THE CONCEPT OF EXPERIMENTAL RESEARCH ON THE BEHAVIOR OF SAND COVER MATERIAL FOR PROTECTIVE SHELTERS FOR CIVILIANS

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Abstract

The article proposes the concept of experimental dynamic tests of aggregate behavior - sand used as a material for covering temporary protective shelters for the population and civil defense. These shelters are part of the construction shielding infrastructure useful in crisis situations. Laboratory tests of loose soil, including sand, with impact loads are based on the Split Hopkinson Pressure Bar using a clamp. The work describes both this experimental method and the original laboratory stand for impact tests based on a pneumatic launcher with a projectile - bar. This position was built at the Institute of Civil Engineering of the Military University of Technology taking into account the requirements of generally applicable legal provisions. Examples of preliminary experimental research on the behavior of selected aggregate - dry sand under dynamic load - are presented.

Key words: protective structure, sand covering, Split Hopkinson Pressure Bar (SHPB)

INTRODUCTION

Protective structures intended for civil defense and civil protection equipment have very important tasks assigned to them, both in peacetime and in war. The key challenge is to guarantee proper protection against various non-military (e.g. floods, landslides, storms, hurricanes) and military (intentional military and/or terrorist activities). The need to analyze this issue results from the growing importance of the phenomenon of terrorism in the unstable situation in the modern world. For the security of the state, it is important to consider and analyze various protective structures ready for urgent application under specific conditions. In most European countries, shelters and temporary shelters are used for civil protection and civil defense. Unfortunately, in Poland, in currently existing shelters and hiding places (stationary type), security can only be ensured for about 4,4% of the population [8]. This fact causes the necessity to create shelters (ad hoc type) in the event of a specific crisis. Shelters (ad hoc type), according to the definition of fortification literature, is an open structure that protects people or specific equipment against assumed factors of destruction only from specific sides. Such constructions can be made of hand-held elements and materials in the area (e.g. steel sheets, wood, composites) and prefabricated elements (e.g. reinforced concrete prefabricated elements). Fig. 1 shows an example of temporary shelter (ad hoc type) in the form of a trench and laminate covering elements. The building was loaded with the effects of the improvised explosive charge (IED) as a result of terrorist activities. Analyzes related to the impact of explosives and methods of protection against their effects have been dealt with in publications [3 – 6]. The effect of the combined phenomenon of a sharp increase in shock wave pressure and smooth relief is defined as a blast wave. Fig. 1 shows the Mach wave propagation scheme (it is a blast wave with a smoothed and uniform course). The Mach wave, according to the definition, is the resultant of the incident and reflected waves with almost even distribution [7].

