

## **INCREASING THE COUNTRY'S SECURITY AND PUBLIC TRANSPORT ACCESSIBILITY BY CREATING A NETWORK OF SMALL AIRPORTS**

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### **Abstract**

It has been shown that by creating a network of small airports, it is possible to increase the communication accessibility of large population groups and the country's security, including safety at sea. The airports mentioned above may also be located on land considered to be weak from an engineering point of view. This includes, for example, wetlands, swamps, flood embankments, poor coastal belt grounds, and reclaimed land. A quick and effective method of adapting the aforementioned land for locating airport infrastructure on has been put forward. It is a method for reinforcing the ground with blasting agents. This method can be successfully used in all conditions. In combat conditions, it can be used for quick construction of spare airports, additional runways and reconstruction of damaged runways. It can also be used to create a dispersed network of airports and airstrips, which is important not only from the military point of view, but also from the civil.

**Key words:** country security, blasting charges, camouflet explosion, runways

### **Introduction**

Creation of airports, landing areas, runways, etc., (temporary - in crisis or combat conditions) and their location, especially in cases of greater necessity, may less and less often be adapted to the engineering requirements of the foundation of the

buildings. In general, the situation is reversed, i.e. first we have the location and then the decision on the method of reinforcing the ground. In crisis or combat conditions, the basic factor determining success is time and location, which should not be limited by ground factors. Here, the time needed for the process of ground reinforcement is more important than its costs. Reducing this necessary time is very important.

The above conditions force decision-makers / commanders to also place these civilian or military objects on soils considered to be difficult from the point of view of their suitability for broadly understood transport and communication activities. This concerns swamps, organic land, dumping grounds, industrial waste, and rubbish dumps. The choice of such difficult places may also be indicated as beneficial for tactical reasons.

It should also be remembered that airport infrastructure may be destroyed, for example as a result of unexpected circumstances (failure, catastrophe, natural disaster, terrorist attack). The reconstruction of this infrastructure in the aforementioned crisis situations should make it possible to restore it in the shortest possible time.

In war conditions, one of the basic tasks is to secure an appropriate number of airports with well-functioning runways. This task is difficult due to the fact that modern combat aviation requires airports with runways with parameters that allow them to carry large dynamic loads. The reconstruction of damaged airport infrastructure is not always a good solution. From a tactical point of view, a good solution is the ongoing creation of a dispersed network of airports in difficult engineering and hard-to-reach areas. Here, methods to strengthen the ground surface are helpful in the struggle against time. However, from the point of view of the limited time needed to prepare the subsoil for designed aerodrome objects, an important and effective method for using explosives for reinforcing the subsoil at these aerodromes and access roads, including railways or railway sidings, should be considered.

The use of the possibility of creating airports with limited certification under different conditions of ground subsoil allows for the creation of innovative solutions for the national economy, security and defence of the country. It will increase the communication accessibility of citizens. It will also be an impulse for action for local government units, transport, forwarding, logistics, tourism, medical, rehabilitation, free time industry etc.

### **Modification of the subsoil to improve its geotechnical properties**

Organic soils (e.g. peat) subjected to stress are notable for their high compressibility. During consolidation<sup>1</sup>, internal parameters change<sup>2</sup>. Organic soils exhibit low initial

1 Z. Meyer, T. Kozłowski, *Osiadanie gruntu organicznego o właściwościach sprężysto-plastycznych*. XV Seminarium Naukowe z cyklu Regionalne Problemy Ochrony Środowiska w Ujściu Odry. Szczecin, lipiec 2007.

2 Z. Wiłun, *Zarys Geotechniki*, WKiŁ Warszawa 1987.

strength, high deformability and a wide variety of properties depending on the type and content of minerals and organic components. It follows that this type of land cannot be directly used as a foundation for the engineering structures necessary for performing aerial operations. Generally, it can be concluded that low-bearing soils without being modified cannot be used to implement the aforementioned ventures.

Modification of the soil substrate to improve its geotechnical properties can be implemented in many ways. Geotechnical parameters of the soil substrate can be changed or their consolidation can be accelerated by reinforcing or improving the soil properties with various methods to the extent that they meet the requirements of engineering structures for the implementation of air operations, including runways, engineering facilities and various types of access roads.

