LIMIT ANALYSIS OF BEAM-COLUMN CONNECTIONS (Ⅲ—1)

— Type Connections of Wideflange Members Subjected
to Strong-axis Bending —

by Dr. Hisashi TANAKA*, Yung Chuan LIN**
Members of A.I.J.

§ 1 Introduction

In the previous papers, (Part (I) and Part (II)¹⁾ of the same titled,) the authors analyzed the yield moments of cruciform and *L* type connections of wideflange members subjected to strong-axis bending, and clarified how the yield moment is affected by the proportions of connections. In this paper — type connections subjected to strong-axis bending are treated for the same purpose as denoted in the previous papers.

The dimensions of the connections to be analyzed herein are shown in Fig. 1, and the dimensionless parameters defined by

$$\alpha = \frac{h_c}{h_b} = \frac{A_{fc}}{A_{fb}}, \quad \beta = \frac{A_{fb}}{2 h_b t}, \quad \lambda = \frac{t_p}{t} \quad \alpha > \frac{1}{\sqrt{2}}, \quad \beta > 0, \quad \lambda \geq 1 \quad \dots (1.1)$$

are introduced and the same assumptions in the analysis described in § 2 of Part (I) are adopted herein. For shortening the paper and brevity of expression, the following parameters are defined by

$$a = \frac{1}{2\alpha} \quad \dots (1.2)$$

$$b = a \sqrt{4\alpha^2 - 1} \quad \dots (1.3)$$

$$c = \frac{2\alpha - a}{2\beta + 1} \quad \dots (1.4)$$

$$d : \text{a real solution of } d^4 + 4\left(\frac{\beta}{\alpha} + d\right)^2 - \lambda^2 = 0$$

$$\text{where } 0 \leq d \leq \frac{1}{2\alpha} \quad \dots (1.5)$$

$$e = f \sqrt{1 - d^2} \quad \dots (1.6)$$

$$f = \frac{2\alpha d - d^2}{1 - d^2} \quad \dots (1.7)$$

$$g = \frac{(1 - d^2) \cdot f}{\frac{\beta}{\alpha} + d} \quad \dots (1.8)$$

$$h = \frac{\frac{\beta}{\alpha} + d - 2\alpha\beta}{\frac{\beta}{\alpha} + d} \quad \dots (1.9)$$

$$i = \frac{2\alpha d - d^2}{\frac{\beta}{\alpha} + d} \quad \dots (1.10)$$

$$j : \text{a real solution of } j^4 \lambda^2 k^2 + 4 \left[\frac{\beta}{\alpha} + k \lambda j \right]^2 - \lambda^2 = 0$$

$$\text{where } k \lambda \leq 1 \text{ and } 0 \leq j \leq \frac{1}{2\alpha} \quad \dots (1.11)$$

$$k = \sqrt{1 - \left(\frac{2\beta}{\alpha \lambda} \right)^2} \quad \dots (1.12)$$

$$l = \frac{(2\alpha j - j^2) \lambda k}{1 - j^2 \lambda k} \quad \dots (1.13)$$

Fig. 1 Type and Dimensions of Beam-Column Connection

* Proc., Inst. of Indu. Sci., Univ. of Tokyo

** Graduate student, Univ. of Tokyo

$$m = l \sqrt{1 - j^2 \lambda k} \dots\dots\dots(1.14)$$

$$p = \frac{\frac{\beta}{\alpha} + j \lambda k - 2 \alpha \beta}{\frac{\beta}{\alpha} + j \lambda k} \dots\dots\dots(1.16)$$

$$r = \frac{\lambda k (4 \alpha^2 - 1)}{4 \alpha^2 + \lambda k} \dots\dots\dots(1.18)$$

$$n = \frac{(1 - j^2 \lambda k) l}{\frac{\beta}{\alpha} + j \lambda k} \dots\dots\dots(1.15)$$

$$q = \frac{2 \alpha j \lambda k - j^2 \lambda k}{\frac{\beta}{\alpha} + j \lambda k} \dots\dots\dots(1.17)$$

$$s = \frac{\lambda k (4 \alpha^2 - 1)}{2 \alpha (2 \beta + \lambda k)} \dots\dots\dots(1.19)$$

§ 2 Classification of Statical Analysis

The statical analysis is classified into ten cases as shown in Table 1. and graphically shown in Fig. 2(a), (b).

The case (I) does not exist for $\alpha \leq \frac{\sqrt{2} + \sqrt{5}}{2}$, and the case (E) and (H) for $\alpha \geq \frac{\sqrt{2} + \sqrt{5}}{2}$.

