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Experimental investigation on longitudinal residual stresses for cold-formed thick-walled square hollow sections

Lewei Tong [a,b,*], Gang Hou [a], Yiyi Chen [a,b], Feng Zhou [a,b], Kai Shen [c], Ana Yang [c]

[a] State Key Laboratory for Disaster Reduction in Civil Engineering, Tongji University, Shanghai 200092, China
[b] Department of Building Engineering, School of Civil Engineering, Tongji University Shanghai 200092, China
[c] Baosteel Group Corporation, Shanghai 200092, China

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ABSTRACT

This paper presents the experimental study on cold-formed thick-walled square hollow sections with thickness greater than 6 mm. Square hollow sections are formed using two different forming processes of a "direct square" way and an "indirect way from circular to square". Two test methods of the hole-drilling method and the X-ray diffraction method are used to measure the magnitudes and distributions of longitudinal residual stresses. The magnitudes and distributions of longitudinal residual stresses along the section perimeter as well as along the section thickness are obtained in this study. It is shown that the longitudinal residual stresses are in tension at outer surface and in compression at inner surface, and present nonlinear distributions, which seems like "sine" curve along the section thickness. Furthermore, the effects of forming process and cross-section geometry on the magnitudes and distributions of longitudinal residual stresses for cold-formed thick-walled square hollow sections are discussed. At last, two distribution patterns have been proposed for the square hollow sections formed using two different forming processes, respectively.

1. Introduction

Cold-formed structural section steel has been widely used in civil engineering. In early stage, only thin-walled section steel could be manufactured usually with a thickness from 0.4 to 6 mm, for which the cross section may be open shape or closed shape [1]. The thin-walled section steel is often applied in lightweight structures, for example, as beams or columns in a low-story house. Nowadays, it is not a problem to manufacture the section steel with a thickness greater than 6, referred to as "thick-walled" in the paper. In China, it is commonly fabricated to be closed shape such as circular or square hollow section, and used increasingly in columns of high-rise buildings. As for the square hollow section, the maximum size usually comes to 350 mm wide by 20 mm thick.

Cold-formed square hollow section can be formed by rolling an annealed flat strip directly into a square hollow section, which is then welded at the edges. Besides, cold-formed hollow section also can be formed by rolling an annealed flat strip into a circular hollow section first, which is then welded at the edges. The process is completed by further rolling into a square hollow section. These two forming processes are called "direct square way" and "indirect way from circular to square" in this paper, respectively. It is well known that the process of cold forming may produce considerable amount of residual stresses in section steel. Residual stresses will influence structural behavior, particularly for buckling of a compressive member. However, little test data are available on the residual stresses for cold-formed thick-walled section steel in the literature. Therefore, there is need to find out magnitudes and distributions of residual stresses for cold-formed thick-walled section steel. Different conditions such as manufacturing process, cross section shape as well as thickness may cause different residual stress distributions. As for manufacturing process, cold-formed section steel can be fabricated by press bending or by roll bending, but the latter process almost replaces the former one at current stage due to its better effective production [1–3].

The residual stress distributions in cold-formed section steel can be obtained either theoretically or experimentally. The theoretical researches were reported in some references [4–11]. For theoretical approach, in most cases some ideal conditions must be assumed in order to simplify analysis. In fact, the residual stress distributions in cold-formed section steel are rather complex, so experimental approach is the most reliable way to get real distribution information. The most of experimental investigations conducted so far dealt with the thin-walled section steel less than 6 mm thickness and shown that the longitudinal residual stresses were in tension at outside surface, but in compression at inside surface [12–15]. The stresses were assumed to have linear distribution along the thickness as it was difficult to measure the stresses within the thin-walled section. As for cold-formed no-thin-walled section steel, Weng et al. measured transverse residual stresses in C-section plates made by press bending with thickness

* Corresponding author at: Department of Building Engineering, School of Civil Engineering, Tongji University Shanghai 200092, China. Tel.: +86 21 6598 6551; fax: +86 21 6598 6345.
E-mail address: tonglw@tongji.edu.cn (L. Tong).

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