Centrum Rzeczoznawstwa Budowlanego

**Inżynieria Bezpieczeństwa**
**Obiektów Antropogenicznych 3 (2024) 36-46**
https://inzynieriabezpieczenstwa.com.pl/

Inżynieria Bezpieczeństwa Obiektów Antropogenicznych

# Analysis of rapid reconstruction airport pavements

Oksana MARIAK[1], Szymon MITKOW[2], Ryszard CHMIELEWSKI[3*]

*[1] 21. Tactical Air Force Base, Świdwin, Poland*
*[2] Faculty of Safety, Logistics and Management, Military University of Technology, Warsaw, Poland*
*[3] Faculty of Civil Engineering and Geodesy, Military University of Technology, Warsaw, Poland*

**Abstract**

The article discusses principles and guidelines for rapid reconstruction of military airfield pavements. The possible repair materials to be used as well as the basic types of lightweight collapsible pavements were defined . Various technologies and principles for organizing construction work related to the repair of damaged pavements in accordance with the STANAG 2929 standard are presented. The article presents selected scientific principles of work organization that affect the maintenance of a high pace of construction project implementation. Additionally, the article highlights the need to protect aircraft and other sensitive elements of airport infrastructure, suggesting the use of double-bent sheet metal structures. These structures are relatively inexpensive and can be erected in a very short time.

**Keywords:** airport pavement, rapid reconstruction, work organization

## 1 Introduction

The Air Force in every country plays a crucial role in the course of armed conflicts and wars. The importance of airfields in the Air Force's combat operations makes them prime targets for enemy attacks. During many conflicts, airfields have been raided because they are strategic military facilities. Often, these attacks occur early in operations. Recent years of military development further underscore the increasing operational and logistical importance of military airfield operations.

The proper functioning of an airfield depends on its facilities and equipment, collectively known as airfield infrastructure. This infrastructure is vital to the state's defense system and the execution of strategic tasks. Consequently, military airports are particularly vulnerable to enemy attacks.

* **Corresponding author:** E-mail address: (ryszard.chmielewski@wat.edu.pl) Ryszard CHMIELEWSKI

https://dx.doi.org/10.37105/iboa.218
Received 01 August 2024
Available online 03 September 2024
ISSN 2450-1859, eISSN 2450-8721
Published by Centrum Rzeczoznawstwa Budowlanego

The primary targets are not only the aircraft but also the airfield infrastructure, aiming to inflict maximum damage on the enemy, thereby preventing flight operations and excluding the airfield from military operations to achieve air superiority. Military airports face various threats, with military threats from air attacks being the most dangerous for airport infrastructure. Strikes by means of air assault cause the greatest damage to airport infrastructure. For this purpose, manned aircraft are used by the enemy, i.e. strategic bombers, fighter aircraft using long- and medium-range means of destruction, tactical ballistic missiles equipped with maneuvering warheads, winged missiles and unmanned aircraft carrying bombs, which are gaining increasing use. Thus, damage to the pavement can arise mainly from missiles, bombs or mines. The greatest damage is inflicted by aerial demolition bombs, which create funnels of large size. High damage is also caused by explosive charges in terms of destroying the surface structure. Methods of destroying airfields range from the classic bombing of maneuvering planes, to their erratic mines. However, the aerial assault can be more deliberate and strategic, which will involve, for example, cutting across the runway so that flight operations cannot be carried out on any section.

While these threats are difficult to neutralize, there are ways to counter them. Although the means and methods of reconnaissance used make it virtually impossible to conceal the entire airfield, at least camouflage is used, such as by overgrowing vegetation on the roofs of shelter-hangars or imitating plots of farmland in the area of the airfield. In addition, individual airfield facilities are deployed over a large area to spread them out in order to reduce the effects of enemy fire. The defense and protection of the airfield is also organized by conducting air surveillance, air defense, posting guards and soldiers' posts, and installing signaling and alarm equipment [1].

Despite these precautions, it is impossible to fully prevent threats, and enemy air attacks often lead to significant damage that precludes the takeoff and landing of combat aircraft. Therefore, it is crucial to efficiently rebuild airfield pavements to enable the rapid resumption of flight operations.

## 2 An assessment of the expected manner and extent of destruction of airports

An airfield is an extremely attractive target for a potential adversary. Primarily, the adversary will focus his impact on the artificial airfield surface, which includes elements of priority importance for maintaining the operational capabilities of air bases [2].

From the perspective of aviation combat tasks, the most important components are the runway, taxiways, and fortified marshalling areas. The goal of an air strike is to damage the runway to such an extent that takeoffs and landings become impossible. This would completely immobilize aircraft at the air base and prevent the landing of aircraft already in the air. Damage to taxiways would make it impossible for aircraft to reach the runway, thus preventing takeoff. Additionally, damage to the front gates of the shelter-hangars would prevent aircraft from accessing the taxiway and ultimately the runway. These components are the most critical elements of airport infrastructure, as they are essential for aircraft movement. (highlighted in blue in Figure 1).

