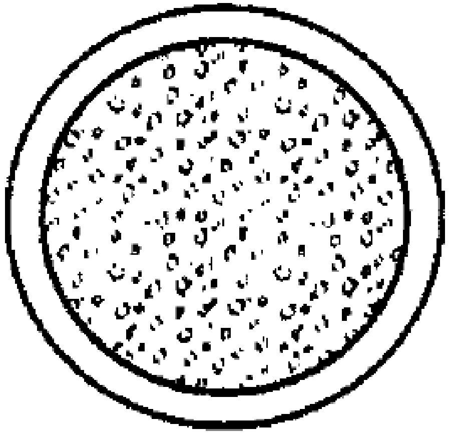
انجمن ایرانی
مهندسان محاسب ساختمان

ستون های مرکب CFT
(Concrete Filled Tube)

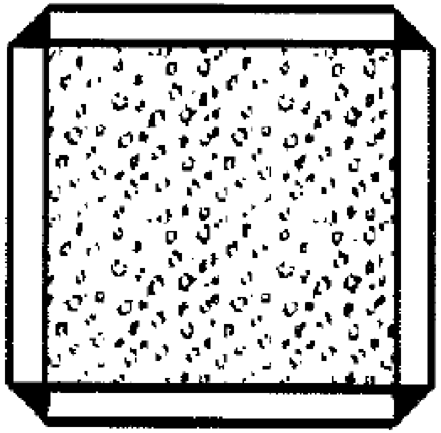
صمد آقازاده

بهمن ماه ۱۳۹۵

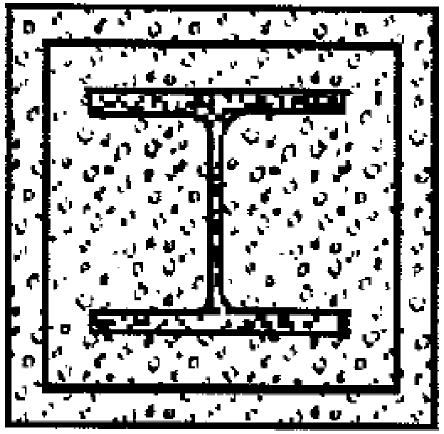
Concrete Filled Tube (CFT)



(پ) عضو محوری مختلط لوله پرشده با بتن



(ب) عضو محوری مختلط قوطی شکل پرشده با بتن



(الف) عضو محوری مختلط محاط در بتن

Steel Reinforced Concrete (SRC)

۱۰-۲-۸-۱-۲ محدودیت‌های مصالح در اعضای با مقطع مختلط

بتن، میلگرد و مقاطع فولادی اعضای با مقطع مختلط باید دارای شرایط زیر باشند. مگر آنکه استفاده از مصالح با شرایط مغایر با شرایط زیر توسط آزمایش یا تحلیل توجیه شده باشد.

۱. مقاومت فشاری مشخصه نمونه استوانه‌ای بتن (f_c) برای بتن‌های با وزن مخصوص معمولی نباید از ۲۰MPa کمتر و از ۷۰MPa بیشتر و برای بتن‌های سبک نباید از ۲۰MPa کمتر و از ۴۰MPa بیشتر باشد. مصالح بتن پرمقاومت را می‌توان برای محاسبات مربوط به سختی اعضا مورد استفاده قرار داد، لیکن برای محاسبات مقاومت اسمی اعضای با مقطع مختلط نمی‌توان به آن تکیه کرد، مگر این‌که نتایج آزمایش یا تحلیل استفاده از آن را توجیه نماید.

۲. تنش تسلیم میلگردها و مقاطع فولادی اعضای با مقطع مختلط نباید از ۵۰۰MPa تجاوز نماید.

