Influence of Semi-Rigid Joints on the Behaviour of Steel Beam-Column Structures

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Summary

Conventional analysis and design of structures used to assume that connection behaviour of beam-columns are either rigid or pinned. However, experimental observations showed that all connections used in practice have stiffness which falls between these two extremes.They are classified as semi-rigid connections or flexible joints.

The beam-columns connection flexibility is caracterised by a moment-rotation curve ($M - \Theta$) which is nonlinear.

The rotation deformation represents the total response of the connection and the ($M - \Theta$) relation defines the connection behaviour.

This rotational stiffness affects significantly the behaviour of a flexibly connected frames.
In this paper, a practical method of analysis taking into account the rotational stiffness, is presented.

Introduction

In steel structures, the behaviour of beam-columns joints are classified semi rigid [1,6]. Because of the large number of the parameters being able to influence this behavior, it becomes very complex to study.

The sources of deformabilities are multiple and the most importants which cause the semi-rigidity of the joints are the deformation of the fasteners according to the assembled parts (bolts, extended plates, etc), kind of connections and their position [2], and the local deformations (web, flanges etc..) of the assembled elements (beam-columns).

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Because of the significant number of parameters being able to influence the behaviour of the joints do not make easy their study.

However, two essential characteristics are taken into accounts: initial rigidity and ultimate moment [4]. On these two parameters will depend modeling and the choice on the model suggested.

Formulation

The theoretical approach aims at translating into mathematical language the simple and easily usable behavior, often complex, of the various parts of the joint and the various bodies of assembly.

The curve moment rotation of a node is nonlinear [5].In its form exponential (1), it is presented in the form [6]:

$$\Theta = kM^{\alpha} \tag{1}$$

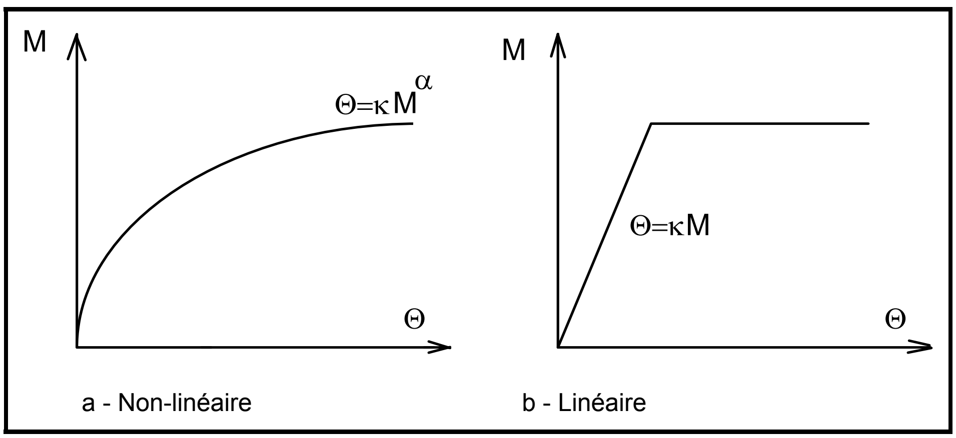

figure 1: Real behavior of the joint (a) and its linear idealization

The bilinear idealization of the moments rotation curves and its sedentary character is justified within the framework of a practical dimensioning for which a globalisation of the characteristics of deformabilities of the joints is essential.

The beam column connections flexibility is characterised by a moment rotation curve which is nonlinear over pratically the entire loading range (fig.1). Since the axial and shearing deformations are usually small compared to the rotational deformation.

Thus, the rotational deformation represents the total response of the connection and the ($M-\Theta$) curve relationships defines the joint behaviour.

The intern forces are calculated by the well known relation

$$[K_e]\{U_e\}=\{F_e\} \tag{2}$$

The matrix of rigidity is given in the local reference below by:

$$\overline{K_e}=\begin{bmatrix} k_{11} & k_{12} & k_{13} & k_{14} \\ k_{21} & k_{22} & k_{23} & k_{24} \\ k_{31} & k_{32} & k_{33} & k_{34} \\ k_{41} & k_{42} & k_{43} & k_{44} \end{bmatrix} \tag{3}$$

where :

k_{ij} :élément of the matrix of rigidity, which is the reaction according to the direction "j" due to unit displacement following the direction "i"

For the element k_{24} of the matrix $\overline{K_e}$, its expression is given by

$$k_{24}=\frac{6\omega}{4(1+3k_1\omega)(1+3k_2\omega)-1} \tag{4}$$

where k_1, k_2 elastic constants of the springs in rotation and $\omega=\dfrac{EI}{l}$.

And for the moment M_i , we have :

$$M_i = -\frac{(1+2A_2)}{4(A_1+B)(A_2+B)-(1-2B)^2}\,\frac{6\omega}{l} \qquad (5)$$

Where $A_1 = (1+3k_1\omega)$, $A_2 = (1+3k_2\omega)$ and $B = \dfrac{3\omega(C_1^v + C_2^v)}{l^2}$.

C_1^v, C_2^v being the elastic constants of constantes of the vertival springs and C_1^u, C_2^u the elastic constants of axial springs.

