quality of works should be measured in terms of their accuracy and effectiveness, which are particularly important for works to be covered. The quality problem is presented graphically in Figure **1**.



1. Component elements of the process related to obtaining the appropriate quality of works

Improving the quality of pavement works at airports can be achieved by improving the acceptance of individual works, in particular works to be covered. An important issue that can be observed in practice is a certain discrepancy between the solutions presented in the design and the realities of execution.

Operational and reliability states of concrete airfield pavements

When analyzing the reliability and operational conditions of airport pavements, theoretical (methodological and cognitive), as well as experimental and operational issues, should be taken into account. During the use of the pavement, it may be in the following operational conditions:

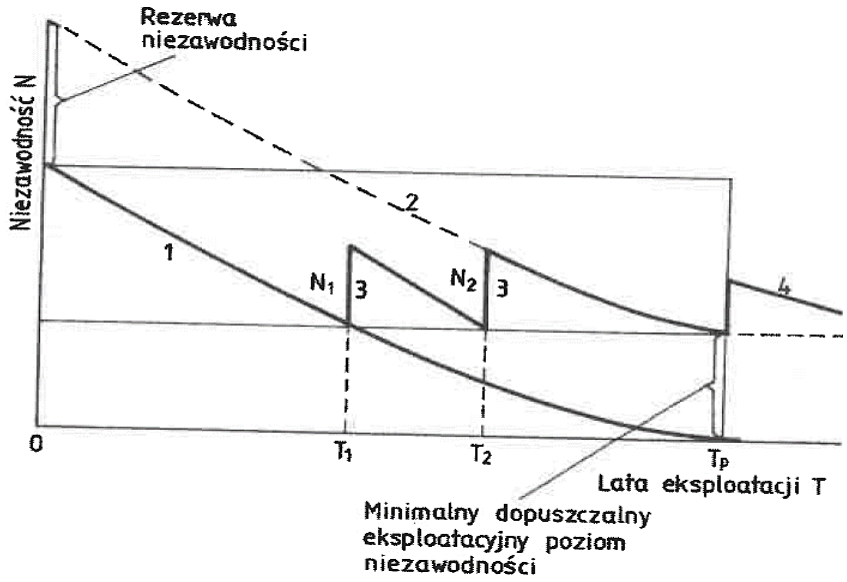
a) Full operational readiness (E^1),
b) Limited operational capacity (E^2),
c) Operational failure (E^0).

In this situation, it is necessary to be able to accurately recognize the operational conditions of the pavement in accordance with the appropriate assessment criteria. The basic criterion for the technical condition of the pavement is always the stresses where $б_{rzecz} \leq б_{oblicz}$. For this basic relationship, the following relations are distinguished:

$$\begin{gathered} б_{rzecz}/б_{oblicz} = 1 \rightarrow E_i \in E^{(1)} \\ 0 \leq б_{rzecz}/б_{oblicz} \leq 1 \rightarrow E_i \in E^{(2)} \\ б_{rzecz}/б_{oblicz} = 0 \rightarrow E_i \in E^{(0)} \end{gathered} \tag{4}$$

Stresses $б_{rzecz}$ and $б_{oblicz}$ are the actual average stresses in the middle section of the concrete slab (actual and design). The expected load-bearing capacity is always the consequence of correct stress relations in the pavement. The pavement exploitation period with the assumed time is shown in Figure **2**.

The airport pavement, regardless of whether it occurs in the classic system of layers, or in a system composed of layers and with different mechanical parameters, is a probabilistic system. The description of the condition of the pavement can be represented as the probability of transition from one condition to another. These states can be described in the form of sets of statistical data that are created during periodic (spring and autumn) technical inspections and are archived.



