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UNIFORM CLASSIFICATION SYSTEM FOR RHS VIERENDEEL BEAMS CONNECTIONS

In the 70's and especially in the 80's the loading response of frames with partial-rigid connections was extensively studied. These studies led to the conclusion, that the traditional model of joint behaviour should be replaced by more advanced models. So, in a design process of the particular structure for any moment we need to know the following data about proposed connections:

a) What are their initial (secant, tangent) stiffnesses?

b) What are their elastic loads?

c) What are their ultimate loads?

d) What are their rotation capacities ?

The first three of these are necessary to calculate the serviceability and ultimate load limits . The fourth ensures stress distribution and the safe working of joints. The uniform classification system (UCS) developed by the author is one possible approach, Fig. 1. The solution to this problem is not obvious. However, the development of a classification system for different connections seems to be the path we ought to follow. The basic concept was presented a few years ago (EC-3 1992, Bjorhovde, Brozzetti, Colson 1990, Szlendak 1995). Research efforts are focused on the easy transformation of a particular connection to a uniform one, which could be recognized by numerical procedures Some information is available from practice. Very often the geometry of the structure has already been decided by the architect if not in a direct then in an indirect way. Reasonable dimensions of beams and columns are not difficult to establish and in the preliminary design the steel grade is usually assumed. This basic information about a steelstructure framework is enough to define its uniform connections.

This system is suitable for any beam-to-column connection.

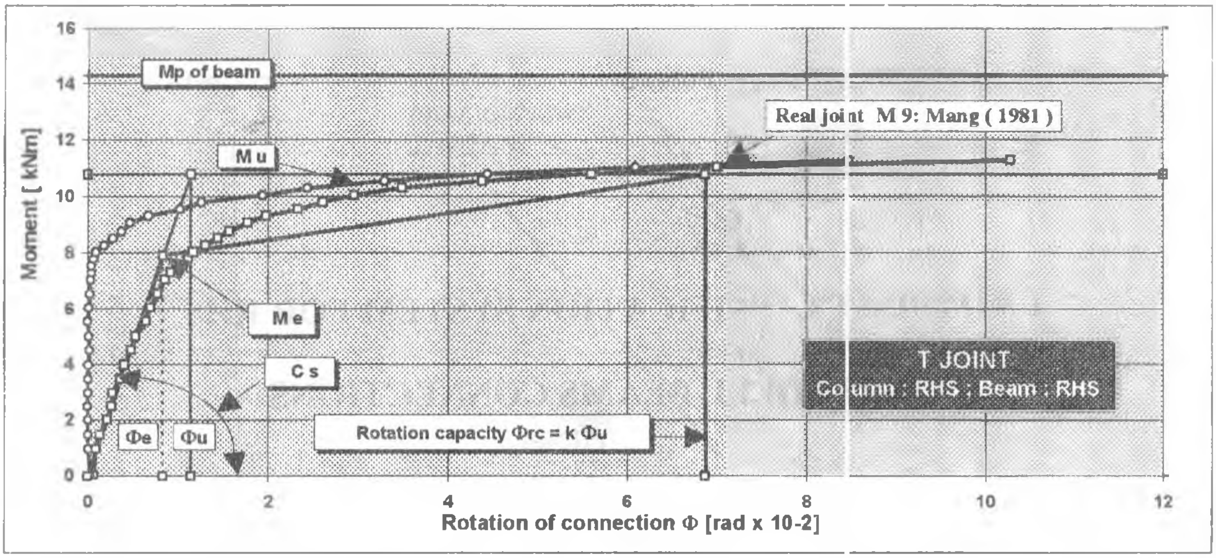

Fig. 1 Uniform classification system (UCS)

where: C_c - initial stiffness of connection, C_s - secant stiffness of connection, M_e - elastic load of connection, M_p - plastic moment of beam section, M_u - ultimate load of connection, Φ_e - elastic rotation = M_e / C_s, Φ_u - ultimate rotation = M_u / C_s, Φ_{rc} - rotation capacity = $k\ \Phi_u$, k - rotation capacity coefficient, = 4 for RHS sections, or = 6 for seismic requirements.

1. CLASSIFICATION COMPONENTS

1.1 SECANT STIFFNESS

The stiffness of joints , especially when they are rather flexible then rigid ones, is very often overestimated. Generally, a designer is particurally interested in the stiffness of connections for serviceability load limit of structure, which are sufficiently less then one predicts by the initial stiffness equations. Anyway, the above ideas suggests that some smaller stiffness could be the better estimation.

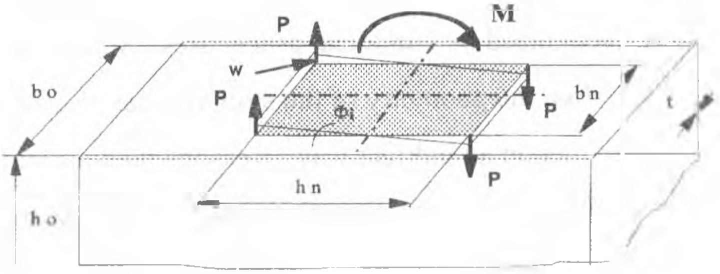

Fig. 2 Vierendeel branch to chord connection

where: b_n - width of branch section, b_o - width of chord section, h_n - depth of branch section, h_o - depth of chord section, M - moment (general), P - load, t_o - wall thickness of chord section, w - displacement,Φ_i - initial rotation

β - branch to chord width ratio = b_n/b_o, η -branch depth to chord width ratio = h_n/b_o, λ_o - slenderness of chord flange = b_o/t_o.