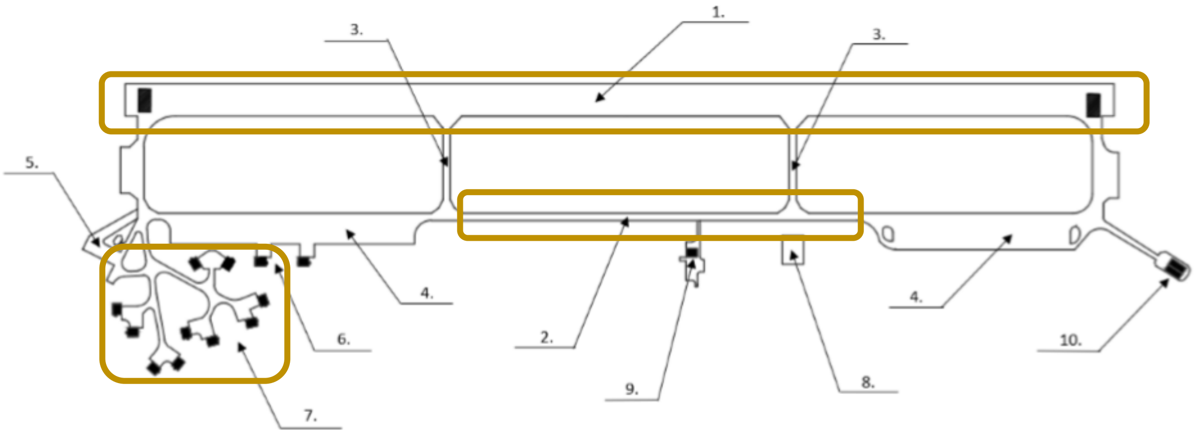


**Fig. 1.** *Essential elements of airport infrastructure: 1 - runway, 2 - main taxiway, 3 - rapid descent roads, 4 - central aircraft staging planes, 5 - aircraft engine test plane, 6 - pre-hangar planes, 7 - fortified centering zone, 8 - flight control tower, 9 - squadron building, 10 - hangar*

Considering the possibility of an attack on an airport, it is crucial to have appropriate procedures in place for identifying and repairing airport damage. The first step is to estimate the potential level of damage to the airfield pavement well in advance of any potential attack. When forecasting the extent of possible damage, several priority factors are considered [1]:

(a) in the operational/strategic aspect:

- tasks carried out at the airport (depending on the aircraft stationed there, different for fighter vs. transport aircraft);

- the geographic location of the airfield (related to the distance from a potential adversary);

(b) in terms of the effectiveness of the airfield's counter-strike measures:

- local air defense measures (including the type and quantity of air defense systems);

- the redundancy of the airfield, determined by the availability of separate primary aircraft lanes that can be deployed without overlap.

Being well prepared for a potential enemy attack on an airfield and knowing the preliminary scope of repair work required makes the repair process more efficient. Airfield Damage Repair (ADR) involves a series of measures implemented to restore the operational readiness of an airfield after an enemy attack. These measures include:

(a) Identifying and assessing damage to determine the scope of necessary repairs;

(b) Neutralizing and removing explosives;

(c) Restoring the minimum operational plane for the independent movement of aircraft;

(d) Restoring the operational capability of equipment and services needed to conduct air operations.

The rules for repairing airport pavements are defined in the STANAG 2929 standardization agreement [3]. This document is intended for use by NATO member states, providing detailed repair standards. According to STANAG 2929, the types of damage that can occur on a military airport pavement after a bombing or missile attack include craters (funnels) and both surface and structural damage to the pavement.

Repairing airport pavement involves reconstructing both craters and surface damage (spalling). Craters require the most repair work. A crater (Figure 2) is a deep form of damage that affects the entire pavement structure and subsoil, typically reaching an average depth of 3 meters and a diameter of 12 meters. Surface damage (spalling), on the other hand, affects only the top layers of the pavement, extending to a maximum depth of the pavement substructure layer without compromising the underlying pavement structure.

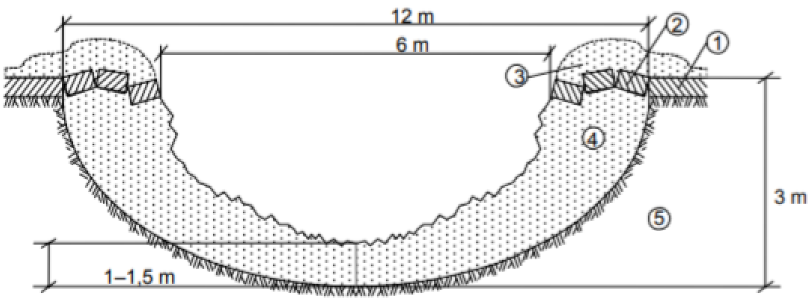


**Fig. 2.** *Standard crater according to NATO, 1 - undamaged pavement, 2 - damaged pavement, 3 - soil ejected during the explosion, 4 - loosely deposited soil that fell after the explosion, 5 - native soil [3, 4]*

In addition, the document [3] defines terms directly related to the repair of artificial airport pavement. The distinctions are:

- the primary runway (MOS - Minimum Operating Strip) is the minimum runway section that meets the minimum operational requirements for the types of aircraft stationed at the airport after taking into account their maximum load. The length of the MOS depends on the length of the aircraft takeoff or landing, while its width depends on the wingspan,

- the basic aircraft operating zone (MAOS - Minimum Aircraft Operating Surface) is the minimum area on the airport that is necessary for the movement of aircraft between their centered regions and the MOS. This surface includes the aircraft centering area, the MOS area and the taxiways between them. In simple terms, MAOS are the taxiways running from the aircraft centering area to the MOS.

