ANALYSIS OF STEEL-REINFORCED CONCRETE-FILLED STEEL TUBULAR AND CONCRETE-FILLED STEEL TUBULAR COLUMNS UNDER CYCLIC LOADING

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Dedicated to my beloved family and friends

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ABSTRACT

In recent decades, concrete-filled steel tubular (CFST) and steel-reinforced concrete-filled steel tubular (SRCFST) structural members have been widely used in the construction of modern buildings and bridges. However, there is a limited finite element analyses and experiments under cyclic loading. These composite constructions ideally combine the advantages of both steel tube and concrete, namely the speed of construction and high strength. Moreover, they have lighter weight, higher bending stiffness, and better cyclic performance than the reinforced concrete construction. In this respect, a new form of composite column, steel reinforced concrete filled steel tubular column (SRCFST), has been proposed to further enhance load capacity, stiffness and cyclic performance. The new column consists of a steel reinforced concrete inside and a steel tube outside. Therefore, in this study, cyclic performance of two CFST and four SRCFST columns are examined based on review of existing studies and ABAQUS software. Eventually, a holistic comparison in cyclic features of these two types of columns and a parametric study on axial load levels are carried out which results in the higher axial load level, stiffness and deformability in SRCFST columns. Apart from load levels consequences, it is observed that the SRCFST column has a higher stiffness and ductility than those of the CFST column preliminary due to confining effect of steel section inside.

ABSTRAK

Sejak kebelakangan ini, anggota struktur tiub keluli diisi konkrit (CFST) dan tiub keluli diisi konkrit bertetulang keluli (SRCFST) digunakan secara meluas dalam pembinaan bangunan dan jambatan moden. Walaubagaimanapun, terdapat analisis unsur terhingga yang terhad dijalankan ke atas struktur ini di bawah pembebanan kitaran. Bahan rencam CFST dan SRCFST secara unggulnya menggabungkan pembentukan daripada tiub keluli dan konkrit, penggunaannya boleh mempercepatkan pembinaan di samping mempunyai kekuatan yang tinggi. Tambahan pula, bahan ini adalah ringan, tinggi kekukuhan lenturan dan baik prestasi kitaran berbanding konkrit bertetulang biasa. Dalam hal ini, pembentukan baru tiang rencam, tiub keluli diisi konkrit bertetulang keluli (SRCFST), dicadangkan bagi peningkatan keupayaan pembebanan, kekukuhan dan juga prestasi kitaran. Tiang baru ini mengandungi konkrit bertetulang keluli pada bahagian dalam dan tiub keluli pada bahagian luar. Dengan itu, dalam kajian ini, prestasi kitaran bagi dua sampel tiang CFST dan empat sampel tiang SRCFST diselidiki berdasarkan kajian sedia ada dan perisian ABAQUS. Akhirnya, perbandingan menyeluruh tentang ciri kitaran bagi kedua-dua jenis tiang ini dan kajian parametrik ke atas paras beban paksi dijalankan dengan penghasilan paras beban paksi yang tinggi, kekukuhan rendah dan kebolehubahbentukan. Selain kesan paras beban, tiang SRCFST didapati mempunyai kekukuhan dan kemuluran yang tinggi berbanding tiang CFST berdasarkan kesan pengurungan keratan keluli di dalamnya.

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LIST OF ABBREVIATIONS

BS	-	British Standard
EN	-	European Standard
SRCFST	-	Steel Reinforced Concrete filled Steel Tubular
CFST	-	Concrete Filled Steel Tubular

LIST OF SYMBOLS

ν	-	Poisson ratio
E	-	Modulus of elasticity
f_c	-	Compressive strength
F_{cu}	-	Characteristic strength of concrete
K	-	Buckling coefficient
n	-	Life time
D	-	Diameter
A_S	-	Area
F_{sy}	-	Yield strength of steel
N	-	Level of axial loading

CHAPTER 1

INTRODUCTION

1.1 Background

CFST columns rank a class of structure in which the best properties of both steel and concrete are used to their maximum advantage. These types of columns offer a number of advantages; provision of economy in construction is used in variety of applications. Due to their excellent ductility, these have been used in earthquake-resistant structures. The significant benefits in the practice of concrete in-filled steel tubular columns fascinated the researchers throughout the world to study this type of structural members.

Concrete filled steel columns have been used extensively in order to speed up errection procedure by eliminating formwork and the need for tying of longitudinal reinforcement. Current international codes such as the ACI-318 and Eurocode 4 guarantee adequate design guidance when the component plates of the columns are typically stocky in terms of plate slenderness and if the strength of the concrete is fairly moderate.

Association of New Urban Housing Technology “guidelines for structural design, recommends methods to be used in different levels of construction from design to construction and Fire-Resistive Design and Construction for CFT structures." and Architectural Institute of Japan "Standard for Structural Calculation of Steel Reinforced Concrete Structures" [1].

What is CFST and SRCFST?

Concrete-filled steel tubes (CFST) and Steel-reinforced concrete-filled steel tubes (SRCFST) are composite structural elements comprised of a rectangular or circular steel tube with concrete infill which in latter form steel sections are incased in concrete. These mentioned structural members efficiently combine the tensile strength and ductility of steel with the compressive strength of concrete.

