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Airstrip Ground Improvement Works by Blasting Charge Technique and Dredged-Ash Material Mixture

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Abstract. Soil improvement by blasting charge technique is known in geotechnics as one of the efficient and inexpensive method. It can be used in preparing of underground to found road construction and buildings as well. The technique proves usefulness especially when dynamic load is applied. It is because of non-stiff or rather resilient type soil after improvement. In noncohesive or organic soil, blasting charge must be used with well-graded soil or similar granular material layered as working platform. Explosions cause exchange of soil. Using dredged-ash material mixture it can be benefitable in resource management and ecology. The purpose of research was finding a fast method of soil improvement to prepare special constructions like airstrips for landing and taking off light and small aircrafts. Expected results can be achieved after using blasting charge technique.

1. Introduction

Airstrips are special places to landing and taking off small aircrafts. The concept functions in the world, especially where road transportation is limited. Small aircrafts, usually up to 10000 kg start weight, are used in tourism, medical care service, forest fire extinguishing, air patrol, small cargo transportation, fast connection charter flights of large airports with local district area. It can also support industry of leisure time activities. The remote location of the aviation objects may give a new stimulation for the surrounding area to the commercial development and may be profitable to the public.

Airstrips are provided with minimum equipment and auxiliary facilities. The runway is relatively short it means about 800 m long and 80 m wide. The pavement is performed as natural resilient surface made of well-graded soil.

Airstrips are often placed on soft or loose soil underneath. The economical and fast mode of ground improvement and formation of a runway is benefitable and desirable. This effect can be obtained with using the blasting charge technique to weak soil improve and mixture of dredged material and coal combustion ashes to build the pavement of runways.

Many years of practice in Poland confirms effectiveness of blast charge technique in loose sandy soil but also in cohesive soil. Mechanical phenomena in noncohesive and cohesive saturated soil differ when impulse of high energy affects. Cohesive soil including muds and peats are partially replaced but also processes of resedimentation and drainage of excess pore pressure are observed which are typical for noncohesive soil.

Dredged materials dumped at sea or from riverbeds mixed with coal combustion ashes are used in road embankment constructions and even in dike construction [1]. The material proves to have a good potential to be considered as fully usable in many applications.

2. A brief review of small aircrafts action on a runway

An airplane accelerating run along runway and decelerating run immediately after landing affects on runway in many different modes. It can be thermal, chemical, acoustic and mechanical action. In the case of small and light aircrafts, the most important is mechanical action especially while a plane lands and wheels touch the ground surface.

Vertical loading of runways depends on the aircraft running speed, braking after landing, weight of aircraft and piloting techniques. If the landing is proper (smooth) loading do not exceed beyond the weight of aircraft but if the landing is improper (hard) loading can be higher than the weight of aircraft and it behaves like “kangaroo” jumper (figure 1).

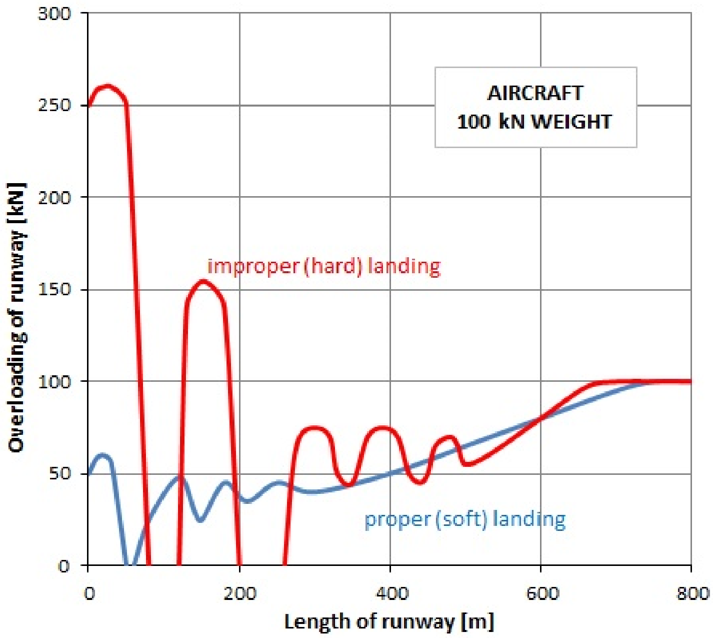

Figure 1. Loading of runways after proper and improper landing [2].