۱۰-۲-۸-۲-۲ اعضای محوری با مقطع مختلط پرشده با بتن

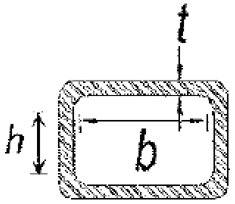
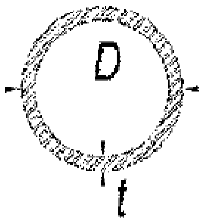
الف) محدودیت‌ها

اعضای محوری با مقطع مختلط پرشده با بتن باید محدودیت‌های زیر را برآورده نمایند.

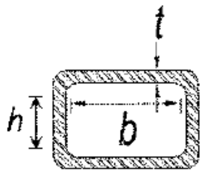
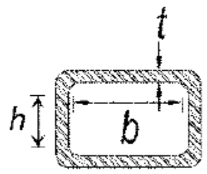
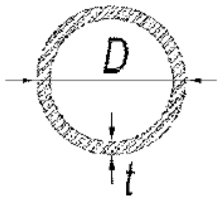
۱. مساحت مقطع فولادی باید حداقل یک درصد مساحت کلی مقطع مختلط باشد.

۲. نسبت پهنا به ضخامت در اجزای مقطع فولادی باید مطابق با الزامات بند ۱۰-۲-۸-۱-۳ تعیین شود.

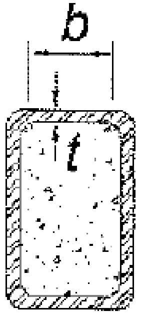
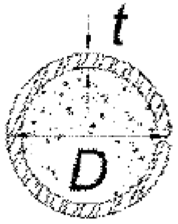
جدول ۱۰-۲-۸-۱ نسبت پهنا به ضخامت اجزای مقطع مختلط پر شده با بتن در اعضای تحت اثر فشار محوری

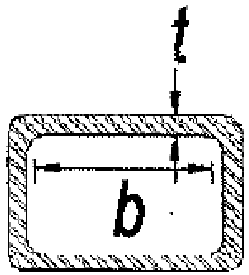
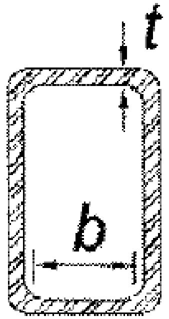
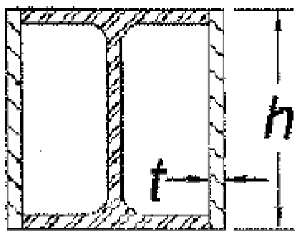
حالت	شرح اجزا	نسبت پهنا به ضخامت	حداکثر نسبت پهنا به ضخامت λ_p (غیرفشرده/فشرده)	λ_r (لاغر/غیرفشرده)	حداکثر نسبت مجاز	مقاطع فولادی نمونه
۱	بال‌ها و جان‌های مقاطع توخالی مستطیلی نورد شده و جعبه‌ای با ضخامت یکنواخت	b/t و h/t	$۲/۲۶\sqrt{\frac{E}{F_Y}}$	$۳\sqrt{\frac{E}{F_Y}}$	$۵\sqrt{\frac{E}{F_Y}}$	
۲	مقاطع تو خالی دایره‌ای شکل	D/t	$۰/۱۵\frac{E}{F_Y}$	$۰/۱۹\frac{E}{F_Y}$	$۰/۳۱\frac{E}{F_Y}$	

جدول ۱۰-۲-۸-۲ نسبت های پهنا به ضخامت اجزای مقطع مختلط پر شده با بتن در اعضای تحت اثر خمش

