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The assessment of residual stresses in welded high strength steel box sections

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ABSTRACT

Much work on the investigation of the magnitude and distribution of residual stresses in mild carbon steel sections have been made previously. However, limited efforts have been put on residual stress measurements of high strength steel sections. The differences of stress–strain curves and high-temperature material properties between the high strength steel and mild carbon steel demands a necessary study of the residual stresses in high strength steel welded sections. In the present study, three box columns fabricated from Q460 steel plates of 11 mm in thickness with different details were used for the examination. Both sectioning and hole-drilling methods are adopted for the measurement. The measured residual stress distributions of three different box sections are presented, and the corresponding simplified residual stress pattern is proposed. By comparing with the residual stress patterns for mild carbon steel, it is found that the box section fabricated from HSS plates has the lower compressive residual stress ratio. The differences in the measurement by using sectioning and hole-drilling methods are also compared.

1. Introduction

It is well known that residual stresses exist in most structural steel members induced by welding, flame cutting, uneven cooling or cold forming during processes of manufacture and fabrication. Although the internal equilibrium residual stresses are not detrimental to the resistance of cross section for steel members, the presence of residual stress will significantly jeopardize the stiffness of compression members and shorten the fatigue life of steel members under periodical load or dynamic load. In order to investigate the effect of residual stress, the magnitudes and distributions of regular strength steel sections have been extensively investigated in the past decades [1].

High strength steel (HSS, yield strength ≥460 MPa) has been applied in many buildings, spatial structures and bridges [2] by providing benefits when compared with regular strength steel, such as reducing structural dead load and dimensions of members, saving material and space. However, the research works on residual stresses in HSS welded sections is very limited. It is expected that the residual stresses of HSS members are different from regular strength steel, since the stress–strain curves and high-temperature material properties of HSS are different from regular strength steel. For this reason, the ultimate bearing capacities under compressive load and fatigue life under cyclic load of HSS members will be different from mild carbon steel members. For the safe and efficient application of HSS members in civil engineering structures, especially compression members, it is important to evaluate the magnitudes and patterns of residual stresses in HSS members.

1.1. Previous residual stress researches in HSS box-section

In 1967, Nishino, Ueda [3] et al. considered the effect of residual stress on local buckling of HSS stub columns. The work is mainly focusing on the magnitudes and distributions of HSS (yield strength 717 MPa, 800 MPa) welded box sections which has a thickness of plates of 6.5 mm and width-thickness ratios of 26.2 and 44. In 1982, the average residual stress of three square box sections, which have the b/t ratios of 22, 33 and 44, were given by Usami and Fukumoto [4]. The box specimens were fabricated from 6 mm plates, the yield strength of which is 741 MPa. In 1984, the average residual stress of three box sections (thickness is 4.5 mm, yield strength is 568 MPa, b/t ratios are 29, 44 and 58) were obtained by Usami and Fukumoto [5]. In 1992, Rasmussen and Hancock [6] fabricated six welded box struts from 670 MPa steel of 5 mm thick plates to investigate the plate slenderness limits for high strength steel sections. The compressive residual stresses near the centerline of each side for three different sections (b/t ratios are 16, 22 and 28) were measured. In 1995, Rasmussen and Hancock [7] measured the residual stresses near the half-width of each component plate (5 mm) of a welded box column (yield strength 705 MPa, $b/t=18$). In 2001, Uy [8] measured the residual stresses of 3 box sections which were welded together by 5 mm HSS (yield strength 784.2 MPa) plates. The width-thickness ratios are 20, 30 and 40 respectively. The typical values and an idealized distribution for residual stress were given in the results. Clarin and Lagerqvist [9] tested the residual stress in square hollow sections made of high strength steel (nominal yield strengths from 420 to 1100 MPa) by hole drilling method. The test results indicated that, for steels with higher strength than approximate 600 MPa, the tensile residual stresses along the weld bead might be less than the yield strength of base material.

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