The resulting craters can vary in size depending on the type of munition used. Craters typically range in diameter from 3 to 20 meters. For practical purposes, a standard diameter of 12 meters is often used as an average size. These craters, numbering 6 each for Main Operating Strips (MOS) and Main Auxiliary Operating Strips (MAOS), serve as the primary model for assessing airfield destruction and Airfield Damage Repair (ADR) capabilities. Once airfield infrastructure has unfortunately been damaged, the repair process begins during combat operations. This starts with a real-time assessment of the required repairs based on reconnaissance and damage identification from enemy attacks. This allows adjustments to be made based on the actual conditions present. The extent of necessary repairs depends on the specific locations designated for MOS and MAOS. The selection of Main Operating Strips (MOS) and Main Auxiliary Operating Strips (MAOS) serves the following purposes::

- to identify areas requiring minimal repair efforts,

- to choose access routes from aircraft staging areas to MOS with the shortest possible taxi times.

Initially, reconnaissance activities are conducted to identify the minimal runway section required for aircraft to take off promptly after an attack. The MOS is selected as the takeoff and landing surface, prioritizing areas that require minimal repair. A preliminary analysis determines the MOS by excluding heavily damaged sections. Areas of the Main Operating Strip (MOS) with numerous craters, scattered mines, or unexploded ordnance are excluded. Conversely, the location of the Main Auxiliary Operating Strip (MAOS) is chosen to be as close as possible to aircraft staging areas. This minimizes the need for extensive reconstruction, allowing aircraft to reach the MOS swiftly.

In addition, the determination (calculation) of the MOS and MAOS at a given airport requires data on the aircraft used at the airport (the so-called calculation aircraft) and an airport plan showing all its planes. MOS and MAOS are determined taking into account a given aircraft that can take off from the airport. The operating parameters from the technical characteristics of a given aircraft that are needed to determine the MOS and MAOS are the minimum takeoff as well as landing length for a given type of aircraft, its wingspan, the width of the landing gear and the maximum takeoff weight of the aircraft. To determine the MOS and MAOS, the length and width of the primary runway and the width of the taxiway are determined.

During the preliminary planning stages of repairing a damaged airport, priority is given to the Main Operating Strip (MOS). Reconstruction of taxiways at the MOS is considered less urgent compared to the MOS itself. Since aircraft taxi at slower speeds, they can tolerate relatively uneven and lower-quality surfaces.

The designation of the MAOS is guided by the principle that an aircraft in combat conditions is to get from its basing location to the place where it performs takeoffs, i.e., from the centering zone to the MOS, in the fastest possible time. This procedure is applied so that the aircraft is on the ground for as short a time as possible, as it is unable to realize its combat potential while grounded. Our own example of a designated MOS and MAOS taking into account the principles described above is shown in Figure 3.