حالت	شرح اجزا	نسبت پهنا به ضخامت	حداکثر نسبت پهنا به ضخامت		حداکثر نسبت مجاز	مقاطع فولادی نمونه
			λ_p (غیرفشرده/فشرده)	λ_r (لاغر/غیرفشرده)		
۱	بال‌های مقاطع توخالی مستطیلی نورد شده و مقاطع جعبه‌ای با ضخامت یکنواخت	b/t	۲/۲۶ $\sqrt{\frac{E}{F_Y}}$	۳ $\sqrt{\frac{E}{F_Y}}$	۵ $\sqrt{\frac{E}{F_Y}}$	
۲	جان‌های مقاطع تو خالی مستطیلی نوردشده و مقاطع جعبه‌ای با ضخامت یکنواخت	h/t	۳ $\sqrt{\frac{E}{F_Y}}$	۵/۷ $\sqrt{\frac{E}{F_Y}}$	۵/۷ $\sqrt{\frac{E}{F_Y}}$	
۳	مقاطع توخالی دایره‌ای شکل	D/t	۰/۰۹ $\frac{E}{F_Y}$	۰/۳۱ $\frac{E}{F_Y}$	۰/۳۱ $\frac{E}{F_Y}$	

جدول ۱۰-۳-۴-۱ محدودیت نسبت پهنا به ضخامت در اجزای فشاری اعضای با شکل‌پذیری متوسط و زیاد

حالت	شرح اجزا	نسبت پهنا به ضخامت	حداکثر نسبت پهنا به ضخامت		مثال‌های نمونه
			λ_{md} اعضای با شکل‌پذیری متوسط	λ_{hd} اعضای با شکل‌پذیری زیاد	
۹	بال‌ها و جان‌های مقاطع قوطی‌شکل‌پرشده با بتن	b/t	$۲/۲۶\sqrt{\frac{E}{F_y}}$	$۱/۴\sqrt{\frac{E}{F_y}}$	
۱۰	جداره‌های مقاطع توخالی دایره‌ای شکل‌پرشده با بتن	D/t	$۰/۱۵\frac{E}{F_y}$	$۰/۰۷۶\frac{E}{F_y}$	

	۴	بال‌های متقاطع توخالی مستطیلی شکل (HSS) بال‌های مقاطع قوطی شکل ساخته‌شده از ورق ورق‌های کناری مقاطع I شکل قوطی‌شده وقتی به عنوان مهاربند به کار می‌رود.	b/t b/t d/t	۰/۶۴ $\sqrt{\frac{E}{F_y}}$ [۳]	۰/۵۵ $\sqrt{\frac{E}{F_y}}$ [۲]	  

Moments of Inertia - Composite Columns

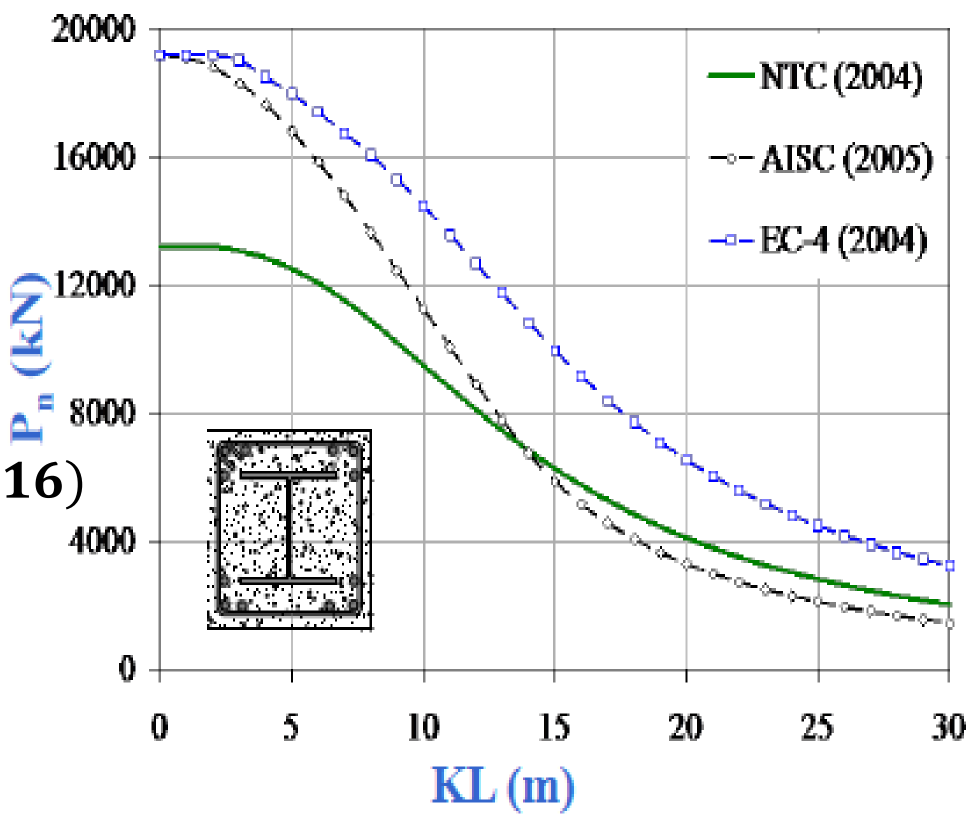
SRC new effective stiffness:

