Available online at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.elsevier.com/locate/acme

Original Research Article

Experimental study of water tank under impulsive loading

Y. Wang*, S.C. Lee

Department of Civil and Environmental Engineering, National University of Singapore, Singapore

A R T I C L E I N F O

Article history:
Received 24 May 2014
Accepted 18 September 2014
Available online 1 August 2015

Keywords:
High velocity impact
Water tank
Impulsive loading
Gas gun

A B S T R A C T

The performance of stainless steel water tank subjected to impulsive loading was experimentally studied in this paper. The gas gun was utilized to activate the projectile with high impact velocity. The activated projectile then impinged the impact transfer plate which pressed the airbag behind it. The inflated airbag between the impact transfer plate and water tank was adopted to transfer the impulsive loading from impact transfer plate to the water tank. The ultra-thin pressure sensors were placed between the airbag and water tank to record the pressure imposed onto the water tank and the potentiometers were attached at the back of water tank to record the displacement histories. The water tanks with two different front and rear plate thicknesses were investigated. In addition, the same water tank with and without filled water was compared to study the water effects on the response of water tank under impulsive loading. Besides the experimental studies, the FE method was adopted to reproduce the experiment and improve the current test method. Finally, the experimentally verified FE models were further used to study the water effects in reducing the deformation of water tank under blast loading.

© 2014 Politechnika Wrocławska. Published by Elsevier Sp. z o.o. All rights reserved.

1. Introduction

The probability of bomb attack on structure has seen an increasing trend in recent years. Consequently, many critical buildings were designed for blast resistance either in the before-built design stage or by means of retrofitting with additional protective layers. Since the probability of the occurrence of blast threat is usually very low, the benefits of adopting a blast-mitigating or blast-enhanced design could be maximized by considering other aspects of the buildings operations such as sustainability and energy efficiency. The water tank system was proposed to harvest solar energy and meanwhile reduce the thermal heat penetration into buildings in hot climate region. Its energy saving performance has been studied by numerical method [1]. Since the current water tank has potential blast resistant function, this work aims to study the performance of water tank under blast loading to extend the multi-uses of current water tank system and evaluate the workability of utilizing inflated airbag to generate blast loading.

Water effects on blast wave mitigation have been studied by experimental and numerical methods for decades [2–8]. Both experimental and numerical results showed that water

* *Corresponding author*. Tel.: +65 94654835.
E-mail addresses: wangyonghui@nus.edu.sg, yonghui_hit@163.com (Y. Wang).
http://dx.doi.org/10.1016/j.acme.2014.09.006
1644-9665/© 2014 Politechnika Wrocławska. Published by Elsevier Sp. z o.o. All rights reserved.

had significant effects on mitigating blast wave, especially for the case that water was stored close to the explosive. The principle of water in mitigating blast wave is that the high pressure shock wave produced by detonation aerosolizes the water placed close to the explosive and causes both a phase change of water and the redistribution of internal and kinetic energy over the detonation gases, blast wave and barrier material [8]. The aforementioned research on water mitigation effects on blast wave was based on the scenario that water directly interacts with blast wave. However, the research on confined water effects on water tank's response has so far been little. Since confined water does not interact with blast wave, it cannot reduce the blast loading. In addition, the energy dissipation by confined water under blast loading is usually little due to the high bulk modulus and extremely small viscosity of water. However, confined water still can reduce the water tank's response by increasing the overall mass and ensuring the front and rear plate deforming together to absorb the blast energy.

