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Estimation of explosive charge mass used for explosions on concrete surface for the forensic purpose

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ABSTRACT

The method of choice used by most terrorists for achieving political goals remains the utilization of explosive devices and there is always visible evidence at a crime scene after the deployment of such devices. Given favorable circumstances, forensic analysis can determine the cause of the explosion — the type of the explosive device, the means of detonation, the type and mass of the explosive charge that has been used and perhaps provide information to lead to the identity of the individual who may have constructed or deployed the explosive device, etc. Evidence of an explosion may take the form of a crater or other damage which may provide some information facilitating and estimating the mass of explosive material used. This paper reports the findings obtained by performing experimental explosions of known charges on a concrete surface, in order to establish the correlation between the charge weight and the effects of the explosion. Known masses of explosives were fired and the dimensions of craters made by explosions were measured. Five empirical equations for estimation of the explosive charge mass from crater dimensions were used.

1. Introduction

An explosion is a gas-dynamic phenomenon which under ideal theoretic circumstances will manifest itself as an expanding spherical heat and pressure wave front [1]. When a device explodes, a rapid release of stored energy is characterized by an audible blast. By detonations on or near the surface, a compression wave is created which compresses the surrounding medium. The shock wave expands through the air and through the surface. An explosion may give rise to the following effects: blast damage, thermal effects, missile damage, ground shock, crater and injury [2]. When an explosion takes place near to a surface, whether above, on or below it, a depression is produced which is usually described as a crater [3]. Forensic analysis has the potential to determine the cause of an explosion from the effects manifested by the event.

The primary crater is usually the surface in contact with or closest to the explosive. Secondary craters are formed when the explosive generates missiles which penetrate an object, such as a piece of furniture, wall, ceiling, and/or a vehicle floor. The seat of the explosion is the area or point within the scene that has the greatest concentration of damage [4]. A *seated explosion* is one having an identifiable crater or a place where there is an area of greatest damage. Normally, a seated explosion is the result of the initiation of a condensed phase explosive at or near the surface [5]. Craters can also be a source of fragments [3].

The destructive action of an explosion is determined by the type of explosive (TNT, PETN, RDX, HMX, C4, etc.), the shape and mass of the explosive charge and the position of the charge relative to the ground surface (how the charge was placed) [6]. Dynamic loads due to explosions cause large deformations, with strain rates from 10^{-1} to 10^{-3} s^{-1} [7].

Following an explosion on or near the open ground, dirt, rock, and other debris are blasted to form a crater. These materials are then deposited around the scene, around the top of the crater, and at the bottom of the crater. An explosion on a hard surface such as concrete would produce a similar effect but the crater would not be as deep. Because we cannot categorize and control all of the various states and kinds of dirt (earth, gravel, etc.) we cannot make precise analytical models of the cratering process [8]. Generally, simplifying assumptions must be made in order to solve specific problems. Most practical

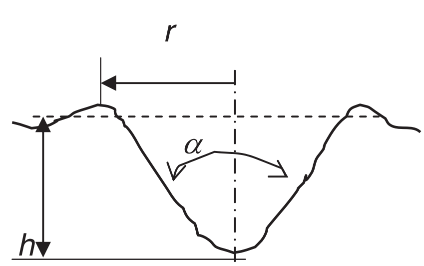

Fig. 1. Crater after an explosion on concrete (definitions of crater dimensions: r — radius of crater, h — depth of crater, α — crater angle).

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Table 1
Characteristics of explosives used in experiments.

Ordinal	Characteristics	Measure unit	Explosive		
			TNT	PETN	Amonex 1
1	Density	kg/m^3	1560	1700	1060
2	Detonation velocity	m/s	6825	8300	4235
3	Temperature of ignition	°C	300	225	39.2
4	Power (Trauzl)	cm^3	300	523	370
5	Oxygen balance	%	−73.9	−10.1	+0.24

problems have been solved through empirical approaches to produce the relevant charts or equations and the mass of explosive charge is usually estimated from this empirical data [9,10].

This paper provides a test for these equations by detonating a known mass of high explosive charge on a concrete surface. The dimensions of the resultant crater are used to estimate the explosive mass and the values of mass obtained, after which those are compared to the known values. Typical measurements of crater that are taken are presented in Fig. 1 [11].

Fig. 2. Packing of PEP 500 which has been used in experiments.

Fig. 3. Packing of TNT (TM-200) which has been used in experiments.

Fig. 4. Packing of TNT which has been used in experiments.

2. Estimation of explosive charge mass from crater measurements

The mechanism of crater formation is complex and it is suggested that the mass of explosive used can be estimated by examining the dimensions of the crater. In this study the estimation of explosive charge mass put on the concrete surface from the measurement of crater is done from the following empirical equations [12]:

$$m_e = 38\kappa_1 h^3\left(0,4+0,6n^3\right)[\mathrm{kg}](\mathrm{Boreskov},\ \mathit{Stamatovic\,A.},\ 1996) \quad (1)$$

where κ_1 is the coefficient depending on the sort of explosive charge, h is the depth of the crater, r is the radius of the crater and $n = r/h$ is the ratio of the crater measurement.

$$m_e = 2\pi\rho u_{kr} r^3/100[\mathrm{kg}](\mathrm{Vlasov},\ \mathit{Vlasov, O.E.},\ 1957) \quad (2)$$

Fig. 5. Packing of Amonex-1 which has been used in experiments.

Fig. 6. Detonation cap photographed with measure tape.