POST-TEST STUDY OF PRECAST RC BEAM-COLUMN JOINT AGAINST CLOSE-IN DETONATION

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ABSTRACT

A blast test was conducted with precast reinforced concrete column subjected to contact detonation. The test is part of an ongoing effort to investigate the implementation of blast-resistant precast concrete components that are subjected to contact/ close-in detonation, as well as to develop a numerical methodology that can reliably capture the structural response of said scenario. The test results were used to improve the numerical model built in a pre-test study, and this paper presents the improved model using 3D ALE mapping method.

INTRODUCTION

Precast concrete structures are widely implemented in construction due to better quality control and reduced construction time. The main difference between a precast and a cast-in-situ concrete component is in their structural continuity, where precast concrete components are assembled on site with various types of wet or dry mechanical connections. Due to their non-monolithic nature, the discontinuity at the connections is often considered as a critical point when subjected to accidental loadings such as seismic, impact, or blast. There are studies that have been done to investigate the performance of precast components under dynamic loadings, but the implementation of blast-resistant precast components subjected to close-in or contact detonation has not been studied extensively.

Literature Review

Precast concrete structures have been widely implemented in the construction industry due to their various advantages over conventional cast-in-situ concrete structures. The components are manufactured off-site in a more controlled environment, and assembly of the precast components on site can also be done in a significantly shorter amount of time compared to conventional methods of casting concrete components. The government of Singapore has been actively promoting the implementation of precast structures via guidelines and incentives in hopes to propel the construction industry towards industrialization and automation.

One of the challenges of implementing precast structures arise when there's a need for the structure to withstand accidental loadings such as blast loadings. There are limitations in the existing codes and guidelines to implement precast components as blast-resistant components that are capable to withstand close-in/ contact detonation. Unified Facilities Criteria (UFC) 3-340-02 has stated that the use of precast structures in blast design is recommended to be limited to single story buildings [1]. PDC TR-06-01 has also stated that implementation of well-connected precast components is possible for cases with larger scaled standoffs, but no detailed guidelines were given on the subject matter of close-in and contact detonation [2].

With the increasing use of precast structures over the years, research on the difference between the structural behaviour of a conventional cast in-situ concrete component and precast concrete component that is subjected to dynamic loading have been conducted. Liu [3] had conducted experimental testing with precast and cast-in-situ beam joints subjected to simulated seismic loading. It was found that precast joints exhibit concentrated cracks near the beam-column interface, cross sections at both sleeve ends, and close to the plastic zone of the beam when subjected to cyclic loading. In contrast, cast-in-place joints have cracks dispersed mainly at the beam ends, with uniform crack widths. This discrepancy is attributed to the presence of the grouting sleeve which causes uneven stiffness distribution in the beam cross sections. A numerical study conducted by Li [4] had also drawn similar conclusion where the differences in damage patterns between a precast and cast-in-situ beam during impact are attributed to interfaces between components and the presence of grout sleeves, which affect stiffness, stress distribution, and damage propagation.

Existing studies has also shown that the discontinuity of precast joints remains a subject of concern when they are subjected to blast loadings. Tin [5] studied the stress wave propagation and structural response of precast concrete segmental column subjected to blast numerically. It was deduced that the reflected tensile stress waves at the concrete interface between segments may cause tensile failure when the explosive charge is detonated near the joints. In a study conducted by Tran [6], it was found that increasing number of segments in precast segmental concrete beams can reduce the damage to concrete due to blast loading, but the joints of the segments represent the weakest points in the structure and are susceptible to damage from blast loads. Explosions occurring at these joints can result in severe structural damage and could lead to collapse of the structure.

With said background, it is essential to have a dependable analysis approach capable of capturing the behaviour of both reinforced and unreinforced precast structures when exposed to close-in and contact detonations. This is crucial for the widespread adoption of precast components in blast-resistant design. Finite Element Method (FEM) has been proven to be a reliable tool for this purpose and parametric studies conducted with FEM also allows engineers to systematically explore various design parameters to optimize the performance, safety, and resiliency of precast structures in the face of explosive events. Tin [7] has demonstrated in his study that Finite Element models have the capability to generate reliable outcomes for analysing the performance of precast components under dynamic loads.

Using FEM for blast analysis can be computationally intensive and time-consuming, especially for close-in and contact blast analysis where precision is crucial. Mapping technique has shown to be a reliable and efficient approach to significantly reduce computational requirements with minor compromise to accuracy. Vincent [8] has demonstrated that 2D ALE mapping can significantly reduce the computational time that is required while still maintain a very low error in blast overpressure, even when the mesh variation after mapping is relatively big. Anil [9] has also conducted similar study and found that the FEM model incorporating mapping technique is able to produce blast pressure-time history that are in agreement with theoretically calculated results.

Objective

There's relatively less study that has been conducted on the subject matter of precast structures subjected to contact or close-in detonation. A blast test was conducted as part of an effort to investigate the implementation of blast-resistant precast concrete components that are subjected to contact or close-in detonation as well as to develop a numerical methodology that can reliably capture the structural response of said scenario. A precast column specimen with typical grouted sleeve pipe joint were tested against contact detonation. The results of the test were then compared with a pre-test numerical study that was conducted using LS-DYNA. In the pre-test study, a finite element model adopting Load Blast Enhanced (LBE) method was built and it was found that the model is unable to reliably capture the localized damage of the column.

The main objective of this paper is to present our improved methodology to assess the response of precast RC beam-column when subjected to close-in detonation.