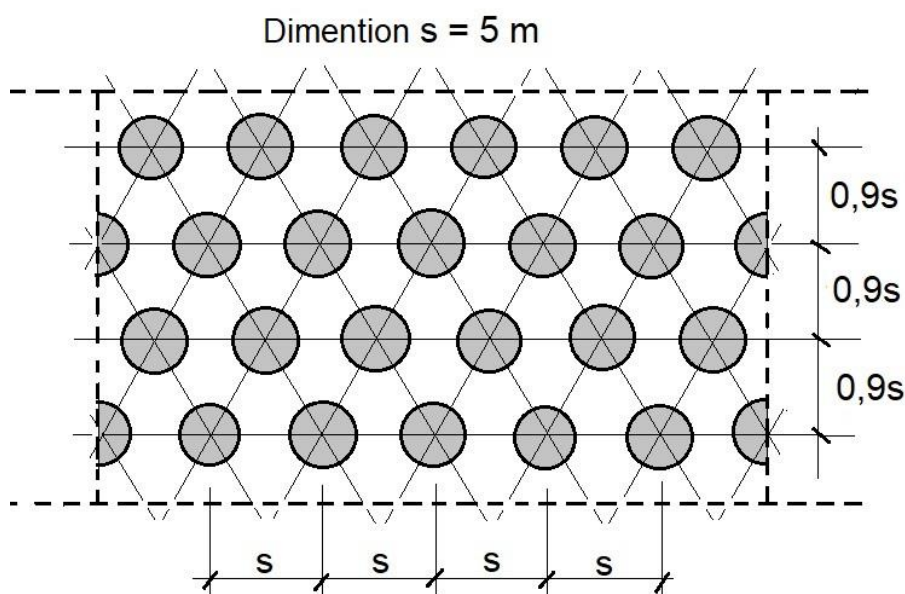
From the point of view of the problems discussed here, two groups of ground improvement can be distinguished: soil improvement methods and soil reinforcement methods for engineering objects related to the implementation of aviation operations. The first group are the methods in which the soil is modified by using various types of injections in order to obtain a more compacted or tight substrate. This modification consists in strengthening the contact between the ground grains, which simultaneously reduces its porosity, creating a useful base for taking up large dynamic loads from landing aircraft. The second group are the methods consisting in introducing a structural element to the ground in order to increase its mechanical strength or mechanical violation of the internal structure of the soil thus improving the soil strength parameters.

Detailed methods for strengthening or improving the ground surface include: ordinary injections, microcement injections, vibroflotations, chemical injections, dynamic exchanges, dynamic consolidations, deep dynamic compaction, vibrating methods, vertical drains, compacted columns from granular soils, soil mixing with additives, deep soil mixing, soil reinforcement, static overloading etc.

One more method should be added here - the method that uses explosives - blasting agents. This is a method important from the point of view of the subject considered here, which has some common features as to the principle / idea with dynamic exchange or dynamic consolidation.

The dynamic exchange method is a combination of methods used for compaction of the soil, and especially impact methods with the method of land exchange, the concept of which consists in increasing the load-bearing capacity of the ground by introducing stone, gravel or sand columns on it. It works best when strengthening organic soils, irrigated cohesive soils and anthropogenic soils. This technology consists in the dynamic formation of load-bearing gravel columns or columns made of aggregate (e.g. crushed structural concrete, blast furnace slag, stone breakage) by means of rammers (most often weighing from 8 to 15 Mg) dropped by gravity from a height of usually 15 to 30 m. Such compacting causes the overpressure of water in the pores of the ground, which dissipates and causes the outflow of filtration water to the column performing the drainage function. Detailed selection of the appropriate type of method is possible after thorough assessment of the parameters of the soil to be improved, as well as the depth of deposition and stratification of

the low-bearing substrate. In the process of soil reinforcement, the distribution of impact points is important (Figure 1), as well as the selection of other technological parameters, including the frequency of impact. After this operation, the ground surface is prepared for constructing, for example, runways on it.

