I-116 A DESIGN PROCEDURE FOR IN-PLANE FAILURE OF STEEL FRAMES BY ELASTIC FINITE DISPLACEMENT ANALYSIS

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1. INTRODUCTION

Structural steel design codes are revised continuously to incorporate the latest developments in structural engineering. When codes were revised in the past, it seems that structural designs are based on linear small displacement analysis except in a few simple cases. The analysis does not predict the carrying capacity of structures. The nonlinear behavior such as geometrical and material nonlinearities needs to be considered to predict the carrying capacity. Therefore, it was included in the past in the form of clauses in codes to guarantee safety of structures. Structural theory has developed extensively. Computing facilities have developed even more and the cost of computation is getting much cheaper. The efforts beyond linear small displacement analyses are better made in the analyses of practical designs, if they lead to more economical and safer designs.

2. PROPOSED METHOD

An equivalent initial crookedness of the shape of the eigenvector with a constant maximum magnitude, α, is given to members of frames in such a way that the first yielding of a fiber using finite displacement elastic analysis agrees closely with the carrying capacity of frames. In this study, the failure of a structure is defined by the formation of the first plastic hinge in a structure. The stress is to be evaluated by $\sigma = N/A \pm Mh/fI$, where σ=axial stress; N=axial force; A=area; M=bending moment; f=shape factor; I=moment of inertia; and h=distance from an extreme fiber to the centroid.

3. CARRYING CAPACITY OF COLUMNS

The exact carrying capacities of six simple columns as shown in Fig.1 were evaluated numerically by the nonlinear finite displacement analysis. The stress-strain relationship was assumed to be elastic perfectly plastic. The shape of eigenvector was selected as for the initial crookedness with the maximum magnitude equal to *0.001* of the total length *L* of each column. The presence of compressive residual stress of *25 %* of yield strength with welding type pattern is incorporated.

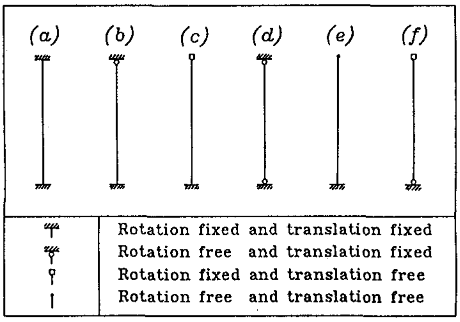

Fig.1 Simple Columns

4. EQUIVALENT INITIAL CROOKEDNESS α

Following the proposed procedure, the value of α has to be selected. The applicability of the proposed method depends on the accuracy of predicting the carrying capacities of various structures using the constant α. The magnitude of α was selected for the best fit to the exact column strength curves for the six columns shown in Fig.1, which resulted in to be *0.0033 L*. The carrying capacities, P_u, by the proposed method together with the numerically exact capacities, both non-dimensionalized by the yield load P_y, are plotted in Fig.2, where the maximum error of the carrying capacity by the proposed method is mere

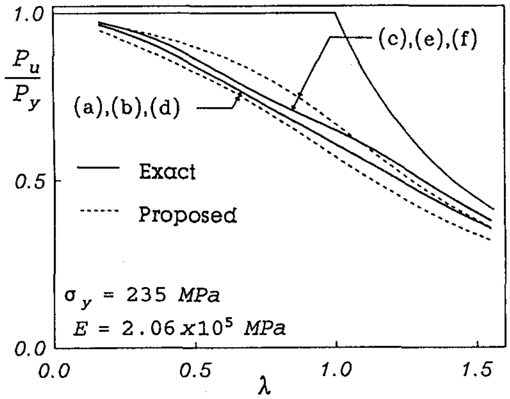

Fig.2 Exact and Proposed Carrying Capacity Curves

10 % compared with the numerically exact carrying capacity.