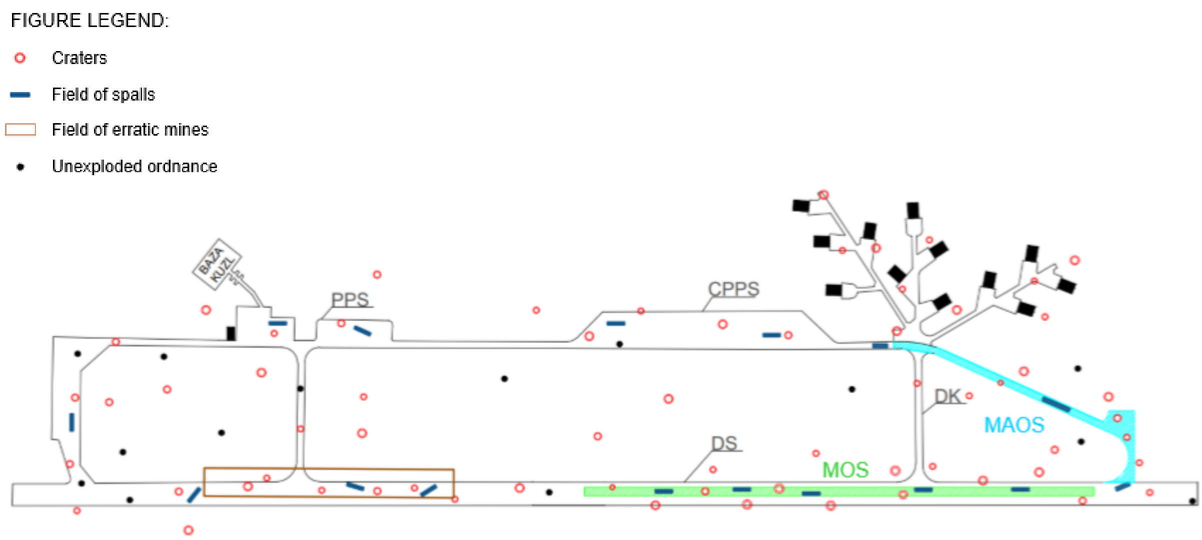


**Fig. 3.** *Designated MOS and MAOS on the airport damage plan*

When analyzing the amount of repair work required, the type of pavement damage caused by bombs, rockets and debris (crater, spall, crack area), the location of the damage (MOS, MAOS), the approximate size, i.e. the diameter of the crater, and the amount of craters, spalls and debris damage are taken into account. The scope of work in repairing an airfield depends on the amount of damage caused by aerial bombs, rocket shells, and erratic mines.

The critical first step in restoring airport operations is to assess the extent of damage and then identify priority areas for pavement repair, focusing initially on determining the minimal necessary runway sections.

## 3 Method and scope of action to restore the usability of the airport

Ensuring airport security during direct attacks on airport infrastructure poses significant challenges. Consequently, established procedures exist for rebuilding airport pavement following damage. Given the time required to restore airport functionality, two methods of pavement repair have been defined: traditional-temporary and rapid. The assumptions of both methods are outlined in Table1.

**Table 1** *Assumptions of the traditional-temporary method and rapid airport repair*

| | traditional-temporary metod | rapid method |
|---|---|---|
| Repair time | max. 48 h | 4 h:<br>1 h - for MOS recognition<br>3 h - for full crater reconstruction |
| Load carrying capacity | 5000 flight operations | 100 air operations |
| Operation of the temporarily repaired airport | 1 - 2 months | min. 24 h |

These methods primarily differ in the duration required for airport damage restoration. As a result, different materials and approaches are employed to ensure the prompt usability of the airport pavement.

Ensuring the required operability of the airport is included in the document [3]. According to the established requirements, the total time to restore the operability of the airport is 4 hours, this is known as rapid reconstruction. It is this method that has been established as essential to use due to the need to restore the airport to operational readiness as soon as possible.

The minimum scope for rapid restoration includes activities to restore the usability of the damaged airfield, which are divided into two stages:

- Stage I - pre-repair activities lasting 1 hour: reconnaissance and identification of damage, identification of contamination and explosive charges, designation of MOS, destruction of explosive charges, deployment of repair groups and their equipment, identification of soil and water conditions;

- Stage II - repair activities lasting 3 hours involving standard reconstruction of craters and spalls. The reconstruction of craters is much more time-consuming and requires greater precision than the repair of surface damage.

An essential part of the airport pavement repair is the reconstruction of the crater (Figure 4). The scope of reconstruction includes three main works:

1. reconstruction of the lower part of the crater - from the bottom of the crater to the level at which the pavement structure should be made (from 45 to 100 cm counting from the surface of the airport apron). It involves pushing into the crater the loose material found around the crater or removing it (depending on soil and water conditions) and filling with additional aggregate with a grain size of up to 63 mm,

2 reconstruction of the upper part of the crater (pavement construction zone) - from the level of the filled lower part to the surface of the airport slab. It consists in filling the crater with crushed aggregate of grain size 0/31.5 mm and 0/16 mm,

3. laying the top layer (pavement finishing) - consists in laying the airport covering in the form of a mat (composite or aluminum), which must be properly attached to the existing airport surface. The mats are used for the sake of enabling takeoffs and landings as quickly as possible, due to the ease and speed of their installation and their long shelf life (compared to other repair materials).

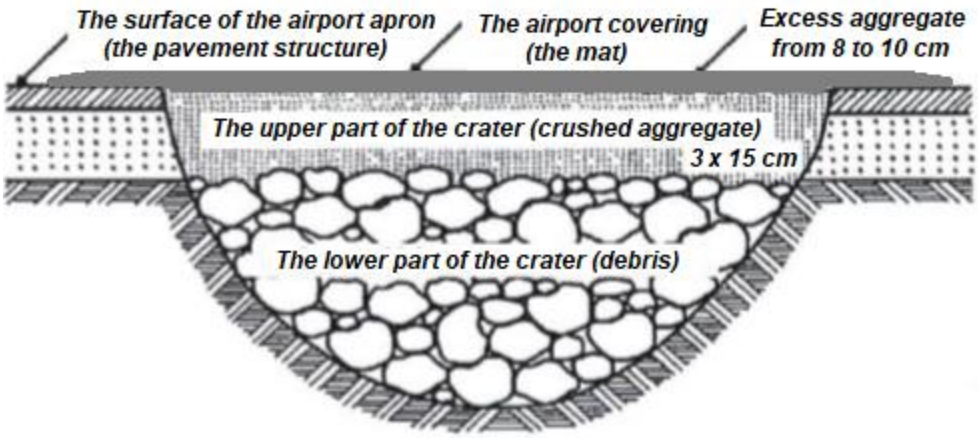


**Fig. 4:** *Diagram of the reconstructed crater*

The choice of restoration equipment and materials used depends on their availability and the type of damage, another for craters and another for surface damage. Mats that are airport coverings are shown in Photo 1. Composite mats are recommended for rapid reconstruction in the case of crater reconstruction, the use of which is more common.


