Chapter 13

Pre–Test and Analysis of a Reinforced Concrete Slab Subjected to Blast From a Non–Confined Explosive

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ABSTRACT

A large scale experimental program consisting of testing 10 RC slabs with different variations of concrete compressive strength, reinforcement ratio and retrofit was conducted in Brazil. As part of that test program, a small-scale blast pre-test setup and associated dynamic analysis were conducted in order to confirm the proper functioning of the blast test sensors (pressure gages, displacement meter and accelerometers). The results of the pre-test were compared with theoretical blast wave parameter predictions using established equations and maximum displacement predictions using simplified dynamic analysis. The pre-test experiment provided useful insights and was shown to be critical for the success of the subsequent large scale blast tests.

INTRODUCTION

In recent years, threats of terrorism, civil wars and accidental explosions have been heard routinely around the world. These actions can impact the performance of structures such as those made from reinforced concrete (RC). RC is one of the common materials used to construct most buildings and bridges around the world. Most of these structures are not designed to resist the effect of explosions. These explosions generate dynamic loads against essential supporting structural elements, such as slabs, columns or beams. In addition, protective structures made from RC can works as barrier, when the structure is designed to resist close-in detonation, or as shelter that is designed to prevent its content from blast effects (De-
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Understanding the behavior of these elements and the whole structure for the effects of blast is important because these structures hold people and private or government assets. Knowledge of blast wave parameters and how the energy coming from the blast generates damage to structures, will enable structural engineers to design RC structures efficiently incorporating short-duration dynamic effects. Many agencies have concerns about loses in both peaceful time and during conflicts generated from explosions close or in buildings (Di Stasio, 2016). Instructions giving guidance for better constructions to resist blast wave have been published due to those concerns (Department of Defense, 2008) in order to increase survival rates of structures and people after a blast event.

Full-scale tests having RC as a target have been tested with or without retrofits in order to increase the structures capacity to support blast loads (Jayasooriya et al., 2011; Maji et al., 2008; Mendonça et al., 2016; Zhao and Chen, 2013). These blast tests were conducted with proper care and were successful in collecting useful data that can increase our knowledge about the response of structures subjected to blast loads. In this book chapter, we present a small-scale blast pre-test setup and associated analysis in order to confirm the blast effect measuring sensors work properly (pressure gages, displacement meter and accelerometers) as part of a large-scale blast test program conducted in Brazil.

REPRESENTATIVE BLAST TEST EXPERIMENTS USING RC SLABS

The study of RC structures subjected to blast has been growing since the 20th century. Lessons from many accidents and two World Wars boosted research efforts in this area. In 1960, the first edition of the manual “Structures to Resist the Effects of Accidental Explosions” (Department of Defense, 2008) was published. Nevertheless, construction materials continue to evolve in composition and continue to provide more resistance to blast loads. Design codes and practice still lag behind in adopting or mandating requirements for blast analysis and design. Nonetheless, researchers have been conducting blast tests to improve our understanding of structural response for blast effects (Choi et al., 2008; Urgessa, 2009; Urgessa and Maji, 2010). Zhao and Chen (2013) conducted blast tests to verify the response of a thin RC slab with 42 MPa (6.09 ksi) having three different equivalent TNT mass and stand-off distance. Their tests verified that the higher the TNT mass and the lower the stand-off distance, the higher the damage recorded. In addition, their results pointed out that the response of concrete and reinforcement when subjected to blast have an increase in resistance, the dynamic increase factor (ASCE, 2010; Ngo et al., 2007; Urgessa, 2010).

Castedo et al. (2015) presented full-scale slab tests with variations in concrete mix composition. They showed that adding steel and polypropylene fibers to the slab resulted in a higher capacity to support blast waves. The steel fibers improved the tensile strength of the concrete and the polypropylene improved the capacity to absorb energy in opening cracks.

Li et al. (2016) conducted a full-scale field test with two RC slabs of 40 MPa (6.0 ksi) and five ultra-high performance concrete (UHPC) of 145 MPa (21 ksi). The slab with UHPC had micro steel fibers measuring 15 mm in length and 0.12 mm in diameter. The explosive in the test was positioned in contact to the upper face of the slabs and measured 0.1 kg and 1.0 kg of equivalent TNT. Slabs with UHPC had less damage than the slabs with normal RC. Diameter of perforation on the bottom surface of UHPC slabs were around 50% smaller than the slabs with normal concrete.