A constitutive model for confined concrete in composite structures

Qing-Xuan Shi[1)] and *Chong Rong[2)]

[1), 2)] Department of Civil Engineering, Xi'an University of Architecture and Technology, Yanta Road 13, China
[2)] tmgcrong@126.com

ABSTRACT

The constitutive relation is an important factor in analysis of confined concrete in composite structures. In order to propose a constitutive model for nonlinear analysis of confined concrete, lateral restraint mechanism of confined concrete is firstly analyze to study the generalities. As the foundation of the constitutive model, peak stress and peak strain is the first step in research. According to the generalities and the Twin Shear Unified Strength Theory, a novel unified equation for peak stress and peak strain are established. It is well coincident with experimental results. Based on the general constitutive relations and the unified equation for peak stress and peak strain, we propose a unified and convenient constitutive model for confined concrete with fewer material parameters. Two examples involved with steel tube confined concrete and hoop-confined concrete are considered. The proposed constitutive model coincides well with the experimental results. This constitutive model can also be extended for nonlinear analysis to other types of confined concrete.

1. INTRODUCTION

The constraint of lateral pressure around the confined concrete can restrict the development of internal microcrackS. The compressive features of the confined concrete are improved, and the compressive strength and ductility are increased (Tian et al. 2014; Han and Yang 2007; Soliman and Oniki 2011; Takahama 2014; Samani and Attard 2012). This characteristic has been widely adopted in practice. For example, steel tube, hoops and FRP always are used to confine the concrete members, which are the main structural members. With lateral constraint, the filled concrete toughness is obviously improved, and the anti-collapse property of structure is increased (Cai 2003; Yu 2010; Lee and Lee. 2007; Ren et al. 2014; Toutanji and Saafi 2002). Therefore, confined concrete has a wide practical engineering.

The constitutive relation for confined concrete is an important factor to study the

---

[1)] Professor
[2)] Ph.D Student

*Note: Copied from the manuscript submitted to
"Steel and Composite Structures, An International Journal" for the purpose of presentation at ASEM17/ANBRE17.

nonlinear property of structure. Many scholars have proposed their own constitutive relation models (Shi et al, 2011; Mander et al. 1988; Scott et al. 1982; Daniel and Patrick 1995; Han and Yang 2007). Numerous studies have shown that the difference in the rising stage is less significant. Therefore, main research focus on the declining stage of the models (Shi et al, 2011). Mander (1988) puts forward the effective restraint coefficient to describe the arching effect and proposes the unified constitutive model for the rising and declining stages of low-strength hoops confined concrete. But the computation values of both peak stress and peak strain of high-strength hoop specimen are generally higher, conversely, the computation values of peak strain with high constraint are lower. The model proposed by Scott (1982) assumes that the improvement of both peak stress and peak strain are just the same, and the declining stage of constitutive relation for the hoops confined concrete is simply fitted in a linear form. However, this model can be merely used to reasonably calculate the peak strain for the confined concrete with lower constraint degree and fit the constitutive relation for the concrete with weaker constraint effect. Afterwards, Daniel and Patrick (1995) put forward the constitutive model of high-strength hoops confined concrete. The declining stage of stress-strain curve is an exponential function form which is fitted by a series of parameters. To be more reasonable, the more parameters in this model and involve the iterative calculation method. Therefore, this model is unsuitable to the practical application. Han and Yang (2007) build the constitutive model of steel tube filled concrete, based on changing the control parameters of declining stage in the constitutive model of plain concrete. The confined concrete in square steel tube and circular steel tube has been discussed in the model. However, the declining stage curve of square steel tube filled concrete declines fast, while that of circular steel tube filled concrete declines slowly and even rises up.

The filled concrete has been investigated by many scholars through the experiments (Toutanji 2001; Shi et al, 2014). Their respective constitutive models of the particular confined concrete are put forward. However, there is not a unified model which is suitable for most types of confined concrete and could also be convenient for engineering application. Through the research, there are common characteristics of most types of confined concrete. Therefore, based on the Twin Shear Unified Strength Theory, this paper analyzes the confined concrete in the perspective of lateral compressive stress of concrete in the core area. Then the article builds unified computational equation of axial compressive mechanical properties. Furthermore, the unique constitutive model for most types of confined concrete is proposed.

2. Computation for stress and strain of confined concrete

2.1 Lateral restraint force of confined concrete

According to different section shapes of confined concrete, the common confined concretes in the practical engineering are circular steel tube filled concrete, square steel tube filled concrete and hoops confined concrete. These three kinds of concretes are studied in this paper. For the confined concrete, the main difference among various types is focused on lateral restraint force. The diagrammatic sketches of constraint forces generated by the lateral pressure on steel tube filled concrete and hoops confined concrete are shown in Fig. 1.