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Flexural behavior of circular concrete filled steel tubes (CFST) under sustained load and chloride corrosion

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ABSTRACT

This paper studies the flexural behavior of circular concrete filled steel tubes (CFST) under sustained load and chloride corrosion. 7 CFST specimens were tested under a four-point bending load. It was found that corrosion causes noticeable deterioration to the flexural strength, while the ductility of CFST keeps well. A finite element analysis (FEA) model was developed to study the full-range behavior of CFST under corrosion. A parametric study was conducted to find the main parameters that influence the residual flexural strength, based on which a simplified model was proposed to calculate the residual flexural strength of circular CFST under long-term load and corrosion.

1. Introduction

Concrete filled steel tubes (CFST) have an increasing utilization in different types of infrastructures in China, such as residential and office buildings, high rise structures, bridges, and subway stations, et al. (Han et al. [1]). A very recent construction with CFST is the electric transmission tower built near the East China Sea, as shown in Fig. 1. It has a height of 370 m and the main structure was constructed with circular CFST members. As a steel-concrete composite structure built in the coastal area, the corrosion of the steel tube is quite an important factor to be considered. Corrosion reduces the sectional area of the steel tube and thus deteriorates the loading capacity of the structure. So there is a basic need for understanding the behavior of CFST structures working under corrosion environment.

The mechanism of corrosion has been studied in the past. Melchers [2] summarized various types of factors that may influence the corrosion rate of structural steel immersed in seawaters, in which uniform corrosion is considered. Bhandari et al. [3] provided a review on the pitting corrosion problem, including the mechanism and development of pit, and the modelling of pitting corrosion in structural steel. The effect of corrosion on the strength of engineering structures has also been a critical topic, as a vast amount of structural failures in ocean environment is due to corrosion (Melchers [2]). Saad-Eldeen et al. [4] studied the effect of corrosion on the ultimate strength of a steel box girder. Accelerated corrosion test set up was used to achieve uniform corrosion along the structural surface. Some other researchers studied the effect of pitting corrosion on structural strength. For example, Sultana et al. [5] used finite element modelling to study the ultimate compressive strength of steel plates and stiffened panels under pitting corrosion. A nonlinear time-dependent corrosion model was employed to describe the development of corrosion pit. Another important thing to notice is that corrosion is often localized in engineering structures. For instance, the local area of a structural column around the water surface is more likely to be severely corroded. Some studies tried to analyse the effect of local corrosion on the global structure behavior. Karagah et al. [6] tested the corroded H-shaped short steel columns under axial loading. The local corrosion was modelled by milling the webs of flanges of the column near the mid-height. These studies generally show that corrosion has quite significant influence on the structural strength.

This paper is an attempt to study the effect of chloride corrosion on circular CFST beams. Some research outcomes on square CFST beams and columns and circular CFST stub columns have been achieved by the authors in the past. In Han et al. [7] and Hou et al. [8], experimental and numerical studies have been carried out on square CFST stub columns and beams. It was found that corrosion has a noticeable influence on the axial and flexural

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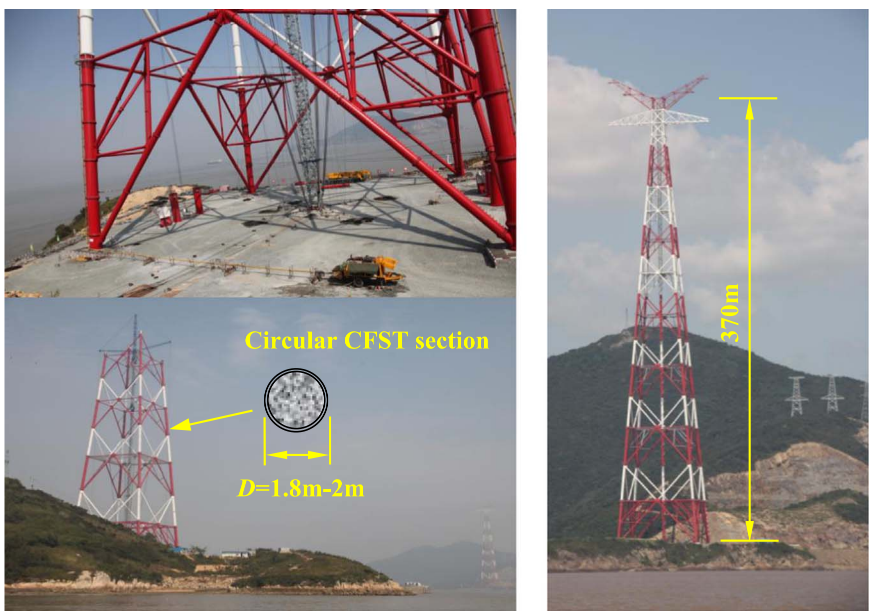
Nomenclature

