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ELASTIC-PLASTIC BEHAVIOR OF CIRCULAR HOLLOW STEEL TUBE SECTIONS SUBJECTED TO BENDING

A Thesis Submitted to Council of College of Engineering, University of Diyala in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering

By

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DEDICATION

Every challenging work needs self efforts as well as guidance of elders especially those who are very close to our heart

My humble effort I dedicate to the first teacher for this nation, the great prophet Mohammed (peace be upon him)

Then I dedicate it to my family

Especially to

My father may Allah have mercy on him

And to my sweat and loving mother,

Whose affection, love, encouragement and prays of day and night make my able to get such success and honor

Manahel Shahath Khalaf

2017

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ABSTRACT

The current study aims to investigate the elastic-plastic behavior of steel circular hollow sections under bending loading.

The experimental work of this study included a series of bending tests in order to examine and determine the effect of the section thickness, diameter and beam span on the structural behavior of steel tubes. In addition, the effect of the presence and number of square openings on the behavior of these sections was studied. The loading type used to study the bending behavior of steel tubes was simply supported beam test by two points load.

Ten circular hollow beam specimens were performed and tested up and post to failure stage with thickness (2, 3 and 6 mm), diameter (76.2, 101.6 and 219 mm) and span (1000, 1500 and 2000 mm). From these specimens, one was chosen as a reference specimen and used with thickness, diameter and span equal to (3, 101.6 and 1500 mm) respectively.

The experimental results showed that increasing the section thickness to (6 mm) improved the structural strength capacity by (81.75%) compared with the reference specimen, at the same time led to increase the specimen ductility significantly by (58.04%) which led to the gradual drop in the loads carrying capacity for this specimen. While decreasing the section thickness to (2 mm) reduced the structural strength capacity and ductility by 38.87%, and 64.86% respectively compared with the reference specimen.

Increasing the specimen diameter to (219 mm) led to a very high increase in the structural strength capacity by (237.59%) compared with the reference specimen, but it led to reduce the ductility significantly by (76.67%) which caused the sudden drop of the specimen loads when it reached to the ultimate load. While decreasing the specimen diameter to (76.2 mm) reduced the structural strength capacity by (56.75%).

Increasing the specimen span to (2000 mm) reduced the structural strength capacity and ductility by 3.28% and 37.13% respectively compared with the reference specimen. While it was found that the decrease in the specimen span to (1000 mm) improved the strength capacity by (89.78%) compared with the reference specimen, but at the same time reduced the specimen ductility.

The presence of one, two or three square openings in the specimens reduced their ultimate strength by (17.88%, 19.71% and 14.23%) respectively, and also reduced their ductility significantly by (72.40%, 67.71% and 60.88%) respectively and caused the sudden failure for these specimens.

In addition to the experimental work, a theoretical analysis has been conducted for these ten specimens by using the ANSYS program (version 13), the load-deflection results of this analysis showed a good agreement with the experimental results. It also has been performed a parametric study that included two variables which were the effect of the presence of circular rings and the change of opening location in the length direction on the specimens behavior. The results of this study showed that the presence of the circular rings in the specimen led to increase its ultimate strength by (53.24%) compared with the non-presence of these rings. While the presence of opening at (30%, 40% and 50%) from the specimen length reduced the strength capacity by (8.76%, 14.23% and 17.88%) respectively.

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CHS: Circular hollow section.

Fy: Yield stress of steel specimen (MPa).

Fu: Ultimate stress of steel specimen (MPa).

t: Thickness of circular hollow section (mm).

D: Outside diameter of circular hollow section (mm).

L: Span of specimen (mm).

c/d: Ratio of compression zone depth to test specimen diameter.

με: Micro strain.

CHAPTER ONE

INTRODUCTION

1.1 General

In recent years, the steel structures have become more popular as construction applications therefore attracted many of research efforts to determine and study the strength and structural behavior of steel sections. In many cases, steel constructions are prepared as alternatives for reinforced concrete ones because of the following (Steel, T., 2011):

1- Structural steel differs from the concrete in its attribution compression strength as well as tensile strength.
2- Structural steel is having high strength, toughness, stiffness and ductile properties therefore, it is one of the most materials used in industrial and commercial structures.
3- Steel can be developed into any shape, which are either welded or bolted together in construction.
4- Steel construction is fast which contributes to reduce the time required for construction the project. It can be disassembled easily without losing the integrity of the structure.

Development of steel in construction structures led to increase the varieties of steel sections that are used as a construction materials. One type of these sections is the structural hollow section which is considered one of the most reliable sections, due to their excellent properties.

1.2 Circular Hollow Sections

Circular hollow sections (CHSs) are the most effective and variable form in the mechanical and construction applications.

In present time, many of the most beautiful and strongest steel structures in world couldn't have been possible without using the circular hollow sections in its construction.

Using the steel (CHSs) in construction applications gives the buildings a better ratio of strength to weight. Increasing the strength to weight ratio led to reduce the using of materials and allow for greater span buildings, this enhances the structural efficiency and reduces the cost (Steel, T., 2011).

