Buckling behavior of stiffened plates in concrete-filled steel tubular bridge towers

Lipeng Sun, Yongjian Liu

Chang'an University, Xi'an, Shannxi, China

Contact: slpbridge@qq.com

Abstract

The steel panels on concrete-filled steel tubular bridge towers are large aspect ratio stiffened plates subject to unilateral restraint from concrete, whose local stability performance can be improved by setting multiple longitudinal stiffeners. In this paper, the elastic buckling coefficient of such a unilaterally restrained stiffened plate was derived using the Ritz method. Then, the critical relative stiffness of the stiffeners was proposed to identify the buckling mode of the plate. Further, the effective area method was proposed to evaluate the ultimate strength of the stiffened plates. The numerical simulation of the unilaterally restrained stiffened plates under axial compression was conducted using the verified finite element models. The results show that the buckling coefficient and effective area method proposed in this paper can evaluate the ultimate strength of unilaterally restrained stiffened plates under axial compression with high accuracy.

Keywords: local buckling, concrete-filled steel, bridge tower, stiffened plate, Ritz method, finite element, effective width

1 Introduction

Concrete-filled steel tubular (CFST) bridge towers consist of steel box sections welded by stiffened plates and concrete infill, which are characterized by high resistance, construction convenience and good economy [1, 2]. It has become increasingly popular on cable-stayed and suspension bridges in recent years in China, such as Lichuan Bridge (2017), the Fifth Nanjing Yangtze River Bridge (2020) and Yuanshuo Bridge (2021).

Due to the huge width-to-thickness ratio of the plates in steel bridge towers or CFST bridge towers, it's common practice to set longitudinal stiffeners to avoid local buckling. However, the plates in CFST bridge towers are unilaterally restrained by the concrete infill, which cannot buckle freely on both sides outside the face like the plates in steel bridge towers, resulting in an increase in local stability. In addition, the stiffeners are embedded in the concrete, which will not suffer from torsional instability like stiffeners in steel bridge towers. Hence, the design method of stiffened plates in steel bridge towers cannot be directly applied to those in CFST bridge towers.

The plates in the CFST bridge towers can be simplified to a rectangular stiffened plate with four fixed edges and unilateral constraints. The local buckling performance of unilaterally restrained flat plates without stiffeners has been extensively investigated by Wright [3], Uy et al. [4-6], Azad et al. [7, 8], Sun et al. [9, 10]. Tao, et al. [11-14] conducted a series of experimental studies on the buckling performance of square CFST columns with single or double longitudinal stiffeners on a single panel and proposed a

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