E3S Web of Conferences **390**, 06036 (2023) https://doi.org/10.1051/e3sconf/202339006036
AGRITECH-VIII 2023

Determination of loads of blast wave on aboveground and underground structures

Sharif Akhmedov[1], *Toyir* Juraev[2], *Akbar* Abrorov[2*], *Nigora* Gafurova[2], and Jasurbek Mirzaev[3]

[1]Bukhara Institute of Natural Resources Management of the National Research University of "TIIAME"
[2]Bukhara Engineering-Technological Institute, Bukhara, Uzbekistan
[3]Namangan Engineering-Technological Institute, Namangan, Uzbekistan

Abstract. The article covers the problem of determination of loads of blast wave on aboveground and underground structures. In industrial production, the chemical sources of explosion occur, for which the environment is air. The most common and typical source of explosion is solid products of the explosion (PE) in the form of a packed charge. In a chemical explosion, highly compressed and heated gaseous products of the explosion (PE) are formed in the volume of the charge. The main parameters of the shock wave that determine its effect on the structure, i.e., excess pressure on the wave front, time of the wave's actionτ, and the impulse of the wave have been determined according to the empirical formulas obtained by experiment for each explosion source. Therefore, in this work, the formulas for determining the incident wave in large-scale experimental studies are presented. It has been found that loads on the structure of barriers of buildings are increase significantly as a result of secondary returning waves superimposing the first incident wave.

1 Introduction

Stresses and deformations occur in the environment of earth during the propagation of the waves caused by the explosion, which can negatively affect the strength of protective structures. In a number of cases, especially during strong earthquakes, visible cracks appear in the surface layer of the earth's crust [1-3]. They can be hundreds of kilometers long, several meters wide, and tens meters or even more deep. As a result, there is a sharp change in the topography of large areas, i.e., rising or falling and horizontal shifts reaching significant values. Such deformations of the earth, as a result of tectonic movements in the upper layers of the earth's crust, cause local earthquakes without a great depth. When studying the consequences of destructive earthquakes, especially in cases where the soil is covered with vegetation, the residual seismic deformations of the earth are not always detected. In such conditions, it is appropriate to study the deformations of underground pipes, which record the elastic seismic deformations of indirect roads, i.e., soil, highway and urban road pavements, as well as often not only residual, but also subgrade soils.

* Corresponding author: abrorov1975@mail.ru

It should be noted that under sufficiently strong earthquakes, aboveground structures undergo residual deformations, and the foundations of structures located in relatively sparse soils can have very large values. The nature and degree of soil deformation, in addition to the intensity of the earthquake, largely depends on the geological conditions of the area.

Considering the obtained results, we can see that the calculations show that the largest seismic stresses in the soil environment occur during wave propagation in grooves that cause soil subsidence. If we use the law of movement of soil recommended by Yu.P. Nazarov, from the correlation we can determine deformations of the following form.

In the shortest and most general form, an explosion can be described as an extremely rapid release of energy from the source of the explosion, which occurs along with the propagation of a shock wave into the environment [4]. Sources of explosion can be chemical (explosive substances and gas mixtures), nuclear, electrical (lightning), mechanical (impact of a solid object). Chemical sources of explosion occur in industrial production, for which the environment is air. The most common and typical source of explosion is solid products of the explosion (PE) in the form of a packed charge. In a chemical explosion, highly compressed and heated gaseous products of the explosion (PE) are formed in the volume of the charge, which expand rapidly, compressing the air surrounding them and forming a spherical air shock wave moving at a speed greater than the speed of sound. Behind the wave front, the pressure decreases in the spheric layer of air, i.e., the compression phase, and then the pressure goes to the rarefaction phase, where the pressure is less than the atmospheric pressure.

After the front of the shock wave, the air flow moves with great speed, during the rarefaction phase, this flow moves in the opposite direction, towards the center of the explosion. As the energy of the shock wave is transferred only to the expanding products of the explosion, as the pressure propagates along the wave front, it decreases much faster and the shock wave becomes a sound wave [5-7].