Application

With an aim of illustrating the importance of semi-rigidity one proposes to study, the example of the frame (fig.2), whose curve characteristic of all the semi-rigid assemblies is such as:

$$\omega = \frac{EI}{l} = 15067\,KN.m$$
$$W = 35KN/ml$$

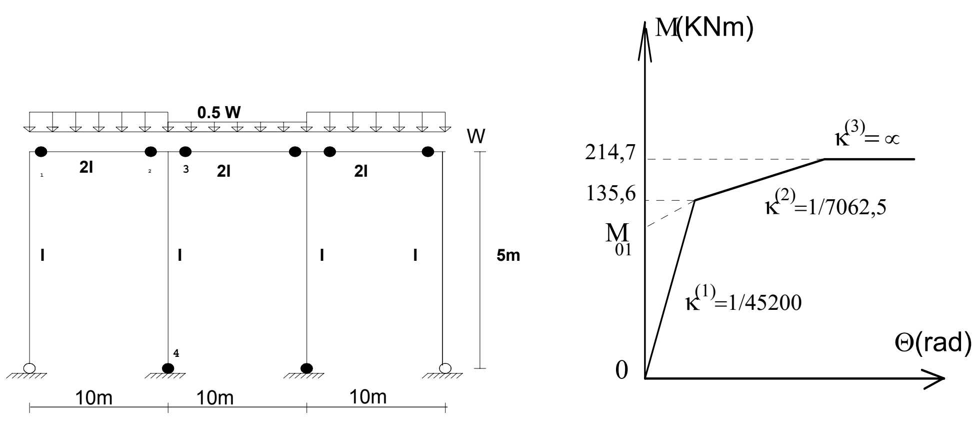

Figure 2: Example [5].

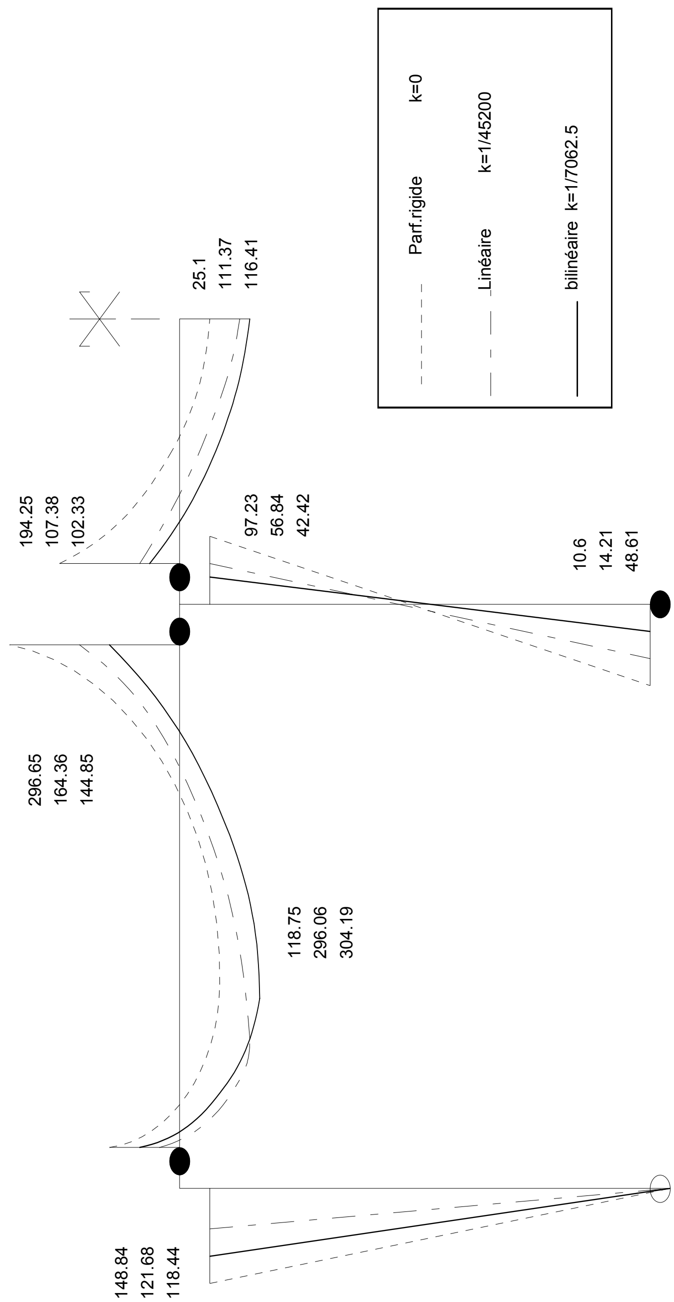

Figure 3 : Comparaison of the moment diagrams.

The moment diagrams for semi rigid joints with linear and nonlinear modelisation, and the rigid joints is given below :

Conclusion

The semi-rigid joints influence considerably the distribution of the bending moments in the hyperstatic frames. In the treated example, the difference between the bending moments (fig.3) for the frame with semi-rigid joints and that with with rigid jointd are approximately 30%. This shows us an important modification of the internal efforts.

The modeling suggested is also extended to the non-linear case (bilinear modeling). Thus, the effects of the flexibility on the structures are determining and the taking into account is more than necessary, because real.

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