2. A graph showing the period of pavement operation with the assumed time

Figure **3** shows the influence of various factors that affect the existence of appropriate technical conditions of the pavement. The physical (technical) states of the structure determine the set of reliability states. Depending on the requirements related to reliability, there is a relation that means the probability of individual measurable parameters of the Δ set entering the **Ω** set, which describes the pavements as a determined structural system represented by the relation:

$$R = R\{\Delta\ \mathcal{E}\ \Omega\} \tag{5}$$

Determining the reliability states of the pavement requires the knowledge of the genesis, duration, and operation of the pavement in the time related to its operation. The process of transition from one operational state to another under normal conditions (excluding forced - random states) is a continuous process. An illustration of this state (process) is shown in Figure **3**, in which attention is drawn to the intermediate states of the transition of the pavement from the state of full operational capacity $E^{(1)}$ to the state of operational inability E^{0}.

Symbols used in the drawing:

a) the reversible aging process of the pavement without reaching the state $E^{(0)}$,
b) the reversible aging process of the pavement reaching the state $E^{(0)}$,
c) irreversible pavement aging process,
d) tep process, reversible without reaching the state $E^{(0)}$,
e) step process, reversible with reaching the state $E^{(0)}$,
f) irreversible step process.

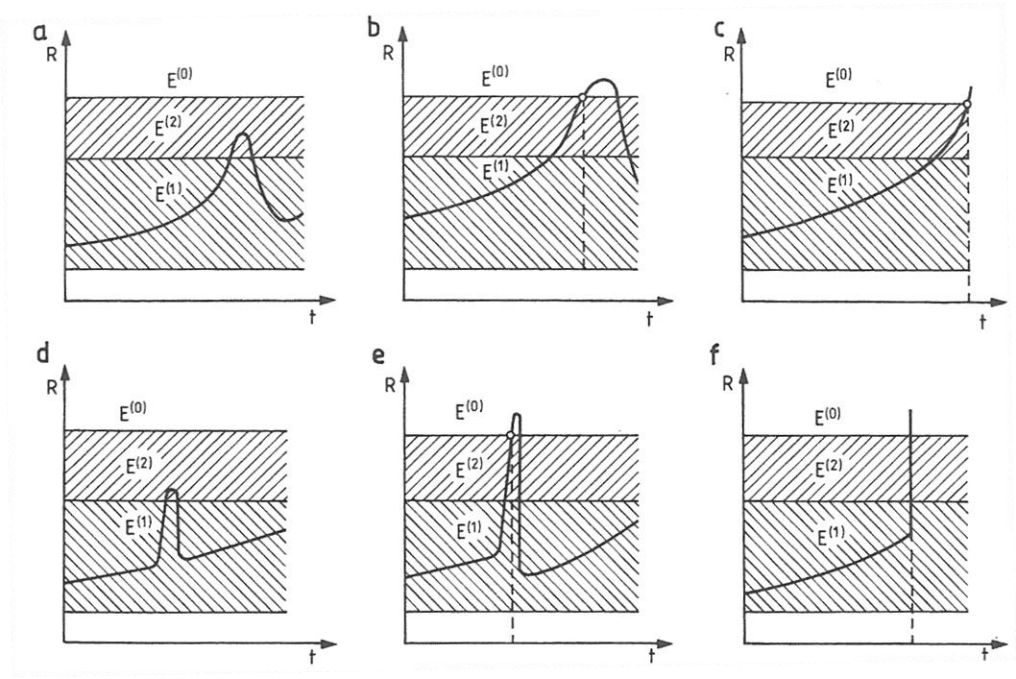
An important issue in technical diagnostics of the pavement is the possibility of forecasting its behavior under given conditions and determining the time of safe operation. The technical reliability of the pavement can be understood in two ways, i.e. in terms of description and value. In the descriptive sense, the reliability of pavement is its ability to meet certain technical and operational requirements.

In the value sense, the reliability of this structure is the probability of the proper meeting of the technical requirements by the pavement in a time t not less than the assumed (expected) time t_0. This relationship can be presented in the form of dependencies.