While touchdown appears, horizontal loading depends on vertical loading but also on the angle of landing [2]. If an approach path is consistent with flight instructions for an aircraft, then expected horizontal loading of the runway is less than 50% of vertical loading. Increase of the angle of landing and not reduced aerodynamic acceleration may cause growth of horizontal loading but it is, limited by strength of an aircraft gears, of course. Damages of an aircraft construction appear before soil will lose its bearing. So that the most important case is to ensure optimal parameters of a pavement founded on improved evenly consolidated soil.

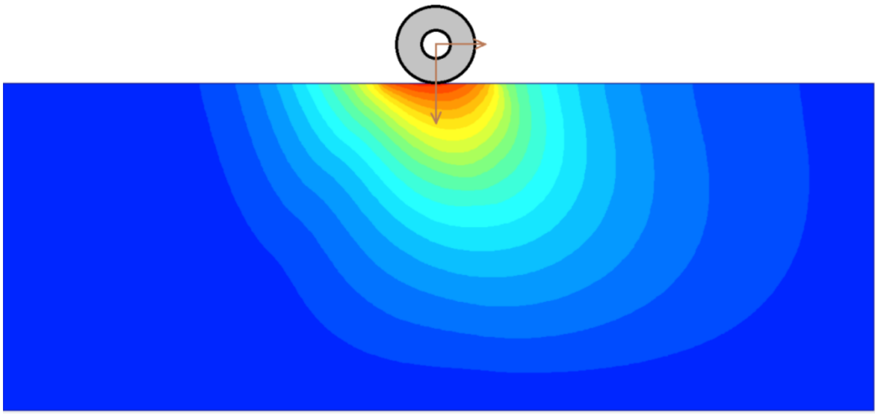

Figure 2. Aircraft wheels' touchdown softly. Prediction of total stress distribution in a pavement.

For small aircrafts, total stress distribution, shown at figure 2, do not predict extreme horizontal displacement, which could dramatically slip soil under wheels. The range of stress distribution seems to be no more than 2 meters deep in soil.

2.1. Dynamic response of soil on an aircraft touchdown

An aircraft landing generates propagation of elastic waves in soil. In the moment of touching-down also shock waves may act. This is disadvantageous situation, which causes negative influence on a runway construction, underneath soil and an aircraft construction.

The waves provoke changes in equilibrium state of soil particles as a granular body, i.e. phenomenon of wave movement is observed because of vibrations. It can be described using partial differential equations.

To obtain one-dimensional wave equation, the equilibrium equation is considered as follows [3]:

$$\frac{\partial \sigma_x}{\partial x} = \rho \frac{\partial^2 u}{\partial t^2} \tag{1}$$

Taking Hooke's linear elastic equation:

$$\sigma_x = E\varepsilon_x \tag{2}$$

in addition, assuming linear dependence in equation:

$$\varepsilon_x = \frac{\partial u}{\partial x} \tag{3}$$

One-dimensional elastic wave equation is obtained:

$$\frac{\partial}{\partial x} E\left(\frac{\partial u}{\partial x}\right) = \rho \frac{\partial^2 u}{\partial t^2} \tag{4}$$

Assuming independence of elastic modulus *E* from dimension *x*, one-dimensional elastic wave equation can be described as:

$$\frac{\partial^2 u}{\partial x^2} = \frac{\rho}{E}\frac{\partial^2 u}{\partial t^2} \tag{5}$$