$$E\,I_{eff} = E_s I_s + 0.5\, E_s I_{sr} + C_1 E_c I_c$$

$$C_1 = 0.1 + 2\,[A_s / (A_c + A_s)] \le 0.3$$

(concrete effectiveness factor)

$$\boldsymbol{C1 = 0.25 + 3\left\{\frac{As + Asr}{Ag}\right\} \le 0.7 (\text{AISC2016})}$$



CFT new effective stiffness:

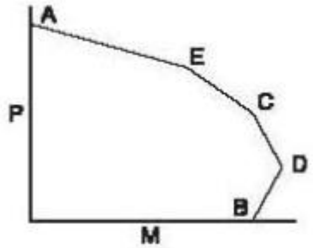
$$E\,I_{eff} = E_s I_s + E_s I_{sr} + C_3 E_c I_c$$

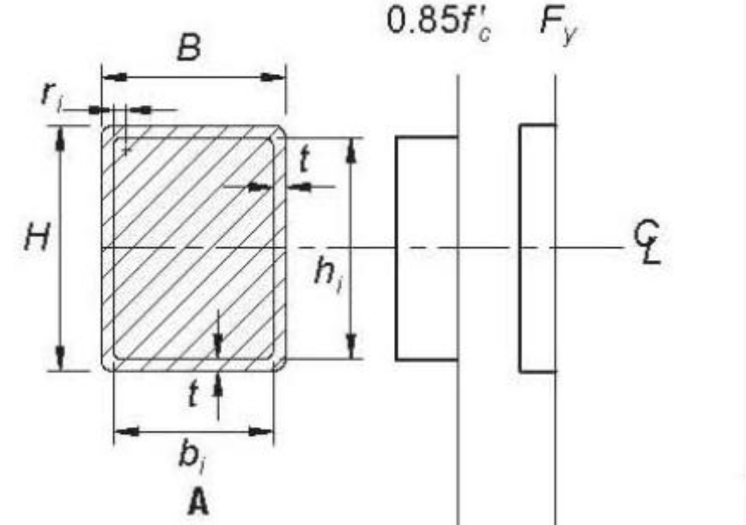
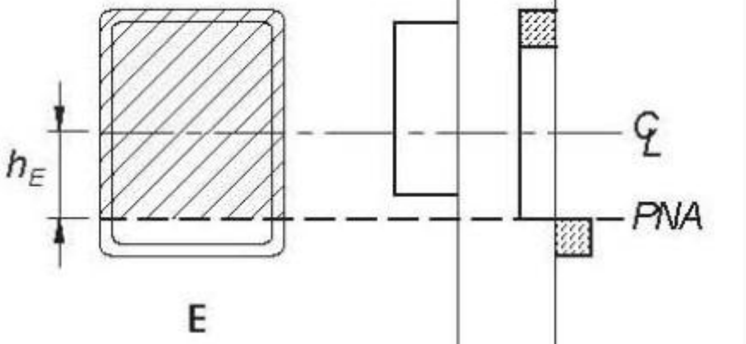
$$C_3 = 0.6 + 2\,[A_s / (A_c + A_s)] \le 0.9$$