$$R(t_0) = P\ (t \geq t_0) \tag{6}$$

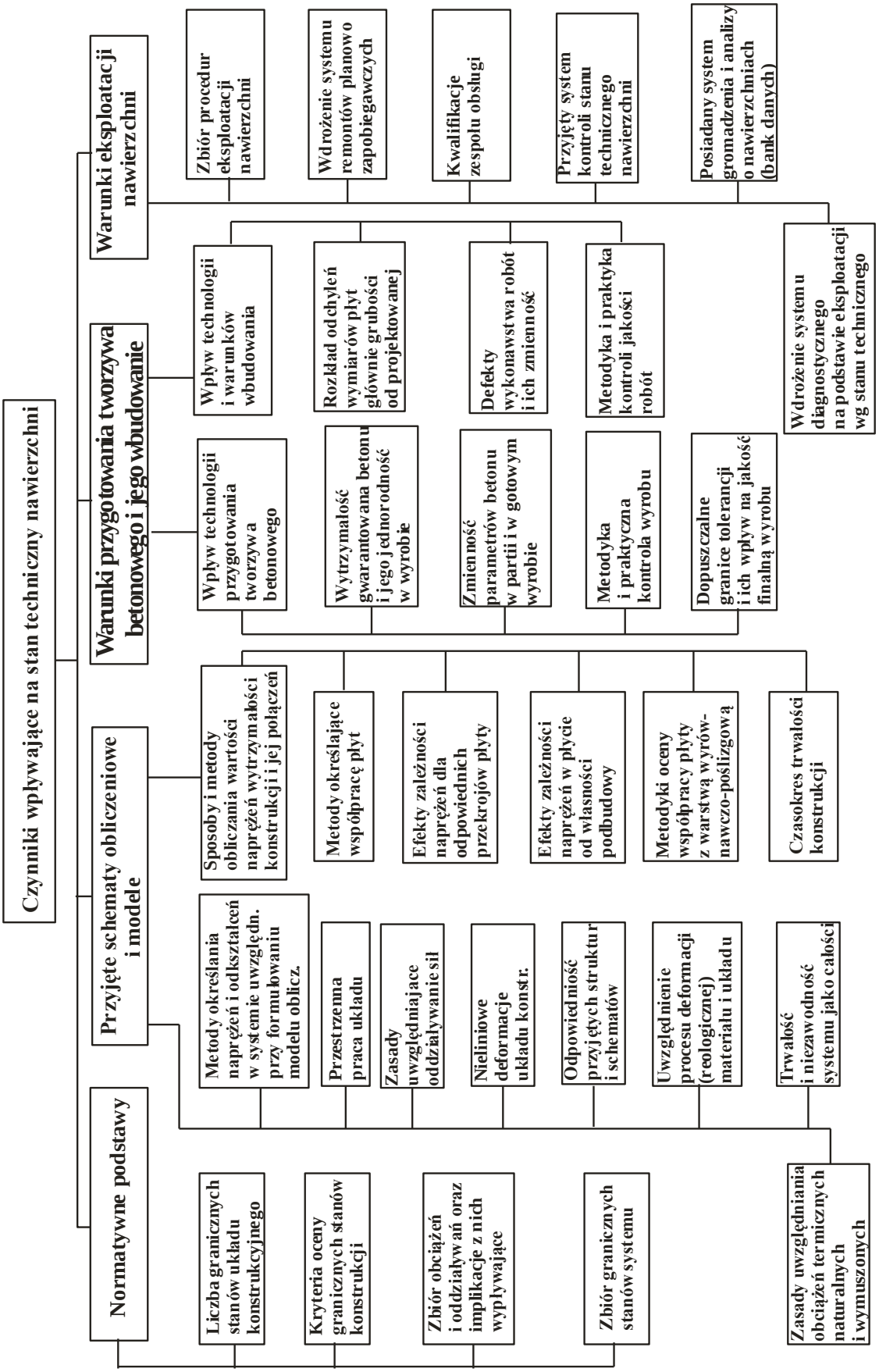
This relation can also be presented as the probability of performing a certain amount of work, which can be equated with the amount of cargo transported Q_0