**Fig. 5.** *Airport coverings for rapid reconstruction of airport pavements: a) FFM composite mat, b) KRATER composite mat, c) Class 60 aluminum mat, [5].*

A composite mat is a specialized covering designed for rapid repair of runways damaged by bombing. Currently, two types of composite airport coverings are used at airports. These are US-made mats belonging to the FFM (Folded Fiberglass Mat) technology (Fig. 1.a) and domestically produced KRATER-type coverings (Fig. 1.b). The mats ensure the restoration of airport operational readiness in a relatively short period of time and under various weather conditions.

The standard dimension of the composite mat when unfolded is 16.5 x 18.2 m (two joined coverings, each consisting of nine composite panels) and weighs less than 3 t. The mat thus created is sufficient to cover a standard crater. The mat must be properly attached to the existing airport surface.

Another type of airport covering is Class 60 aluminum matting (Fig. 1.c). The covering is formed by joining two mats along the long side, thus obtaining a dimension of 22 x 16 m. The mat is very heavy, weighing about 12.5 t. The covering is attached to the undamaged surface of the runway with special dowels. For immediate use, the mats should be prepared in advance, rolled and stored on a rack near the runway. The mats are laid transverse to the direction of aircraft movement.

Portable airport coverings make it possible to restore the operational readiness of damaged airport pavement in the shortest possible time and provide safe conditions for flight operations. Rapid reconstruction of airport pavement involves three stages of repair work. Preliminary work consists of preparing the crater for laying a layer of crushed aggregate. Substantial work includes reconstruction of the lower and upper parts of the crater, followed by the laying of mats. The unrolled mat is stretched over the rebuilt crater in the right place. Final works are related to cleaning the repair region [6].

Simultaneously with the restoration of the crater, the repair of surface damage takes place. Spall repair technology is divided into two stages [7, 8]:

- preparatory stage - cleaning the repair site from loose sediment, dust, debris and oily substances;

- filling with repair material and possible care.

The following materials are used:

- very fast setting mortars based on magnesium phosphate - they do not require care and have high compressive strength after a short time (after about 2 h);

- cement-based mortars (hydraulic binders) - a mixture of water and cement with fine aggregate or other fill to set; require care;

- bituminous (mineral-asphalt) cold mixes - a mixture of aggregate, asphalt and other additives designed for immediate, permanent repair of cold damage to pavements.

Mortars are used for concrete pavements, and bituminous mixes are used for bituminous and concrete pavements. Quick-setting mixes are characterized by high strength, the ability to be used in freezing temperatures and, above all, a very short setting time (up to 22 minutes). In the process of repairing surface damage, preliminary work consists of preparing the damaged pavement for repair. The primary works focus on the correct application of the mortar to the damaged pavement. Final work, on the other hand, coincides with the scope of the crater reconstruction work.

The selection of equipment used in the process of repairing airport pavements depends on the type of damage [9] 10]. Heavy equipment such as bulldozers, excavators, graders, sweepers, dump trucks, low-loader trailers, vibratory rollers, are used for crater reconstruction. These machines and equipment are utilized for tasks including debris removal, filling both the lower and upper parts of craters with aggregate, laying crushed aggregate, compacting, grading, transporting aggregate to the site, and cleaning the repair area. Additionally, concrete cutting saws are used for elevated pavement sections, along with measuring equipment and spray paint for marking purposes. A set of tools included in the installation kit is used to install the mat. In turn, brooms, shovels and small tools such as patches, wedges, trowels, spatulas, masonry floats, mortar mixers, buckets, traffic cones, etc. are used to repair surface damage. The detailed activities that re carried out in the process of rapid reconstruction of the airport pavement are shown in the schedule for carrying out the work (Figure 6).

