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Bearing failure in stainless steel bolted connections

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ABSTRACT

Although the mechanical behaviour of stainless steel and carbon steel differs significantly, design provisions for stainless steel connections in current standards are essentially based on the rules for carbon steel. For bolted connections, the design resistances in EN 1993-1-4 and the SCI/Euro Inox Design Manual for Structural Stainless Steel are based on those in EN 1993-1-8 and EN 1993-1-3 with only some minor modifications. In this paper, an investigation into the bearing behaviour of stainless steel connections between both thick and thin plates has been conducted. Numerical models for previously tested specimens in austenitic and ferritic stainless steel have been developed and validated. The validated models were then used to perform parametric studies to investigate the key variables affecting the bearing failure of bolted connections; these include edge distance e_2, end distance e_1 and plate thickness t. The investigation showed the deformation behaviour of stainless steel connections to be somewhat different from that of carbon steel connections, with stainless steel exhibiting pronounced strain hardening. However, the locations of fracture initiation obtained from the numerical models matched those observed during experimental studies of both carbon steel and stainless steel connections and this feature has been used as the basis for defining a consistent, strength based criterion of failure. The results of the parametric studies have been utilised as the basis for design provisions for bearing failure in stainless steel bolted connections that cover both the ultimate and the serviceability limit states and which are both more economic and more straightforward than the present EC3 provisions.

1. Introduction

Although its usage in structural situations is still only a small fraction of that of conventional carbon steel, stainless steel is steadily growing in popularity [1]. Corrosion resistance is the property most often cited as the reason for its adoption while the high initial material cost acts to limit the number of suitable applications. This situation may, however, be about to alter with the introduction of low nickel (lean duplex) stainless steel [2] at a material cost of around twice that of carbon steel — this could make hitherto prohibitively expensive applications much more cost effective.

This situation of growing popularity has been assisted during the past decade through the production of Design Standards [3–6]. All of these, however, borrow heavily from design rules for carbon steel [7–9] taking little, if any, account of the fundamentally different stress–strain properties of stainless steel. The most important of these for structural behaviour is the rounded uniaxial stress–strain curve, meaning that there is no sharp yield-point and that as the strains increase so material strength continues to rise. Current Design Codes for stainless steel [3–6], therefore, tend to follow rules for cold-formed (or light gauge) steel [8,9] — even though the physical properties of the materials are somewhat different.

Work on the behaviour of stainless steel members, covering local and member buckling [10] has shown that explicit recognition of stainless steel's stress–strain behaviour leads to significant improvements in design capacity. Moreover, concepts such as cross-sectional classification have been shown to be inappropriate [11], leading to the development of more suitable treatments; some of these e.g. the continuous strength method for determining cross-sectional strength, have subsequently been shown to be advantageous when dealing with carbon steel [12].

Joints between stainless steel members may generally involve either bolting or welding, with bolted connections typically favoured on site. The authors [13] have previously reviewed all the available test data on stainless steel bolted connections. This previous study [13] did, however, focus on net section failure, while the present paper covers arrangements in which bearing failure of the plate elements governs. This is done through the use of a comprehensive and rigorous finite element analysis, suitably validated against test data that has permitted several detailed facets of behaviour, not previously fully understood, to be explained. Of particular significance is the development of a rational and consistent

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