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Thickness of shear flow zone in a circular RC column under pure torsion

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A R T I C L E I N F O

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A B S T R A C T

This study proposes a rational method capable of analyzing the behavior of circular reinforced concrete (RC) columns under pure torsion with or without axial compression. The developed method is based on the concept of the rotating-angle softened truss model (RA-STM) and incorporates the recently updated material models. In particular, the most important factor in estimating torsional capacity of RC structures – thickness of shear flow zone – is investigated in-depth for the circular RC column and discussed together with other mechanical aspects. The concept of thickness of shear flow zone for rectangular RC members is theoretically well established, while it is not clearly understood for circular RC members. This is due to the lack of existing experimental and analytical research work in this area. Recently, a circular RC column under pure torsion was tested at Missouri S&T. Test results of the column were used to validate the proposed method in terms of overall column behavior and local behavior of each component (concrete, both longitudinal and transverse reinforcement). The comparisons proved that the proposed method was in reasonable agreement with experimental results. In addition, the concept of the proposed method can be applied for any arbitrary section and is free from mechanical assumptions such as concrete cover spalling.

1. Introduction

From a mechanical point of view, torsional behavior of a circular member seems to be simpler than a rectangular one due to linearly distributed shear stresses across the whole cross section. This is true for linear elastic material and within the elastic region for nonlinear materials. However, this explicit phenomenon for a circular member is no longer valid in the inelastic region of a non-linear material such as the post-cracking region of concrete. Since Rausch's [1] space truss model had been developed for the torsional behavior of reinforced concrete (RC) members having arbitrary sections, most research works concentrated on the torsional behavior of rectangular members. Literature on the torsional behavior of a circular RC member, or mostly in the form of RC columns, has not been reported to date. Hence, this paper attempts to investigate the torsional behavior of a circular RC column in detail by developing a rational method incorporating the recently updated material models. In particular, the most important factor in the space truss model, thickness of shear flow zone (t_d), is investigated in-depth along with other mechanical aspects.

The behavior of RC members under shear and torsion can be predicted using the three most well-known two-dimensional truss models: the Modified Compression Field Theory (MCFT) [2], the Rotating-Angle Softened Truss Model (RA-STM) [3], and the Fixed-Angle Softened Truss Model (FA-STM) [4,5]. These theories commonly assume an RC member as assemblies of two-dimensional membrane elements, also called panels, subjected to in-plane shear and normal stresses. Thus, the behavior of an RC member under shear and torsion can be predicted through the knowledge of the membrane element behavior. The behavior of membrane elements were understood by satisfying Navier's three fundamental principles of mechanics of materials: stress equilibrium, strain compatibility, and material laws. Numbers of experimental works have been carried out to establish the analytical models satisfying Navier's principle. Based on these theoretical and experimental studies for membrane elements, current analytical space truss models have mostly been applied for predicting the torsional behavior of a rectangular RC member. This tendency is caused by an easier application of membrane elements to a rectangular member with respect to geometrical conditions than to a nonrectangular member, especially to a circular member. As a result, very limited analytical and experimental studies have been reported on the torsional behavior of a circular RC column.

The most critical issue, when combining the membrane elements to an RC member subjected to torsion, is the proper estimation of the thickness of shear flow zone, t_d, during the torque–twist response. Estimation of t_d for a rectangular member is well established owing to the out-of-plan warping effect, an apparent physical action of a rectangular section member. Although a considerable debate over the estimation of t_d exists between RA- or FA-STM and MCFT with respect to the physical

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