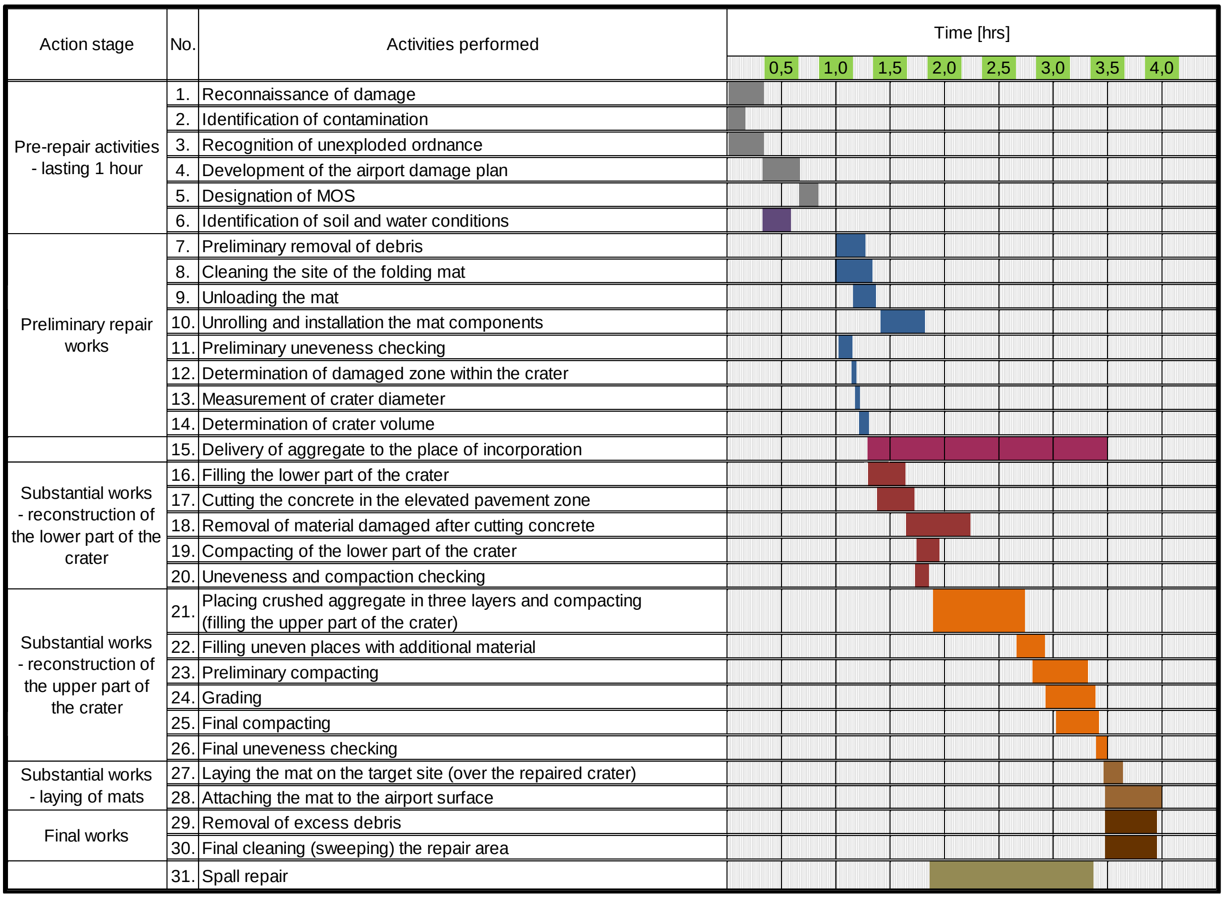

**Fig. 6.** *Schedule for reconstruction of airport damage by rapid method using composite mats*

## 4 Discussion on implementation of rapid reconstruction of airport pavements

The rapid reconstruction of airport pavement is facilitated by a specialized and dedicated team for pavement repair. This team is tasked with rebuilding 6 craters and repairing up to 200 minor surface damages (spalls). Each team comprises 6 "CRATER" reconstruction groups and one "SPRAY" repair team. These groups work concurrently, conducting repairs simultaneously to expedite the restoration process.

It is noteworthy that various regions across the country maintain multiple rapid reconstruction teams for airport pavements, ensuring prompt response in the event of attacks on several airports. This approach eliminates delays associated with team mobilization and ensures an adequate number of qualified personnel available for the task. Each team is assigned a specific territorial responsibility covering designated airfields, enhancing the capability to swiftly restore operational readiness at affected airfields without the need for mobilization from distant locations. Nonetheless, an even more effective strategy would involve having dedicated reconstruction teams stationed at each airport.

Before initiating repairs during the first hour allocated for reconstruction, reconnaissance and damage assessment, identification of contamination, and disposal of explosives must be conducted. It is recommended to assign a skilled mine-clearance group (sappers, chemists) for this task, along with an engineering team dedicated to developing a reconstruction strategy. This team identifies the Main Operating Strip (MOS), maps it, and integrates it into the airport's plan.

The rapid reconstruction of airport pavement is achieved through the efforts of a specialized and dedicated team focused on the task. This team is responsible for rebuilding 6 craters and repairing up to 200 minor surface damages (spalls). It is structured with 6 “CRATER” reconstruction groups and one “SPRAY” repair team. Each reconstruction group performs identical repairs simultaneously, working in parallel to expedite the restoration process.

It is worth noting that in different parts of the country there are several teams for rapid reconstruction of airport pavements in case of an attack of several airports. This approach eliminates delays associated with team mobilization and ensures an adequate number of qualified personnel for the task. Each team is territorially assigned its region of responsibility covering the airfields in question, and there would be an increased possibility of immediately restoring the operability of the attacked airfield without having to move the team from its location. However, an even more effective strategy would be to establish such teams permanently stationed at each airport.

