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Structural behavior of cold-formed thick-walled rectangular steel columns

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ABSTRACT

Cold-formed rectangular steel columns with large and thick walls are increasingly applied in engineering recently. The section dimension and wall thickness have increased continuously to 800 and 22 mm, respectively, which causes the significant differences of cold-formed effects between cold-formed rectangular steel columns with thin and thick walls. Therefore, the mechanical performance and design method of cold-formed rectangular steel columns with thick walls should be studied. In this study, two section dimensions (700 mm × 20 mm and 600 mm × 16 mm) were selected for the axial load test and analysis of cold-formed rectangular steel columns with large and thick walls. The conclusions are as follows. (1) The indirect cold-formed rectangular steel columns have lower cold-formed effects than direct cold-formed rectangular steel columns. (2) Cold-formed rectangular steel columns with large and thick walls have high-bearing capacity under axial loads, which are manifested by local plate instability. (3) Calculation formula of ultimate bearing capacity with considerations to local plate buckling is proposed. The calculated and test results are in accordance with numerical simulation results.

1. Introduction

Cold-formed steel is an efficient, economic, and environment-friendly building material with a reasonable section shape, good mechanical properties, and high steel utilization. Cold-formed steel possesses promising application prospects in the modern construction industry [1]. Currently, considerable research has mainly focused on cold-formed steel columns with thin walls. Relative systematic standards and guidelines for cold-formed steel columns with thin walls are issued [2–7]. The demands for cold-formed steel columns with thick walls have increased gradually with the development of cold-formed technology and large engineering construction. With the development of cold -formed steels, the height and thickness of cross-section of cold-formed thin-walled rectangular steel columns has reached 800 mm and 22 mm respectively, which have been used in the Tianjin Wanhui Square Project in China (Figs. 1–2). However, few studies have referred to the mechanical properties and the design method of large-section cold-formed steel columns with thick walls.

Wen conducted an experimental study on the axial bearing capacity of short cold-formed steel columns with wall thickness ranging 7.5–16 mm [8]. Li discussed the reliability of an axial compression member with 8–12 mm thick cold-formed steel columns [9–11]. Chen investigated the ultimate bearing capacity of cold-formed rectangular steel columns with 8–9 mm thick walls [12]. Liu examined the axial compression performance of cold-formed rectangular steel columns with 22 mm thick walls [13].

The previous research on cold-formed thin-walled and thick-walled section steel found that the cold hardening effect is intensified as the thickness increases; where the strength increases by 4% to 34% for thin-walled rectangular steel tube (0.4–6 mm thick) [14–16], but increases by 8% to 41% for thick-walled one (6–16 mm thick) [10,17–20]. For thin-walled cold-formed steel tube made by direct method, the yielding strength in the corner part is 30%–55% higher than that in the flat part, especially when the width-to-thickness ratio is large [10,14–16,19]; the strength of cold-formed member made by direct method is 6%–20% higher than that by indirect method [13,17].

Similar to rolled steel, the cold-formed steel also would experience different failure modes (overall buckling or local buckling) due to different slenderness ratio and width-to-thickness ratio [8,12,21,22], and the local buckling mainly occurred to the welding parts [19,11]. As

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Fig. 1. Overview of Tianjin Wanhui Square Project.

Fig. 2. The construction site of Tianjin Wanhui Square Project.

the thickness grows, the material strength and the cold hardening effect increase, the yielding strength increases by 16%–41% compared to base metal [19,11].

The previous numerical studies for cold-form steel members was usually used FEM analysis, which considering the initial imperfection, material nonlinearity and geometric nonlinearity [5–7,13,14,23]; however, few research concerned about residual stress. The residual stress had some effect on the bearing capacity of cold-formed rectangular steel tube, for example the load bearing capacity would decrease by about 7% and the member would experience earlier failure [12,24–26].

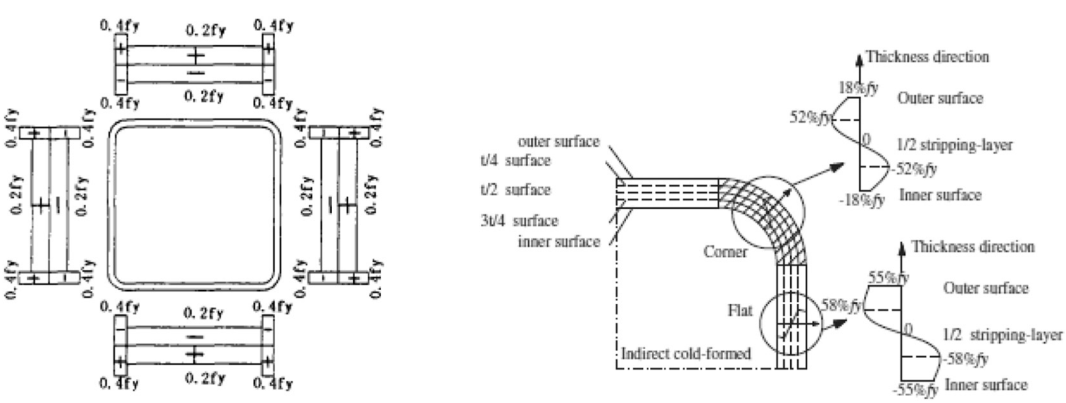

Fig. 3. Longitudinal distribution of residual stress for thin-walled cold-formed rectangular steel tube (0.4–6 mm).