INFLUENCE OF RESTORING-FORCE CHARACTERISTICS OF BRACES ON DYNAMIC RESPONSE OF BRACED FRAME

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SYNOPSIS

Dynamic response analysis of a single-story braced frame is presented. The hysteretic characteristics of the bare frame is assumed to be bi-linear, and the restoring-force of braces is evaluated by the hysteresis function proposed by the author and/or computed by the detailed numerical method. Both results are in good agreement, and it is confirmed that the proposed restoring-force function of a single brace can be applied to the response analysis with enough accuracy.

A parametric study using the proposed function shows that the ductility response of the braced frame much depends not only on the brace slenderness but also on the strength ratio of columns to braces.

INTRODUCTION

Braces play an important role on the earthquake resistant property of a steel structure. So, it has been desired to develope the simple and accurate mathematical expression, which approximates well the actual hysteretic behavior of steel braces. Formulated expressions should realize the following properties: 1) The axial force of a single brace subjected to random displacement history is explained as the explicit function of the axial displacement, and 2) the deterioration of strength and rigidity during the repeated loading, which is characteristic of steel braces, is precisely estimated. The author and others proposed the mathematical expression of the hysteretic rule of a single-brace at the 6 WCEE (1), which seems to satisfy the above mentioned properties better than other proposals. Although it was confirmed that the proposed formula well approximates the static test results of single brace under alternately repeated load, it must be certified that the proposed function can be applied to the dynamic response analysis with enough accuracy.

In this paper, dynamic response analysis of a single-story braced frame is presented where the hysteretic characteristics of braces is evaluated by the detailed numerical analysis (2), and the results are compared with the solution where the restoring-force of the brace is estimated by the proposed hysteresis function. A parametric study using the proposed function is also performed and the influence of the restoring-force characteristics on the maximum response is discussed.

HYSTERETIC BEHAVIOR OF A SINGLE BRACE

Formulated loop Based on the proposed hysteresis function (1), shown in Fig. 1, the non-dimensional axial force n of the brace is expressed as the single-valued continuous function of the non-dimensional axial displacement δ, untill the next unloading occurs, provided that the characteristic points A, B, P and Q, in Fig. 2, are determined at the latest unloading point.

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n = \begin{cases} -f_c(\delta^B + n_o - \delta) & : \delta \leqq \delta^Q, \ \dot{\delta} < 0 \quad \text{[Stage C]} \\ n^Q + (\delta - \delta^Q)\cdot\dfrac{n^P - n^Q}{\delta^P - \delta^Q} & : \delta^Q < \delta < \delta^P \quad \text{[Stage D]} \\ f_t(\delta^A - \delta) & : \delta^P \leqq \delta < \delta^A, \ \dot{\delta} > 0 \quad \text{[Stage B]} \\ 1 & : \delta^A \leqq \delta, \ \dot{\delta} > 0 \quad \text{[Stage A]} \end{cases} \tag{1}
$$

$$f_t(x) = (p_1\cdot x + 1)^{-3/2}, \quad f_c(x) = (p_2\cdot x + p_3)^{-1/2}$$

$$p_1 = 1/(3.1\cdot n_E + 1.4), \quad p_2 = (10/n_E - 1)/3 \geqq 0, \quad p_3 = 4/n_E + 0.6 \geqq 1$$

where n_E is the ratio of the Euler load of the brace to the limit axial force, and n_o is the solution of the following equation.

$$p_2\cdot n_o^3 + p_3\cdot n_o^2 - 1 = 0 \tag{2}$$

At the unloading point, the characteristic points A, B, P, Q and the auxiliary characteristic points C and D in Figs. 3(a),(b) should be defined again. Fig. 3(a) shows the case of the unloading at Stage B,

$$\delta^A = \delta^C$$

$$\delta^B_{new} = \delta^B_{old} + (\delta^A - 1 - n_o - \delta^B_{old})\cdot(\delta - \delta^P_{old})/(\delta^A - \delta^P_{old})$$

$$\delta^P_{new} = \delta, \quad n^P_{new} = n$$

$$\delta^Q_{new} = \delta^D = \delta^B_{new} - (\delta^A - \delta)/q_1, \quad n^Q_{new} = -f_c(\delta^B_{new} + n_o - \delta^Q_{new})$$

the case of the unloading at Stage C is shown in Fig. 3(b),

$$\delta^C = \delta^A + \ln\{q_2\cdot(\delta^D - \delta) + 1\} - q_3\cdot(\delta^B - \delta^D) \geqq \delta^A$$

$$\delta^Q_{new} = \delta, \quad n^Q_{new} = n$$

$$\delta^P_{new} = \delta^C - (\delta^B - \delta)\cdot q_1, \quad n^P_{new} = f_t(\delta^C - \delta^P_{new})$$

and the case of the unloading at Stage A is expressed as follows,

$$\delta^A = \delta^P = \delta, \quad \delta^B = \delta^D = \delta^Q = \delta - 1 - n_o, \quad n^P = 1, \quad n^Q = -n_o$$

where q_1, q_2 and q_3 are the constants.

$$q_1 = 0.3\cdot\sqrt{n_E} + 0.24 \leqq 1, \quad q_2 = (3 - 1/n_E)/10, \quad q_3 = 0.115/n_E + 0.36$$

The initial values of these parameters are as follows.

$$\delta^A = \delta^C = \delta^P = n^P = 1, \quad \delta^B = \delta^D = \delta^Q = n^Q = -n_o$$