The airport pavement rapid reconstruction team should undergo regular training sessions. It is recommended to conduct training several times a year, focusing on practical exercises on damaged sections (DS) and damaged pavements (DK) using necessary equipment and repair materials. Training should include practicing the placement of mats on repaired craters and conducting takeoffs from these prepared surfaces, simulating real operational conditions. Consideration should be given to utilizing decommissioned or partially destroyed airfields as emergency sites for realistic rapid reconstruction exercises. These exercises would involve complete pavement reconstruction, followed by validation through actual use scenarios. Additionally, to assess the efficiency of rapid reconstruction, exercises could emphasize achieving repairs within a strict timeframe, such as four hours, testing the team's capability to perform under time constraints.

The training should deal with construction work under conditions that are most similar to a possible conflict and attack on the airport, since the most important factor is to fit in time due to the fastest possible provision of aircraft takeoff and landing. Then this kind of training would test the ability of personnel to act efficiently and quickly. Exercisers should rebuild the crater using heavy equipment, as well as practice laying out and installing airport covering in the form of both composite and aluminum mats, so that they can learn about the technological problems of the material during its actual operation.

Only practical exercises can verify the ability of personnel to quickly rebuild airport pavements and train them accordingly. Training should be conducted with personnel so that they can be properly qualified to carry out pavement reconstruction.

Neglecting practical exercises on facilities of target size hinders the implementation of new solutions aimed at enhancing the operations of dedicated airport pavement reconstruction teams. Another debatable issue is the required quantity and type of local materials needed for the reconstruction of the airport pavement. According to the requirement, the reconstruction team should have an adequate amount of repair materials. According to the provisions in the STANAG 2929 study, the amount of accumulated repair materials should be sufficient to repair damage after two enemy attacks. Repair machinery and equipment should be equipped with a radio system and should be deployed on the airfield so that they can reach any point on the runway in no more than 45 minutes. Further supplies of materials should be contracted among local companies so that they can be replenished within 24 hours.

Repair materials to be stockpiled at the airport include aggregate for reconstruction of the lower as well as the upper part of the crater, and quick-setting mortars, cements and bituminous mixtures. Airports must also be stocked with sufficient components and mobile airport coverings, or mats. In the case of mat coverings, one available stockpiled type of airport covering can be accumulated.

Considering that some of the materials remaining in or near the crater will be utilized for its repair, the anticipated amount of aggregate required for reconstructing the lower part of the crater may be reduced by approximately 20-30% of the total volume.

It's important to note that construction materials have expiration dates specified by the manufacturer. Once expired, these materials lose their properties and should be replaced promptly with new ones. Rotation is necessary to ensure compliance with the manufacturer's shelf life guidelines.

Furthermore, each airport should establish agreements with construction companies capable of supplying equipment and necessary materials continuously. This measure enhances the reliability of recovery operations.

Moreover, the issue of mat availability needs addressing. Stockpiling airport coverings is crucial, as acquiring or producing them during a crisis escalation, especially in conflict scenarios, may exceed operational time constraints. Mats should be stored at each airport in adequate quantities to cover reconstructed craters in case of an attack, eliminating the need for transportation from other airports.

Teams dedicated to rebuilding airport pavements should be equipped with more equipment, especially dump trucks, as this would speed up the cycle of delivering construction materials to the repair site. In addition, having more equipment would increase the likelihood of engineering machines remaining capable of working after an air attack.

## 5 Conclusions

An essential component for effective planning of airfield damage restoration is the availability of current airfield maps. Using prepared, developed, and regularly updated airport plans enables precise planning for damage repair (including mapping damage locations, identifying unexploded ordnance, and determining Main Operating Strips (MOS) and Main Auxiliary Operating Strips (MAOS). It is crucial that these plans undergo continuous updates, particularly following pavement repairs or infrastructure expansions. Updated airport maps, reflecting the latest upgrades and expansions, form the foundation for ensuring that post-attack repairs align with the current state of airport infrastructure.

Today, military airports are particularly vulnerable to damage due to the fact that they are critical infrastructure facilities. They are fundamental to the functioning of the country's defense system.

Air and missile strikes pose significant threats, inflicting extensive damage on airport pavements and critical facilities such as fuel depots, spare parts warehouses, ammunition depots, and personnel buildings housing technicians and pilots. While the loss of aircraft is consequential, the loss of trained crews is far more impactful, as human resources remain the most valuable asset in the Air Force.

Simultaneously, it is crucial to acknowledge the increasing threat posed by drones, as evidenced by their impact in conflicts like Ukraine. Activities conducted by reconnaissance and diversionary groups are also gaining prominence, being challenging to counter. These groups operate remotely, aiming to damage stationed aircraft not only by breaching the apron area but also by deploying drones from afar. Protecting aircraft becomes complex, prompting consideration during conflicts of dispersing them across multiple airports within the country. Such dispersion reduces the attractiveness of individual airports as targets. Moreover, planning missions to target aircraft at airports becomes challenging due to their relocated positions.

