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Strength and behaviour of reinforced double-coped beams against local web buckling

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ABSTRACT

Double-coped beams are usually employed to avoid spatial interference when similar elevations of both the top and bottom flanges of the connected beams are required. Due to the removal of the flange parts, the load resistance can be significantly compromised. This paper discusses the effectiveness of various reinforcing strategies aiming to increase the load resistance of newly designed double-coped beams or to upgrade the existing ones. A series of full-scale tests are conducted first, covering a set of reinforcement types and varying coping dimensions. Local web buckling is found to be the governing failure mode for the unreinforced specimens, and the presence of the considered stiffeners can effectively increase the load resistance. In particular, a pair of longitudinal stiffeners for the top cope edge is shown to completely mitigate the risk of local web buckling, and the final failure mode is tensile cracking at the bottom cope corner. The doubler plates, either full-depth or partial-depth, can delay the initiation of local web bucking, and as a result the load resistance is remarkably increased. The effects of the varying reinforcement types and coping dimensions on the utilisation efficiency of section capacities are discussed in detail. A finite element study is subsequently conducted to enable further understanding of key structural characteristics and to help explain some test phenomena. Preliminary design comments and recommendations are finally proposed based on the exiting test and numerical data.

1. Introduction

In steel structures, a similar elevation is often required for the flanges of the secondary beams (stringers) and the primary beams (girders) to satisfy architectural and construction purposes at member intersections. To achieve this, the secondary beams are usually coped at one or both flanges, as illustrated in Fig. 1(a), to avoid interference of the connected structural members, so that sufficient clearance can be provided. From the perspective of structural resistance, however, the load capacities of coped beams can be substantially decreased due to the influence of the coped region. A commonly found failure mode for a coped beam is local web buckling (LWB) [1–4]. In addition, block shear [5–9] and fatigue failures [10–12] of coped beams have also been observed and studied. The basic mechanisms and design solutions of the various local failure modes were comprehensively reviewed by Yam et al. [13]. Lateral-torsional buckling, a global buckling mode, could also occur for coped beams if insufficient lateral restraint is applied along the compressive flange [14–15].

In order to increase the load resistance of coped beams, especially with the aim of improving the LWB performance, various reinforcing strategies have been proposed for single (compressive) flange coped beams (SCBs), as typically shown in Fig. 1(b). A numerical study on SCBs with three types of web stiffener, namely, longitudinal web stiffener (Type A), combined longitudinal and transverse web stiffeners (Type B), and doubler plate (Type C), was first conducted by Cheng et al. [16]. It was concluded that if the stiffeners were appropriately arranged, no reduction of strength occurred for the reinforced beams. The longitudinal stiffener reinforcement and doubler plate types were recommended for hot-rolled steel sections, and combined longitudinal and transverse stiffeners could be adopted for thin web members with $D/t_w > 60$ (D = beam depth, t_w = web thickness). Recently, the benefits of stiffeners on SCBs were further investigated by the authors and co-workers [17–18] via experimental investigations, where a total of 10 full-scale tests were conducted. It was found that for the specimens with longitudinal stiffeners only, the general failure mode was flexural yielding of the full beam section at the location of maximum bending moment followed by web crippling near the end-of-cope section (the section is defined in Fig. 1(a)). The general failure mode for the specimens with combined longitudinal and transverse stiffeners (Types B and D) consisted of flexural yielding of the full beam section at the

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Notation

c	coped length
D	beam depth
d_c	cope depth
L_{Rx}	extension of the stiffener or doubler plate
$M_{AISC,co}$	design moment capacity of coped section based on AISC [25]
$M_{max\text{-}co}$	test maximum bending moment of the beam specimen at the end-of-cope section
$M_{max\text{-}p}$	test maximum bending moment of the beam specimen at the loading position
$M_{el,co}$	yield moment capacity of coped section, either with or without stiffeners
$M_{pl,b}$	plastic moment capacity of uncoped full beam section
$M_{pl,co}$	plastic moment capacity of coped section, either with or without stiffeners
M_u	coped end moment at ultimate applied load
P	applied load
P_u	ultimate applied load
R	coped end reaction
R_f	far end reaction
R_u	ultimate coped end reaction
R_{vy}	shear capacity of coped beam section
R_{wb}	elastic local web buckling capacity of DCBs without stiffeners, according to Cheng's method [16]
t_d	doubler plate thickness
t_f	flange thickness
t_w	web thickness
δ_u	in-plane deflection at ultimate load