2 Materials and methods

Physical parameters of the shock wave, i.e., the speed of the front – D, the speed of the air flow from the rear of the front – U_f and the open pressure of the atmosphere at the front R_f, and the waves are connected by the following ratios:

$$\frac{P_f}{P_a} = \frac{2\gamma}{\gamma+1}(M^2 - 1), \tag{1}$$

$$U_f = \frac{2D}{\gamma+1}\left(1 - \frac{1}{M^2}\right), \tag{2}$$

where Pa is atmospheric pressure, MPa; M = D/G is Max number;

$\gamma=C_P/C_v$ (for air γ=1,4); C_o=340 340 m/s is the speed of sound in air under normal conditions. Substituting (2) into (1), we get the following formulas

$$D = 340\sqrt{1 + 8.5P_f} \qquad U_f = \frac{2400P_f}{\sqrt{1+8.5P_f}} \tag{3}$$

The length λ of the compression phase of a shock wave in space can be determined from the approximate condition: the rear boundary of the wave (at the point of transition to the rarefaction zone) propagates with the speed of sound $\lambda \cong C_0\tau$ [3] or, more precisely, with the average speed:

$$\lambda = \frac{D+C_0}{2}\tau, \tag{4}$$

where τ is the duration of the compression phase (time of action).

The main parameters of the shock wave, which determine its effect on the structure, i.e., excess pressure on the wave front, the time of the wave actionτ and the impulse of the wave, are determined according to the empirical formulas obtained by experiment for each explosion source [9]

 https://doi.org/10.1051/e3sconf/202339006036

$$i = \int_0^\tau \rho(t)dt \tag{5}$$

The law of geometric similarity is observed in the detonation of different mass charges from the same explosive material. According to this, the function describing the dependence of pressure Rf on the energy and distance of the explosion source should have an argument of the ratio rз /R, but if the charge mass is C ~ r $^3_3$, then it can be written as follows [10]

$$P_f = f_1\left(\sqrt[3]{C/R}\right) \tag{6}$$

A more general law of energetic similarity is appropriate for charges of various explosives [11]

$$P_f = f_2\left(\frac{\sqrt[3]{E/P_\alpha}}{R}\right), \tag{7}$$

where E is the energy of the blast wave.

3 Problem statement and results

This consists in increasing the accuracy and optimization of the relations representing the explosion process. The practical significance of the task is as follows. Due to the fact that many areas of the earth, including our country, are in a seismically active zone, the design of underground structures creates some difficulties. Of course, it is very important to assess the earthquakes that may occur there, to study the characteristics of the ground located there. From a large number of experiments, it follows that the law of pressure drop behind the wave front, i.e., the compression phase, in addition to the considered basic parameters of the shock wave, is used in the calculation of constructions. With sufficient accuracy for practical purposes, this law can be approximated by a function of the following form:

$$P(t) = P_f(1 - \frac{1}{\tau})^n \ . \tag{8}$$

In order to simplify calculations, expression (8) is usually replaced by a linear function

$$P(t) = P_f(1 - \frac{t}{\tau_{el}})^n \tag{9}$$

The value of the effective movement time τэ in (9) is determined from the condition for determining the wave pulse:

$$\int_0^\tau P_f\left(1 - \frac{t}{\tau}\right)^n dt = \frac{1}{2}P_f\tau_{el}, \tag{10}$$

hence $\tau_{el} = \frac{2}{n+1}\tau.$

$$P_{ref} = 2P_f + \frac{0.7I + 4P_f}{0.7I + P_f} \tag{11}$$

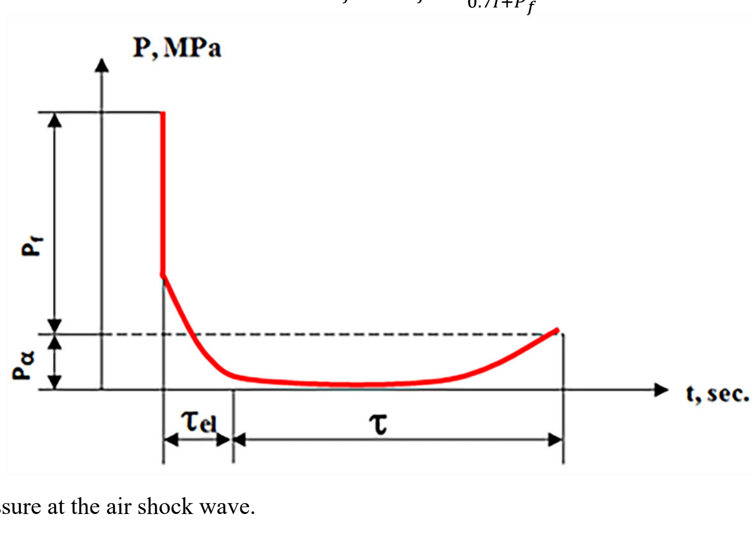

Fig. 1. Pressure at the air shock wave.

