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Numerical simulation analysis of explosion process and destructive effect by gas explosion accident in buildings

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ABSTRACT

Every year, the widespread use of natural gas in buildings results in a number of accidental gas explosions. On December 7th, 2015, a gas explosion accident occurred within buildings in the Shijingshan District of Beijing, China. Three people were slightly injured when a flammable concentration of natural gas had accumulated in the enclosed building space and ignited, resulting in a gas explosion. To study the process of this explosion and its destructive effect, a physical model that was consistent with the actual event was firstly established, using accident data from the above accident. Windows and doors in the building were designed for pressure relief. According to different leakages and scopes, numerical simulation of gas explosion was carried out by computational fluid dynamics explosion simulation software. In the simulation, the finite volume method was used to solve the compressible N-S equation in the three-dimensional Cartesian grid.

In this paper, the shock wave propagation process in the building was analyzed and typical blast-wave curves were plotted at different locations. By comparing numerical simulation results with actual event, the most consistent filling scheme and equivalent ratio of gas reactions were obtained, and the calculation showed that the overpressure field and temperature field were consistent with the actual scene.

Simulation results agreed well with actual destruction in the accident and verified the validity of the scheme. This research can provide suggestions for evaluating injuries and damages when gas explosions occur and might help in anti-blast designs and accident investigations.

1. Introduction

Natural gas is becoming an important energy option and world production capacity is surging (Martins et al., 2011). In recent years, natural gas leakage and explosion accidents have occurred frequently. Natural gas has chemical characteristics of rapid diffusion, low minimum ignition energy, and easy combustion/explosion, which might also lead to smoke inhalation dangers. Once natural gas has leaked, mixed with air, and reached its minimum explosion concentration, any ignition source could initiate combustion and explosion. The safety of natural gas pipelines in the gas supply chain is crucial for meeting the public's gas demands (Bariha et al., 2016). There have been a number of natural gas leaks, which have led to fires and explosions as well as property loss and human injuries (Cheng et al., 2015). However, the response to such accidents has been to pay more attention to post-accident treatment rather than attention to the accident process and its origins.

The response of buildings to explosions and research of anti-explosion strategies under explosive load have become a hot research topic. Scholars have performed some theoretical and experimental studies on building damage effects under blast loading (Remennikov and Rose, 2005; Smith and Rose, 2006). Usually, the explosion damage effects of natural gas in a building are related to the volume of gas, ignition source location, gas diffusion range, and space size (Rose and Smith, 2002; Clutter et al., 2007). However, there are few reports on accident calculations and simulations of gas explosions in large-scale buildings. At present, there are three main kinds of theoretical explosion models, including the TNT equivalent, TNO multi-energy method, and multi-energy model. However, there are gaps between the above

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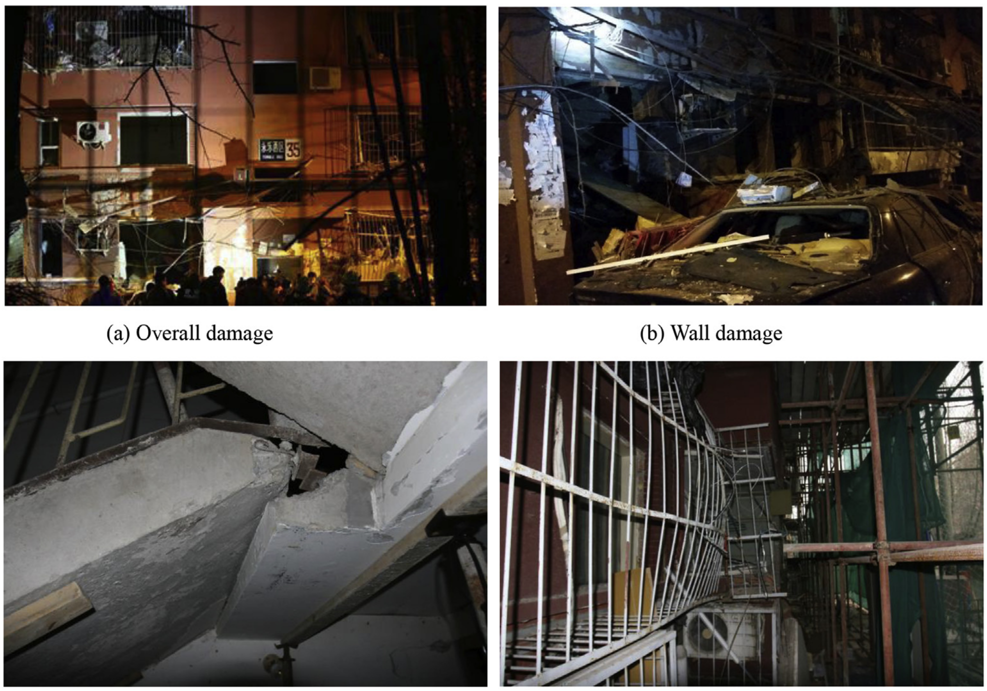
three kinds of calculation theory and actual situations. In most cases, gas explosions are firstly converted to TNT equivalents for simulations, ignoring the influence of combustible gas properties, such as density and buoyancy, on the explosion process and its destructive effects.