The conditions of classification in Table 1 are expressed in the following inequalities:

$$\frac{2\beta}{\alpha\lambda} \leq 1 \dots\dots\dots(2.1)$$

$$\frac{2\beta}{\alpha\lambda} > 1 \dots\dots\dots(2.2)$$

$$\frac{1}{\lambda} \sqrt{1 + 4 \left(\frac{\beta}{\alpha} \right)^2} \dots\dots\dots(2.3)$$

$$\lambda k < 1 \dots\dots\dots(2.4)$$

$$\frac{1}{\lambda} \sqrt{a^4 + 4 a^2 (2 \beta + 1)^2} < 1 \dots\dots\dots(2.5)$$

$$d \leq \frac{1}{2\alpha} \dots\dots\dots(2.6)$$

$$[a(2\beta + 1) - a \sqrt{4\alpha^2 - 1}] \frac{1}{\lambda} \geq 0 \dots\dots\dots(2.7)$$

$$\frac{a(2\beta + 1)^2}{2\alpha - a} \leq 1 \dots\dots\dots(2.8)$$

$$\frac{\beta}{\alpha} \cdot \frac{1}{\lambda} + \frac{d}{\lambda} - \frac{e}{f} \cdot \frac{1}{\lambda} \geq 0 \dots\dots\dots(2.9)$$

$$\left(\frac{\beta}{\alpha} + d \right) \frac{f}{g} \leq 1 \dots\dots\dots(2.10)$$

$$\left(\frac{\beta}{\alpha} + j \lambda k \right) \frac{l}{n} \leq 1 \dots\dots\dots(2.12)$$

$$\left(\frac{\beta}{\alpha} + d \right) \frac{i}{h} + d^2 \leq 1 \dots\dots\dots(2.14)$$

$$\left[j^2 \lambda k + \frac{q}{p} \left(\frac{\beta}{\alpha} + j \lambda k \right) \right] \leq 1 \dots\dots\dots(2.16)$$

$$\frac{1}{\lambda} \left[a^4 \lambda^4 k^2 + 4 \left(\frac{\beta}{\alpha} + a \lambda k \right) \right] \leq 1 \dots\dots\dots(2.17)$$

$$j \leq \frac{1}{2\alpha} \dots\dots\dots(2.18)$$

Table 1

Case	boundary conditions for each case				
A	A~F (2.3)	A~B (2.7)	A~C (2.5)	—	—
B	B~I (2.3)	B~A (2.8)	B~D (2.5)	—	—
C	C~F (2.3)	C~D (2.9)	C~A (2.6)	—	—
D	D~G (2.3)	D~C (2.10)	D~B (2.6)	D~E (2.13)	—
E	E~H (2.3)	E~A (2.6)	E~D (2.14)	—	—
F	F~J (2.1)	F~C (2.4)	F~G (2.11)	F~I (2.18)	—
G	G~J (2.1)	G~D (2.4)	G~F (2.12)	G~I (2.18)	G~H (2.15)
H	H~J (2.1)	H~E (2.4)	H~G (2.16)	—	—
I	I~B (2.4)	I~G (2.17)	—	—	—
J	J~F (2.2)	J~G (2.2)	—	—	—

$$\left(\frac{\beta}{\alpha} + j \lambda k - \frac{m}{l} \right) \frac{1}{\lambda} < 0 \dots\dots\dots(2.11)$$

$$\left(\frac{\beta}{\alpha} + d \right) (1 - f) \leq 2 \alpha \beta \dots\dots\dots(2.13)$$

$$\left(\frac{\beta}{\alpha} + j \lambda k \right) (1 - l) \leq 2 \alpha \beta \dots\dots\dots(2.15)$$

Fig. 2 (a)

Fig. 2 (b)

Classification of Statical Analysis

§ 3 Statically Admissible Stress Fields

To obtain statically admissible stress fields, the webs and flanges are divided into several regions by the straight lines as shown in Fig. 3, and assumed that the stresses in each web region are uniformly distributed and the flange forces are constant or vary linearly in each region. The web stresses σ_x , σ_y , τ , flange forces F and parameters ξ_1 , ξ_2 and η in each case are shown in Table 2~11, where σ_0 denotes yield stresses, the subscripts b , c of F refer to beam and column and the superscripts of F indicates the boundary points of flange. We can verify that these stresses are in equilibrium and that they satisfy the Tresca's yield conditions described in § 2 of Part (1)., by applying the conditions denoted in Table 12 for each case.

