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Study of autoclaved aerated concrete masonry walls under vented gas explosions

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ABSTRACT

A total of nine full-scale in-situ tests were carried out to investigate the performances of autoclaved aerated concrete (AAC) masonry walls subjected to vented gas explosions. The testing data including overpressure time histories of vented gas explosions, displacement time histories, and damage characteristics of AAC masonry walls in each test were recorded and analysed. It was found that the responses of masonry walls mainly depend on the peak value of overpressure and couple with the time history of gas explosion loads. Typical one-way or two-way flexural mode dominates the failure of AAC walls under vented gas explosions. A detailed micro model for masonry walls was developed in LS-DYNA, incorporating material parameters that were obtained from material tests. The accuracy of numerical model in predicting the responses of masonry walls was verified with the testing data. Parametric studies were conducted to explore the influences of block strength, boundary condition and wall thickness on the performances of masonry walls. The results reveal both wall thickness and boundary condition have significant influences on the response of the masonry wall while block strength has limited effect on its performance. The testing data were compared with the analytical predictions by using design code UFC 3-340-2 and equivalent single-degree-of-freedom (SDOF) methods developed respectively by Biggs and Morison. The results indicate that these predictions on one-way specimens agree well with the testing data, while the performance of two-way specimens is overestimated by using these three methods.

1. Introduction

With the popularization of natural gas used in the industrial and civilian fields, gas explosion accidents have been reported frequently, which caused massive damage and structural failure [1,2]. Autoclaved aerated concrete (AAC) has been widely used in construction of load-bearing and non-load-bearing walls owing to its low thermal conductivity, high fire resistance and lightweight. However, the characteristics of low material strength and inhomogeneity lead to the vulnerability of AAC masonry walls under out-of-plane loads [3,4]. In order to reduce the potential hazards to structure, and enhance the safety of properties and human lives, it is necessary to investigate dynamic response and failure mechanism of AAC masonry walls under gas explosions.

In order to ensure the industrial safety, vented gas explosions have been investigated intensively in recent decades [5–7]. The generation mechanism of different peaks in the overpressure time histories of gas explosion was studied. The effects of key parameters including gas concentration, vent area, vent pressure and ignition location on the vented gas explosion loads and different peaks were experimentally investigated and analysed by Cooper et al. [5], Mercx et al. [6], and Bao et al. [7]. Based on the testing data and theoretical analyses, some formulae predicting vented gas explosion loads were developed for engineering design [8,9]. It should be noted that only peak overpressures but no time histories of vented gas explosion loads have been considered in the design codes, although structural responses are highly dependent on the loading time histories. This is mainly because of a general lack of information on gas explosion loading time history and the difficulty in reliably predicting it. In the study on the anti-blast performance of stiffened panels, i.e. blast walls for offshore platforms reported by Louca et al. [10], the gas explosion load was simplified as a symmetric triangle load with constant duration. This simplification was also used by Parisi et al. [11] in their research on the tuff masonry walls. Because of the complexity of gas explosion load

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observed in many blast tests, this oversimplification of gas explosion loads may not lead to reliable prediction of structural responses.

Although the existing study of masonry walls under gas explosion was limited [12], the performance of masonry walls under blast loads generated by high explosives have been intensively studied owing to the increasing hazards from terrorist attacks, conventional weapons and accidental explosions [13–17]. The dynamic responses, failure modes, debris distributions and retrofitting techniques with different retrofitting materials were studied by conducting field blasting tests. Some of the above testing results were used to verify numerical models. Three modelling methods, i.e. detailed micro model, simplified micro model and macro model were developed [18]. The damage level and the safety scaled distance of masonry walls derived from numerical simulations were recommended for engineering practice [15,19,20]. Arching effect of masonry walls was also considered in the theoretical analysis [21–23]. In addition, the equivalent SDOF method was validated and used to develop P-I diagrams for engineering application [24]. Owing to its simplicity, the design approaches were based largely on the equivalent SDOF method in engineering design [25–27]. It should be noted that most previous studies were limited to the reinforced or unreinforced concrete masonry unit (CMU) and clay brick masonry walls.

