Zeitschrift: IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

Band: 10 (1976)

Artikel: Behaviour of hybrid beam-columns under cyclic loading

Autor: Yamada, M. / Tsuji, B.

DOI: https://doi.org/10.5169/seals-10550

Behaviour of Hybrid Beam-Columns under Cyclic Loading

Comportement de montants hybrides soumis à des flexions cycliques

Verhalten von hybriden Stahlstützen unter zyklischer Biegebeanspruchung

M. YAMADA
Prof.

B. TSUJI
Prof.

Faculty of Engineering, Kobe University
Kobe, Japan

1. INTRODUCTION

The cyclic bending deformation behavior of the wide flange section was discussed by the senior auther(1),(2), and it was clarified that the cyclic bending moment-curvature relationship under the constant axial force asymptotes to the relationship of the pure bending due to the strain hardening effect. The cyclic bending behavior of the hybrid member is discussed here.

2.ANALYSIS

2.1. Analytical Model

A wide flange section is simplified into a three points model(2) such as shown in Fig.1. The area of the web is k times the one of the flange. The yield stress σ_{yw} of the web is ρ times the yield stress σ_{yf} of the flange. The stress-strain relationship of the material is tri-linear type such as shown in Fig.2. In general, with the increase of the yield stress σ_y, the yield ratio $\zeta=\sigma_y/\sigma_{max}$ increases and the strain hardening coefficient $\mu=E_{st}/E$ decreases. Fig.3 shows the relationship between the yield ratio ζ or the strain hardening coefficient μ and the yield stress σ_y. Indicating the stresses of each point as $\bar{\sigma}_i=\sigma_i/\sigma_{iy}(i=1,2,3)$, the axial force $N=nN_y$ and the bending moment $M=mM_y$ are obtained as follows:

$$n=\frac{\bar{\sigma}_1+\bar{\sigma}_3+\rho k\bar{\sigma}_2}{2+\rho k}$$

$$m=\frac{\bar{\sigma}_1-\bar{\sigma}_3}{2}$$

The stresses of each point are obtained by summation of the elastic stress and the residual stress such as shown in Fig.4, and are represented as follows:

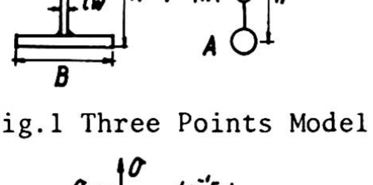


Fig.1 Three Points Model

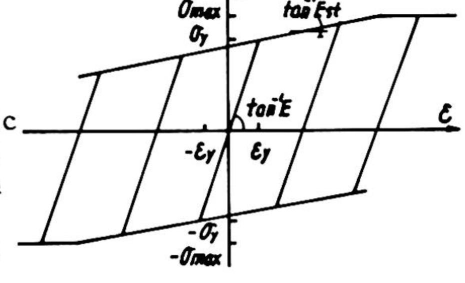


Fig.2 σ - ε Relationship

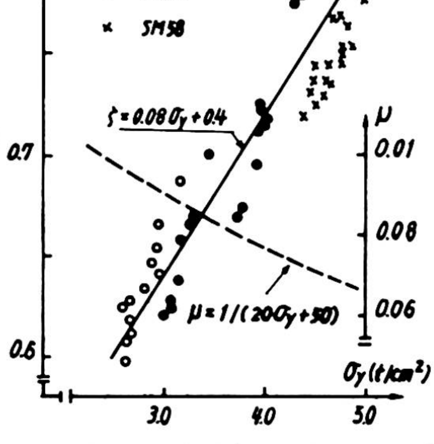


Fig.3 Yield Ratio ζ and Strain Hard. Coeff. μ

$$\bar{\sigma}_1=(2+\rho k)/(2+k)n+m+\xi$$
$$\bar{\sigma}_2=(2+\rho k)/\rho(2+k)n-2\xi/\rho k$$
$$\bar{\sigma}_3=(2+\rho k)/(2+k)n-m+\xi$$

where ξ is a parameter indicating the magnitude of the residual stress. The yield conditions of each point are as follows:

