Engineering Structures 100 (2015) 599–609

Contents lists available at ScienceDirect

Engineering Structures

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

Finite element prediction of reverse channel connections to tubular columns behavior

H. AlHendi, M. Celikag *

Department of Civil Engineering, Eastern Mediterranean University, Gazimagusa – North Cyprus, via Mersin 10, Turkey

ARTICLE INFO

Article history:
Received 29 December 2014
Revised 18 June 2015
Accepted 19 June 2015
Available online 4 July 2015

Keywords:
Reverse channel
Tubular column
Moment–rotation curve
Standardized function
Kishi–Chen and Richard–Abbott

ABSTRACT

This paper attempts to introduce a standardized moment-rotation function for reverse channel flush end-plate connection (RCC). This function is expressed in terms of the geometric parameters for the purposes of either predicting the connection behavior or incorporating the behavior into a frame analysis computer program. With this objective a parametric study was carried out, based on modeling of 140 RCC under monotonic loading by using the general finite element package ABAQUS. Out of the six currently available functions, the Kishi–Chen and Richard–Abbott models were proved appropriate for fitting experimental M–ϕ data for RCC. The two functions were successfully used in this parametric study to express the relationships for 140 specimens, where the analytical and predicted data are in very good agreement. However, the results of the fitted functions indicate that the dimensionless form of Richard–Abbott function provides more accuracy than Kishi–Chen function. Furthermore, the comparison of Eurocode 3 model with numerical M–ϕ curves illustrated a significant overestimation of the knee region behavior for most of the cases, particularly for RCC with low initial stiffness.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Connections need to be strong enough, with adequate rotation capacity, in order to be cable of successfully transferring the forces and undergoing any required deformation without distress. Hence, there are rules already established for connection adequacy under statics or dynamic loading and further rules are needed for newly proposed connections. Since early 1930s, the beam-column connections research had been focused on the moment-rotation characteristics, which correspond to its actual behavior. The experiments done have clearly demonstrated that all joints exhibit a certain degree of flexibility to an applied loading and they behave in nonlinearly manner. This proves that most of the beam-column connections in practice are semi-rigid. In recent years, much effort has been focused on determining the moment-rotation (M–ϕ) relationships of various semi-rigid connections. For the purposes of either predicting the connection behavior or incorporating the behavior into a frame analysis computer program, the results of moment-rotation (M–ϕ) curves were then modeled by using mathematical representation.

Since the early studies, the mathematical modeling of moment-rotation curves for semi-rigid connections have been developed by using different relationships, which was dependent on the degree of accuracy required in the semi-rigid frame analysis. For example, the non-linear representation of the connection M–ϕ relationship shows sufficient reliable representation of the key parts of the connection behavior. As reflected in the available literature, a number of models were proposed on this basis to model M–ϕ curves [1–12]. In addition, for design purpose, the *Eurocode 3-(revised) Annex J* [13] suggested a non-linear M–ϕ curve, which is very close to tri-linear behavior, with plastic rotational stiffness equal to zero. Table 1 briefly elucidates on some of these models along with the relevant equations. Only a few of these models are close to demonstrating the characteristics of moment–rotation behavior through the full range of loading/rotation [12]. For example; the polynomial model may yield negative tangent stiffness at some value of connection moment. In addition, the parameters implemented in this model have very little physical meaning [14]. Despite the high level of accuracy of the multi-parameters exponential function in curve-fitting process, they need a large domain date which makes them difficult to use. As a rule of thumb, a good mathematical function should be simple with few parameters, easy in determination of these parameters, capable of representing a wide range of connection types, physically meaningful, numerically stable and containing no negative first-derivative [15].

One of the most common models used for predicting the behavior of beam-to-column joints is empirical model. It is mainly based on empirical formulations, which are used to express the

* Corresponding author.
E-mail addresses: hashem.alhendi@cc.emu.edu.tr (H. AlHendi), murude.celikag@emu.edu.tr (M. Celikag).

http://dx.doi.org/10.1016/j.engstruct.2015.06.040
0141-0296/© 2015 Elsevier Ltd. All rights reserved.

Table 1
Different non-linear M–ϕ models [14,15,24].

Type of model	Model name	Year	Function	No. of parameters
Polynomial model	Frye–Morries [1]	1975	$\phi = C_1(KM) + C_2(KM)^3 + C_3(KM)^5$	4
	Picard–Giroux [2]	1976	$\phi = C_1(KM) - C_2(KM)^2 + C_3(KM)^5$	4
Power model	Two-parameter [3]	1936 1979	$\phi = CM^{\alpha}$	2
	Ramberg–Osgood [4]	1943	$\phi = \frac{M}{K_i}(1 + K(M/K_i)^{n-1})$	3
	Richard–Abbott [5]	1975	$M = \frac{(K_i - K_p)\lvert\phi\rvert}{\left[1+\left\lvert\frac{(K_i-K_p)\lvert\phi\rvert}{M_\circ}\right\rvert^n\right]^{1/n}} + K_p\lvert\phi\rvert$	4
	Colson–Louveau [6]	1983	$\phi = \frac{\lvert M\rvert}{K_i}\frac{1}{1-\lvert M/M_u\rvert^n}$	3
	Ang–Morris [7]	1984	$\frac{\phi}{\phi_\circ} = \frac{\lvert KM\rvert}{(KM)_\circ}\left[1 + \left(\frac{\lvert KM\rvert}{(KM)_\circ}\right)^{n-1}\right]$	3
	Kishi–Chen [8]	1987	$\phi = \frac{M}{K_i}\frac{1}{[1-(M/M_u)^n]^{1/n}}$	3
Exponential model	Lui–Chen [9]	1986 1988	$M = M_\circ + \sum_{j=1}^{n} C_j\left[1 - \exp\left(\frac{-\lvert\phi\rvert}{2j\alpha}\right)\right] + K_p\lvert\phi\rvert$	4
	Yee–Melchers [10]	1986	$M = M_u(1 - \exp\left(-\frac{\phi}{M_u}(K_i - K_p + C\phi)\right) + K_p\phi$	4
	Wu–Chen [11]	1990	$\frac{M}{M_u} = n\left(\ln\left(1 - \frac{K_i\phi}{M_u}\right)\right)$	3
	Chisala [12]	1999	$M = (M_\circ + K_p\phi)\left(1 - \exp\left(\frac{-K_i\phi}{M_\circ}\right)\right)$	3

