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Case study

Compressive strength capacity of light gauge steel composite columns

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ABSTRACT

The axial compressive strength capacity of concrete-filled light gauge steel composite columns was assessed through an experimental program involving twelve long and fourteen stub columns with width-to-thickness ratio of 125 for the encasing steel section. A comparison between concrete-only and confined stub columns demonstrated that the stub column experiences an increase of strength of up to 16% due to confinement. The compressive strength contribution of the light gauge steel section was limited by local buckling. Specifically, the steel-only stub column sections lacking the concrete core experienced, on average, approximately 33% of its full compressive strength. The full-scale composite columns illustrated that the axial compressive strength capacity was controlled by end bearing capacity and local buckling of the light gauge steel. The axial compression strength capacity of the full-scale composite columns was satisfactorily predicted based on end bearing resistance of the concrete core and local strains in the light gauge steel. Furthermore, the 33% strength contribution established from the steel-only sections provided a satisfactory lower bound estimate for the calculation of axial compressive strength.

1. Introduction

Concrete-filled steel box columns are economical composite structural elements that are increasingly being used in the construction of industrial and high-rise office buildings. The composite action of concrete-filled steel columns provides a significant increase in stiffness, strength, and ductility relative to concrete-only or steel-only sections. The concrete core provides axial stiffness, compression strength, and enhances the buckling capacity of the encasing steel. The encasing steel provides confinement to the concrete and thus increases the axial strength and ductility. Typically, these systems consist of thick steel sections where local buckling is not a controlling performance criterion.

More recently, other construction materials have drawn the attention of the construction industry, such as concrete-filled light gauge steel box columns that are imbedded within the cavities of prefabricated modular walls and serve as gravity load resisting elements for low-rise buildings as illustrated in Fig. 1. Such a system provides stay-in-place formwork in addition to structural capacity for the columns. Furthermore, placing the columns within the cavities of modular walls provides open

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Fig. 1. Concrete-filled light gauge steel composite columns imbedded within prefabricated modular walls [1].

space within the building envelope. The axial compressive strength and confinement of composite columns is a function of the slenderness of the walls of the steel section. To simplify design, code provisions limit the width-to-thickness ratio to prevent local buckling prior to yielding. Light gauge cold formed steel composite columns, however, do not meet this requirement.

Several studies have investigated the response of concrete-filled tubular columns, specifically the effect of local buckling and confinement on the strength capacity. Most of these studies have been conducted on short columns encased within relatively thick hollow structural sections (HSS). Experimental testing has resulted in formulations prescribed by design standards, including: American ACI 318-14 [2], Japanese AIJ [3], Australian AS5100.6 [4], British BS5400-5 [5], Canadian CSA S16-14 [6], Chinese DBJ13-51 [7], and European Eurocode 4 [8]. Shakir-Khalil and Mouli [9], Schneider [10], and Sakino et al. [11] conducted experimental studies on square and rectangular composite columns to investigate the effect of column height, cross section and material properties on the axial strength and confinement of long and short concrete-filled steel columns with width-to-thickness ratios ranging from 15.5 to 73.8. The square and rectangular sections did not provide significant confinement to the concrete, and increasing the width-to-thickness resulted in limited post-yield response. Ge and Usami [12] investigated the effect of internal stiffeners on the local buckling capacity of concrete-filled steel box columns by testing short columns with width-to-thickness ratios between 43 and 73. The internal stiffeners affected the strength of the columns as a direct result of improved buckling response of the encasing steel. The improvement, however, was marginal for stiffeners with low rigidity. Yang and Han [13] investigated the effect of partial loading on circular and square concrete-filled steel sections with width-to-thickness ratio of 50. It was observed that under partial concentric compressive loading, the composite columns had reasonable bearing capacity and ductility. Other column shapes and materials have also been studied. Ren et al. [14] conducted tests on composite stub columns with non-typical rectangular or circular sections, and Zhou and Young [15] conducted tests on composite columns with encasing aluminum tubes.

In addition to experimental research, numerical modelling has been used to investigate the response of concrete-filled steel sections. Schneider [10] conducted numerical analyses to study the effect of width-to-thickness ratio on confinement. El-Tawil and Deierlein [16], and Lakshmi and Shanmugan [17] predicted the nonlinear response of concrete-filled steel columns analytically without the local buckling effect. Uy [18] investigated the effect of local buckling on the response of composite beams and short columns with maximum width-to-thickness ratio of 100. This study demonstrated that the axial strength capacity was limited by the contribution of the steel, which was based on the effective width method, and that local buckling had a significant effect on the response of the composite sections. Liang and Uy [19], and Liang et al. [20] used the nonlinear fibre element method to predict the response of concrete-filled box columns that were affected by local buckling of the encasing steel. An expression was developed to predict the stress-strain response and ultimate strength based on the effective width method. Chen et al. [21] investigated the effect of local buckling and concrete confinement of concrete-filled box columns under axial load by testing and numerically simulating a series of stub columns. Tao et al. [22] and Thai et al. [23] used the finite element method to predict the response of composite concrete-filled steel columns for a wide range of width-to-thickness ratios and material strengths. The finite element method has further been used to assess elliptical stainless steel stub sections filled with concrete [24]. Both strength and ductility of the concrete section were improved due to the elliptical encasing steel.

In general, studies on concrete-steel composite columns have focused on sections fabricated from thick, hot-rolled, steel with maximum width-to-thickness ratio of 100. To the best of the author's knowledge, concrete-filled composite columns incorporating light gauge steel sections with large width-to-thickness ratios have not been investigated. Limited studies incorporating thin encasing composite columns have focused on cold-formed steel sections. Ferhoune [25], Ferhoune and Zeghiche [26], Ellobody and Young [27], and Lam and Gardner [28] conducted tests on composite columns consisting of cold-formed steel sections with thicknesses ranging from 2 mm to 6 mm and width-to-thickness ratios of up to 50.