$$R(Q_0) = P(Q \geq Q_0) \tag{7}$$



3. Possible reliability conditions of the pavement during its operational life

The reliability of the pavement is closely related to the concept of durability, which should be understood as the ability to maintain the essential properties of the pavement over a period of time. Any reduction in the technical requirements for the pavement may be worn or damaged. The airport pavement, in terms of reliability, is a probabilistic system, i.e. a system whose behavior cannot be accurately predicted, but it is possible to investigate and determine the appropriate confidence level of individual events. The airport pavement is in fact a mixed design system. Currently, the goal is to build a reliable reliability model with high utility. The message of this idea is the possibility of replacing any of the possibly damaged various components of the system by taking over its tasks by one or more cooperating elements. A characteristic feature of the pavement operation is the continuity of the process of its use. Renewal of the pavement should be understood as the replacement of a single element or such a number of elements, as a result of which the pavement regains the expected operational properties. The most far-reaching renovation of the pavement is its overhaul. In the diagnostics of airport pavements, the accuracy of the selection of an appropriate method of its assessment, followed by the performance of repair works in the appropriate quantity and quality, contributes to the safety of air operations. The technical and operational condition of airport pavements is the result of many factors: from the adopted assumptions and normative acts, through the selection of appropriate calculation methods and investment implementation methods, to the principles and level of technical culture of their operation. The set of these many factors influencing the entire process of "the development and technical life of the pavement" is shown in Figure **4**.

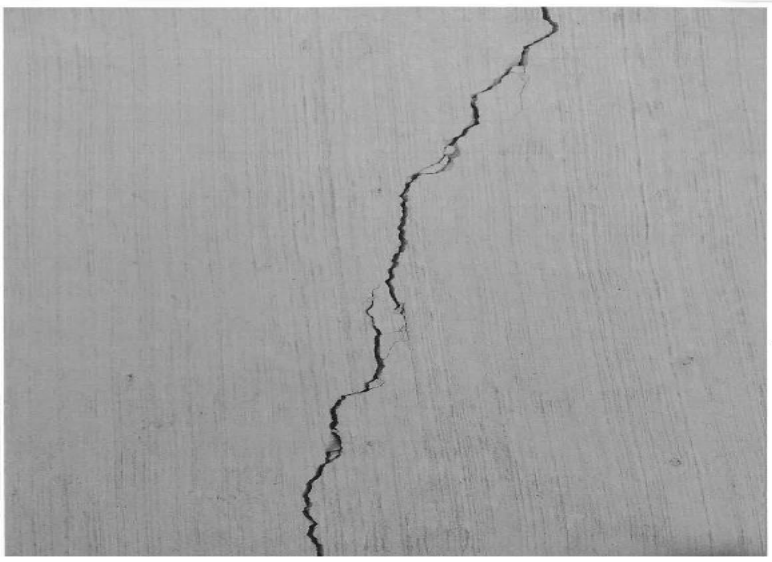


4. Diagram of the structure of various factors that affect the process of designing, building, and maintaining airport pavements

Examples of improper execution of selected elements of pavement works

Figure **4** shows numerous and various conditions that guarantee the high reliability and durability of airport pavements. However, in a few cases, the execution of paving works is burdened with deviations and does not meet all the principles of the praxeological principle resulting from the "Good Work Treaty" [2], this applies primarily to the process of execution of works and, in few cases, design solutions. Figures **5** and **6** show such examples.

5. There is a layer of water in the place where the concrete mix is to be placed



6. Technological crack in the concrete pavement slab, which occurred several hours after the concrete mixture was laid

Summary

The correct course of renovation and modernization works on concrete airport pavements has a fundamental impact on their durability and reliability, and consequently is a condition for the safe performance of air operations.

1. Currently, with the generally good quality of the materials included in the prepared concrete mix, there is a chance to obtain the expected "technological correctness of the works".
2. The factor limiting the achievement of high and expected quality of works so far is the equipment for placing the concrete mix at the destination, i.e. the machines for laying the concrete mix. The equipment used so far in our domestic conditions is technically outdated and does not guarantee the expected quality of works.
3. However, the technological correctness of the works, which is lower than expected, destroys the organizational effort put into the implementation of the investment task and limits the expected durability and reliability effects.
4. One factor that makes it difficult to obtain high-quality works is excessive cooperation of works, but it is not about specialized works.
5. A debatable matter in the field of supervision over the quality of works is the matter of commissioning these activities to organizational structures not related to the investor in terms of organization.

Source materials

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