Fig-3

Fig-3 Statically Admissible Stress Field

Table 2 Case A

regions	$\frac{\sigma_x}{\sigma_0}$	$\frac{\sigma_y}{\sigma_0}$	$\frac{\tau}{\sigma_0}$	$\left \frac{\sigma_1}{\sigma_0} \right , \left \frac{\sigma_2}{\sigma_0} \right , \left \frac{\sigma_1 - \sigma_2}{\sigma_0} \right _{\max}$
(1)	1	0	0	1
(2)	—	—	—	—
(3)	0	1	0	1
(4)	0	0	0	0
(5)	0	-1	0	1
(6)	$\frac{1}{\lambda}$	$\frac{1}{\lambda}$	$a(2\beta+1-\sqrt{4a^2-1}) \frac{1}{\lambda}$	$[1+a(2\beta+1-\sqrt{4a^2-1})] \frac{1}{\lambda}$
(7)	$a^2 \cdot \frac{1}{\lambda}$	0	$a(2\beta+1) \frac{1}{\lambda}$	$\frac{1}{\lambda} \sqrt{a^4+4a^2(2\beta+1)^2}$
(8)	0	$-\frac{1}{\lambda}$	$\frac{\beta}{\alpha} \cdot \frac{1}{\lambda}$	$\frac{1}{\lambda} \sqrt{1+4\left(\frac{\beta}{\alpha}\right)^2}$
ξ_1, ξ_2, η	$\xi_1=b, \quad \xi_2=a, \quad \eta=1$			
F in $\sigma_0 h b t$	$F_b^{(B)}=F_c^{(A)}=F_c^{(D)}=0, \quad F_b^{(H)}=a \frac{\beta}{\alpha}, \quad F_b^{(I)}=a \frac{\beta}{\alpha} + a(2\beta+1)(2\alpha-a-b)$ $F_b^{(F)}=F_b^{(J)}=2\beta, \quad -F_c^{(B)}=-F_c^{(C)}=\frac{\beta}{\alpha}, \quad F_c^{(E)}=F_c^{(F)}=F_c^{(G)}=a[(2\beta+1)-\sqrt{4a^2-1}]$			

Table 3 Case B

regions	$\frac{\sigma_x}{\sigma_0}$	$\frac{\sigma_y}{\sigma_0}$	$\frac{\tau}{\sigma_0}$	$\left \frac{\sigma_1}{\sigma_0} \right , \left \frac{\sigma_2}{\sigma_0} \right , \left \frac{\sigma_1 - \sigma_2}{\sigma_0} \right _{\max}$
(1)	1	0	0	1
(2)	—	—	—	—
(3)	0	$\frac{a(2\beta+1)^2}{2\alpha-a}$	0	$\frac{a(2\beta+1)^2}{2\alpha-a}$
(4)	0	0	0	0
(5)	0	-1	0	1
(6)	$\frac{1}{\lambda}$	$\frac{a(2\beta+1)^2}{2\alpha-a} \cdot \frac{1}{\lambda}$	0	$\frac{1}{\lambda}$
(7)	$\frac{a^2}{\lambda}$	0	$a(2\beta+1) \frac{1}{\lambda}$	$\frac{1}{\lambda} \sqrt{a^4+4a^2(2\beta+1)^2}$
(8)	0	$-\frac{1}{\lambda}$	$\frac{\beta}{\alpha} \cdot \frac{1}{\lambda}$	$\frac{1}{\lambda} \sqrt{1+4\left(\frac{\beta}{\alpha}\right)^2}$
ξ_1, ξ_2, η	$\xi_1=c, \quad \xi_2=a, \quad \eta=1$			
F in $\sigma_0 h b t$	$F_b^{(B)}=F_c^{(D)}=F_c^{(E)}=F_c^{(F)}=F_c^{(G)}=0, \quad F_b^{(H)}=F_b^{(I)}=a \frac{\beta}{\alpha}$ $F_b^{(F)}=F_b^{(J)}=2\beta, \quad -F_c^{(B)}=-F_c^{(C)}=\frac{\beta}{\alpha}$			