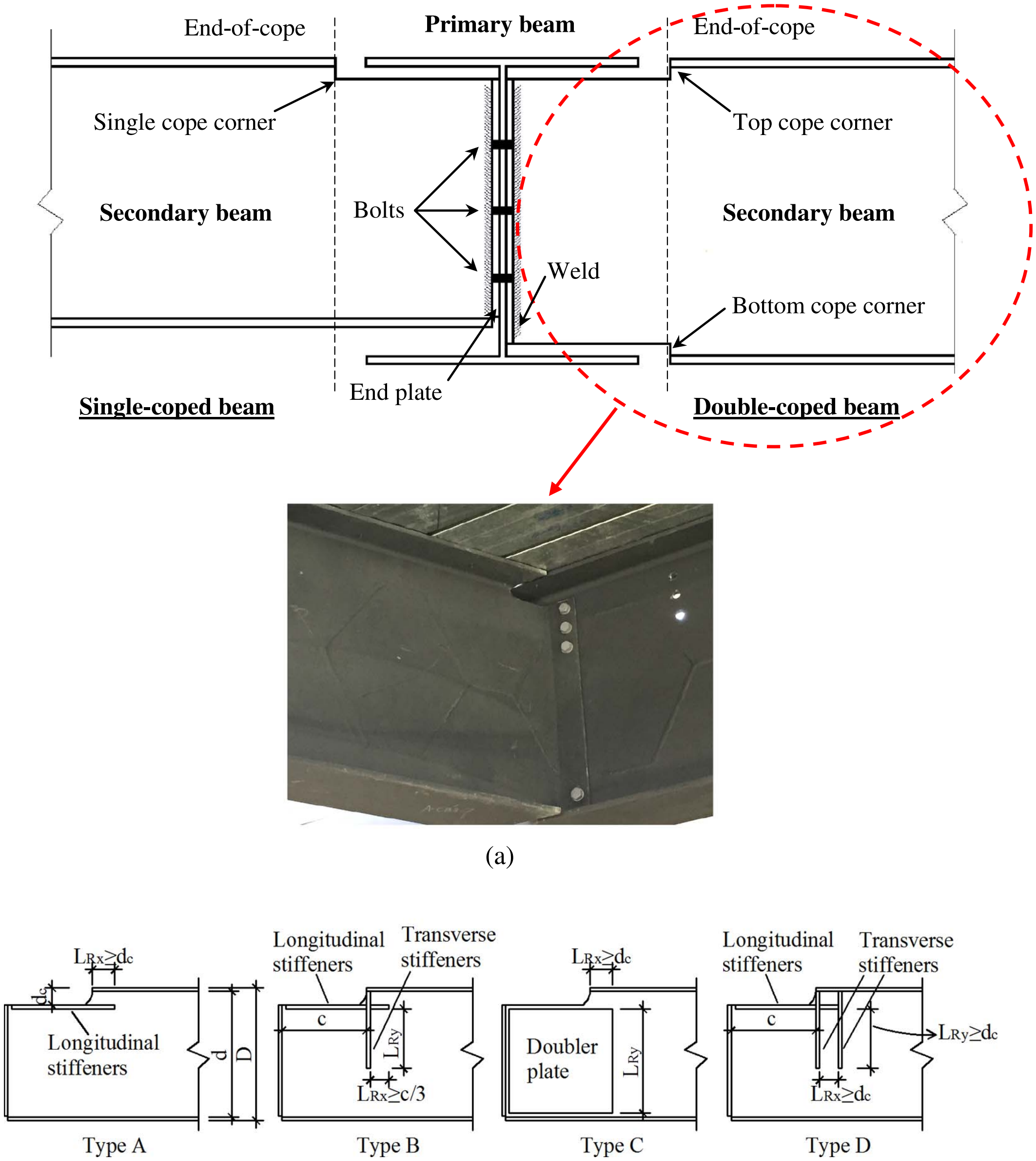

Fig. 1. Detailing of coped beams: a) practical double-coped beams (DCBs), b) typical reinforcing strategies for single-coped beams (SCBs).