The blast loading is an impulsive loading which has extremely high pressure and short duration. The field explosive detonation is a conventional method to generate the blast loading [9–14]. However, the disadvantages of this method are that it is generally quite expensive and a long planning time is also needed. Due to the limitation of the field blast test, many other methods have been proposed to generate the impulsive loading. Shock tube is one of these methods. It is generally less expensive than field blast test and the loads are more reproducible. However, the specimen size is limited by the size of shock tube and the loading duration is relatively longer compared with field blast test [15]. Hence, it is more suitable for simulating far range blast loading. Whisler and Kim have developed a non-explosive test method for generating dynamic blast-type pressure pulse loading [16]. However, only impulse can be recorded in the test, while the pressure–time history is difficult to record. The pressure–time history is necessary for analyzing the specimen if the response of the specimen enters into dynamic or quasi-static response regime. A simple blast load simulation system has been proposed by Mostaghel [17]. As shown in Fig. 1, the invention comprises a test panel and a membrane mounted within a frame system. The membrane in conjunction with the panel forms an airtight chamber. The airtight chamber is inflated with air before testing. The plate is dropped onto the membrane at various heights to achieve the required impulse magnitude and duration. This method is simple and can be easily conducted in the laboratory. Chen and Hao adopted this method and utilized the inflated airbag as the airtight chamber to investigate the multi-arch double-layered panel under impulsive loading [18]. Remennikov et al. also extended this method to simulating the column under impulsive loading [19]. In this study, this method was also adopted to generate impulsive loading since it is cheaper and easier to conduct in the laboratory compared with other methods. The limitation of this test is similar to the shock tube test, i.e. the loading duration is relatively long. This is due to the fact that the velocity of projectile is quite low due to the drop height limitation of the test equipment. In this study, the gas gun was adopted to activate the projectile with velocity up to 478.4 m/s.

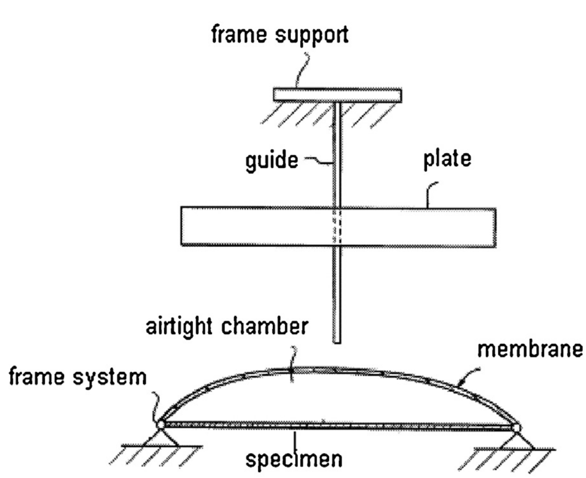

Fig. 1 – Blast loading simulation system [17].

This paper starts with a description on the experimental studies on the water tanks under impulsive loading, following by the FE analysis. The solution to overcome the deficiencies of current test method has been presented and the water effects in reducing the deformation of water tank have been discussed.

2. Description of specimens

The dimension of stainless steel water tank is shown in Fig. 2. Two stiffeners with cut-out holes for water flow were fully welded to the front and rear plate to increase the out-of-plate stiffness. The front and rear plates were extended out and five holes were drilled on the extension to connect the tank to the support system. There were totally three specimens being fabricated, i.e. S1.5, S2 and W2. The stainless steel 316 was adopted for the outer skin and stiffener of water tank, since it has better performance on corrosion resistance than mild steel. The specification of these specimens is given in Table 1. For all the specimens, the thickness of top plate, bottom plate, side plate and stiffener was 2 mm. The front and rear plate thickness was different, as given in Table 1. S1.5 and S2 were designed to study the effects of front and rear plate thickness on the response of water tank. S2 and W2 were designed to study the effects of water on the response of water tank.

Table 1 – Specification of all specimens.

Specimens	Stainless steel 316		Front/rear plate thickness (mm)	Water infilled
	f_y (MPa)	E (GPa)		
S1.5			1.5	No
S2	308.6	198.3	2	No
W2			2	Yes

Download English Version:

https://daneshyari.com/en/article/245948

Download Persian Version:

https://daneshyari.com/article/245948

Daneshyari.com