Table 4 Case C

regions	$\frac{\sigma_x}{\sigma_0}$	$\frac{\sigma_y}{\sigma_0}$	$\frac{\tau}{\sigma_0}$	$\left \frac{\sigma_1}{\sigma_0} \right , \left \frac{\sigma_2}{\sigma_0} \right , \left \frac{\sigma_1 - \sigma_2}{\sigma_0} \right _{\max}$
(1)	1	0	0	1
(2)	d^2	0	0	d^2
(3)	0	1	0	1
(4)	0	0	0	0
(5)	0	-1	0	1
(6)	$\frac{1}{\lambda}$	$\frac{1}{\lambda}$	$\frac{\beta}{\alpha\lambda} + \frac{d}{\lambda} - \frac{e}{f\lambda}$	$\frac{1}{\lambda} \left(1 + \frac{\beta}{\alpha} + d - \frac{e}{f} \right)$
(7)	$d^2 \cdot \frac{1}{\lambda}$	0	$\frac{\beta}{\alpha} \cdot \frac{1}{\lambda} + \frac{d}{\lambda}$	1
(8)	0	$-\frac{1}{\lambda}$	$\frac{\beta}{\alpha} \cdot \frac{1}{\lambda}$	$\frac{1}{\lambda} \sqrt{1 + 4 \left(\frac{\beta}{\alpha} \right)^2}$
ξ_1, ξ_2, η	$\xi_1 = e, \quad \xi_2 = d, \quad \eta = f$			
F in $\sigma_0 h b t$	$F_b^{(B)} = F_c^{(A)} = F_c^{(D)} = 0, \quad F_b^{(H)} = \frac{\beta}{\alpha} d, \quad F_b^{(I)} = \left(\frac{\beta}{\alpha} + d \right) (2\alpha - e) - d^2, \quad F_b^{(F)} = F_b^{(J)} = 2\beta$ $-F_c^{(B)} = -F_c^{(C)} = \frac{\beta}{\alpha}, \quad F_c^{(E)} = \left(\frac{\beta}{\alpha} + d \right) (1 - f), \quad F_c^{(F)} = \left(\frac{\beta}{\alpha} + \alpha - e \right) = 2\alpha\beta - \left\{ \beta d + \left(\frac{\beta}{\alpha} + d \right) [\alpha(2\alpha - d) - 1] + e \left(1 - \alpha \frac{e}{f} \right) \right\}$			

Table 5 Case D

regions	$\frac{\sigma_x}{\sigma_0}$	$\frac{\sigma_y}{\sigma_0}$	$\frac{\tau}{\sigma_0}$	$\left \frac{\sigma_1}{\sigma_0} \right , \left \frac{\sigma_2}{\sigma_0} \right , \left \frac{\sigma_1 - \sigma_2}{\sigma_0} \right _{\max}$
(1)	1	0	0	1
(2)	d^2	0	0	d^2
(3)	0	$\left(\frac{\beta}{\alpha} + d \right) \cdot \frac{f}{g}$	0	$\left(\frac{\beta}{\alpha} + d \right) \cdot \frac{f}{g}$
(4)	0	0	0	0
(5)	-1	0	0	1
(6)	$\frac{1}{\lambda}$	$\left(\frac{\beta}{\alpha} + d \right) \cdot \frac{f}{g} \cdot \frac{1}{\lambda}$	0	$\frac{1}{\lambda}$
(7)	$d^2 \cdot \frac{1}{\lambda}$	0	$\left(\frac{\beta}{\alpha} + d \right) \cdot \frac{1}{\lambda}$	1
(8)	0	$-\frac{1}{\lambda}$	$\frac{\beta}{\alpha} \cdot \frac{1}{\lambda}$	$\frac{1}{\lambda} \sqrt{1 + 4 \left(\frac{\beta}{\alpha} \right)^2}$
ξ_1, ξ_2, η	$\xi_1 = g, \quad \xi_2 = d, \quad \eta = f$			
F in $\sigma_0 h b t$	$F_b^{(B)} = F_c^{(A)} = F_c^{(D)} = 0, \quad F_b^{(H)} = \frac{\beta}{\alpha} d, \quad F_b^{(I)} = F_b^{(F)} = F_b^{(J)} = 2\beta, \quad F_c^{(B)} = F_c^{(C)} = \frac{\beta}{\alpha}, \quad F_c^{(E)} = \left(\frac{\beta}{\alpha} + d \right) (1 - f)$			