Substituting to equation (4) relationship describing velocity of longitudinal wave P:

$$c_L = \sqrt{\frac{E}{\rho}} \tag{6}$$

differential equation for one-dimensional elastic longitudinal wave is obtained:

$$\frac{\partial^2 u}{\partial x^2} = \frac{1}{c_L^2}\frac{\partial^2 u}{\partial t^2} \qquad \text{or} \qquad \frac{\partial^2 u}{\partial t^2} - c_L^2 \frac{\partial^2 u}{\partial x^2} = 0 \tag{7}$$

The wave equation may contain the source influence, i.e. action of an aircraft on elastic waves generation. Then, to the last wave equation (4), (5) or (7) function *f(x, t)* should be added which describes mentioned source. It leads to receiving an inhomogeneous partial differential equation [4, 5].

Analysis of the wave equation with source *f(x, t)* operations *S*, *T*, *s* are helpful. They are described as follows:

$$S = \frac{\partial^2}{\partial t^2} - a^2 \frac{\partial^2}{\partial x^2} \tag{8}$$

$$Tf = \frac{1}{2a}\int_{t_0}^{t}\int_{x-a(t-\tau)}^{x+a(t-\tau)} f(\xi,\tau)d\xi d\tau \tag{9}$$

$$su = \frac{u(x-a(t-t_0),t_0)+u(x+a(t-t_0),t_0)}{2} + \frac{1}{2a}\int_{x-a(t-t_0)}^{x+a(t-t_0)} u_t(\xi,t_0)d\xi \tag{10}$$

and they produce non-classical operational calculus [6, 7].

Using the operations, the wave equation (7) with source *f(x, t)* can be described as follows:

$$Su = f(x,t) \tag{11}$$

and from generalized Taylor equation follows that elastic wave equation can be described as:

$$u = su + Tf \tag{12}$$

of course if the shape and velocity of the wave is known at time t_0.

3. Geotechnical request and solution

Contractors and local government decided to design the airstrip for landing and taking-off light and small aircrafts. The best place for location of the airstrip turned out to be geotechnically difficult (figure 3). Wetland area with weak organic soil 6 meters deep is a challenge from constructional point of view.

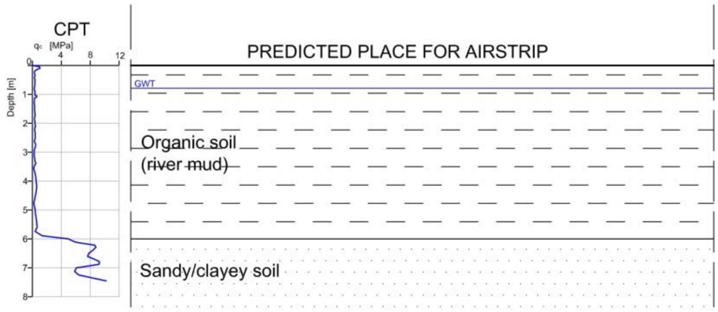

Figure 3. Geotechnical conditions for airstrip foundation.

Recommended solution of the problem was using the blasting charge technique. Implementation of the improvement soil method in noncohesive and organic ground requires better stuff to replace weak soil. Mostly, well-graded sand is used as good compactable and bearing material. Nevertheless, some experiences proved high applicability of dredged sand and ash composite [8].

First stage of earth works starts with filling an embankment as working platform and source of replacement material (figure 4).

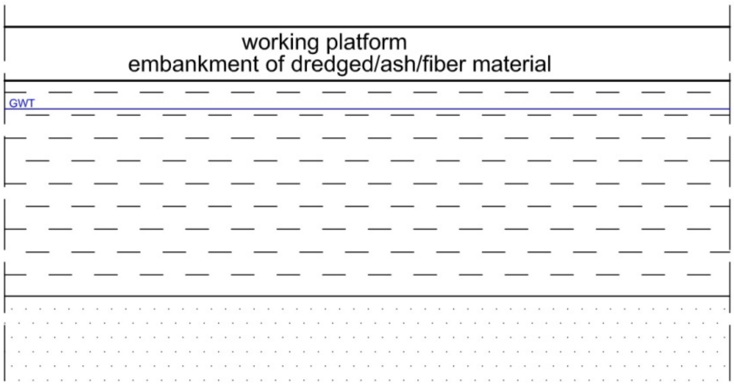

Figure 4. First stage of earth works.