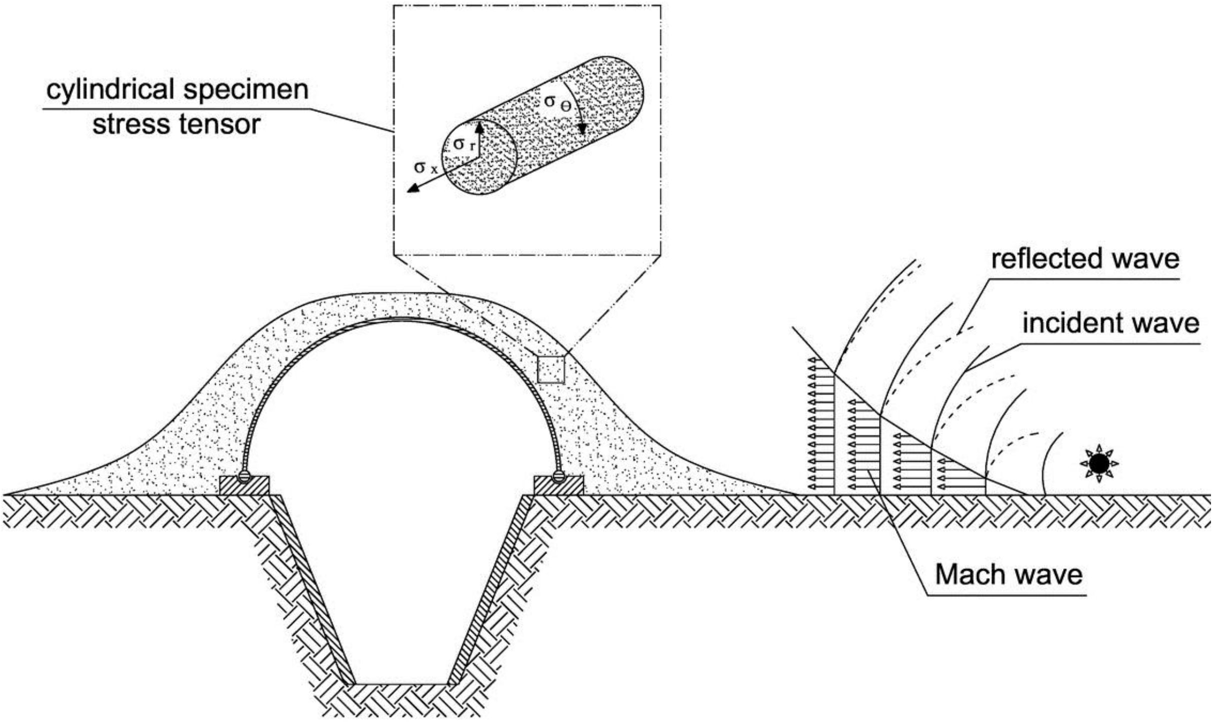

Fig. 1. An example of temporary shelter (ad hoc type) with the Mach wave marked [7, 8].

The temporary shelters (ad hoc type) in their construction have an open casing. In order to increase the level of protection, additional sand covering was used. The role and significance of soil covering was indicated and included in the analysis of prefabricated structure proposals for the protection of critical infrastructure objects in the publication [2]. There is therefore a need for detailed consideration and analysis of the problem of soil covering.

RESEARCH METHOD AND LABORATORY TEST STAND

In order to perform the aforementioned analysis of the problem of soil covering - experimental tests of aggregate behavior on dynamic impact should be performed (in this case sand as a material for covering of temporary shelter (ad hoc type) for the population and civil defense). A modified version of this Kolsky method is used based on two measuring bars (initiating bar and transmitting bar) and a test specimen located between these bars - this arrangement creates Split Hopkinson Pressure Bar (SHPB). The dynamic compression method should be used to determine selected dynamic relationships of the tested sand specimen. This was done based on the SHPB test stand - the diagram is presented in Fig. 2.

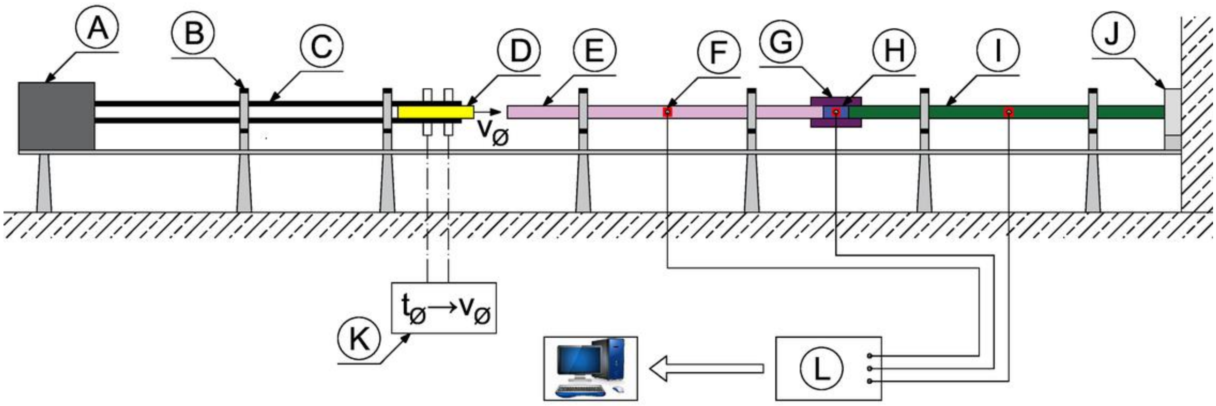

Fig. 2. Diagram of the SHPB test stand.

The test stand consists of the following elements:
A – pneumatic cannon;
B – construction ensuring bar alignment;
C – barrel of loading bar-projectile;
D – bar-projectile;
E – initiating measuring bar;
F – strain gauge set;
G – rigid casing;
H – sand specimen;
I – transmitting measuring bar;
J – damper;
K – laser timekeeping system;
L – measuring device with digital memory and computer software.

As part of the test, a sand specimen was placed between the SHPB measuring bars (initiating bar and transmitting bar) – it is shown in Fig. 3.

