Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 210 (2017) 449–455

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

Behavior of prestressed concrete box bridge girders Under hydrocarbon fire condition

Gang Zhang[a,*], Venkatesh Kodur[b], Jincheng Xie[a], Shuanhai He[a], Wei Hou[a]

[a]*School of Highway, Chang'an University，Xi'an 710064, Shaanxi, China*
[b]*Department of Civil and Environmental Engineering, Michigan State University, East Lansing, MI 48824, USA*

Abstract

Currently, prestressed concrete (PC) bridges are often suffered from fire caused by oil tanker. However, there is very little research information and test data in the literature on the fire resistance of PC bridge girders. This paper presents an investigation into behavior of PC box bridge girder under hydrocarbon fire condition. A numerical model, in the form of the computer program ANSYS, for predicting the influence of a significantly critical factor, namely, prestress degree, on the performance of prestressed concrete bridge with box girder subjected to hydrocarbon fire is presented. The three stages associated with the numerical procedure, for evaluating fire resistance of PC box girders, namely, fire temperature calculation; cross-sectional thermal gradient evaluation and determination of mechanical response in box girders are elucidated. A simplified approach to account for thermal gradient distribution within girder section and deformations of PC box girder under hydrocarbon fire condition is incorporated into the FEM model. The applicability of the computer program for evaluating the fire resistance of PC box girder, resulting from combined effect of thermal and mechanical loading, is demonstrated through a case study. Through the numerical analysis results of case study, it is shown that different prestress degree adopted in girders has significant influence on the fire resistance of PC bridges.

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

Keywords: fire resistance; fire; high temperature; prestressed concrete bridge; box girder; numerical model

* Gang Zhang. Tel.: +86-29-82338170; fax: +86-29-82338170.
E-mail address: zhangg_2004@126.com

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.2017.11.100

1. Introduction

Prestressed concrete (PC) girder is widely used in bridge construction due to number of advantages concrete and presstress strands can offer over other construction materials. These advantages include three aspects: the first is that concrete can be a low price, ease of drawing materials, good durability, rapidly casting and easily shaping; the second is that the structure of the crack resistance is to be improved significantly to prolong the service life due to occurrence of presstress; the last is that the section dimension of PC bridge girder can be diminished to increase their span length resulting from prestress. A major drawback of prestressing strands possesses low fire resistance due to the fact that prestressing strands with high tension stress is vulnerable to be fracture at elevated temperature. In addition, another drawback of PC bridge girder is easy to be crack around prestressing pipe resulting from couple effect of strong pre-compressive stress and high temperature [1,2].

Information from fire-induced PC bridge damages in China, such as the Borui Yanjiang bridge, comprised of PC box girders, on Jinliwen expressway along a river, Zhejiang in 2008, and Caogou bridge, comprised of PC box girders, Shaanxi in 2011, clearly indicates that oil tanker fires can posed a significant destruction of structural members in PC bridges. The rebuilding of these fire damaged PC bridges and the traffic detouring lasted for few of months leading to significant economic losses [3].

In U.S., a PC bridge fire occurred at the Bill Williams River Bridge, AZ in 2006. The bridge was comprised of fourteen spans with a length of 23.2 m. and the super structure was constructed of PC girders underneath a cast-in-place concrete slab [4]. Another disastrous fire broke out on I-85 highway, IA in 2017, and this fire cause a PC bridge collapse after 40 min [5].

The above incidents clearly infer that fires can pose significant threat to PC bridges. This is because the concrete and prestressing strands may suffer severe degradation in strength and stiffness properties due to high temperature exposure. Especially, the tensile strength and modulus of prestressing strands is quite sensitive to high temperatures. In addition, thin-walled box girders are quite frequently used as flexural members in long-span PC bridges due to reduced mass (thin web and flanges). Thus, PC bridges are highly vulnerable to damage under severe fire exposure condition (See Fig. 1) [3,6-8].

Fig. 1 Fire-damaged PC box girder

In past years, most studies have focused on the development of finite element analysis and experiments on the steel girders [9-11], and a few studies concentrated on reinforced concrete beams [12-16]. There are nearly no studies on the fire resistance of PC bridges. This paper presents an analysis of PC box bridge girder, using program ANSYS.

2. Approach for modeling fire behavior in PC bridge girders

To illustrate the applicability of finite element models for the analysis of fire resistance, a PC box bridge girder was analyzed under hydrocarbon fire and structural loading.