Autoclaved aerated concrete (AAC), as an 'ultra-lightweight' concrete material with micro cellular structures, has been used as an alternative to conventional normal-weight or lightweight concrete products [3,4]. The existence of entrained air bubbles enhances the physical properties, such as excellent thermal and sound insulation properties, but leads to the strength reduction and heterogeneity of the material. In addition, AAC is of less density than traditional concrete or clay. Although the seismic performance and fire resistance capacity of AAC masonry structures have been well investigated [28,29], the study on the blast resistance capacity of AAC masonry walls is very limited. Muszynski and Purcell [30] conducted field tests on the air-entrained concrete (AEC) masonry walls subjected to high explosive detonations. Their study focused on investigating the effectiveness of using composite materials for retrofitting the masonry wall therefore the structural behaviour of was not emphasized in the study. Yankelevsky and Avnon [31] carried out the tests to study the localized responses of AAC under contact explosion and the effectiveness of surface treatment on the wall performances. Test results showed that the surface treatment enhanced the tensile strength and ductility of AAC blocks, and contributed to higher resistance to tensile wave spalling. No study of AAC masonry wall subjected to gas explosion can be found in the open literature yet. Because the blast loads generated by gas explosions have very different characteristics such as lower amplitude, longer rise time, longer duration and possibly multiple peaks. As compared to those by high explosives, the response mechanism and damage mode of ACC masonry walls subjected to blast loads from gas and high-explosive explosions could be very different. Therefore, it is necessary to study the ACC masonry wall responses to gas explosion for reliable predictions of the masonry wall damages and better design of protection measures for such walls to resist accidental gas explosions.

In this study, an experimental program was designed to perform a series of full-scale field tests on AAC masonry walls sub-

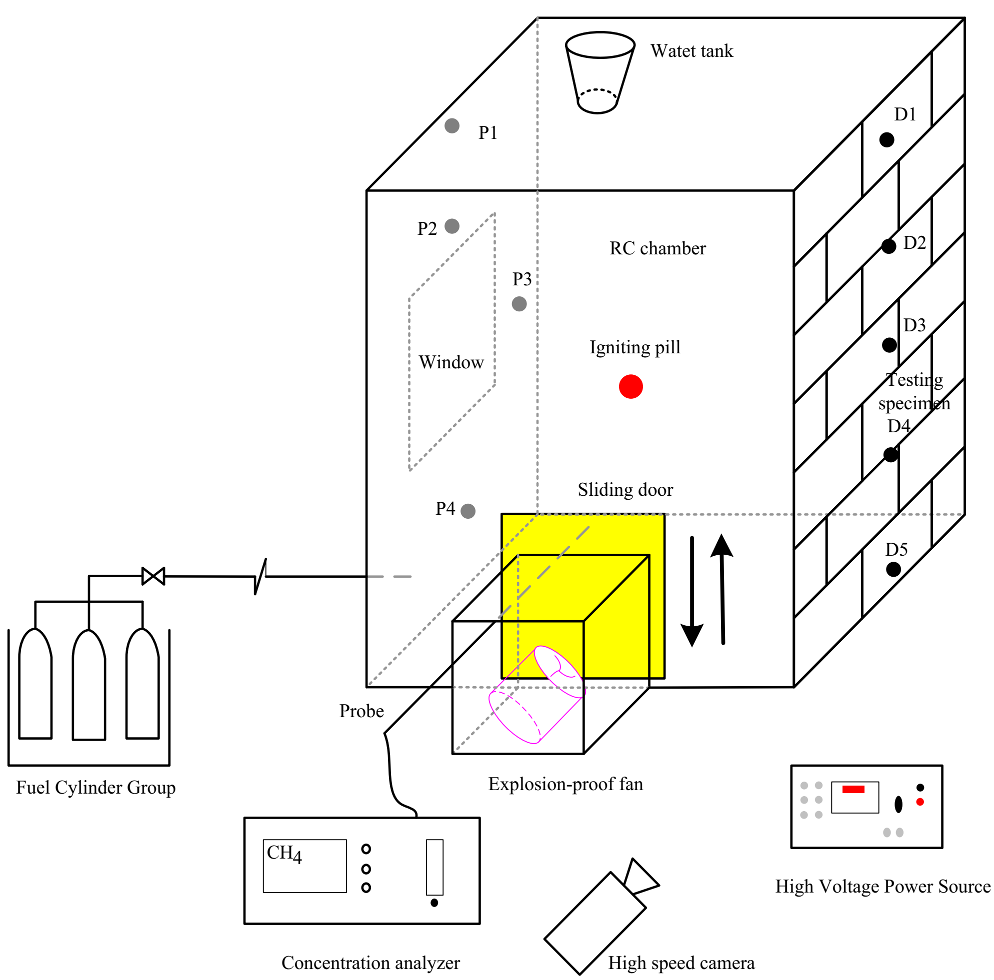

Fig. 1. Schematic diagram of testing setup.