I - A78 CYCLIC INELASTIC SECTIONAL BEHAVIOR OF STEEL MEMBERS

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INTRODUCTION: The present paper is concerned with the cyclic inelastic sectional behavior of steel members subjected to the combined axial force and bending moment. For this purpose, a two surface model in force space (2SM-FS)[1),2)] has recently been developed by extending the basic assumptions used in the two surface model in stress space (2SM-SS)[3)]. First, the procedure for determining of the model parameters is described. Then, the accuracy of the 2SM-FS is verified by comparing the cyclic sectional behavior of steel members obtained from the 2SM-FS with those of the direct integration method using 2SM-SS and experiments.

CONCEPT OF 2SM-FS: The 2SM-FS is based on the assumptions of no distortion of the cross section and only normal stress acting on the cross section. As shown in Fig. 1, in the non-dimensional axial force $n(=N/N_y)$ and bending moment $m(=M/M_y)$, the 2SM-FS is described by the loading (yield) curve which, initially, coincides with the initial yield curve F_0 defined by:

$$F_0(m,n) = |m| + |n| - 1 = 0 \tag{1}$$

The loading curve progressively changes in shape analogous to that of the yield plateau curve F_y defined by:

$$F_y(m,n) = \left(\frac{m}{f_y}\right)^{c_1} + n^{c_2} - 1 = 0 \tag{2}$$

and the bounding curve F_b defined by:

$$F_b(m,n,\beta_m,\beta_n,r_b) = \left(\frac{m-\beta_m}{r_b f_b}\right)^{c_3} + \left(\frac{n-\beta_n}{r_b}\right)^{c_4} - 1 = 0 \tag{3}$$

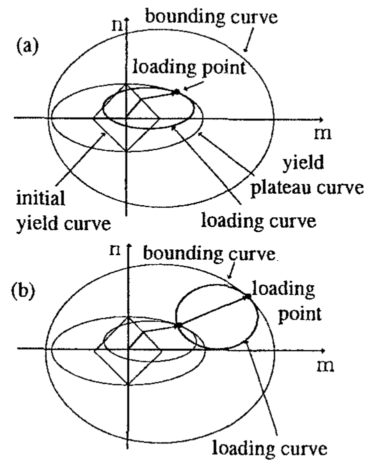

Fig. 1 Concept of 2SM-FS

Here, N_y and M_y denote, respectively, the yield axial load and yield bending moment of the cross-section. c_1, c_2, c_3, c_4= constant values related to the type of cross section and material; f_y, f_b= shape parameters; $r_b = \bar{\kappa}/\kappa_0$; $\bar{\kappa}$ = the radius of bounding curve; κ_0 = the radius of initial yield curve; (β_m, β_n) = the coordinates of the center of bounding curve. The loading curve is always enclosed by the bounding curve and the value of plastic modulus[2),3)] is determined by the proximity of the two curves in the course of their coupled translation and change in size and shape during plastic deformation.

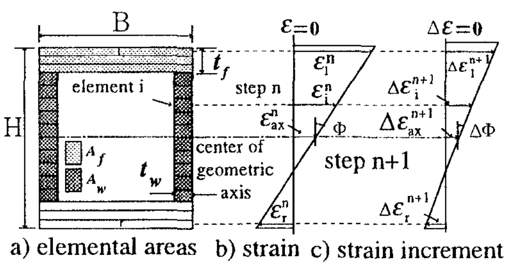

Fig. 2 Subdivision of cross section and strain distribution for a box section

MODEL PARAMETERS: The direct integration method[4)] is used to determine the 2SM-FS parameters. In this approach, the section analyzed is divided into elemental areas, as shown in Fig. 2. The incremental stress-strain relation for each elemental area is described by the uniaxial 2SM-SS. The stress resultants of axial force N and bending moment M are calculated simply by summing the contribution of each elemental area over the cross-section.

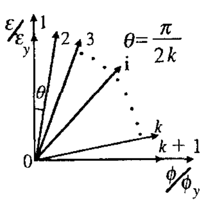

Fig. 3 Loading paths

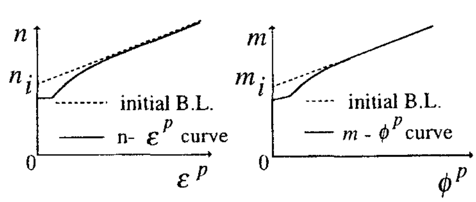

Fig. 4 Definition of initial bounding line

The axial strain and curvature, with a prescribed ratio as shown in Fig. 3, are increased incrementally and the axial force and bending moment are calculated. From the $m-\phi$ and $n-\varepsilon$ curves the values of m_i and n_i corresponding to the yield plateau and bounding curves are determined for a specific ith loading path, cross-section and material, example of which is shown in Fig. 4.

