Fragility Analysis of Girder Bridges Subjected to Multi-hazards

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Abstract

Numerous terrorist attacks and frequent natural disasters over the past quarter century have heightened widespread concern about the safety of bridges subjected to multi-hazards especially the combined effect of earthquake and blast. Analysis of girder bridges under composite action requires good understanding of the dynamic behavior of bridge components. In this paper, a new and effective approach for implementing combined action of blast and earthquake by coupling blast at several different time points during the earthquake is put forward. Based on existing researches, El Centro and specific blast load are selected to work as applied loads on bridge model built in LS-DYNA. Dynamic response of various components including main girder and piers under different loading directions are analysed. Results show that the damage of bridge components would be much severer under combined effect comparing with that under individual load. Severity of damage and the time when the most serious damage appears are related to loading directions.

Keywords: multi-hazards; girder bridges; earthquake; blast; dynamic responses; damage conditions.

1 Introduction

Large number of terrorist attacks happen around the world in recent decades such as the September 11 attack occurred in the United States. It is of great significance to protect critical public infrastructures from such catastrophic events. Terrorist attacks on bridges which are attractive targets because of their easy accessibility as well as the devastating consequence on society has increased. Among these attacks, blast is one of the destructive ways needed to be focused on. Blast load applied on bridges can exceed the design capacity of the components. Consequently, severe damage may occur resulting from a relatively slight blast. Urgent challenges that needed to be dealt with by engineers are to assess the reliability and vulnerability of bridges and design better bridges to counter blast. This resulted in the recent publication of a number of documents addressing this concern [1–4]. Although several guidelines for the design of blast resistant buildings have been published, limited information on analysis and design of bridges subjected to blast load is presented. National Cooperative Highway Research Program 645 report entitled "Blast-Resistant Highway Bridges: Design and Detailing Guidelines" is the most detailed literature in the field of blast mitigation and reduction for bridges [5]. However, much related information on failure modes of different bridge components during blast has not been provided in it.

Besides blast, earthquake is another costly disaster that may be encountered during the service life of bridges. Recent disasters, such as the 2011 Great East Japan Earthquake, the April 2015 Nepal Earthquake and the 2016 Ecuador Earthquake all cause tremendous casualties and enormous economic loss. Among all kinds of infrastructures, bridges play a significant role in post-event recovery and disaster resiliency [6]. Thus, it is necessary to understand the robustness

https://doi.org/10.2749/nantes.2018.s5-55
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