When the shock wave meets an obstacle, it rebounds, and the wave that returns to the incident wave begins to propagate. In this case, the pressure exerted on the barrier is more than doubled, because the extremely high pressure of the compressed air in the wave creates additional speed pressure from behind the front. Accordingly, the pressure $P_{от}$ applied to the barrier can be imagined as the sum of two expressions for the shock wave's return from it [12]. The return character of the shock wave at different points of the flat barrier depends on the angle of incidence α of the wave (Figure 1 and 2). Shock waves are also generated when explosive charges such as TNT, ammonite and many others explode in the surrounding air [13]. The above-mentioned formulas are taken as standard, with which the explosions of other explosives should be compared, for charges from bulk or pressed TNT with a density of $y=1.5 \div 1.6\ g/cm^3$, obtained experimentally. The excess pressure at the wave front is defined as follows

$$P = 0.084x + 0.27x^2 + 0.7x^3, \quad (12)$$

where $x = \sqrt[3]{c/R}$; C is explosive charge mass, kg; R is distance, m. The impact time τ of the shock wave is determined by the following formula:

$$\tau = K\sqrt[6]{c}\sqrt{R_0},$$

and it is the value of the coefficient K that is taken in the interval 62 x<1, and when K=1, 0.1 ≥ x ≥ 0.6, then K=1.2 is accepted.

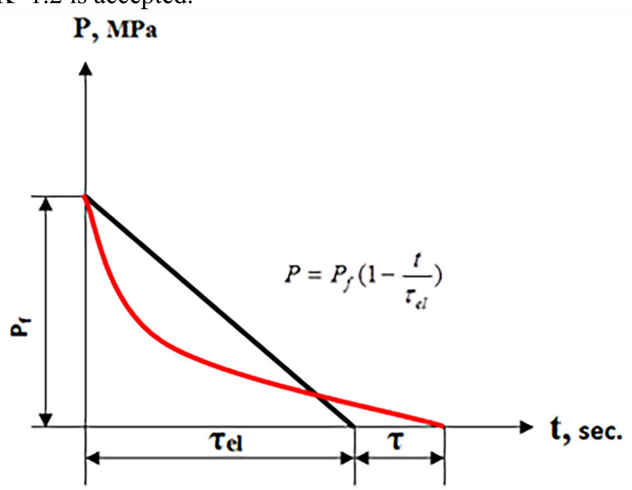

Fig. 2. Calculated pressures in the shock wave.

The relative impulse value i (HC/ m²) (12) is determined by the formula $i=A\sqrt[3]{C^2}/R$Loads on the structure of barriers of buildings can be greatly increased by secondary returning waves superimposing the first incident wave. In order to determine the blast load acting on the protective structure, the following formula is proposed: $P(t) = P_{pit}(t) + P_{ref}(t)$ or

$$P(t) = P_{pit} + \sum_{k=1}^{N} P_{ref}^{(K)}(t) \quad (13)$$

where N is the number of returned waves.

Similarly, the following formula can be proposed for the explosion contained in the chamber

$$P(t) = \sum_{n=1}^{N} P_{\phi n}\left(1-\frac{t}{T}\right)^m. \quad (14)$$

Considering the returning waves (in the calculations, n=1,2,3), the formula (14) for determining the internal explosion pressure can be written in the following form

$$P(t) = P_0\left(1-\frac{t}{\tau}\right) + \sum_{n=0}^{\infty} C_n i^n \left(1-\frac{t}{T}\right)^n \quad (15)$$

or

$$P(t) = \sum_{k=1}^{N} (a_K + B_k i^K)x^K. \quad (16)$$

In particular, from (14) follows formula (12) proposed in [14, 15]

