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Blast pressure leakage into buildings and effects on humans

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Abstract

In the event of a bomb blast taking place outside a building at the ground level, a hemispherical pressure wave travels in all directions and impacts the buildings and other structures in its path. The exterior walls, windows, doors and the structural system are impacted. The pressure wave enters the building through broken glass at doors and windows, blast damaged exterior cladding and any other openings in the exterior of the building. The increase in ambient pressure experienced inside the building depends upon the area of openings in the exterior walls and the roof, the air pressure due to the blast at the exterior wall and roof surface, the duration of the blast and the volume of the interior space. Depending upon these factors, the interior pressure can increase above the threshold of human tolerance, thereby causing injuries to the occupants in the form of damage to lungs and eardrums, in addition to injuries caused by broken glass and other damaged building components. This paper will present a simple method of estimating pressure buildup near the exterior walls and other locations subject to leakage of blast pressure from the outside. The threshold of human tolerance to high air pressure will also be indicated.

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1. Introduction

Blast resistant design of buildings generally includes safety of the structural system and the building envelope. The methods for designing for bomb blast are well documented in various codes, standards and other industry publications. Majority of the injuries as a result of a bomb blast event are known to be caused by shattering of glass and the resulting shards projecting into the building or out of the building, depending upon the location of the explosive device. Major

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injuries and fatalities have also been caused by the total or partial collapse of the structural system. However, the effect of overpressure upon the human body and consequent damage to different body parts has received very little attention. In the three recently published documents [3] [4] [5], there is no mention of injuries caused directly due to overpressure.

Due to an explosion outside the building, the ambient pressure inside the building can increase as result of leakage of external high pressure into the building through openings created as a result of broken glass in the building envelope, damaged exterior cladding, doors that will be thrown open and the existing openings and vents in the walls and roof of the building.

2. Pressure Increases within a Building Due to Leakage

When a blast takes place outside a building, it is surrounded in the blast wave generated by the explosive. Due to the rise in air pressure outside the building, leakage of pressure from outside to inside takes place through any openings in the exterior envelope of the building. There may already be openings in the exterior envelope in the form of roof vents, air intake and exhaust, cracks in the joints between windows and walls and gaps between the exterior walls and the roof; no building is completely airtight. The construction details of the building under investigation should be reviewed to determine the existing air leakage potential of the building. In addition to existing openings, the pressure/impulse from the blast wave may create new openings in the form of shattering of window glazing, and damage to exterior doors and walls. Even glazing designed to conform to some of the performance conditions in [2] breaks and can let blast pressure into the building.

The interior of the building experiences an increase in pressure that depends upon the volume of the existing building, the area of the openings in the exterior envelope and the applied external pressure and duration. The effects of openings on the exterior of buildings struck by blast waves from accidental explosions upon the pressure inside the buildings are of two types: a) the first type is for buildings which have exterior envelope elements that are designed to withstand applied blast loads, but have very small openings due to vents and ducts, which are not able to withstand the blast, or small openings are created by the blast loads, but the openings are not large enough that a blast front can develop inside the building. b) The second type is for exterior envelope elements in buildings that are not designed to resist blast loads and the openings are large enough that a blast front can develop inside the buildings. The two different methods are presented herein.

2.1. Method 1

The following method is adapted from [1] for calculating average pressure increase for buildings with small openings/building volume ratios and applied pressure of less than 1000 kPa (150 psi). Refer to equation 1. It must be noted, however, that this method only provides average pressure increase in the volume Vo used in equation 1, the pressure increase near the openings, such as caused by shattered glazing, will be much higher. It is proposed that the pressure in the vicinity of the opening may be calculated by using volume Vo as the volume of space closer around the window. Or Method 2 may be used to estimate blast pressures in line with the axis of the opening.

The change in pressure, ΔPi, inside the building within a time interval, Δt, is a function of the pressure difference at the openings, P-Pi, and the openings area/volume ratio, A0/V0 [1]

$$\Delta P_i = C_L [A_0/V_0] \Delta t \qquad (1)$$

Where

ΔPi = P-Pi ; interior pressure increment, kPa

P = peak overpressure (kPa) applied to the exterior of the building to be determined as follows.

In case the building exterior is parallel to the blast wave, use peak reflected overpressure. In case the building exterior is perpendicular to the blast wave, use peak incident overpressure. The pressure wave from the explosion