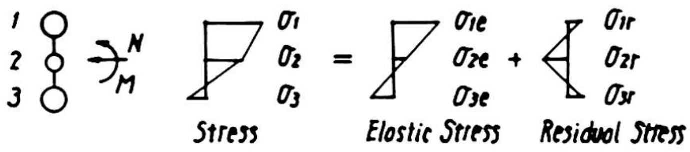


Fig.4 Stress Distribution

$$\alpha_i-2\le\bar{\sigma}_i\le\alpha_i$$
$$-1/\zeta_i\le\bar{\sigma}_i\le 1/\zeta_i$$

where α_i shows the subsequent yield stress. Fig.5 shows the yield polygon. The broken line shows the envelope of the yield polygon and a stress point can not go out of this range.

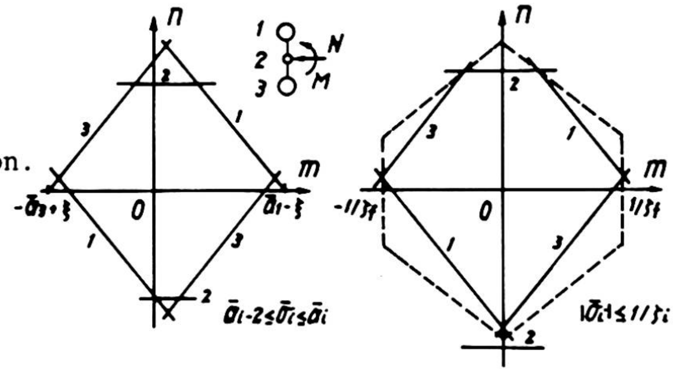


Fig.5 Yield Conditions

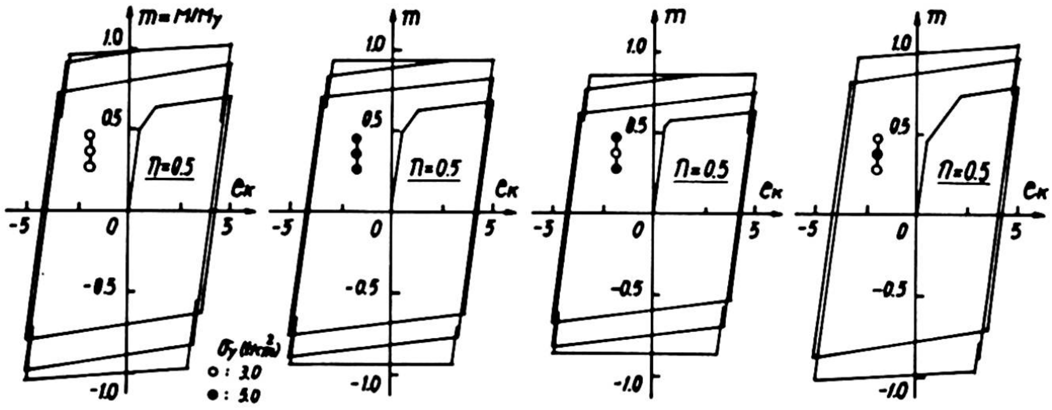
2.2. Bending Moment-Curvature Relationship

Fig.6 shows the bending moment-curvature relationship under the constant axial force of $N=0.5N_y$. Four types of the cross section computed are shown in Table 1. Figs.(a) and (b) correspond to the homogeneous members using a mild steel and a high strength steel, and Figs.(c) and (d) to the hybrid member using a high strength steel as the flange and the web, respectively. In each case, the relationships converge to the steady state loop at the three or four cycles. In the case of type A and D, the relationships converge to those of the pure bending due to the strain hardening effect, whereas in the case of type B and C, the loops converge to the steady state ones, the maximum bending capacity of which is somewhat smaller than that of the former case, due to the fully plastic state of the web and the compression flange.

