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# Time-dependent reliability analysis of circular CFST stub columns under environmental corrosion

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**Abstract**

Concrete filled steel tubular (CFST) columns subjected to environmental attack can experience changes in resistance that are time-variant. In this study, the axial compressive strength loss in circle CFST stub columns due to corrosion of the outer steel tube is investigated. The assessment of the time-dependent reliability analysis of circular CFST stub columns under environmental corrosion is presented. A probabilistic axial compression model for circular CFST stub columns is developed based on an analytic formula that considers corrosion-related and time-dependent factors. This study involves the formulation of a limit states function, the development of load models, the development of resistance models for corroded circular CFST columns, time-dependent reliability and resistance analysis for a hypothetical stub column. The results of this study can be applied to achieve a better prediction of the service life of deteriorating circular CFST columns and the development of optimal reliability-based maintenance strategies.


*Keywords:* Reliability analysis; Time-dependent; CFST; Column; Corrosion; Probabilistic model

## Introduction

The current codes and standards procedures only address with the adequacy of a structure at the time of assessment. Assessment of existing structures over their whole-life is increasingly important with natural aging, increased load spectra, deterioration versus time due to corrosion and other problems [1].

Methods for structural reliability have become better understood and approved by engineers in recent decades. Structural reliability can be considered a rational assessment for circular concrete filled steel tubular (CFST) stub column performance. At present, there are few studies related to the behavior of circular CFST columns due to corrosion.

Han et al. [2] studied concrete filled steel tubular (CFST) stub columns and beams with square sections. The specimens were set to work under a corrosive environment, which was simulated by an electrolytic corrosion solution. The test results showed that

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corrosion had a noticeable influence on the strength of the specimens, and the failure modes of the specimens were still ductile. An FEA model was developed to predict the behavior of square CFST stub columns and beam structures under chloride corrosion by Hou et al. [3]. Han et al. [4] studied the effect of corrosion on the behavior of circular CFST stub columns. A simplified model was suggested to calculate the residual axial strength ratio of CFST stub columns under long term loading and corrosion.

The aim of this study is to develop a time-variant reliability-based model for the evaluation of circular CFST stub columns with regard to environmental corrosion during their lifetime. The structural performance is measured in terms of the reliability index, $\beta$. Three different types of corrosion environments are considered, including marine, urban and rural. The effects of the steel tube thickness and the live load ratio on the time-dependent reliability are compared.

## Corrosion model

Corrosion of the circular steel tubing is a destructive reaction of the material with its environment and is one of the most important causes of deterioration in circular CFST stub columns.

### *Forms of corrosion*

There are several forms of steel corrosion. Generally, they are described by how the corrosion attacks the steel. Fontana [5] classified eight forms of corrosion that affect circular steel tubing on the basis of the visual appearance of the corrosion damage. They range from uniform corrosion, which can be observed by the human eye, through pitting and crevice corrosion, to stress corrosion, which cannot be recognized by the human eye. Kayser and Nowak [6] described five of the most important forms of corrosion: general corrosion, pitting corrosion, crevice corrosion, galvanic corrosion and stress corrosion. The most prevalent form of steel corrosion is general corrosion, which is uniformly distributed on the surface. In this paper, only general corrosion is considered. General corrosion is defined as the section loss of circular steel tubing.

### *Corrosion rates and pattern*

The corrosion rate of a steel circular steel tube depends on the atmospheric environment (low, medium, high), the protective treatment of the steel and the influence of de-icing. As a result, it is difficult to accurately predict the corrosion rate; it can only be estimated using approximate formulations. The formulation used in this study was initially proposed by Komp [7]:

$$C = At^B \tag{1}$$

where $C$ is the average corrosion penetration after t years, $t$ is number of years, and $A$ and $B$ are parameters to be determined from the regression analysis of the experimental data.

Parameters $A$ and $B$ depend on the environment surrounding the bridge. Albrecht and Naeemi [8] studied the behavior of different types of steel exposed to different types of environments, including marine, urban, and rural. Table 1 gives the mean values and coefficients of variation for $A$ and $B$ [7]. Generally, the degree of penetration is the lowest in rural environments and the highest in marine environments, as seen in Fig. 1.

An important part of the circular CFST tubular column's corrosion model is the corrosion pattern and the areas of concentration of high corrosion rates within the structure. In this study, it is assumed that corrosion occurs on the whole tube surface over the concrete-filled steel circular tubular column, as seen in Fig. 2. In Fig. 2, $t_s$ is the initial wall thickness of the circular steel tube without corrosion, $R_1$ is the radius of the circular tube section, and $C$ is the thickness loss of the circular tube due to corrosion.

## Load model

Structural elements are designed to withstand the combined load effects due to permanent load, live load, and environmental load with a target reliability.

In this paper, we only consider the circular CFST tubular columns under dead and sustained live loads. The dead load is treated as a normal random variable. The basic statistical parameters are the bias factor $\lambda$, which is the ratio of the mean to the nominal value, and

Table 1
Distribution of corrosion parameters.

| Environments | Parameters | Carbon steel | | Weathering steel | |
|---|---|---|---|---|---|
| | | $A$/μm | $B$ | $A$/μm | $B$ |
| Rural | Mean | 34 | 0.65 | 33.3 | 0.498 |
| | COV | 0.09 | 0.1 | 0.34 | 0.09 |
| Urban | Mean | 80.2 | 0.593 | 50.7 | 0.567 |
| | COV | 0.42 | 0.4 | 0.3 | 0.37 |
| Marine | Mean | 70.6 | 0.789 | 40.2 | 0.557 |
| | COV | 0.66 | 0.49 | 0.22 | 0.1 |