The state of the art of this problem leads to more complex conclusions because when the structure is under serviceability load conditions particular conections are in the more or less effort state. So, the tangent stiffness, different for the each connection seems to be a best idea. However, the suitable analitical functions of M - Φ relations are very rare available and fit by them the real experimental data is often not better then the secant approximation of the tangent stiffness. The Autor suggests that the secant stiffness could be calculated for the serviceability load of connection what is proposed to be assumed equal to 0.8 of the elastic load of joint, eq. (1.3).

After careful study of parameters' influence and when the appropriate resistance factor is assumed, such that the level of confidence 0.05 has been satisfied, then after the analysis of 215 test results the median value of secant stiffness is proposed :

$$C_s = 0.1\,E\,t_o^3\,\beta^2\,\eta^2\,\lambda_o^2 \qquad (1\ 1)$$

1.2 ELASTIC LOAD

Significant numbers of internationally proposed solutions are available to predict the yield and elastic load of the beam-to-column RHS connections. Especially Mang et. al. (1981), Szlendak (1982) and Design Guide by Packer et. al. (1992) give suitable formulae to solve this problem. In practical calculations, however, these are rather too complicated to use in the classification system. The elastic load formula should have at least the follows components :

$$M_e = k_e\,f_e(\beta, \eta, \lambda_o)\,\frac{f_{yo}}{f_{yi}}\,M_p \qquad (1.2)$$

After analysis of 215 test results and the careful study of the parameters' influence, the following formula is suggested :

$$M_e = 25\sqrt[6]{\frac{\beta\,\eta^3}{\lambda_o^8}}\;\frac{f_{yo}}{f_{yi}}\,M_p \qquad (1.3)$$

, where :

$0.35 \leq \beta \leq 1.0,\ 0.50 \leq \eta \leq 2.0,\ 10 \leq \lambda_o \leq 35$

1.3 ULTIMATE LOAD

Up to now, no ideas have been available for how to estimate the ultimate load of such connections. The experiments show that significant increase in the joint strength over the elastic load is observed especially for small values of parameter $\beta < 1$ and large values of parameter λ_o. So, the ultimate load prediction should have the follow components :

$$M_u = k_u\, f_u\,(\beta, \eta, \lambda_o)\, M_e \qquad (1.4)$$

where k_u - coefficient, f_u - function.

After many simulations the median value of ultimate load is estimated as follows :

$$M_u = 19\,\sqrt[6]{\frac{\beta^2\,\eta}{\lambda_o^7}}\;\frac{f_{yo}}{f_{yi}}\,M_p \qquad (1.5)$$

The fit of the test results is not as good as for elastic load but they are influenced by many other variables which involve additional deviations.

1.4 ROTATION CAPACITY

A lot of parameters influence the rotation capacity of structural connections. For the beam-to-column welded joints with rectangular hollow section at least two main problems should be considered. The main geometrical and material properties are one of the most important factor. The second one, is the weld geometry and the quality of the weldment It is rather clear that during the serviceability and predicted design load conditions the deformation of the structure and the rotation in their joints do not exceed the elastic deformation limit For the connections it means the elastic rotation limit Φ_e . However, the real connections always must have the larger rotation then above limit. This is necesary for save work of the structure and for the expected reserve of its failure load capacity. Internationally, there is no agreement up to now , what should be the rotation limit of structural connections. Bjorhovde, Brozzetti, Colson (1990) proposed that for the compact sections and for RHS members $\Phi_{rc} = 4\,\Phi_u$ However, for the seismic conditions $\Phi_{rc} = 6\,\Phi_u$ is rather suggested. For the UCS $\Phi_{rc} = 6\,\Phi_u$ is adopted. So, the rotation capacity is proposed as :

$$\Phi_{rc} = 1140\ \sqrt[6]{\frac{\eta}{\beta^4 \lambda_o^7}}\ \frac{1}{\beta\,\eta^2 \lambda_o^2}\ \frac{f_{yo}}{f_{yi}}\ \frac{M_p}{E t_o^3} \qquad (1.6)$$

2. CONCLUSIONS

The aim of this work is to provide a practical method of implementing partial-rigid connections in advanced numerical calculations of Vierendeel girders made of RHS members

For this reason the uniform clasification system (UCS) has been established. The simple relations between M_e, M_u and M_p define a particular design situation. For calculating the secant stiffness, eq. (1.1) is proposed.

Elastic load M_e can be calculated from the three formulae. The modified Packer et al. (1992) estimate is slightly better than the modified Szlendak (1982) estimate and this one only slightly better than the simplest one by eq. (1.3). All of these predictions are comparable. So, the better known Packer et. al. (1992) modified prediction is a good approach in practical applications.

The other classification components have had no alternatives up to now and the predictions suggested in this paper are recommended. In a particular situation the rotation capacity of connection Φ_{rc} could be less then $6\,\Phi_u$ or could be limited by crack initiation. For such cases, experimental data (e g. data bank Szlendak et. al. (1995)) provide the required information.

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