Critical stiffness of horizontal support at the eave by frames with semi-rigid joints

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The effect of a bracing system in the plane of the roof or the supporting effect of the cladding can be considered as a semi-rigid horizontal support of the frame structure at the height of the eave. The stiffness of this horizontal support has significant effect on the critical force of the column. By increasing the stiffness of the support at the eave, at low rigidity values, the critical force of the columns increases significantly. After a special point the further increasing of the support stiffness will not result increase in the critical force. This value of the stiffness is defined as the critical stiffness.

Columns of simple steel frames with semi-rigid base joint and semi-rigid beam-to-column joint will be examined in this work. Two kind of method of defining the critical stiffness will be presented. The examinations are carried out in the plane of the frame.

The first method is based on the matrix displacement method. The stiffness matrix of the frame consists of twelve rows and twelve columns. It contains stability functions. This way the stability problems can be examined. The nodes at the beam-to-column joints are supported horizontally with the use of a semi rigid support, and are loaded with vertical forces. In the first step, the critical force of the frame is defined with the assumption of high value of stiffness of the horizontal supports at the beam-to-column joint. If the determinant of the stiffness matrix equals to zero, that means stability problem by the examined structure. Conventional method of defining the critical force is, calculating the value of the determinant in every load steps. The change of the sign of the determinant means stability problem. In the second step there is a second iteration cycle. In this cycle the loading force is the critical force, calculated in the first step. The variable is the stiffness of the horizontal support at the beam-to-column joint.

The second method is based on the equilibrium equations of the sway and non-sway kind of displaced shape of the column. The critical force of the column with given cross section and length, depends on its restraint conditions. On the bottom of the column, the only variable is the rotational stiffness of the base joint. Horizontal and vertical supports are assumed to be infinite rigid ones. The displacement of the top of the column is only restricted with the use of a semi-rigid horizontal support. The stiffness of the rotational support of the top end of the column depends on the stiffness of the beam-to-column joint and the relative stiffness of the beam.

This method also has two steps. At the first step, the critical force of the column is calculated in the non-sway failure mode. This is iteration operation, as by the former method. In this case, only a certain part of the stiffness matrix of the column is examined. The starting value of the load in the iteration, is the Euler force of the column with pinned supports at both ends. This way, the non-sway critical force of the structure can be calculated much faster compared to the first method. On the basis of the equilibrium equations of the sway kind of displaced shape of the column the critical stiffness can be calculated with the use of an explicit formula.

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