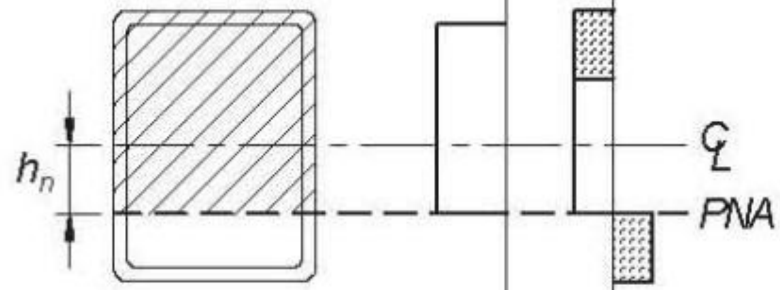
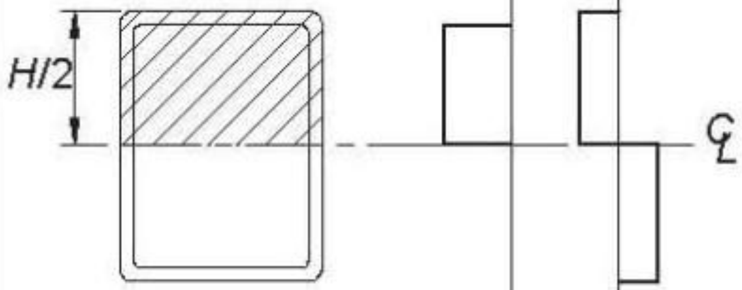
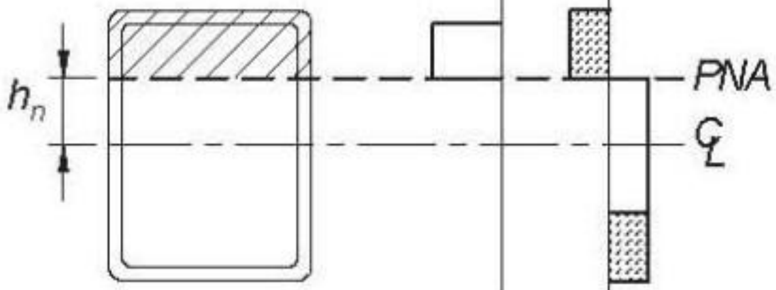
(concrete effectiveness factor)

$$\boldsymbol{C3 = 0.45 + 3\{\frac{As+Asr}{Ag}\} \le 0.9} \text{ (AISC 2016\}}$$

Plastic Capacities for Composite Filled HSS Bent About Either Principal Axis



Section	Stress Distribution	Pt.	Defining Equations
		**A**	$P_A = F_y A_s + 0.85 f'_c A_c$ $M_A = 0$ A_s = area of steel shape $A_c = b_i h_i - 0.858 r_i^2$ $b_i = B - 2t$ $h_i = H - 2t$ $r_i = t$
		**E**	$P_E = \dfrac{0.85 f'_c A_c}{2} + 0.85 f'_c b_i h_E + 4 F_y t h_E$ $M_E = M_D - F_y Z_{sE} - \dfrac{0.85 f'_c Z_{cE}}{2}$ $Z_{cE} = b_i h_E^2$ $Z_{sE} = 2 t h_E^2$ $h_E = \dfrac{h_n}{2} + \dfrac{H}{4}$