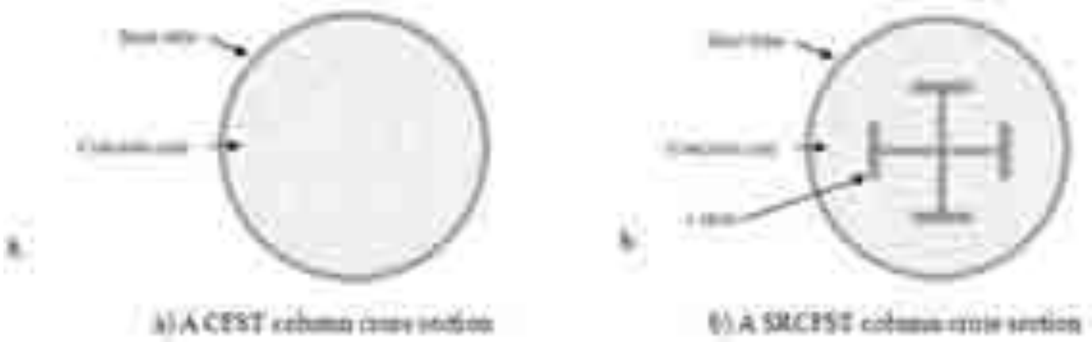

Figure 1. 1 Two types of circular composite section; a) CFST section, b) SRCFST section.

1.2 History

Americans John Lally used steel tube and concrete in circular form of CFST in high-rise building in 1897, as a residential structure in the load-bearing column (known as Lally column) [2]. In the late 80s, due to modern high-strength, and high performance concrete, pumping irrigation technology and rapid development of concrete technology CFST has proposed a kind of new vitality in Europe and USA.

CFST in first major usage has a long history, nearly 40 years, in structural engineering. In 1966, consultant engineers made use of CFST for Beijing Subway Station [3]. Designers used CFST to solve the “fat-pillar” issue. It is entirely apparent that in subway structures during application, construction is encountered with cyclic excitation and as a consequence, a couple of solutions should be foreseen. The most problematic issues in this concern would be as listed below:

- Brittle high-strength concrete columns in case of not using CFST or SRCFST.
- Large section required.

By implementing CFST column, designers could overwhelm the stated obstacles.

Over the past 10 years, China has manufactured more than 100 high-rise building by implementing CFST or SRCFST members, such as Shenzen SEG Plaza, which built in 1999 [4]. Some specifications of this masterpiece can be mentioned involving, 291.6 high, 16 inner columns with 3 meter spacing and C60 and above as a concrete strength.

Figure 1. 2 Shenzen SEG plaza in China

Over last several decades, high rise buildings or group of structures arises in China, Australia, Japan and some other countries. The more increment in span-length and height, the more required cross area of a column to ensure greater bearing capacity. For example, the diameter of CFST columns in first story of ShenZhen Saibo Plaza Building reaches 1600 mm [5]. Such a large cross area of a column results in a reduced useful indoor area. This is why today; there is an extensive trend in using sections with more efficiency. To fulfil this purpose, designers implement steel reinforced concrete embedded in steel tube. In this way, greater confinement which leads to more loading capacity and lateral load would be satisfied. Apart from strength, this section could provide more ductility compared to CFST sections. In mentioned regard, few numerical analyses and tests have been conducted; as a consequence limited results concerning deformability and strength are available.

Last but not least, in material science, fatigue is the progressive and localized structural damage that mostly occurs when a material exposed to cyclic loading. The nominal maximum stress values are less than ultimate tensile stress and may be below the yield stress limit of material. Under this condition, employing steel tubes in CFST column and a steel tube which is accompanied by steel reinforced concrete SRCFST will enable the element to resist more cyclic load. In other word, these steel sections will boost durability property of the member and fatigue life. In addition, this should be kept in view in fatigue respect, normally; the fatigue is ignored for life time (N) which for ordinary constructions is less than 2×10^5 cycles [3]. Unlike, in frames which support the lifts and bridges fatigue effect should get involved.

1.3 Statement of problem

Despite the excellent engineering properties of CFSTs and SRCFSTs, they are not as widely used as traditional structural steel and reinforced concrete members. Although much research has been performed on the topic, the amount of finite element analysis regarding CFSTs and SRCFSTs is significantly less than that available for traditional steel or reinforced concrete members. Current design methods for them especially under cyclic loading are limited and the experimental research is not sufficient to establish dependable engineering methods.

1.4 Objectives of study

- Develop a finite element model using ABAQUS that can predict the behavior of CFST and SRCFST columns subjected to constant axial load and various cyclic loading..
- Comparison of the ductility and load-carrying of CFST and SRCFST columns under mentioned loading.
- Observing the influence of diverse axial load levels on columns behavior.

1.5 Scope of study

The main purpose of current study is evaluating and idealizing the relationship of various cyclic loading and displacements of SRCFST and CFST columns within their length under constant axial load. In this study, in addition to using prior test results, finite element software, ABAQUS is applied to investigate this issue in six specimens. The circular columns are pin at both ends and the cyclic lateral loading is applied at column mid-height.

1.6 Research significance

Why CFST and SRCFST?

Lighter CFST and SRCFST columns can replace traditional steel or reinforced columns with equivalent resistance.

The tube provides large confining and bending capacity by placing the steel at the outer perimeter of the section where the moment of inertia and radius of gyration are greatest.

Steel and concrete composite behavior

- The steel can perform most effectively in tension with the minimum amount of material
- The concrete core provides compressive strength and flexural stiffness to the section
- The concrete prevents local buckling of the steel tube
- The steel tube enhances the shear resistance and confines the concrete

- Confining the concrete will increase the ductility, compressive strength and strain capacity of the concrete
- Better cyclic performance.

Economic benefits

- By reducing section sizes, CFST and SRCFST members provide economic benefits by reducing costs associated with traditional steel or concrete construction
- CFST and SRCFST construction can proceed rapidly[3]
- Erection of the tubes and framing elements in a building can precede concrete pouring by several stories
- CFST and SRCFST columns reduce time and costs associated with reinforced concrete construction by eliminating the need for formwork and additional reinforcement

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