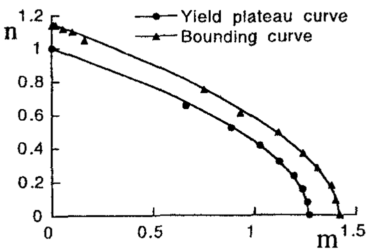

Fig. 5 Definition of the yield plateau and initial bounding curves

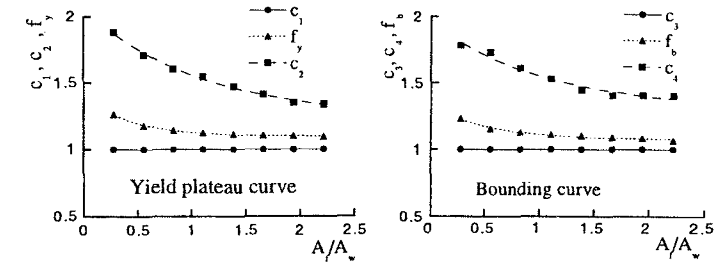

Fig. 6 2SM-FS parameters for I and box sections

The results for different loading paths are plotted in the $n-m$ coordinate system and the values of c_1 to c_4, f_y, and f_b are determined by fitting the yield plateau and bounding curves using the least square method, as shown in Fig. 5 for a box section and SS400. The values of model parameters are examined for different sectional parameters (B/H ratio for rectangle, A_f/A_w ratio for box and I sections, and D/t ratio for a tube). The results for a typical example are shown in Fig. 6. Finally, the model parameters determined for the I and box sections corresponding to the SS400 are given in Table 1.

Table 1 2SM-FS model parameters for I and box sections (SS400)

c_1	1.0
c_2	$1.23+0.83exp\{-0.92(A_f/A_w)\}$
f_y	$1.10+0.31exp\{-2.29(A_f/A_w)\}$
c_3	1.0
c_4	$1.29+0.66exp\{-0.93(A_f/A_w)\}$
f_b	$1.08+0.26exp\{-1.92(A_f/A_w)\}$

VERIFICATION: The cyclic sectional behavior of steel members are analyzed using the 2SM-FS and the results are compared with those of the direct integration method and experiments[4]. As shown in Figs. 7 and 8, a good correlation between the two analytical methods and experiments are achieved indicating the accuracy of the 2SM-FS model.

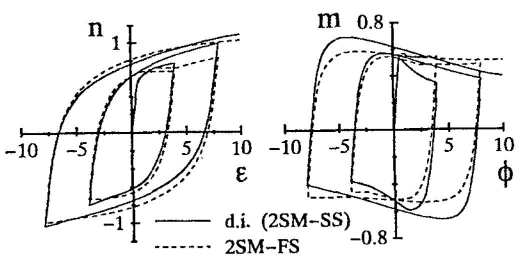

Fig. 7 Comparison between the direct integration method with the 2SM-FS (box section, $B=H=125mm$, $t_f=8.7mm$, $t_w=6.1mm$, SS400)

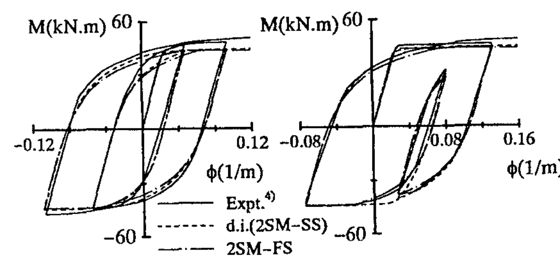

Fig. 8 Comparison with experiments ($H125\times125\times6.5\times9$, SS400)

CONCLUSIONS: This paper was concerned with the cyclic inelastic sectional behavior of steel members using 2SM-FS. The procedure for determining the model parameters were described and the values of the parameters for I and box sections were given. Finally, the accuracy of the 2SM-FS was verified by comparing the obtained results with experiments.

REFERENCES: [1] Suzuki, T., Mamaghani, I.H.P., Mizuno, E., Usami, T., "Finite displacement analysis of steel structures with two-surface plasticity model in stress resultant space." *Proc. of the 50th Annual Meeting, JSCE,* Vol.1(A), 110-111, 1995. [2] Mizuno, E., Mamaghani, Iraj H.P., and Usami, T., "Cyclic large displacement analysis steel structures with two-surface model in force space". *ICASS'96,* Vol. 1, pp. 183-188, 1996. [3] Shen, C., Mamaghani, I.H.P., Mizuno, E., and Usami, T., "cyclic behavior of structural steels. II: Theory." *J. Engrg. Mech., ASCE,* Vol. 121(11), pp.1165-1172, 1995. [4] Minagawa, M. Nishiwaki, T. and Masuda, N., "Prediction of hysteresis moment-curvature relations of steel beams", *J. of Structural Engineering, JSCE,* Vol. 34A, pp.111-120, 1988.