Table 1 Types of Members

	Type	$\sigma_{yf}(t/cm^2)$	$\sigma_{yw}(t/cm^2)$
Homogeneous Member	A	3.0	3.0
	B	5.0	5.0
Hybrid Member	C	5.0	3.0
	D	3.0	5.0

$\sigma_y(t/cm^2)$	$\mu=E_{st}/E$	$\zeta=\sigma_y/\sigma_{max}$
3.0	1/110	0.64
5.0	1/150	0.80

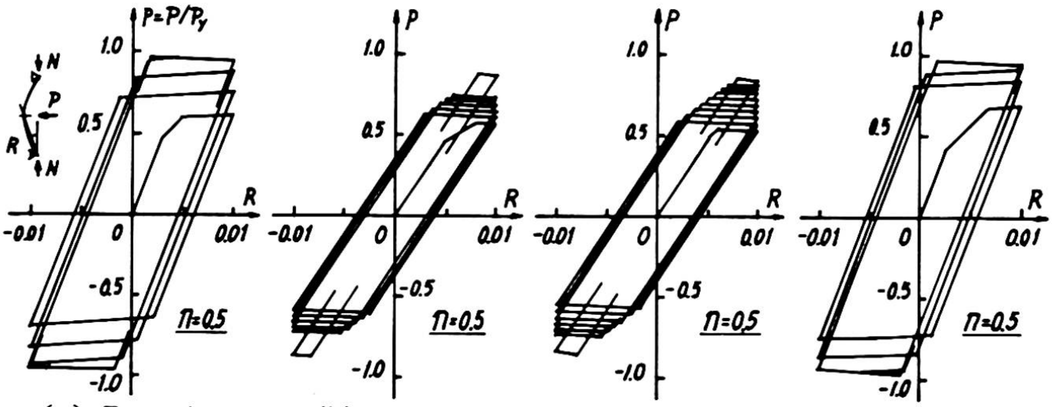


(a) Type A (b) Type B (c) Type C (d) Type D

Fig.6 Bending Moment-Curvature Relationship

2.3. Load-Deformation Relationship

Fig.7 shows the lateral load-deflection relationship of the column, the slendreness ratio of which is 25, under the constant axial load of $N=0.5N_y$. Alternately repeated horizontal force $P=pP_y$ is applied at the constant lateral



(a) Type A (b) Type B (c) Type C (d) Type D

Fig.7 Load-Deformation Relationship

sway rotation angle of R=±0.01. Figs.(a) and (b) correspond to the homogeneous member and Figs.(c) and (d) correspond to the hybrid one. In the case of the columns having a mild steel flange (type A and D), the load-deflection relationships converge to the steady state loop at the few cycles because of the small yield ratio (ζ=0.64) and of the large strain hardening coefficient (μ=1/110). The relationships of type B and C columns having high strength steel flange converge to the steady state loop at 17 and 13 cycles,respectively.

2.4. Variation of Maximum Strength and Accumulated Plastic Strain

Fig.8 shows the relationship between the maximum strength and the number of cycles. The abscissa W shows the number of half cycles. The maximum strength increases with the number of cycles. The strength of the hybrid member using a high strength steel as the web (type D) is the largest and using a mild steel as the web is the smallest. Convergence to the steady state loop is rapid in the case of the member having mild steel flange. Fig.9 shows the variation of the accumulated plastic strain of the web. The accumulated plastic strain induced is large in the case of a hybrid member using the mild steel web, and small in the case of the member using high strength steel web. In some cases, the plastic strain increases with the number of cycles even after the maximum strength converges to the steady state value.