Table 6 case E

regions	$\frac{\sigma_x}{\sigma_0}$	$\frac{\sigma_y}{\sigma_0}$	$\frac{\tau}{\sigma_0}$	$\left \frac{\sigma_1}{\sigma_0} \right , \left \frac{\sigma_2}{\sigma_0} \right , \left \frac{\sigma_1 - \sigma_2}{\sigma_0} \right _{\max}$
(1)	$\left(\frac{\beta}{\alpha} + d \right) \frac{i}{h} + d^2$	0	0	$\left(\frac{\beta}{\alpha} + d \right) \frac{i}{h} + d^2$
(2)	d^2	0	0	d^2
(3)	0	$\left(\frac{\beta}{\alpha} + d \right) \frac{h}{i}$	0	$\left(\frac{\beta}{\alpha} + d \right) \frac{h}{i}$
(4)	0	0	0	0
(5)	0	-1	0	1
(6)	$\left[\left(\frac{\beta}{\alpha} + d \right) \frac{i}{h} + d^2 \right] \frac{1}{\lambda}$	$\left(\frac{\beta}{\alpha} + d \right) \frac{h}{i} \cdot \frac{1}{\lambda}$	0	$\left[\left(\frac{\beta}{\alpha} + d \right) \frac{i}{h} + d^2 \right] \frac{1}{\lambda}$
(7)	$d^2 \cdot \frac{1}{\lambda}$	0	$\left(\frac{\beta}{\alpha} + d \right) \frac{1}{\lambda}$	1
(8)	0	$-\frac{1}{\lambda}$	$\frac{\beta}{\alpha} \cdot \frac{1}{\lambda}$	$\frac{1}{\lambda} \sqrt{1 + 4 \left(\frac{\beta}{\alpha} \right)^2}$
ξ_1, ξ_2, η	$\xi_1 = i, \quad \xi_2 = d, \quad \eta = h$			
F in $\sigma_0 h b t$	$F_b^{(B)} = F_c^{(A)} = F_c^{(D)} = 0, \quad F_b^{(H)} = \frac{\beta}{\alpha} \alpha, \quad F_b^{(I)} = F_b^{(F)} = F_b^{(J)} = 2\beta, \quad F_c^{(B)} = F_c^{(C)} = \frac{\beta}{\alpha}, \quad F_c^{(E)} = F_c^{(F)} = F_c^{(G)} = 2\alpha\beta$			

Table 7 case F

regions	$\frac{\sigma_x}{\sigma_0}$	$\frac{\sigma_y}{\sigma_0}$	$\frac{\tau}{\sigma_0}$	$\left \frac{\sigma_1}{\sigma_0} \right , \left \frac{\sigma_2}{\sigma_0} \right , \left \frac{\sigma_1 - \sigma_2}{\sigma_0} \right _{\max}$
(1)	1	0	0	1
(2)	$j^2 \lambda k$	0	0	$j^2 \lambda k$
(3)	0	1	0	1
(4)	0	0	0	0
(5)	0	$-k \lambda$	0	$k \lambda$
(6)	$\frac{1}{\lambda}$	$\frac{1}{\lambda}$	$\left[\frac{\beta}{\alpha} + j \lambda k - \frac{m}{l} \right] \frac{1}{\lambda}$	$\left[\frac{\beta}{\alpha} + j \lambda k - \frac{m}{l} \right] \frac{1}{\lambda}$
(7)	$j^2 \lambda k \cdot \frac{1}{\lambda}$	0	$\left[\frac{\beta}{\alpha} + j \lambda k \right] \frac{1}{\lambda}$	1
(8)	0	$-k$	$\frac{\beta}{\alpha} \cdot \frac{1}{\lambda}$	1
ξ_1, ξ_2, η	$\xi_1 = m, \quad \xi_2 = j, \quad \eta = l$			
F in $\sigma_0 h_b t$	$F_b(B) = F_c(A) = F_c(D) = 0, \quad F_b(H) = \frac{\beta}{\alpha} j \lambda k, \quad F_b(E) = \left(\frac{\beta}{\alpha} + j \lambda k \right) (2\alpha - m), \quad F_b(F) = F_b(J) = 2\beta, \quad F_c(B) = F_c(C) = \frac{\beta}{\alpha}$ $F_c(E) = \left(\frac{\beta}{\alpha} + j \lambda k \right) (1 - l), \quad F_c(F) = \frac{\beta}{\alpha} + j \lambda k - m = 2\alpha\beta - \left\{ \beta j + \left(\frac{\beta}{\alpha} + j \lambda k \right) [\alpha(2\alpha - j) - 1] + m \left(1 - \alpha \frac{m}{l} \right) \right\}$			

