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ScienceDirect

Procedia Engineering 210 (2017) 334–340

Procedia Engineering

www.elsevier.com/locate/procedia

6th International Workshop on Performance, Protection & Strengthening of Structures under Extreme Loading, PROTECT2017, 11-12 December 2017, Guangzhou (Canton), China

Numerical Study on Dynamic Response of Reinforced Concrete Columns under Low-speed Horizontal Impact Loading

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Abstract

In this study, seven vertical reinforced concrete (RC) columns of 150×150 mm^2 square-section subjected to low-speed horizontal impact loadings were conducted, and the effect of impact weight and velocity on the dynamic responses and failure mechanism of RC columns were studied. The shear span ratio of specimens was designed to be 8, which exhibited flexural failure under large impact energy. With the increase of impact weight and velocity, the maximum impact force and the displacement promote almost linearly. On the other hand, finite element model (FEA) validated by experimental results using ABAQUS was developed for further investigation on the structural response under impact issue. Through the comparison between impact force and shear force of bottom cross-section, it can be found that the inertial effect takes a critical role in impact-resistance performance.

Peer-review under responsibility of the scientific committee of the 6th International Workshop on Performance, Protection & Strengthening of Structures under Extreme Loading.

Keywords: horizontal impact; finite element model; RC column; dynamic response; inertial effect;

1. Introduction

With the development of waterborne transportation industry, vessels show an obvious tendency toward large-size and frequency of docking or leaving the ports. When vessel draws alongside, in the case of improper control of vessels speed or human misoperation, large impact energy will be induced, which might seriously influence security and stability of high-piled wharf structures. In the current design codes, impact force is commonly regarded as

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1877-7058
Peer-review under responsibility of the scientific committee of the 6th International Workshop on Performance, Protection & Strengthening of Structures under Extreme Loading.
10.1016/j.proeng.2017.11.085

equivalent static forces calculated by existing formulas, which are mostly proposed based on limited physical experiments and numerical simulations. Inertial effect that influences dynamic response significantly is neglected in the equivalent static method. Thus, to investigate differences between static and dynamic responses and evaluate the equivalent static method rationally, some studies were carried out using drop weight impact facility to research on inertia effect quantitatively [1,2]. It can be found that inertia effect changes structural behaviors significantly, which turn out that shear mechanism plays an important role in overall response of simply supported RC beams, and cause shear failures even for those static flexure-critical members.

To date, experimental studies on RC vertical members subjected to lateral impact loading are in a minority, which are mainly performed by mass pendulum facility [3,4] or horizontal impact facility [5], with the aim to model the vehicle-RC bridge pier collision issue. In the studies, time histories of impact force and deflection, damage development, and dissipated energy under vehicular velocity were discussed. Moreover, corresponding numerical analysis towards further understanding on structural response has not been reported yet.

In general, with the objective to feature high-piled wharf subjected to collision of vessels characterized by "large-weight and low-speed", this study investigated the dynamic responses of seven RC columns under horizontal impact with varying impact weight (1.2/1.5/1.8 ton) and velocity (0.4/0.6/0.8/1.0/1.2 m/s). Furthermore, FEA models using ABAQUS were developed to study sectional bending moment and shear force during impact.

2. Experimental program

A total of seven RC columns, with identical structural construction (see Fig.1), are designated as L0.8, H0.8, M0.4, M0.6, M0.8, M1.0, M1.2, in which the front letter L/M/H represents light(1.2 t) /medium(1.5 t) /heavy(1.8 t) weight of test truck, and the following number represents impact velocity (unit: m/s). All specimens have an identical square-section of 150×150 mm^2, effective height of 1200 mm, concrete cover thickness of 25 mm and longitudinal reinforcement ratio of 1.4%. Details of reinforcement distribution are shown in Fig.1, in which the yield stress of Φ8 and Φ10 are 408.8 MPa and 424.6 MPa, while the ultimate stress are 541.1 MPa and 642.3 MPa, respectively. The compressive cube strength of concrete is 60.39 MPa. Moreover, to implement the boundary of axial pre-loading on the top surface, pre-loading system consisted of reaction beam, pre-stressed tendons and hydraulic jack was adopted as presented in Fig.2. The axial load ratios of all specimens kept consistent at 0.1. The foundation of RC column specimen was solidly fixed by four high-strength bolts.

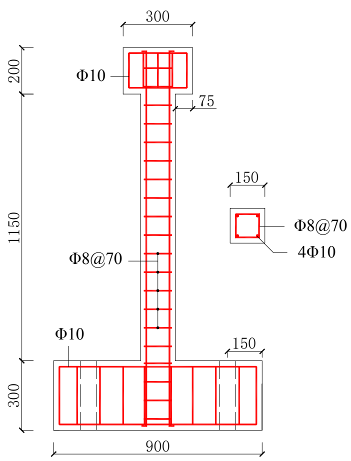

Fig.1 Schematic of RC column

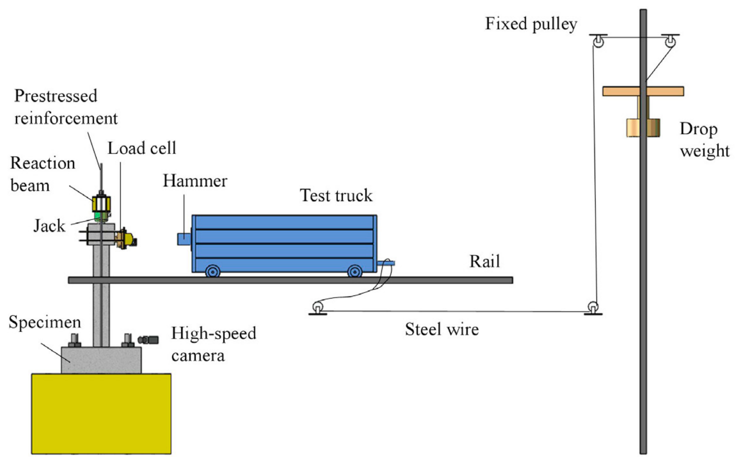

Fig.2 Horizontal impact test setup

The experimental setup of horizontal impact test is illustrated in Fig.2, which is composed of drop weight and horizontal impact facility. Connected by steel wire and fixed pulley, the falling drop weight transferred velocity to the test truck, forcing it to impact the specimens. During the impact test, with a framing rate of 200 fps at