parameters of the mathematical representation of the M–ϕ curve in terms of the geometrical and mechanical properties of the joints. These formulations can be obtained by using regression analyses of data, which can be derived in different ways, such as: experimental testing [1–2,7,16–18], parametric analyses developed by means of Finite Element (FE) models [3,19–22] and analytical or mechanical models [23–24].

In 2007, Ding and Wang [25] suggested the use of reverse channel connection (RCC) to connect I-beam to tubular column (Fig. 1) to overcome the difficulty of access to the internal face of tubular columns from inside of the channel. Since then numerous researches have been carried out, which were mainly concentrated on fire [25–30], earthquake resistance of RCC [31–34] and very

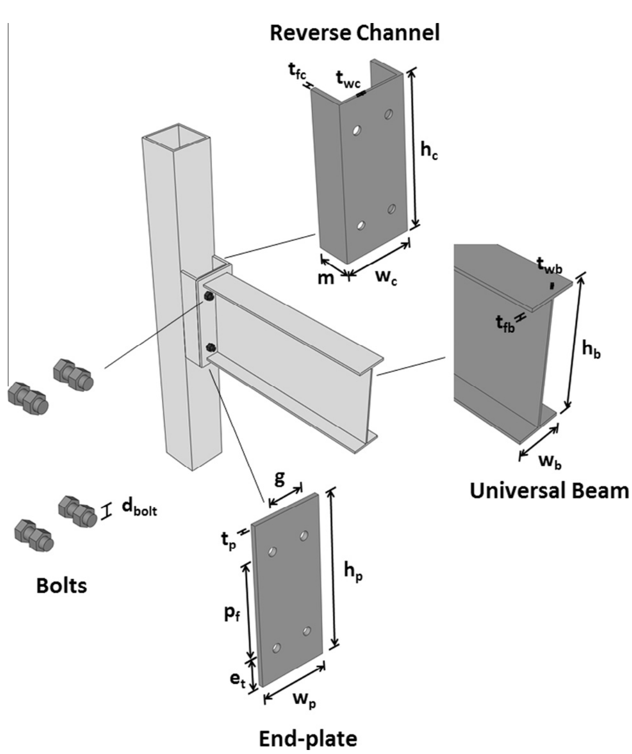

Fig. 1. Typical components of reverse channel connection (RCC).

limited research was done on its basic structural behavior [35–37]. Nevertheless, there is still need for further study to develop the mathematical formulation of the moment-rotation (M–ϕ) relationship of RCC, in order to predict the connection behavior or incorporate the behavior into a frame analysis computer program.

The main objective of this research is to derive a standardized moment-rotation function for reverse channel flush end-plate connection; which is expressed in terms of the geometric parameters. Moreover, the suitability of the representation of moment-rotation curve suggested by Eurocode 3 in its Annex J [13] for RCC is also examined. This research is one more step toward establishing the requirements for the design of semi-rigid/partial-strength I-beam to tubular column connections. It is trying to contribute to the development of a simple and accurate moment-rotation (M–ϕ) relationship for the purpose of structural design and elastic–plastic analysis. For this purpose, a three-dimensional (3-D) FE model using ABAQUS (v.6.12) software was developed and validated for hundred forty specimens with varying dimensions of column sizes, beam sections, channel types, flush end-plates and bolts. Subsequent sections of this paper describe the methodology used for selecting the modeling function; which will be adopted in this study to represent the moment-rotation (M–ϕ) relationship of RCC. The description of the finite element modeling and the results of the validation approach, previously carried out in Ref. [36], are presented. The main results of the parametric study are then presented. The characteristics of the standardized function and the procedures for deriving its parameters, in terms of geometric RCC parameters, are also illustrated. Finally, the suitability of Eurocode 3-Annex J [13] representation for moment-rotation curve for RCC is discussed.

2. Modeling functions

Based on literature survey (Table 1), it is clear that some models are better than others in terms of accuracy and convenience. Therefore, there is necessity to select adequate and accurate function to represent RCC behavior in order to be used in computerized structural analysis. The selection of the adequate model has to be based on the comparison of the curve fitting results with the available experimental ones. Hence, six models; Ang–Morris [7], Kishi–Chen [8], Yee–Melchers [10], Chisala [12], Richard–Abbott [5] and Wu–Chen [11]; were fitted to the dimensionless forms of experimental results by Wang and Xue [35]. The optimization toolbox

Download English Version:

https://daneshyari.com/en/article/266142

Download Persian Version:

https://daneshyari.com/article/266142

Daneshyari.com