Table 8 case G

regions	$\frac{\sigma_x}{\sigma_0}$	$\frac{\sigma_y}{\sigma_0}$	$\frac{\tau}{\sigma_0}$	$\left \frac{\sigma_1}{\sigma_0} \right , \left \frac{\sigma_2}{\sigma_0} \right , \left \frac{\sigma_1 - \sigma_2}{\sigma_0} \right _{\max}$
(1)	1	0	0	1
(2)	$j^2 \lambda k$	0	0	$j^2 \lambda k$
(3)	0	$\left(\frac{\beta}{\alpha} + j \lambda k \right) \frac{l}{n}$	0	$\left(\frac{\beta}{\alpha} + j \lambda k \right) \frac{l}{m}$
(4)	0	0	0	0
(5)	0	$-k \lambda$	0	$k \lambda$
(6)	$\frac{1}{\lambda}$	$\left(\frac{\beta}{\alpha} + j \lambda k \right) \frac{l}{n \lambda}$	0	$\frac{1}{\lambda}$
(7)	$j^2 \lambda k \cdot \frac{1}{\lambda}$	0	$\left(\frac{\beta}{\alpha} + j \lambda k \right) \frac{1}{\lambda}$	1
(8)	0	$-k$	$\frac{\beta}{\alpha} \cdot \frac{1}{\lambda}$	1
ξ_1, ξ_2, η	$\xi_1 = n, \quad \xi_2 = j, \quad \eta = l$			
F in $\sigma_0 h_b t$	$F_b(B) = F_c(A) = F_c(D) = 0, \quad F_b(H) = \frac{\beta}{\alpha} j, \quad F_b(I) = F_b(F) = F_b(J) = 2\beta,$ $F_c(B) = F_c(C) = \frac{\beta}{\alpha}, \quad F_c(E) = F_c(F) = F_c(G) = \left(\frac{\beta}{\alpha} + j \lambda k \right) (1 - l)$			

Table 9 case H

regions	$\frac{\sigma_x}{\sigma_0}$	$\frac{\sigma_y}{\sigma_0}$	$\frac{\tau}{\sigma_0}$	$\left \frac{\sigma_1}{\sigma_0} \right , \left \frac{\sigma_2}{\sigma_0} \right , \left \frac{\sigma_1 - \sigma_2}{\sigma_0} \right _{\max}$
(1)	$j^2 \lambda k + \frac{q}{p} \left(\frac{\beta}{\alpha} + j \lambda k \right)$	0	0	$j^2 \lambda k + \frac{q}{p} \left(\frac{\beta}{\alpha} + j \lambda k \right)$
(2)	$j^2 \lambda k$	0	0	$j^2 \lambda k$
(3)	0	$\frac{p}{q} \left(\frac{\beta}{\alpha} + j \lambda k \right)$	0	$\frac{p}{q} \left(\frac{\beta}{\alpha} + j \lambda k \right)$
(4)	0	0	0	0
(5)	0	$-k \lambda$	0	$k \lambda$
(6)	$\left[j \lambda k + \frac{p}{q} \left(\frac{\beta}{\alpha} + j \lambda k \right) \right] \frac{1}{\lambda}$	$\frac{q}{p} \left(\frac{\beta}{\alpha} + j \lambda k \right) \frac{1}{\lambda}$	0	$\left[j \lambda k + \frac{q}{p} \left(\frac{\beta}{\alpha} + j \lambda k \right) \right] \frac{1}{\lambda}$
(7)	$j^2 \lambda k \cdot \frac{1}{\lambda}$	0	$\left(\frac{\beta}{\alpha} + j \lambda k \right) \frac{1}{\lambda}$	1
(8)	0	$-k$	$\frac{\beta}{\alpha} \cdot \frac{1}{\lambda}$	1
ξ_1, ξ_2, η	$\xi_1 = q, \quad \xi_2 = j, \quad \eta = p$			
F in $\sigma_0 h_b t$	$F_b(B) = F_c(A) = F_c(D) = 0, \quad F_b(H) = \frac{\beta}{\alpha} \cdot j, \quad F_b(I) = F_b(F) = F_b(J) = 2\beta$ $F_c(B) = F_c(C) = \frac{\beta}{\alpha}, \quad F_c(E) = F_c(F) = F_c(G) = 2\alpha\beta$			