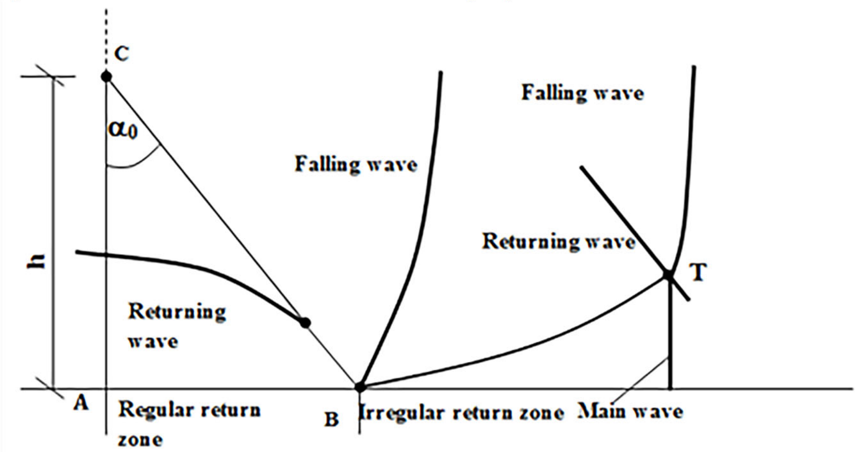

Fig. 3. Reflection of an air shock wave from a flat surface.

The description of the scene of propagation of shock waves in a limited space becomes more complicated when there is an explosion in a closed volume. In the relatively small dimensions of the structures, comparable to shock waves, the secondary waves returned from the adjacent wave wall are "laid down" (added) to the primary wave, which can lead to a serious increase in the load (Figure 3).

4 Conclusion

In conclusion, due to the return of two or three shock waves, the phenomenon of excess stresses and deformation occurs in the corners of quadrangular structures. This happens when the internal waves "crack up", causing secondary effects. As the theoretical study of phenomena similar to the interaction of shock waves in a limited volume is very complicated and insufficient in the practice of calculations, theoretical calculation formulas have been recommended. Therefore, in this work we do not use approximate models for theoretical calculations.

References

1. Wang H. Feng, Structure-Soil-Structure Interaction between Underground Structure and Surface Structure [Internet]. Earthquakes - Forecast, Prognosis and Earthquake Resistant Construction. InTech (2018). http://dx.doi.org/10.5772/intechopen.76243
2. A. Marassulov, Sarsenov, Bakytbek, S. Maulenov, Journal of Physics: Conference Series **1260**, 112019 (2019). https://www.doi.org/10.1088/1742-6596/1260/11/112019
3. I. I. Safarov, Z. I. Boltaev, Open Access Library Journal **5**, e4262, 1-29 (2018). https://doi.org/10.4236/oalib.1104262
4. B. S. Rakhmanov, H. K. Sagdiev, Problems of mechanics **3**, 18-22 (2007)
5. I. I. Safarov, N. U. Kuldashov, Z. I. Boltaev, International Journal of Emerging Engineering Research and Technology **6(3)**, 27-32 (2018)
6. I. I. Safarov, *Oscillations and waves in dissipative heterogeneous media and structures* (Toshkent, Fan, 1992)

7. George Gazetas, George Mylonakis, *Soil-Structure Interaction Effects on Elastic and Inelastic Structures*. International Conferences on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics **2** (2001). https://scholarsmine.mst.edu/icrageesd/04icrageesd/session13/2
8. M. B. Bozorov, I. I. Safarov, Yu. I. Shokin, *Numerical simulation of oscillations of dissipative homogeneous and inhomogeneous mechanical systems* (Siberian Branch of the Russian Academy of Sciences, Novosibirsk, 1966)
9. B.S. Rakhmanov, Problems of mechanics **3** 17-20 (2007)
10. B. S. Rakhmanov, On the issue of predicting the behavior of underground structures under the influence of seismic blast waves *Collection of international scientific works* (Novosibirsk State Agrarian University, Novosibirsk, 2006), pp. 149-152
11. B. S. Rakhmanov, H. K. Sagdiev, V. G. Fasakhov, Problems of mechanics **3**, 29-32 (2007)
12. Sh. R. Khurramov, Izvestiya Vysshikh Uchebnykh Zavedenii, Seriya Teknologiya Tekstil'noi Promyshlennosti **4**, 153-158 (2021)
13. T. O. Juraev, *Oscillations of a deformable half-space with protective structures under the action of explosive loads* (Publishing house of Bukhara Region Printing House LLC, 2020)
14. T. R. Rashidov, G. Kh. Khojimetov, B. M. Mardonov, *Oscillations of structures interacting with the soil* (Fan publishing house, Tashkent, 1975)
15. Mikhail Kholmyansky, *Dynamic Soil-Structure Interaction Considering Random Soil Properties*. 12th International Conference on Computer Methods and Advances in Geomechanics **4** (2008)