4. STRUCTURES FOR APPLICABILITY CHECK

Various numerical examples were selected to check the accuracy of the proposed method in predicting carrying capacity and hence to evaluate the applicability of the proposed design procedure. They are: (1) a stepped column consisting of two different sections of equal length, W12x120 and W12x210; (2) a tapered column, of which the dimension varies linearly from W12x120 at one end to W12x210 at another end; (3) a W12x210 two span continuous column of equal span lengths loaded at the middle support; (4) a beam-column, W12x210; and (5) a simple frame subjected to a concentrated load in the mid-span of the girder.

5. ACCURACY OF THE METHOD

Figs.3-5 show comparison of the proposed method and the numerically exact carrying capacities. Fig.3 shows the result for the above structure (1). The results for the above structures (2) and (3) are similar to that of Fig.3. The error is less than *10 %*. The structure (4) is for investigating the applicability of the proposed method to the member subjected to a combination of axial force P and equal moments M at both ends. The carrying capacities, P_u and M_u nondimensionalized by P_y and full plastic moment M_p, were plotted in Fig.4. The maximum error is less than *8 %*. For the structure (5), the nondimensional relation between columns and girders is defined by $\gamma = I_g L_g / I_c L_c$ where the subscripts g and c describe the property of the girder and columns, respectively. By keeping $L_c = 110\ in$; $I_c = 110\ in^4$; $I_g = 238\ in^4$ and changing L_g, the error, E_r, of the proposed method compared with the exact carrying capacity of the frame were plotted in Fig.5. The results show that the error is mere *10 %*.

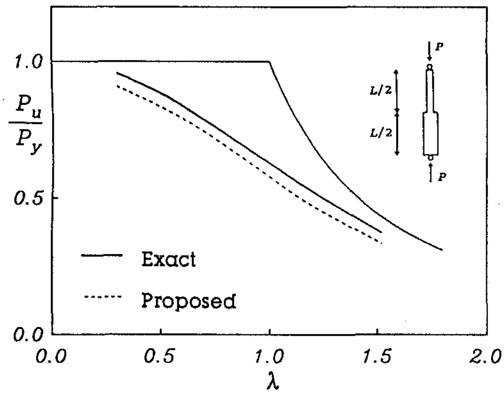

Fig.3 Stepped Column

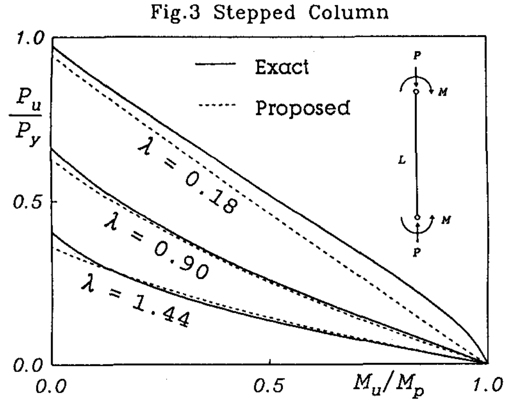

Fig.4 Interaction Curves of Beam-column

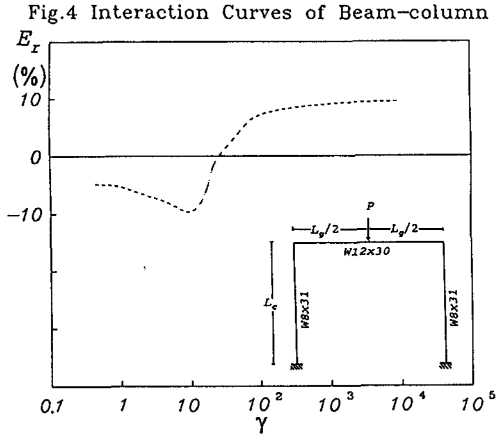

Fig.5 Simple Frame Structure

5. CONCLUSION

A method to evaluate the carrying capacity of frames is proposed. The carrying capacities predicted by the proposed method agree within the error which can be tolerated in practical designs with the exact carrying capacities for the simple structures considered in this study. One of the features of this proposed method is that the concept of effective lengths, which are not well defined in the current design practice, is not used. Another feature is that it can predict the carrying capacity of a structure well without introducing any kind of formulas for the carrying capacity of structural components. Further, it is in a similar level in its simplicity with the linear small displacement analysis.