Construction and Building Materials 144 (2017) 686–701

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Review

Recent research on cold-formed steel beams and columns subjected to elevated temperature: A review

Muhammad Faisal Javed [a,*], Nor Hafizah [a,*], Shazim Ali Memon [b,*], Mohammad Jameel [c], Muhammad Aslam [a]

[a] Department of Civil Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
[b] Department of Civil Engineering, Nazarbayev University, Kazakhstan
[c] Dept. of Civil Engineering, Lords Institute of Engineering & Technology, Hyderabad, India

HIGHLIGHTS

- Review on studies performed on CFS members at elevated temperatures is presented.
- Buckling modes, ultimate capacity and critical temperature of members are discussed.
- Research gaps and needs, as well as new directions for researchers, are highlighted.

ARTICLE INFO

Article history:
Received 28 September 2016
Received in revised form 22 December 2016
Accepted 29 March 2017

Keywords:
Cold-formed steel
Elevated temperature
Beams
Columns
Buckling
Fire curves

ABSTRACT

CFS members are more vulnerable to fire due to high section factor (fire-exposed area to the heated volume). Hence, an extensive review of experimental and numerical studies performed on CFS beams and columns at elevated temperatures is presented. Various types of buckling under different loading conditions and influence of different factors affecting the ultimate capacity and critical temperature of members are discussed. A comparison between different test methods and fire curves used around the world is presented. The research gaps as well as recommendations are also proposed. Conclusively, this review will provide basic data for the development of design codes.

Contents

* Corresponding authors.
E-mail addresses: arbabf1@gmail.com (M.F. Javed), hafizah_ramli@um.edu.my (N. Hafizah), shazimalimemon@gmail.com (S.A. Memon).

http://dx.doi.org/10.1016/j.conbuildmat.2017.03.226
0950-0618/

1. Introduction

Cold-formed steel (CFS) structures have been used for multiple construction applications [1–4]. American Iron and steel Institute (AISI) and American Institute for Steel Construction (AISC) design specifications defines the CFS members as: "Shapes manufactured by press-braking blanks sheared from sheets, cut lengths of coils or plates, or by roll forming cold- or hot-rolled coils or sheets; both forming operations being performed at ambient room temperature, that is, without manifest addition of heat such as would be required from hot forming" [5,6]. CFS members are made from cold bent steel sheets of 0.5–3.0 mm thickness [7,8]. According to Steel Framing Alliance report, the use of CFS framing in the recent years has increased expressively in residential, commercial and industrial construction. Statistics shows that CFS framing occupies 39% of commercial applications, with 81% of all non-load bearing cases and 23% of structural applications [9]. Some of the reasons for CFS getting popular are high strength-to-weight ratio and stiffness, economy in handling and transposition, ease of fabrication and installation and flexibility of sectional profiles and shapes [10–12]. Furthermore, the development of various design standards and guides by different countries have also helped in increasing the scope of CFS members [13,14]. Although, in literature, many researchers considered CFS framing as "new" construction material, yet its use started in North America more than 100 years ago [15]. For example, in England and United States, the use of CFS members on experimental basis started in the 1850s while in construction building industry its use can be traced back to 1920s [16].

The behavior of CFS members is completely different from hot-rolled steel members both at ambient [17] and elevated temperature. According to Eurocode [18], hot-rolled steel members are mostly in class 1 or 2 cross-sections while CFS belongs to class 3 or 4. Most of the research carried out in past on CFS was at ambient temperature, which helped in the preparation of design code EN 1993-1-3:2005 [19] at elevated temperature. As a result, the various design guidelines for CFS members at high temperatures are not precise and accurate enough to be practiced by designers and engineers. Nowadays, the methods for hot-rolled steel members presented in EN 1993-1-2:2005 [18] are also used for CFS members with class 4 cross-sections, using the same strength reduction factors and critical temperatures. However, recent studies show that the reduction of mechanical properties with change in temperature is different from EN 1993-1-1:2005 [20]. Certain properties of CFS, like high strength steels and very thin cross-sections, make it more vulnerable to elevated temperatures [21,22]. Apart from above, most of the CFS sections are open and shear-center does not overlap with the center of gravity. The CFS cross-sections are either asymmetric or monosymmetric which, cause the buckling of CFS members at a low level of stress then yield point. Furthermore, the strength, modulus of elasticity and stiffness reduction factors for cold-formed steel is significantly lower as compared to hot-rolled steel [23]. The comparison between reduction factors used for modulus of elasticity found by different researchers for CFS [18,24–27] and hot-rolled steel [28,29] is shown in Fig. 1. Hence, in comparison to hot-rolled steel members, CFS members are more vulnerable to instabilities like local, global and distortional buckling. The different shapes of CFS members used for structural framing are shown in Fig. 2.

The main objective of this review paper is to provide an updated and critical review of cold-formed steel research published in lead-

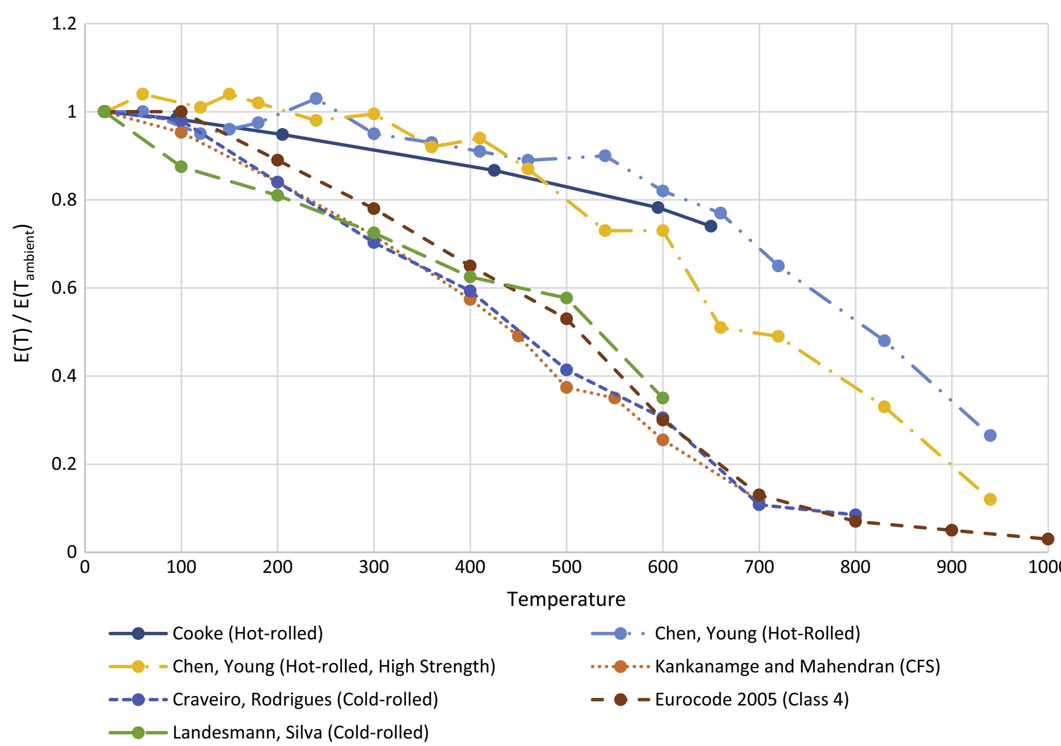

Fig. 1. CFS Vs hot-rolled retention factors for elastic modulus.