 **C**	**C**	$P_C = 0.85 f'_c A_c$ $M_C = M_B$
 **D**	**D**	$P_D = \dfrac{0.85 f'_c A_c}{2}$ $M_D = F_y Z_s + \dfrac{0.85 f'_c Z_c}{2}$ Z_s = full x-axis plastic section modulus of HSS $Z_c = \dfrac{b_i h_i^2}{4} - 0.192 r_i^3$
 **B**	**B**	$P_B = 0$ $M_B = M_D - F_y Z_{sn} - \dfrac{0.85 f'_c Z_{cn}}{2}$ $Z_{sn} = 2 t h_n^2$ $Z_{cn} = b_i h_n^2$ $h_n = \dfrac{0.85 f'_c A_c}{2\left[0.85 f'_c b_i + 4 t F_y\right]} \le \dfrac{h_i}{2}$
		Note: Equations in this table are equally applicable to bending about the shape's X-X axis (when $H \ge B$) and to bending about the shape's Y-Y axis (when $B > H$).

پ) هنگامی‌که انتقال برش در اعضای با مقطع پرشده با بتن از طریق اندرکنش پیوستگی مستقیم به فولاد و بتن صورت می‌گیرد، مقاومت طراحی پیوستگی بین فولاد و بتن مساوی ϕR_n می‌باشد که در آن ϕ ضریب کاهش مقاومت پیوند برابر ۰/۴۵ و R_n مقاومت پیوند اسمی می‌باشد که باید به شرح زیر تعیین شود.

- برای مقاطع فولادی مستطیلی توخالی پر شده با بتن:

$$R_n = B^2 C_{in} F_{in} \qquad (۱۰-۲-۸-۳۱)$$

- برای مقاطع فولادی لوله‌ای و پر شده با بتن:

$$R_n = ۰/۲۵ \pi D^2 C_{in} F_{in} \qquad (۱۰-۲-۸-۳۲)$$

در روابط فوق:

C_{in} = ۲ اگر عضو با مقطع مختلط فقط از یک طرف به محل اثر بار منتهی شود (شرط انتهایی)

= ۴ اگر عضو با مقطع مختلط از دو طرف به محل اثر بار منتهی شود. (شرط میانی)

F_{in}= تنش اسمی پیوستگی و مساوی ۰/۴ MPa

B= پهنای کلی وجهی از مقطع فولادی مستطیلی که انتقال برش از طریق آن صورت می‌گیرد.

D= قطر خارجی مقطع فولادی لوله‌ای شکل

3c. Direct Bond Interaction

Where force is transferred in a filled composite member by direct bond interaction, the available bond strength between the steel and concrete shall be determined as follows:

$$R_n = p_b L_{in} F_{in} \tag{I6-5}$$

$$\phi = 0.50 \text{ (LRFD)} \qquad \Omega = 3.00 \text{ (ASD)}$$

where

F_{in} = nominal bond stress, ksi (MPa)
= $12t/H^2 \le 0.1$, ksi ($2\,100t/H^2 \le 0.7$, MPa) for rectangular cross sections
= $30t/D^2 \le 0.2$, ksi ($5\,300t/D^2 \le 1.4$, MPa) for circular cross sections

D = outside diameter of round HSS, in. (mm)