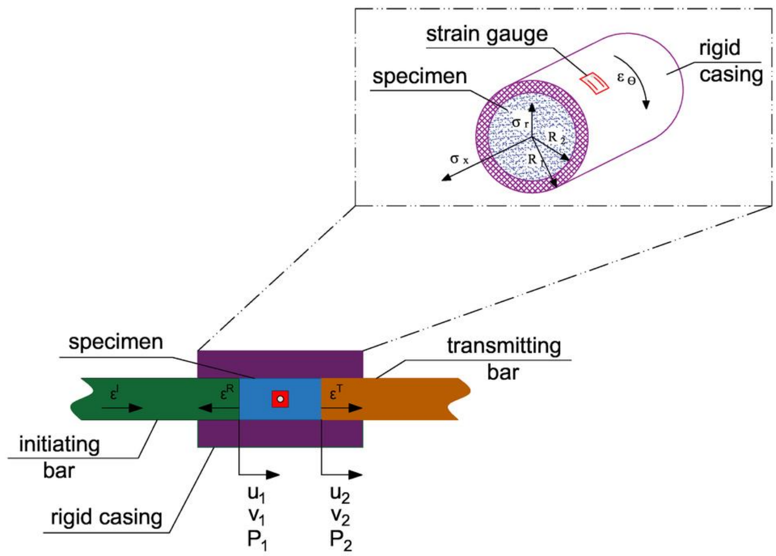

Fig. 3. Cylindrical specimen of sand covering between the SHPB measuring bars.

The SHPB stand is located in the structure testing workshop on the explosive impact of the Department of Military Engineering and Military Infrastructure (MUT - Military University of Technology in Warsaw), its view is shown in Fig. 4. In addition, a cylindrical specimen in rigid casing (with a strain gauge) is shown in Fig. 5.

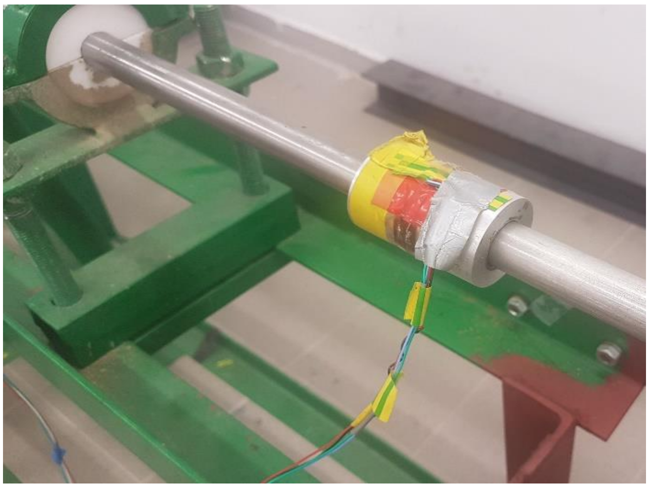

Fig. 4. General view of a SHPB in MUT. Fig. 5. Specimen in rigid casing (with stain gauge).

Transformations and solutions of equations in this area were well presented in the study [1]. Based on the knowledge of the incident, passing and reflected wave characteristics, it is possible to determine the characteristics of the soil tested. The uniaxial strain state ε was also determined in the bars for the initiating wave - ε^I, the passing wave - ε^T and the reflected wave - ε^R. When we assume that:

$$P_1(t) \cong P_2(t); \tag{2.1}$$

$$\varepsilon^I(t) + \varepsilon^R(t) \cong \varepsilon^T(t); \tag{2.2}$$

$$A = A_0; \tag{2.3}$$

we will get the stress equation as a function of time inside the specimen σ_p:

$$\sigma_p(t) \cong \pm E_p \cdot \varepsilon^T(t). \tag{2.4}$$

Average strain in the specimen ε_p is:

$$\varepsilon_p(t) \cong \pm \frac{2 \cdot c_{0,p}}{L_0^p} \cdot \int_0^t \varepsilon^R(t)\, dt, \tag{2.5}$$

and the average strain rate $\dot{\varepsilon}_p$ can be designated as:

$$\dot{\varepsilon}_p(t) = \frac{2 \cdot c_{0,p}}{L_0^p} \cdot \varepsilon^R(t). \tag{2.6}$$

However, to determine the circumferential stress of the casing, the equation must be used:

$$\sigma_\theta(t) \cong \pm E_\theta \cdot \varepsilon^\theta(t); \tag{2.7}$$

RESULTS OF THE EXPERIMENT

The tests were carried out with the following parameters of the selected shot of the cylindrical specimen test of covering sand with a moisture content $w = 4{,}6\ [\%]$:

- specimen weight before the shot – $m_0^p = 19{,}92\ [g]$;
- specimen length before the shot – $L_0^p = 32{,}27 [mm]$;

- bulk density of the soil before the shot – $\rho_0 = 1{,}91 \left[\frac{g}{cm^3}\right]$;
- shot pressure – $p = 5{,}04\ [bar]$;
- bar-projectile speed – $v_0 = 31{,}45\ \left[\frac{m}{s}\right]$.