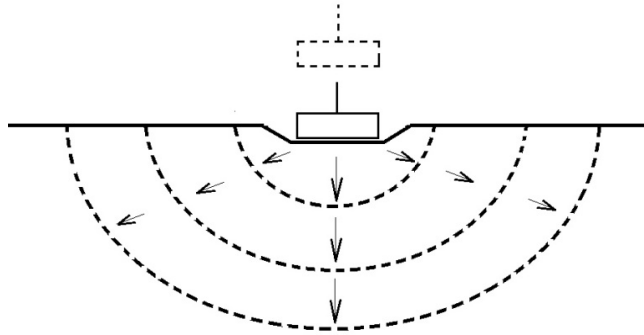


**Fig. 1.** An example of the distribution of hit points in the implementation of a construction project

Similar equipment is used to perform dynamic consolidation of the ground, as in the case of dynamic exchange. This technology consists in repeatedly dropping (generally from 10 to 40 m) a heavy rammer (generally with a mass of 10 to 50 Mg) at a frequency of about 1 to 3 beats per minute. As a result of this operation, solid reinforced soil is formed below the crater in weak ground. The gravitational rammer (Figure 2) causes the formation of overpressure of water in the pores and the formation of volume waves: transverse and longitudinal waves and surface waves<sup>3</sup>.

After a series of impacts generating these waves, the water pressure in the pores of the soil increases to the level corresponding to the state of liquefaction of the soil. The next phase causes dissipation of water overpressure and soil compaction - stronger contact between grains.

**3** E. Mieloszyk, A. Milewska, S. Grulkowski, *Elastic waves in railroad bed and its surroundings analysed using non-classical operational methods*. Proceedings of the Conference CETRA 2018. 5<sup>th</sup> International Conference on Road and Rail Infrastructure. 17-19 May 2018, Zadar Croatia, pp. 1195-1201. ISSN 1848 – 9850, ISBN 978-953-8168-25-3.



**Fig. 2. Dynamic compaction. Propagation of vibrations (waves) in the ground**

After completing the impact process - dynamic consolidation, the surface is leveled up and the compaction proceeds on subsequent possible locations. After the process, the mobile airport covering used to build the basic elements of airports or helipads can be laid out on the leveled ground surface.

### **Use of blasting charges to improve the subsoil**

This technology aims to improve the physical and mechanical parameters of the ground by compacting granular soils or by creating vertical sand piles (improvement) in weak cohesive soils as a result of the use of explosives placed in or on natural soil or embankment to be compacted or consolidated<sup>4</sup>.

The process of explosion and detonation<sup>5</sup> is spread by the already mentioned strong shockwave.

The advantages of this method when reinforcing the ground surface for aerospace purposes include:

- short duration of compaction or improvement, which is particularly important in cases of higher necessity,
- obtaining densification of the substrate layers to a large depth, e.g. up to 40 m,
- effectiveness when there are large single boulders or stones in the ground,
- considerable efficiency in areas exposed to dynamic loads, e.g. large aircraft landing.

The basic feature of this method is the use of high energy generated at the moment of explosion. Detonation of the explosive is possible only when using

<sup>4</sup> E. Mieloszyk, M. Wyroślak, *Airstrip Ground Improvement Works by Blasting Charge Technique and Dredged-Ash Material Mixture*. 2019 IOP Conf. Ser.: Mater. Sci. Eng. 471 042016.

<sup>5</sup> E. Włodarczyk, *Podstawy fizyki wybuchu*. Redakcja Wydawnictw WAT, Warszawa 2012. ISBN 978-83-62954-30-8.

a high voltage electrical impulse. For safety reasons, materials sensitive to detonation under the influence of fire are not used<sup>6</sup>.

In the process of compacting granular soil, certain phases can be distinguished during explosion. At the outset, gas and shockwaves produced during the explosions (Figure 3) propagate in a ground-water medium at a speed of approx. 3000 m/s. The pressure of the detonation wave is approximately 1400 MPa. This process causes a change in the structure of the ground backbone, whose grains or particles are subject to slow or rapid rearrangement due to large shear deformations in the ground, followed by liquefaction of the soil and dissipation of the water pressure in the pores. Detonation of the load causes a sudden increase in the pressure of water in the pores of the ground, which destroys its existing unstable structure, changing it into a useful location for the airport facilities or other structures.