In conclusion, actual aircraft should be kept concealed in shelter-hangars, while dummy aircraft mock-ups should be prominently displayed on the airfield aprons to attract enemy attacks. These mock-ups are constructed from heavy metal sheets and resemble real aircraft from a distance of several hundred meters. By drawing enemy strikes towards these mock-ups, the airfield can avoid actual losses and remain alert and prepared for battle. Another way is to dislocate and shield sensitive infrastructure elements as well as aircraft. For rapid construction of protective elements, lightweight structures made of cold-bent double plates can be used [11,12].

Military airports are susceptible to air attacks due to their crucial role in hosting allied forces, equipment, armaments, and supplies, facilitated by transport aircraft landings. Damage to an airfield significantly impairs the Air Force's operational capabilities. Therefore, it is prudent to consider employing reinforced double-bent sections for the rapid construction of logistics depots with essential ballistic resistance [13, 14].

In countering air attacks, air defense systems and missile detection measures play a crucial role. Continuous development in these areas is essential to mitigate airborne threats effectively. However, fundamental challenges persist in restoring airport operability, including insufficient personnel trained in pavement reconstruction, inadequate stockpiles of repair materials, and a shortage of modern engineering equipment. Furthermore, ensuring the safety of repair crews in conflict situations is critical, necessitating the provision of robust air defense and active protection measures.

Accurately assessing the potential damage to airport pavements is challenging, making it essential to prepare based on estimated and projected scenarios. Effective reconnaissance enables better organization of work and allocation of resources for pavement reconstruction. Research into innovative technologies and materials for airport pavement reconstruction is beneficial. Exploring various admixtures to enhance concrete compressibility, strength, and setting time shows promise. Additionally, investigating resin-based solutions capable of achieving load-bearing capacities similar to concrete with shorter setting times is crucial. Developing new types of mats that can be mass-produced domestically would ensure a steady supply for all airports. Furthermore, exploring new solutions to increase the durability and lifespan of materials is worth pursuing.

Research efforts could also focus on reconstructing airport pavements capable of supporting takeoffs and landings, akin to road sections, considering the growing use of public roads for air operations. Additionally, there is a critical need to prioritize the rapid reconstruction of airport pavements, especially as air superiority in conflicts often dictates the course of military operations.

## Bibliography


1. Dyrektywa Dowództwa Sojuszniczych Sił Zbrojnych NATO ACE 80-15, 1989.
2. Grenda B., Bezpieczeństwo lotnisk wojskowych (Force Protection), Silva Rerum, Poznań 2019.
3. STANAG 2929 – Airfield Damage Repair (ADR), Edition 4, 1st March 1994.
4. Wojewódzki B. (red.), Technologie szybkiej naprawy nawierzchni lotniskowych podczas działań operacyjnych Sił Powietrznych RP, WAT, Warszawa 2000.
5. Blacha K., Wesołowski M., Mobilne pokrycie kompozytowe ELP-1 KRATER do odbudowy elementów funkcjonalnych lotniska w sytuacjach kryzysowych, „Autobusy: Bezpieczeństwo i ekologia", 2016, nr 6.
6. Wesołowski M., Przenośne nawierzchnie lotniskowe, „Prace Naukowe ITWL", Zeszyt 23, 2008.
7. Analiza oraz wybór właściwych technologii i opracowanie organizacji procesu odbudowy zniszczeń lotniskowych w celu wykorzystania w Normie Obronnej, Highway Biuro Projektów na zlecenie 17 TOL, Gdańsk 2013.
8. Odbudowa zniszczeń lotniskowych – Szczegółowe Specyfikacje Techniczne, Highway Biuro Projektów na zlecenie 17 TOL, Gdańsk 2013.
9. Raport z etapu I – Analiza oraz wybór właściwych technologii odbudowy zniszczeń sztucznych nawierzchni lotniskowych metodą szybką i metodą tradycyjną-czasową w czasie kryzysu i wojny, Highway Biuro Projektów na zlecenie 17 TOL, Gdańsk 2013.
10. Raport z etapu II – Opracowanie organizacji procesu odbudowy zniszczeń sztucznych nawierzchni lotniskowych w czasie kryzysu i wojny dla przyjętych rozwiązań technologicznych, Highway Biuro Projektów na zlecenie 17 TOL, Gdańsk, 2013.
11. Piekarczuk A.: Test-supported numerical analysis for evaluation of the load capacity of thin-walled corrugated profiles, Bulletin of The Polish Academy of Sciences Technical Sciences, Vol. 65, No. 6 (2017), https://doi.org/10.1515/bpasts-2017-0087
12. Walentyński R., Cybulski R., Kozieł K.: Numerical models of ABM K-span steel arch panels, Architecture Civil Engineering Environment, no. 4, 2011.
13. Chmielewski R., Baryłka A., Kruszka L., Sankowski J., Modyfikacje konstrukcji z profili giętych dwukierunkowo pod zwiększone obciążenia, Awarie budowlane 2024, ISBN: 978-83-7663-372-5, s. 525-542
14. Baryłka A. Żółtowski M., Designing the organizational structure of construction, Inżynieria Bezpieczeństwa Obiektów Antropogenicznych, No 2 (2024), https://doi.org/10.37105/iboa.211