In the second stage, blasting charge partially exchanges weak soil and strengthens rest of weak soil (figure 5).

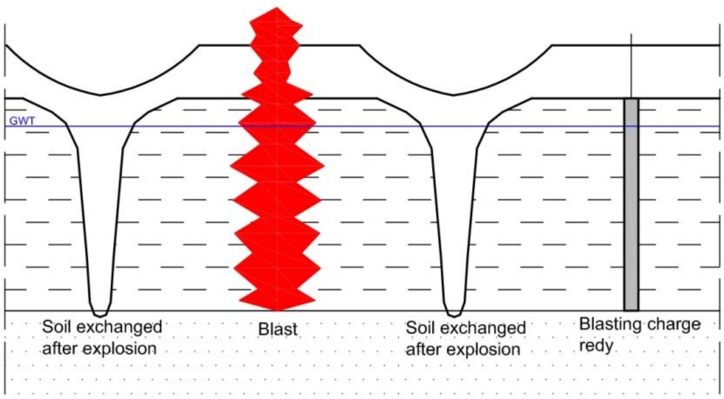

Figure 5. Caverns fulfilled after explosion.

After completing soil improvement, caverns must be compensated and surface levelled. To ensure better transmission of aircrafts loads on a pavement, it should be prepared more resistant on air streaming and dynamic forces during landing and taking-off. Reasonable solution is application of geocells and turf surface (figure 6) as tested and checked runway pavement for small aircrafts.

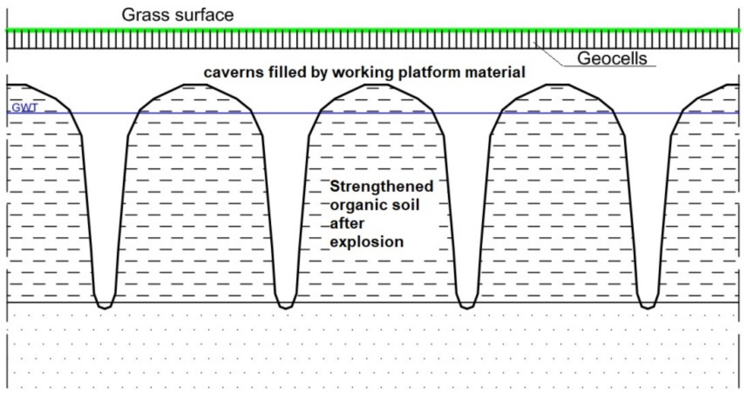

Figure 6. Completed works after soil improvement.

3.1. Dredged-ash-fibre material

Dredged materials are sediments composed of weathered bedrock, sometimes with admixture of organic matter. The materials are removed mainly from riverbeds but also from sea-coastal water. A kind of sediment transportation in water is responsible for the parameters especially differing grain-size. If dredged material is contaminated and rich in organic matter, then should be disposed [1].

Ash generally is a coal combustion product made in coal-fired power plants. Coal is composed primarily of carbon and hydrogen however contains various mineral substrates. The material can be classified regarding the mineral components, combustion technology and size of grains. The main classification is as follows: fly ash, bottom ash, boiler slag, fluidised bed combustion ash. From geotechnical point of view, the ashes differ in grain size. Fly ash comprises predominantly silt-size particles, bottom ash come under sand-size particles but also can contain small amounts of gravel-size fractions [1].

Composite materials, made of dredged sand and ash, are designed due to geotechnical parameters. Material properties such as density, specific gravity, grain size distribution, strength, compressibility, compaction, permeability may differ with proportion of the components. After basic laboratory experiments, recommended content of ash should be in the range of 25-30%. It gives reasonably value of permeability, which should not be very low because partially exchanged soil after blasting must work as drainage. The first task of soil improvement by blasting method is quick consolidation of noncohesive origin soil and dissipation of water pore pressure appeared after shock wave propagation due to charge explosion.