1.3 Reasons for Using Circular Hollow Sections

1. CHSs have many excellent properties as a structural element in resistance to bending, axial and torsion. This is due to the uniform distributed of the cross section materials about the polar axis that leads to the good performance of these sections (Chavan, et al., 2014).
2. For tall bridge structures, it is often used the CHSs in their construction, because it is working to decrease their mass and thus reducing the self-weight that contribute in vibration during earthquake. Also it works to minimize their dimensions of foundations and thus saving the construction cost (Hoshikuma and Priestley, 2000).
3. The CHS section offers many advantages in relation to protection against corrosion because of the CHSs have rounded edges and smaller surfaces area than the open sections as shown in Figure (1-1). The closed shape of these sections and the smooth change from one to another at the joints minimize the corrosion protection costs (Agarwal and Chhatwani, 2015).

4. The CHSs offer good advantages for using in the structures that exposed to fluid currents, because these sections give minimum resistance for water and air wind wave loadings as shown in Figure (1-1), (Agarwal and Chhatwani, 2015).
5. In the CHSs, it is possible to change the section strength through change the wall thickness or by using concrete to fill the section without changing the external dimensions.
6. The internal void of CHSs gives possibility for the combination between the strength function and the other functions such as fire protection, ventilation and heating systems as well as to transfer the electrical wires inside the beams and columns (Wardenier, et al., 2002).

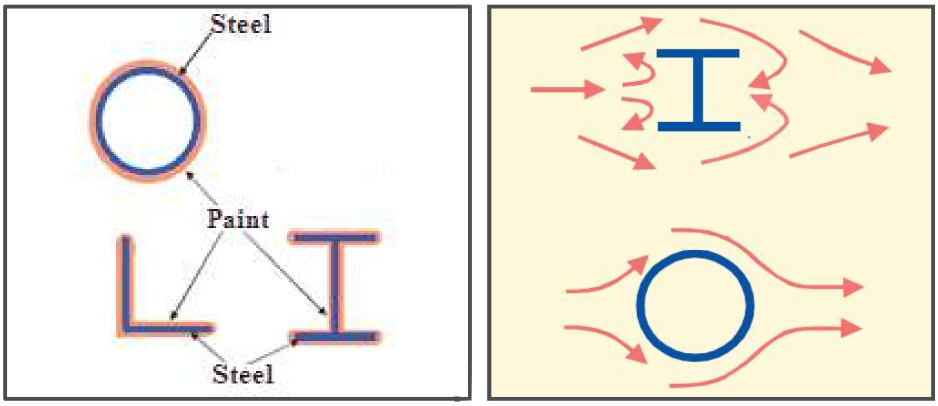

Figure (1-1) Paint surface and Wind flow for circular hollow section vs. open section (Agarwal and Chhatwani, 2015).

1.4 Research Objective

At recent years, the use of the circular hollow sections increased significantly in the structural, architectural and mechanical engineering. This push the researchers to examine the structural properties of these sections. Therefore, this research investigate the circular hollow sections behavior when subjected to bending in order to find out their structural efficiency.

The objective of this research is to study the elastic-plastic behavior of the steel circular hollow sections when subjected to bending through studying the structural behavior, strength and collapse by using specimens with different diameter, thickness and span as well as the presence of square openings.

1.5 Research Justification

In the past, there were a lot of studies about the circular hollow sections but most of these studies mainly focused on the behavior of these sections under axial loads. While the studies that regard to the bending behavior of these sections were little and not comprehensive.

1.6 Methodology and Limitation of Thesis

The experimental program of this study included preparation and testing of ten circular hollow beam specimens up and post of failure stage by using different sizes and with diameter to thickness ratio ranging from 16.93 to 73. The experimental results were analyzed and discussed.

While the numerical program included modeling the same specimens that had been tested in the experimental work in order to compare the results of both programs. And also included the parametric case studies which comprised modeling of six specimens in order to examine the effect of opening location in length direction and the presence of rings on the structural behavior.

1.7 Layout of the Thesis

The present study consists of six chapters as below mentioned:

Chapter 1: The current chapter includes a general introduction about the steel constructions and CHSs, reasons for using CHS, research objective and justification, methodology and layout of the thesis.

Chapter 2: This chapter presents an overview of previous studies and researches that shed light on the behavior of circular hollow sections when subjected to bending.

Chapter 3: This chapter provides the experimental program for the current study, including the results of tests carried out on the steel. It also presents the plan of study that was used for the completion of the tests, sizes of the specimens and the devises used.

Chapter 4: this chapter presents the results that have reached in this study, discussion of this results.

Chapter 5: this chapter includes the numerical study by using the finite elements. It offers a comparative study between the numerical analysis and experimental work as well as other case studies, which have not been experimentally studied due to the limitations of the testing devices.

Chapter 6: this chapter deals with the conclusions that have been reached through the current study, as well as a set of recommendations proposed for future studies.