Simple techniques are not suitable to predict complex explosion dynamics that occur in the near field. The phenomena that drive explosions and the resulting damage in the field are complex in nature. The origin of an explosion might, in fact, differ from the intuitive epicenter determined from oversimplified assumptions (Curtis, 2013). The Flame Acceleration Simulator (FLACS) is a leading computational fluid dynamics (CFD) tool for the simulation of gas dispersion and explosion scenarios, and is extensively used for safety studies in the petrochemical industry. Simulation results show that FLACS exhibits good performance in gas explosion simulations in finite spaces (Middha et al., 2010; Xiangdi et al., 2014;



(a) Overall damage (b) Wall damage

(c) Connection point damage (d) Window frame damage

Fig. 1. Damage to building structures.

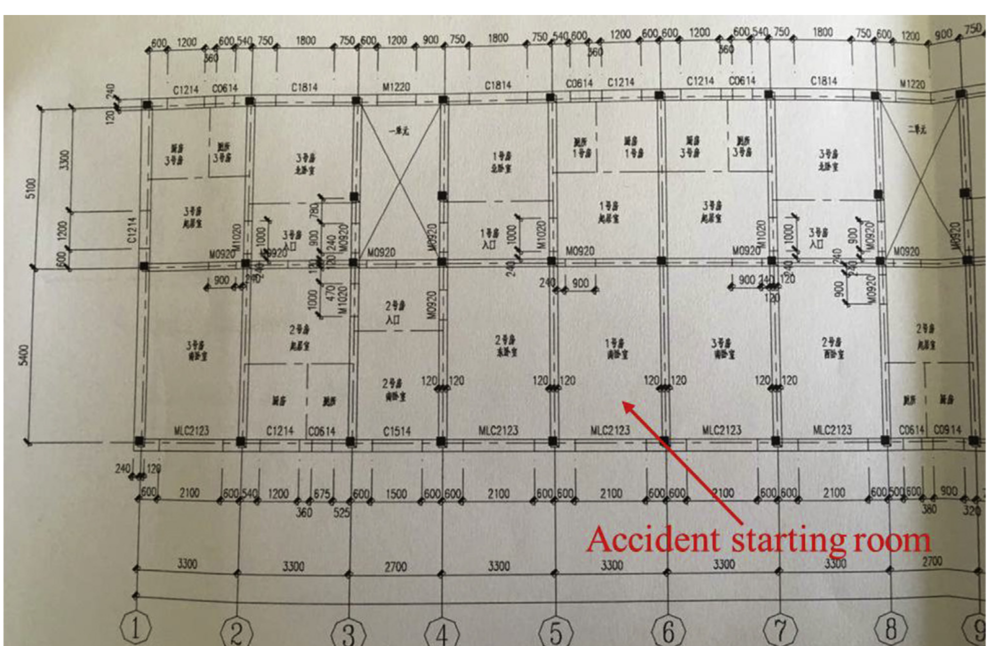


Fig. 2. Floor layout.