The triggered regrouping in the ground environment entails increased soil compaction. It depends on the type of soil and its permeability, the location (placement) of the explosive and the volume of soil to be compacted. To carry out ground reinforcement operations, explosives can be placed on the surface of the reinforced soil or into the ground. In the latter case, concentrated or extended charges are used. In the implementations performed so far, when using concentrated charges, their weight does not exceed 10 kg, while extended charges usually have a unit mass of about 2 kg/m.

The Polish experience has made it possible to work out the above empirical recommendations for the method of strengthening the soil using blasting agents. In the literature<sup>7</sup> we can also find other design parameters. The theoretical range of effective explosion impact in the case of a concentrated charge or a cluster of concentrated charges is:

$$R1 = k \cdot \sqrt[3]{Q_1}$$

where  $Q_1$  is the empirically determined mass of the explosive charge [kg] at depth  $h$ :

$$Q_1 = 0,055 \cdot h^3.$$

The parameter  $k$  is the experimental factor:  $k = 2,5 \div 3,0$ .

Theoretical range of the effective explosion impact in the case of an extended charges is:

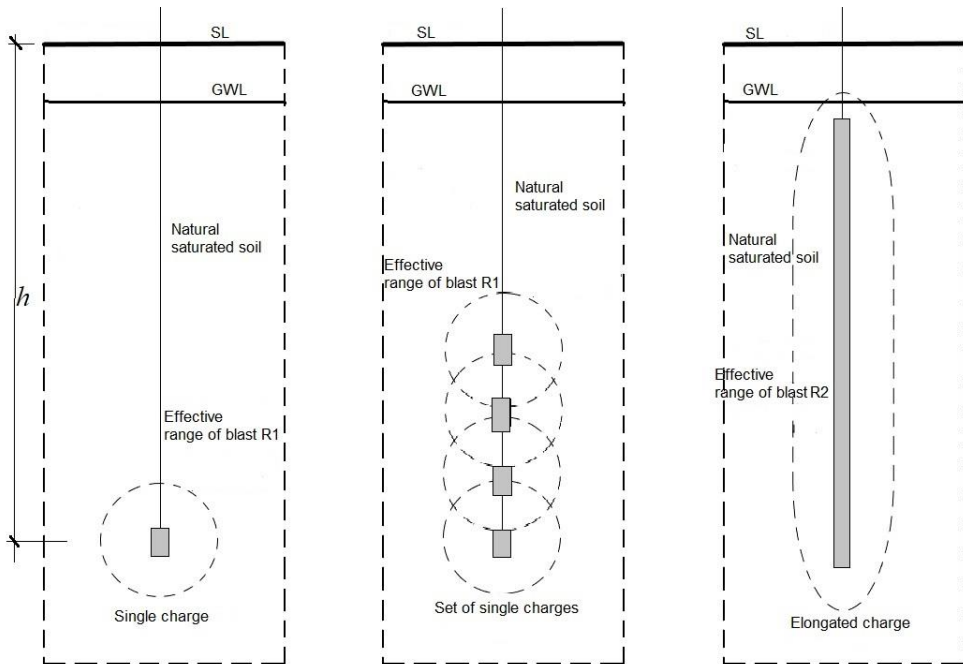
$$R2 = 0,71 \cdot k \cdot \sqrt[3]{Q_2},$$

where  $Q_2$  is the assumed mass of the explosive charge [kg/m].

The previously given magnitudes are illustrated in Figure 3.

<sup>6</sup> Z. Sikora, M. Wyroślak, *Dynamic soil improvement by hybrid technologies*. XVI ECSMGE, Edynburg 2015.

<sup>7</sup> P.L. Ivanov, *Uplotnenie nesvyazanykh gruntov vzryvami. (Compaction of noncohesive soils by explosions)*. Izdat'elstvo Literatury Po Stroitelstvu. Leningrad 1967.



