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FALLIBLE USE OF STIFFNESS RATIO IN CLASSIFICATION SYSTEMS

R. Hasan — M. JSCE, Muroran Institute of Tech.
N. Kishi — M. JSCE, Muroran Institute of Tech.
W.F. Chen — M. ASCE, Purdue University, U.S.A.

1. INTRODUCTION

The key concept used in devising non-dimensional connection classification systems [1,2] is that the initial connection stiffness R_{ki} (herein after referred to connection stiffness) can be expressed as a multiple of beam stiffness either of full length [2] or of a reference length [1] of the connecting beam. In other words, connection stiffness R_{ki} can be expressed as:

$$R_{ki} = \lambda \frac{EI}{L'} \tag{1}$$

where,

$$L' = L \quad : \text{EC3 [2]}, \qquad L' = 5d \quad : \text{Bjorhovde et al. [1]} \qquad (2), (3)$$

and

λ : stiffness ratio between the connection stiffness and the beam stiffness,
EI : flexural rigidity of the connecting beam,
L and d : length and depth of the connecting beam, respectively.

The stiffness ratios λs used to demarcate rigid and semi-rigid connection zones in EC3 classification system [2] are 25, 25/3 for unbraced and braced frames, respectively, while the counterfigure used for Bjorhovde et al's one [1] is L/2d. This study is aimed trace out the real relation between connection stiffness and beam stiffness.

2. ANALYSIS TECHNIQUE

A portal frame is analyzed as shown in Fig. 1. To track down the effect of the I/L ratio of the connected beam on the numerical analyses, three beam sections: W12×14, W14×22 and W14×38 for 200, 300 and 400 in beam lengths, respectively are chosen. The frame spacing is taken as 300 in. Tle loads applied to the frame are: uniform beam loads W_R = 0.0708 kip/in, W_F = 0.2117 kip/in and concentrated wind loads P_R = 3.9 kip, P_F = 7.8 kip for roof and floor beams/nodes, respectively. Wind load is applied for unbraced frame while for braced frame wind load is taken as non-existent.

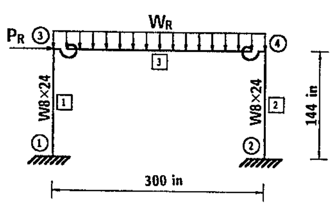

Fig. 1 Portal frame used in analysis

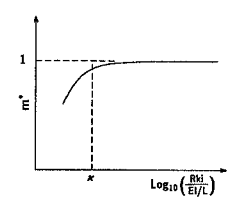

Fig. 2. Ideal m^*–$\log_{10}[R_{ki}/(EI/L)]$ curve

The procedure adopted in the frame analyses are as follows:

(1) Frame analyses are conducted taking all beam-to-column connections are rigid connections. Frame responses (beam end moment, m_1) are calculated by utilizing a second-order elastic analysis program.

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Contact address: 27-1 Mizumoto, Muroran, Hokkaido 050 Tel: 0143−47−3171

(2) Frame analyses are conducted for the same frames replacing the rigid connections with the connections correspond to EC3 [2], Bjorhovde et al. [1] and extended end-plate connections and frame responses (beam end moment, m_2) are obtained. The extended end-plate connections consist of an end-plate extended beyond the beam flange(s), welded to the beam end and bolted to the column flange. A total of 112 extended end-plate connections are utilized in this analysis. On the other hand, the moment-rotation curves for the connections corresponding to the classification systems are prepared based on the prescribed moment-rotation relations.
(3) From the results of frame analyses, $m^* - \log_{10}[R_{ki}/(EI/L)]$ figures are plotted, where m^* is obtained from: $m^* = m_1 / m_2$.
(4) Steps (1) to (3) are repeated for different values of beam lengths.

3. DISCUSSION ON RESULTS OF FRAME ANALYSES

An ideal $m^* - \log_{10}[R_{ki}/(EI/L)]$ figure has been drawn in Fig. 2 based on the results of the frame analysis which reveals that data representing the extended end-plate connections are distributed in the vicinity of $m^*=1$ line on the right hand part of a certain vertical line $\log_{10}[R_{ki}/(EI/L)] = \kappa$. Since, the nodal moments of the frames with real connections are nondimensionalized with reference to those of fully rigid connections, $m^*=1$ for a particular connection obviously means that the connection behavior has sufficient resemblance with that of fully rigid connection. Therefore, a rigid connection zone is defined with the following equation:

$$0.90 \leq m^* \quad \text{for} \quad \log_{10}[R_{ki}/(EI/L)] \geq \kappa \tag{5}$$

With the aid of this definition, the values of κ for different nodes of the frames are determined in such a manner so that most of the experimental data lie in the rigid connection zone of $m^* - \log_{10}[R_{ki}/(EI/L)]$ figures. It is obvious that stiffness ratio λ can be expressed as: $\lambda=10^{\kappa}$. Therefore, obtaining a series of κ from moment analyses, a summerized list of λ is presented in Table 1. This table reveals that the value of stiffness ratio λ varies considerably with the variation of I/L ratio of the connecting beam. This goes contrary to the EC3 [1] proposition that connection stiffness can be expressed as a constant multiple of beam stiffness. Since stiffness ratio λ correspond to Bjorhovde et al.'s classification [1] are expressed in terms of L/d, corresponding values shown in Table 1 reflect obvious inconsistency.

Table 1 List of stiffness ratio λ from frame analysis (node 3)

Length L (in)	I/L (in^3)	Value of stiffness ratio λ					
		Unbraced			Braced		
		Present study	EC3 [4]	Bjor. [3]	Present study	EC3 [4]	Bjor. [3]
200	0.443	28.2	25	8.4	11.5	8.3	8.4
300	0.663	19.9		10.9	11.2		10.9
400	0.963	17.8		14.2	9.1		14.2

4. CONCLUSION

Showing a significant disagreement with the classification systems, the frame analysis conducted in this study reveals that the connection stiffness can not be expressed as a constant multiple of beam stiffness. Therefore, the use of stiffness ratio between connection and beam in devising connection classification system is fallible.

REFERENCES

[1]Bjorhovde, R., Colson, A. and Brozzetti, J. (1990), "Classification System for Beam-to-Column Connections" , *Journal of ASCE*, 116 (ST11), pp. 3059-3076.
[2]EC3 Code (1992), Design of Steel Structures, Part 1.1, European Committee for Standardization, CEN, Brussels.