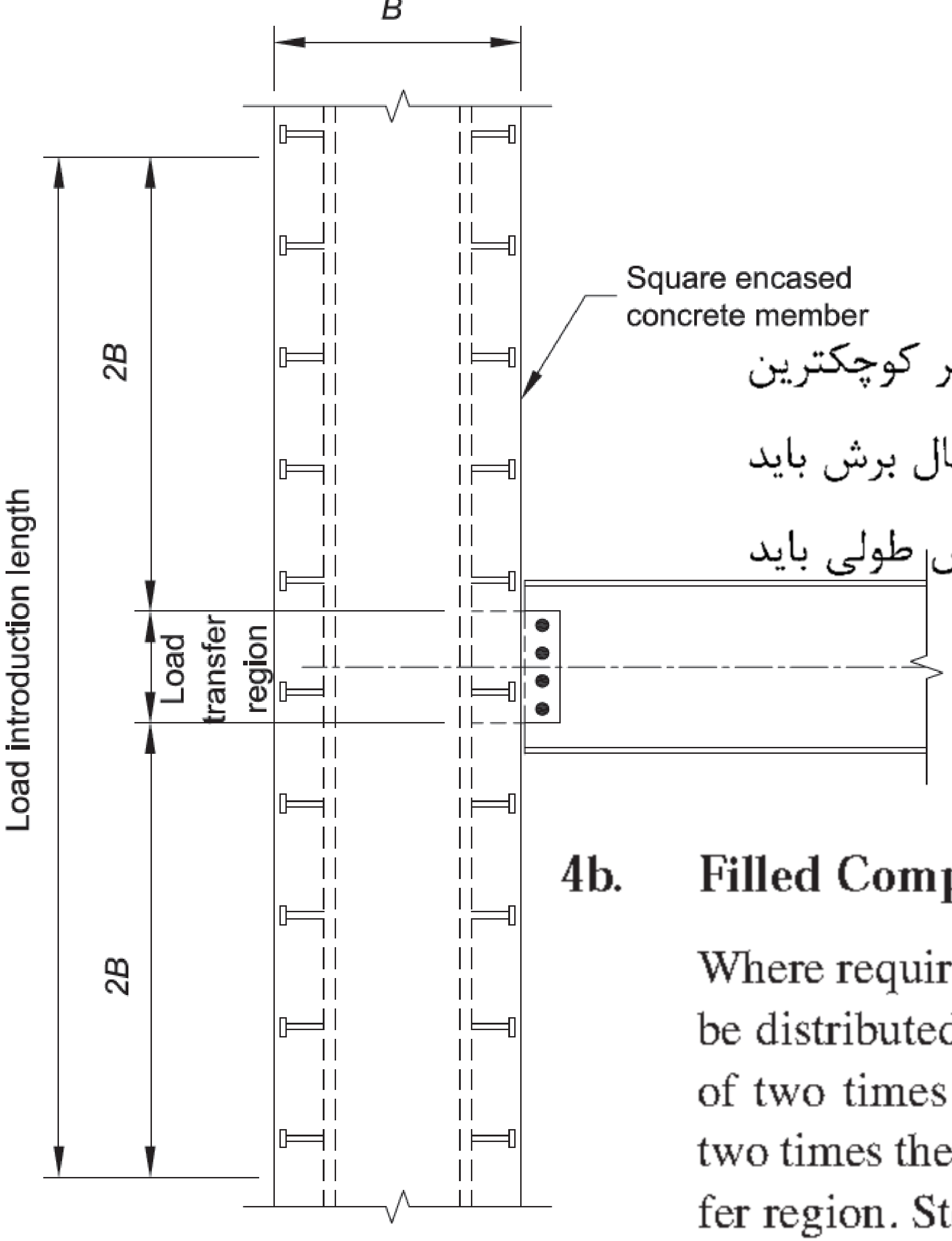
H = maximum transverse dimension of rectangular steel member, in. (mm)

L_{in} = load introduction length, determined in accordance with Section I6.4, in. (mm)

R_n = nominal bond strength, kips (N)

p_b = perimeter of the steel-concrete bond interface within the composite cross section, in. (mm)

t = design wall thickness of HSS member as defined in Section B4.2, in. (mm)



