Explosion Phenomena and Effects of Explosions on Structures. I: Phenomena and Effects

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Abstract: This is Part I of a three-part paper on the phenomena of explosions and effects of explosions on structures. The overall paper is intended to provide the reader with a practical overview of the various types of explosions and methods available to predict explosion effects with emphasis on air blast. The response of structures to air blast is discussed and methods of analysis are presented. Since the subject area is broad, reference sources for more in-depth information on many of the topics presented are provided. In this paper, Part I, the background is provided on explosion phenomena and the types of effects produced by explosions of various general types. Physical, chemical, electrical, and nuclear explosions are discussed. Explosion effects for external (outdoor) explosions presented include air blast characteristics of peak overpressure, positive phase impulse, time of arrival, and positive phase duration. The ranges of peak overpressure and event duration from different types of explosions are compared. Other effects discussed include thermal effects, projectiles, ground shock, and cratering.

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Introduction

The objective of this three part paper is to present a practical overview of explosion phenomena and the effects of explosions on structures. This subject area is quite broad. Work has been done by numerous investigators over many years. The ancient Chinese are generally credited with the development of fireworks several centuries ago, and fireworks evolved into exploding weapons. The modern understanding of explosions as presented in this paper has evolved from military oriented research and development and in response to major explosion catastrophes. This paper is not intended to cover all aspects of this voluminous subject area. Rather, an overview is provided with many references cited, so that the interested practitioner can probe deeper into areas of particular interest. To help narrow the scope, emphasis in this paper is on industrial and residential accidents. In addition, instead of covering all explosion effects in great depth, pressure effects are emphasized. With regard to the response of structures, emphasis is on the use of peak incident pressure as a guide to anticipated damage levels (the most widely used analysis method), although other more comprehensive techniques to estimate structural damage are also discussed.

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In Part I, a background is provided on types of explosions, explosion effects (including air blast, thermal effects, and projectiles), and damage to structures from the effects of explosions. In Part II, analysis methods for predicting explosion effects are discussed for several explosion types with emphasis on air blast. In Part III, various techniques for predicting explosion damage to structures are summarized. A fairly comprehensive compilation of overpressure damage levels is provided as appendixes to Part III. Strong cautions are emphasized for investigators using these simple overpressure damage criteria in the analysis of damage levels. Example cases in which these techniques have been employed are provided in the third and final part of the paper.

Defining an Explosion

The technical literature provides numerous definitions for the term explosion. NFPA 921 (2008) defines an explosion as "the sudden conversion of potential energy (chemical or mechanical) into kinetic energy with the production and release of gas under pressure. These high-pressure gases then do mechanical work such as moving, changing, or shattering nearby materials."

Kinney and Graham (1985) stated that an explosion is "a phenomenon resulting from a sudden release of energy . . . there is a local accumulation of energy at the explosion site. The accumulated energy is then suddenly dissipated in various ways such as in blast waves, propulsion of missiles, or by thermal or ionizing radiation . . . " Glasstone and Dolan (1977) stated that "an explosion, in general, results from the very rapid release of a large amount of energy within a limited space. This is true for a conventional high explosive (HE) such as TNT, as well as for nuclear (or atomic) explosion, although the energy is produced in quite different ways. The sudden liberation of energy causes a considerable increase in temperature and pressure, so that all the materials present are converted into hot, compressed gases. Since these gases are at very high temperatures and pressures, they expand