**Fig. 3. Camouflet explosions with an example of charge distribution**

The single use of explosives does not always give the expected effects of strengthening the ground intended for the construction of runways or access roads, etc. Then a series of explosions<sup>8</sup> must be used, including sequential firing of charges at various points on the surface being reinforced (compare Figure 1).

Runways are linear engineering construction objects, and similarly to different types of roads, railway lines, etc., can be implemented with the use of experience in strengthening land for roads, railways, etc. – Figure 4 and Figure 5. Aviation law (Journal of Laws of 2016, item 605) creates the possibility of public transport by small aircraft, i.e. aircraft with a take-off mass of up to 10 t and a maximum of 19 passenger seats, also known as PAX. This corresponds to the EU transport policy linking Poland with the corridors of the trans-European transport network (TEN-T): (road, rail, inland, maritime, and air) and measures to increase people's transport accessibility and increase the country's security in line with the Responsible Development Strategy.

<sup>8</sup> E. Dembicki, *Zagęszczanie gruntów metodą mikrowybuchów*. Wydawnictwo Naukowe PWN, Warszawa 2018.



**Fig. 4. The method of subsoil improving with blasting charges  
(A2 motorway, Kolo-Dąbnie section)**



**Fig. 5. Dynamic soil compaction (A2 motorway, Kolo-Dąbnie section)**



## **Creating a dispersed network of small airports and runways**

To implement this concept, public airports with limited certification are needed, mainly equipped with innovative new generation runways, with equipment and direct logistics facilities. It is this innovative runway set on the ground reinforced by blasting agents that is the nucleus of the entire system, and such airports should be near the communication airport.

A similar system functions successfully in the USA and Europe, where it operates under the name of the European Personal Air Transportation System (EPATS). It is an air transport system that is to be used by the general public and its concept can be used by the armed forces.

In Poland, apart from airports in the vicinity of large cities, so-called regional airports (communication) and new small airports should eventually be created with public access (including those with limited certification), or on the basis of the existing 28 airports entered in the Register of Civil Airports for 2018, a network of airports serving "small" planes with a take-off mass up to 10 Mg should be created.

All of these airports could have a complementary function and could serve passengers wanting to get to, for example, a central or regional communication airport from places that are at least 3 hours away by other means of transport.

When modernising existing runways, access roads or those under construction, innovative methods based on green geotechnics should be used - abandoning concrete and asphalt. Weak, difficult, undeveloped soils often unsuitable for other purposes, should be used - bogs, peat bogs, etc. In these cases, explosive charges can be used to strengthen them. They may be located in the coastal zone and, hence, they may be used to increase safety at sea.

This is part of the activities of the International Maritime Organisation (IMO), which is an institution of the United Nations, responsible for broadly understood maritime safety.

It is worth adding here that many soils in the coastal belt are poor soils, so you can adapt them to the aforementioned destination using methods that use explosives.

When crossing the cut of the Vistula Spit, it is worth using the silt to create a runway. The compaction of the soil can be achieved with the use of blasting agents. An additional argument for the location of the runway in that area using silt is the presence of the International Waterway E70 which is connected by the Szkarpawa River with the Vistula Lagoon. The created runway is of strategic importance and should be used to increase safety at sea.

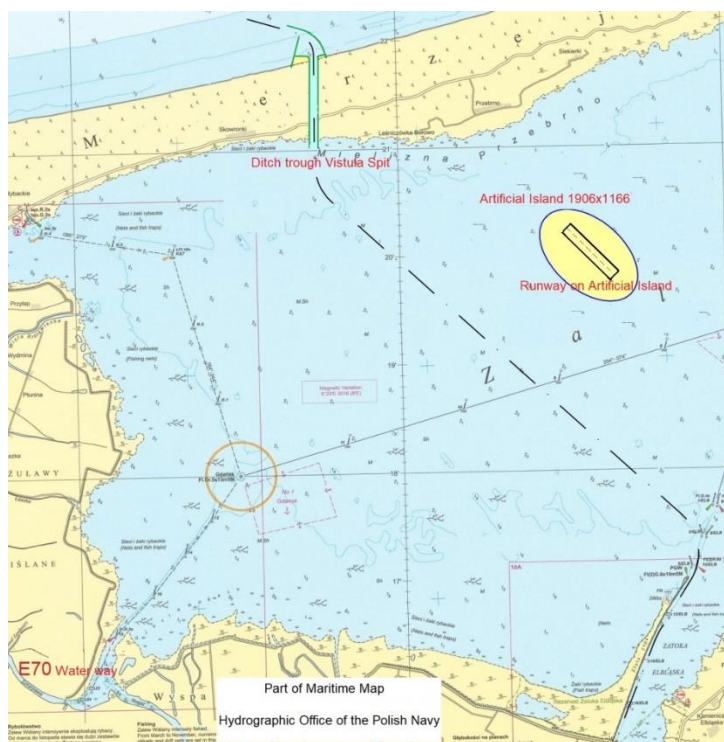
To implement the above concept, the already mentioned planes with a maximum take-off mass of 10 Mg can be used. These are generally nineteen-seat planes plus two crew members. Their maximum speed is about 500 km / h, the maximum range is about 1,300 km.