Table 10 case I

regions	$\frac{\sigma_x}{\sigma_0}$	$\frac{\sigma_y}{\sigma_0}$	$\frac{\tau}{\sigma_0}$	$\left \frac{\sigma_1}{\sigma_0} \right , \left \frac{\sigma_2}{\sigma_0} \right , \left \frac{\sigma_1 - \sigma_2}{\sigma_0} \right _{\max}$
(1)	1	0	0	1
(2)	$a \lambda k$	0	0	$a \lambda k$
(3)	0	$\left(\frac{\beta}{\alpha} + a \lambda k \right) \frac{r}{s}$	0	$\left(\frac{\beta}{\alpha} + a \lambda k \right) \frac{r}{s}$
(4)	0	0	0	0
(5)	0	$-k \lambda$	0	$k \lambda$
(6)	$\frac{1}{\lambda}$	$\left(\frac{\beta}{\alpha} + a \lambda k \right) \frac{r}{s}$	0	$\frac{1}{\lambda}$
(7)	$a^2 \lambda k \cdot \frac{1}{\lambda}$	0	$\left(\frac{\beta}{\alpha} + a \lambda k \right) \frac{1}{\lambda}$	$\left[a^4 \lambda^2 k^2 + 4 \left(\frac{\beta}{\alpha} + a \lambda k \right)^2 \right] \frac{1}{\lambda}$
(8)	0	$-k$	$\frac{\beta}{\alpha} \cdot \frac{1}{\lambda}$	1
ξ_1, ξ_2, η	$\xi_1 = s, \quad \xi_2 = a, \quad \eta = r$			
F in $\sigma_0 h_b t$	$F_b^{(B)} = F_c^{(A)} = F_c^{(D)} = 0, \quad F_b^{(H)} = \frac{\beta}{\alpha} a, \quad F_b^{(J)} = F_b^{(F)} = F_b^{(J)} = 2 \beta$ $F_c^{(B)} = F_c^{(C)} = \frac{\beta}{\alpha}, \quad F_c^{(E)} = F_c^{(F)} = F_c^{(G)} = \left(\frac{\beta}{\alpha} + a \lambda k \right) (1-r)$			

Table 11 case J

regions	$\frac{\sigma_x}{\sigma_0}$	$\frac{\sigma_y}{\sigma_0}$	$\frac{\tau}{\sigma_0}$	$\left \frac{\sigma_1}{\sigma_0} \right , \left \frac{\sigma_2}{\sigma_0} \right , \left \frac{\sigma_1 - \sigma_2}{\sigma_0} \right _{\max}$
(1)	0	0	0	0
(2)	—	—	—	—
(3)	—	—	—	—
(4)	0	0	0	0
(5)	—	—	—	—
(6)	—	—	—	—
(0)	0	0	$\frac{\sigma_0}{2}$	$\frac{\sigma_0}{2}$
ξ_1, ξ_2, η	$\xi_1 = 1, \quad \xi_2 = 1, \quad \eta = 1$			
F in $\sigma_0 h_b t$	$F_b^{(B)} = F_c^{(A)} = F_c^{(D)} = 0, \quad F_b^{(F)} = F_b^{(J)} = \alpha \lambda$ $F_c^{(B)} = F_c^{(C)} = \frac{\lambda}{2}, \quad F_c^{(F)} = F_c^{(G)} = \frac{\lambda}{2}$			

Table 12 Necessary Conditions to Satisfy Yield Conditions

case	Conditions for $\left \frac{\sigma_1}{\sigma_0} \right , \left \frac{\sigma_2}{\sigma_0} \right , \left \frac{\sigma_1 - \sigma_2}{\sigma_0} \right \leq 1$	Conditions for $F_b \leq 2 \beta \sigma_0 h_b t$ $F_c \leq 2 \alpha \beta \sigma_0 h_b t$
A	(2.3), (2.5)	(2.7) [from $\tau^{(n)} > 0$]
B	(2.3), (2.5), (2.8)	—
C	(2.3), (2.6)	$F_b^{(J)} \leq F_b^{(F)}$ [from $\tau^{(n)} \geq 0$ (2.9)] $F_c^{(E)} \leq F_c^{(F)}$ [from $\tau^{(n)} \geq 0$ (2.9)] (2.6), $F_c^{(F)} \leq 2 \alpha \beta$
D	(2.3), (2.6), (2.10)	(2.13), (2.6) $F_c^{(E)} \leq 2 \alpha \beta$
E	(2.3), (2.14), (2.6)	—
F	(2.1), (2.4), (2.18)	$F_b^{(J)} \leq F_b^{(F)}$ [from $\tau^{(n)} \geq 0$ (2.11)] $F_c^{(E)} \leq F_c^{(F)}$ [from $\tau^{(n)} \geq 0$ (2.11)] $j \leq \frac{1}{2 \alpha}, \quad (2.4) \quad F_c^{(F)} \leq 2 \alpha \beta$
G	(2.4), (2.12), (2.18) (2.1)	(2.15), $j \leq \frac{1}{2 \alpha}$ (2.4), $F_c^{(E)} \leq 2 \alpha \beta$
H	(2.1), (2.4), (2.16)	—
I	(2.1), (2.4), (2.17)	—
J	—	(2.2)

柱はり接合部の極限解析(Ⅲ—1)(梗概)