Additionally increase in shear strength of the composite may be obtained using short discrete fibers randomly placed as reinforcement. In the first stage of blasting charge technique, addition of fibers is not needed. But after finishing blasting works, soil surface must be levelled. In this stage, addition of fibers improves composite parameters. Samples of dredged/ash material with 0,5% addition of 30 milimeters long synthetic fibers show increase in mechanical properties.

3.2. Blasting charge technique

Various types of blasting charge techniques are used throughout the world over the last 70 years. One of them involves placing into the borehole elongated explosives and detonation causing propagation of shock wave through the ground (figure 7). The most important thing is ensure so-called camouflaged explosion. The term means that the temporary cavern is created which is filled with well-compacted soil stored on the ground surface [9].

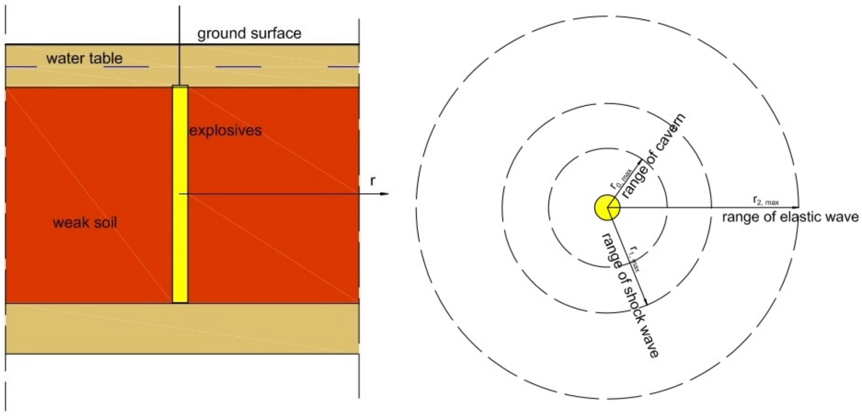

Figure 7. Elongated charge in soil.

The main feature of this method is the use of high energy generated at the moment of the explosion. Detonation of the explosive material is possible by applying an electric impulse of high voltage. A very important issue is not to use the explosives sensitive to detonation under the influence of fire because of safety conditions. Charges of explosives are used, loaded into an airtight sleeve of PVC.

The detonation is defined by physico-chemical parameters like pressure of explosion, explosion energy, the rate of reaction. The detonation differs from the chemical combustion with the rate of the chemical process.

Mechanical behaviour associated with microblasting determines the efficiency of compaction method. In the first milliseconds of detonation, high pressure and temperature as products of explosion are rising because of violent chemical reaction, which passes to physical process. A dozen milliseconds later, detonation wave passes through the ground-water medium at speed about 3000 mps. Due to the elongated shape of the explosive charges, the detonation wave propagates horizontally with the greatest possible momentum.

Detonation wave pressure, acting on ground-water medium, is about 1400 MPa. Detonation wave causes expansion of explosive gases into the cavern. Next, detonation gases are rapidly cooled. According to the principles of thermodynamics, falling down the temperature inside the caverns causes lowering the pressure. In the center of explosion, reduced pressure is produced relative to atmospheric pressure.

As the pore water has a much higher inertia than the air, inside the cavern determines the preferential gradient of pressure equalization directed vertically downwards. Mineral soil from working platform is therefore sucked down before the water from the ground will be able to close the cavern.

In the way consolidation overloading is generated, as well as additional space is filled with a material from the working platform (so called consolidation columns).

4. Conclusions

The most important value of the blasting charge technique is acceleration into the investment process. Proposed method of soil improvement drives innovation and optimization in order to support efficiency, create earthwork technologies more cost-effective and reduce energy consumption.

Airstrip construction is in progress. For now, the venture place is chosen. After completing improvement soil works using the blasting charge technique, set of geotechnical investigations will be done. However, based on many years of experience, successful project is expected. An example of effectiveness of the method is described in [9].

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