Assuming for analysis:

- the average speed of the aircraft - 400 km/h,
- the range - 1000 km,

a schematic map was created (Figure 6) with an area of  $\Omega$  gravitation to CPK with a radius of 800 km (travel time - about two hours).

Figure 7 shows that there are many large cities in this area, and even the capitals of several countries. For example, Boryspol airport in Kiev served 10.55 million passengers in 2017.



**Fig. 6. Cross-cut of the Vistula Spit - scheme**

It is a competitive solution in relation to other means of transport, including even high-speed railways. It creates the possibility of creating a dispersed network of «small» airports in the  $\Omega$  area, without any limitations in relation to their specific location, including location on weak soils. Here, the method of reinforcing the ground with the use of explosives is really helpful.

Such airports can be created and liquidated depending on the requirements. The cost of this operation is low and due to the technology used, neutral for the environment.

It should be added that such airports or runways can also be created in combat conditions, for example for unmanned airplanes. For example, the useful mass of the RQ - 4 Global Hawk unmanned aircraft is about 10 Mg.

Due to the lack of location restrictions, the dispersed system can be well designed, taking into account its architecture and topology adapted to all conditions, including crisis conditions.



Fig. 7. Area  $\Omega$  diagram

«Small» airports and small planes are a more flexible form of air transport than air transport using traditional airports. They should complement the existing network of large communication airports. They should offer passengers comfortable and quick access to selected destinations, including large airports.

## Conclusions

The key to using areas of weak soils is to improve the subsoil of the area. The method of ground reinforcement using explosive materials for the construction of engineering structures designed to perform civil and military aerial operations is an innovative and effective one.

The suggested method is easy to implement, especially with the use of engineering forces.

The short time of implementation of land consolidation, location on poor soil and in areas with difficult access are the advantages of the discussed method in combat conditions too. It takes into account the enemy's anti-access systems.

The method described for compacting the substrate is economically viable.

Areas with difficult access: swamps, wasteland etc. can be used by civil and military aviation. In the last case, their location in difficult areas may be an additional advantage, beneficial from the military point of view.

Small airports are a way to solve many communication and transport problems in all conditions.

It is an air transport system that can be used by the general public.

An additional advantage is the possibility of their dissipation, and this allows them to increase the availability to large groups of society and sign in the concept of Strategy for responsible development, and by dispersing it increases the safety and reliability of the entire system in all conditions.

One more advantage is the possibility of their dissipation, which allows to increase the availability to large groups of society of air transport and fits in with the concept of Responsible Development Strategy, and also increases the safety and reliability of the entire system in all conditions.

The proposed system is flexible, reliable as a whole and scalable (a feature that allows similar system performance to be maintained while increasing the scale of the system - for example, the increased number of related small airports does not disturb or interfere with the quality of the system).

It reduces travel time.

This unconventional and innovative approach to the implementation of civil and military operations should be a desirable and a possible direction of development for the civil and military aviation system in Poland, in which the described method for reinforcing the ground (the use of blasting agents to strengthen the ground) should also be used for construction in difficult areas of infrastructure that supplements the system through the construction of access roads, railway sidings (MPS), warehouses, hangars, halls, and technical facilities.

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