——強軸曲げをうける「」字形接合部——

正会員 田 中 尚*
・ 林 永 全**

§ 1 はしき

Part (I) において、逆対称曲げをうける十字形接合部 Part (II) に L 字形接合部の降伏モーメントの解析を行なった。今回は図—1 に示すワイドフランジ材よりなる「」字形接合部の降伏モーメントを解析する。各部の寸法は図—1 に示す通りで、解析には式(1.1)のパラメータを用いる。解析上の仮定はすべて前報告 Part (I) のものを用いる。また式の簡略化をはかるため、式(1.6)～(1.19)のパラメータが用いられる。

§ 2 静的解析の分類

静的許容応力場による解析は表—1 に示す 10 の場合に分けて行なわれる。表—1 における条件は式(2.1)～

(2.18) で表現される。各場合の境界は図—2 (a), (b) に示してある。ただし $\alpha \leq \frac{\sqrt{2+\sqrt{5}}}{2}$ の範囲において I の場合、 $\alpha \geq \frac{\sqrt{2+\sqrt{5}}}{2}$ の範囲において E と H の場合は存在しない。

§ 3 静的許容応力場

静的許容応力場を求めるため、ウェブとフランジを図—3 に示すような数個の領域に分ける。各ウェブ領域の応力は一様で、フランジの各領域は一様または直線変化と仮定する。表—2～表—11 に各場合における応力とパラメータ ξ_1 , ξ_2 と η の値を示す。これらの応力はすべてつりあい条件を満足していることを確かめることができる。また表—12 に示す条件を用いると、これらの応力が降伏条件を満足していることがわかる。

* 東京大学教授, 生産技術研究所, 工博

** 東京大学, 大学院生, 博士課程

(昭和44年11月13日本稿受理・討論期限昭和44年8月末日)

U.D.C. 624.043 : 624.012

DEFORMATION CAPACITY OF THE TENSION MEMBER OF WHICH STRESS CONCENTRATION MUST BE CONSIDERED

by BEN KATO, Prof. Tokyo Univ., and HIROFUMI AOKI,
Graduate student, Tokyo Univ., Members of A.I.J.

As the typical example of the tension member of which stress concentration must be considered, a plate with a round hole was adopted, and the behavior was investigated until its ultimate state theoretically using the numerical analysis by finite element method to the elastic-plastic range on the basis of the flow theory and experimentally.

And it has been shown as the case of the member of which stress concentration is negligible^{1,2)} that the elongation capacity of the steel plates of which section area change along their length was controlled by the yield ratio of the material used. The larger the value of the yield ratio, the smaller the elongation capacity of the member.

It may be said from this point of view that it should be careful when the high yield strength steel be used in tension member bolted or rivetted at its end connection or in tapered or notched shape because the high yield strength steel generally has the high yield ratio.

U.D.C. 624.042.7 : 624.074

STUDY ON THE EQUIVALENT BEAM FOR THE STEEL TRUSS MEMBER

by TAKESHI OHYA : Engineer of Nozawa Industrial Research Institute Ltd., Members of A.I.J.

Author experimented the Elasto-plastic flexural behaviours of the steel truss member, and discussed the equivalent beam for the steel truss member.

This paper is the fourth report of the series on the dynamic response analysis of the space structure for the earthquake.

These results are as follows :

(a) It is shown that the period of the equivalent beam for the steel truss member approaches to the period of the steel truss member.

(b) In the experiment it is shown that the calculated deflection is smaller than the observed one.

(c) It is also shown that the maximum load of the virgin compression is the largest under the alternating loads, and the deflection curves of the unloading approach to the curve of displacement for the maximum load of the virgin compression.

U.D.C. 624.074.4

STRESS ANALYSIS OF A HYPERBOLIC PARABOLOIDAL SHELL SUPPORTED AT FOUR CORNERS (See Page 37)

by YOSHIKATSU TSUBOI, Dr. Eng. Prof. of Tohoku Univ. Faculty of Engineering and KATSURO NAKATA, Mr. Eng. Tsuboi Research Room, Members of A.I.J.

U.D.C. 624.078.072.2 : 624.043

LIMIT ANALYSIS OF BEAM-COLUMN CONNECTIONS (III)

——|— Type Connections of Wideflange Members Subjected to
Strong-Axis Bending (See Page 45)——

by Dr. HISASHI TANAKA, Prof. Inst. of Indu. Sci. Univ. of Tokyo.,
YUNG CHUAN LINE, Graduate Student, Univ. of Tokyo, Members of A.I.J.

U.D.C. 72.056 : 576.8

STUDIES ON CLEAN ROOM DESIGN (I) ——Airborne Bacteria as Aerosols (See Page 53)——

by ICHIYA HAYAKAWA, Associate Prof. Tokyo Institute of Technology. Member of A.I.J.