As a result of the bar-projectile impact on the soil specimen, some of its parameters have changed:

- specimen weight after the shot – $m_1^p = 19{,}87\ [g]$;
- difference in specimen weight – $\Delta m = 0{,}05\ [g]$;
- specimen length after the shot – $L_1^p = 27{,}98\ [mm]$;
- difference in specimen length – $\Delta L = 4{,}29\ [mm]$;
- bulk density of the soil after the shot – $\rho_1 = 2{,}20\ \left[\frac{g}{cm^3}\right]$;
- difference in bulk density of the soil – $\Delta\rho = 0{,}29\ \left[\frac{g}{cm^3}\right]$.

Fig. 6 shows the result of the experiment in the form of a collective list of dependencies of longitudinal deformation of the bars $(\varepsilon^I, \varepsilon^R, \varepsilon^T)$ and the peripheral deformations of the casing ε^θ depending on the time t for a cylindrical specimen of covering sand with a moisture content $w = 4{,}6\ [\%]$.

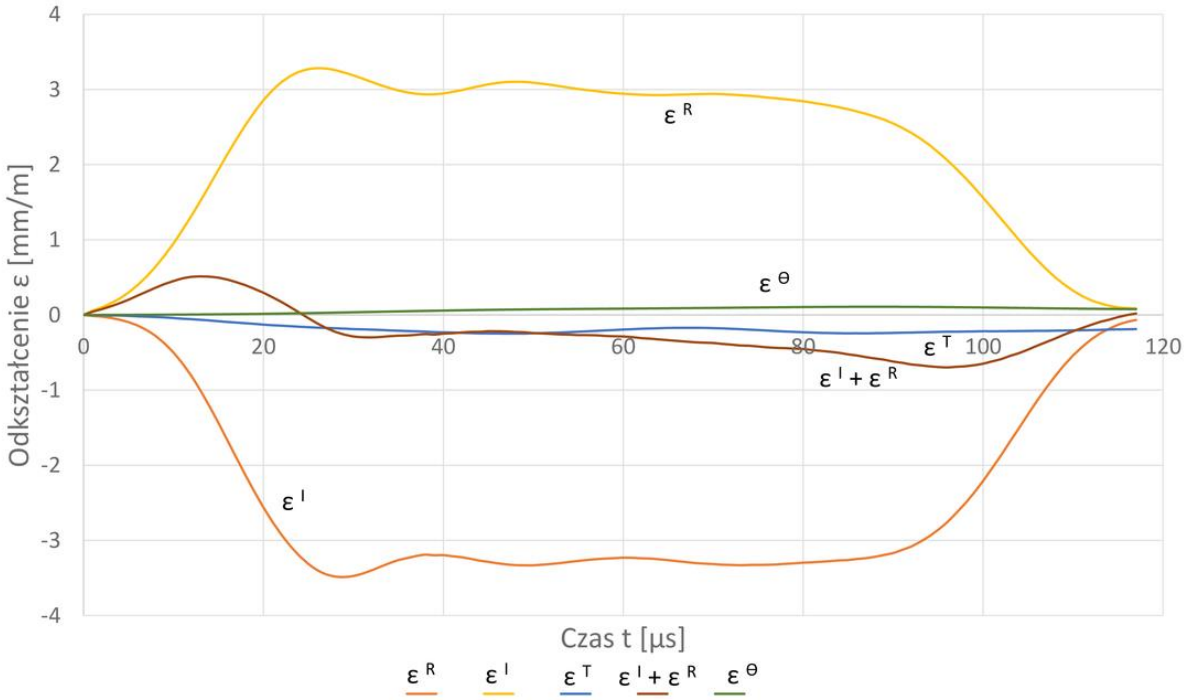

Fig. 6. A collective list of dependencies for a cylindrical specimen of covering sand with a moisture content $w = 4{,}6\ [\%]$.

CONCLUSIONS

The paper presents the concept of a research experiment based on the test stand - Split Hopkinson Pressure Bar (SHPB) in order to determine selected dynamic relationships for a cylindrical sand covering specimen with known a moisture content $w = 4{,}6\ [\%]$, which after hitting the bar suffered a deformation with a the average strain rate $\dot{\varepsilon}_p$ of 10^3. The diagram and view of the test stand, which is located in the Military University of Technology, is shown. The applied research method was also presented. Using measurements from measuring strain gauges located on the initiating and transmitting bar were obtained the diagram of dependencies of longitudinal deformation of the bars $(\varepsilon^I, \varepsilon^R, \varepsilon^T)$ and the peripheral deformations of the casing ε^θ depending on the time t.

In addition, high relevance of the subject of proper protection was indicated in temporary protective shelters for the population and civil defense. In order to learn more about the behavior of the sand covering material, a greater number of tests should be carried out taking into account different moisture content and content of different soil factions.

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