A_c	cross-sectional area of the concrete core of CFST
A_s	cross-sectional area of steel tube
D	diameter of circular tube section
E_c	elastic modulus of concrete
E_s	elastic modulus of steel
f_{ck}	characteristic compressive strength of concrete
f_{cu}	cube strength of concrete
f_u	ultimate strength of steel
f_y	yield strength of steel
P	applied concentrated load on the specimens
I_0	area moment of inertia of the original section
I_c	area moment of inertia of the corroded fully-immersed section
I_{c-h}	area moment of inertia of the corroded half-immersed section
K_i	initial section flexural stiffness
K_s	serviceability-level section flexural stiffness
L	length of specimen
L_s	shear span of specimen
m	loading ratio of specimen ($=M_l/M_u$)
M_l	long-term sustained moment applied on CFST during the corrosion
M_u	ultimate flexural strength of CFST under short-term load without corrosion
M_{uc}	ultimate flexural strength of CFST under long-term load with corrosion
M_{ue}	measured ultimate flexural strength
M_{up}	predicted ultimate flexural strength
RS	residual flexural strength ratio of CFST ($=M_{uc}/M_u$)
t	sustaining days of long-term sustained load
t_s	wall thickness of steel tube
α	steel ratio of CFST section ($=A_s/A_c$)
β	degree of corrosion ($=\Delta t_s/t_s$)
u_m	lateral deflection of CFST
Δt_s	steel thickness loss due to corrosion
ρ	concentration of NaCl solution
ξ	confinement factor of CFST ($=A_s f_y/A_c f_{ck}$)



(a) CFST under construction (b) Global tower structure

Fig. 1. Offshore electric transmission tower with circular CFST members.

strength of CFST. Based on parametric studies, simplified methods for calculating the residual strength of corroded CFST stub columns and beams were proposed. The behavior of circular CFST stub columns under corrosion was then studied in Han et al. [9]. It was found that circular CFST stub columns show similar behavior to square ones under long-term load and corrosion. However, the strength deterioration of circular stub columns is more severe than that of square ones. This is due to the fact that the confinement effect of the steel tube on the core concrete in circular specimens is higher than that in square ones. A simplified method for residual axial strength calculation of circular CFST stub columns under corrosion was then obtained based on a parametric study and regression analysis.

Circular CFST members are not frequently used as beams in engineering applications, as concrete has low bending capacity. However, bending moments are usually present in CFST columns. Take the coastal electric transmission tower shown in Fig. 1 for example. The main structure of the tower is constructed with circular CFST. Although the CFST members are used as columns in the tower, bending moment brought by the wires also presents in the structure. There have been many research outcomes on the flexural behavior of circular CFST [10,11–13]. Simplified models have been proposed for calculating the flexural strength [13–15]. It should be noticed that previous studies mainly focus on CFST working under short-term load.

In this paper, the effects of long-term sustained load and corrosion on the flexural behavior of circular CFST members are studied. The main focus is on the effects of corrosion on the flexural strength and ductility, and it is expected that the corrosion behavior of CFST under bending will show some different features compared with those under axial compression. Another anticipated outcome is a simplified residual flexural strength calculation model for circular CFST under long-term sustained load and corrosion, which can be used in future design work.