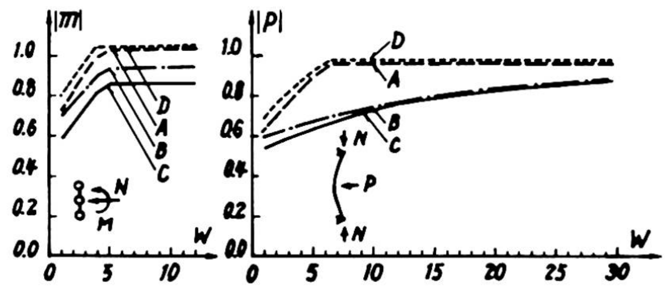


Fig.8 Variation of Maximum Strength

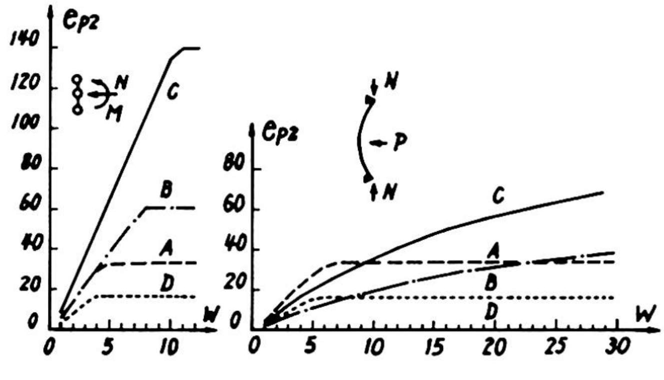


Fig.9 Accumulated Plastic Strain

3.CONCLUDING REMARKES

Elastic plastic behavior of the wide flange columns with homogeneous and hybrid sections was discussed. In the case of the members having high strength steel with large yield ratio and small strain hardening coefficient, the increase in the strength under the cyclic loading is relatively small. The hybrid member having a mild steel web shows a relatively small increment in the strength under the cyclic loading and induces the large amount of accumulated plastic strain in the web even under the small axial force range.

On the other hand, the hybrid member having a high strength steel web shows a relatively large increment in the strength and induces relatively small amount of plastic strain in the web.

BIBLIOGRAPHY

(1) Yamada,M. : Freie Diskussion IIIc, Final Report, 8th. Congr., IABSE, New York, 1968, pp.693-695.
(2) Yamada,M., Shirakawa,K. : Elaso-plastische Biegeformänderungen von Stahlstützen mit I-Querschnitt, Teil II : Wechselseitig wiederholte Biegung unter konstanter Normalkrafteinwirkung, Der Stahlbau, 40. Jahrg., H.3, 1971, S. 65-74 u. H.5, 1971, S.143-151.
(3) Horikawa,K. : Experimental Study on Shape and Size of Tensile Specimen, JSSC, Vol.5, No.48, 1969, pp.52-67, (in Japanese).

SUMMARY

Elasto-plastic cyclic bending deformation behaviour of the hybrid members is discussed assuming a wide flange section as a three points model and stress-strain relationship as tri-linear type. In the case of the hybrid member, the increase in the strength under the cyclic loading are larger and the amount of the accumulated plastic strains are smaller for the member with weaker flange than with weaker web. The limiting axial force level within which the bending resistance of the column asymptotes to that of pure bending is lower for the weaker web member.

RESUME

Les auteurs présentent le comportement élasto-plastique d'éléments hybrides soumis à des flexions cycliques; ils remplacent le profilé à larges ailes étudié par un modèle à trois surfaces et admettent une relation contraintes-allongements du type trilinéaire. Pour des éléments hybrides possédant un âme en acier à haute résistance, l'augmentation de résistance sous charges cycliques est plus élevée et la quantité de déformations plastiques accumulées, plus faible que pour une âme en acier doux. L'effort normal limite permettant asymptotiquement un moment de ruine égal à celui correspondant à la flexion pure est moins élevé lorsque l'âme est en acier doux.

ZUSAMMENFASSUNG

Das elasto-plastische Biegeverformungsverhalten einer zyklisch beanspruchten hybriden Stahlstütze ist unter der Annahme eines drei Punkt-Modelles des Breitflansc Querschnittes und einer tri-linearen Vereinfachung der σ-ε-Beziehung untersucht. Im Fall von hybriden Stahlstützen mit schwächerem Flansch ist der Zuwachs des Widerstandes grösser und die Verzerrungsakkumulation kleiner als für Querschnitte mit schwächerem Steg. Der Grenzwert des Normalkraftniveaus,für das der Biegewiderstand mit demjenigen unter reiner Biegung asymptotisch übereinstimmt, ist niedriger für einen Querschnitt mit schwächerem Steg.