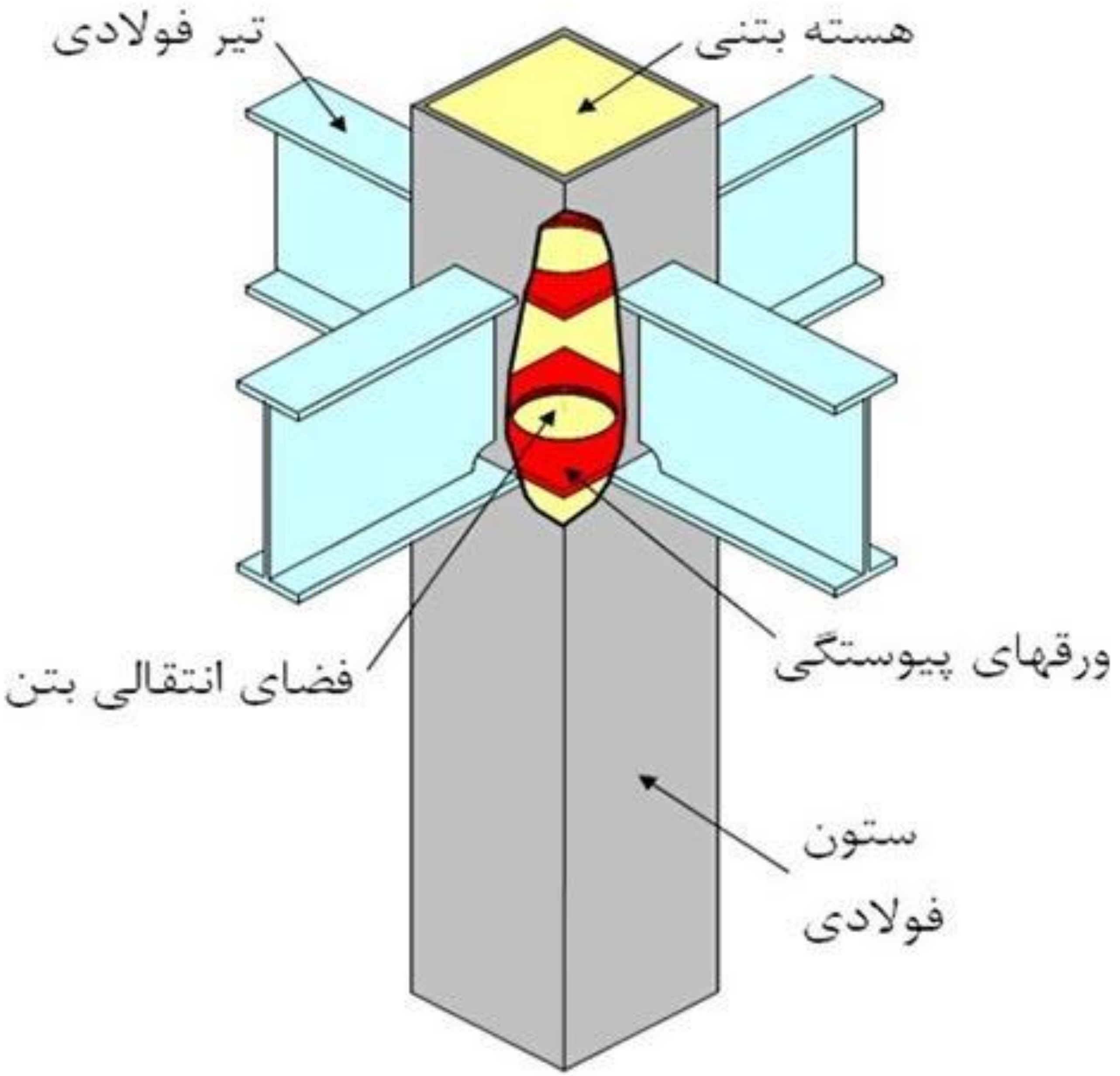
۱۰-۲-۸-۶-۴ جزئیات‌بندی

الف) اعضای با مقطع مختلط محاط در بتن

فاصلهٔ برشگیرهای تعبیه شده در بالا و پایین ناحیه انتقال برش طولی نباید از دو برابر کوچکترین بعد مقطع مختلط بیشتر باشد. همچنین فاصلهٔ برشگیرها در داخل و بیرون ناحیهٔ انتقال برش باید با رعایت الزامات بند ۱۰-۲-۸ صورت گیرد. برشگیرهای تعبیه شده جهت انتقال برش طولی باید حداقل در دو وجه مقطع فولادی و بصورت قرینه مورد استفاده قرار گیرد.

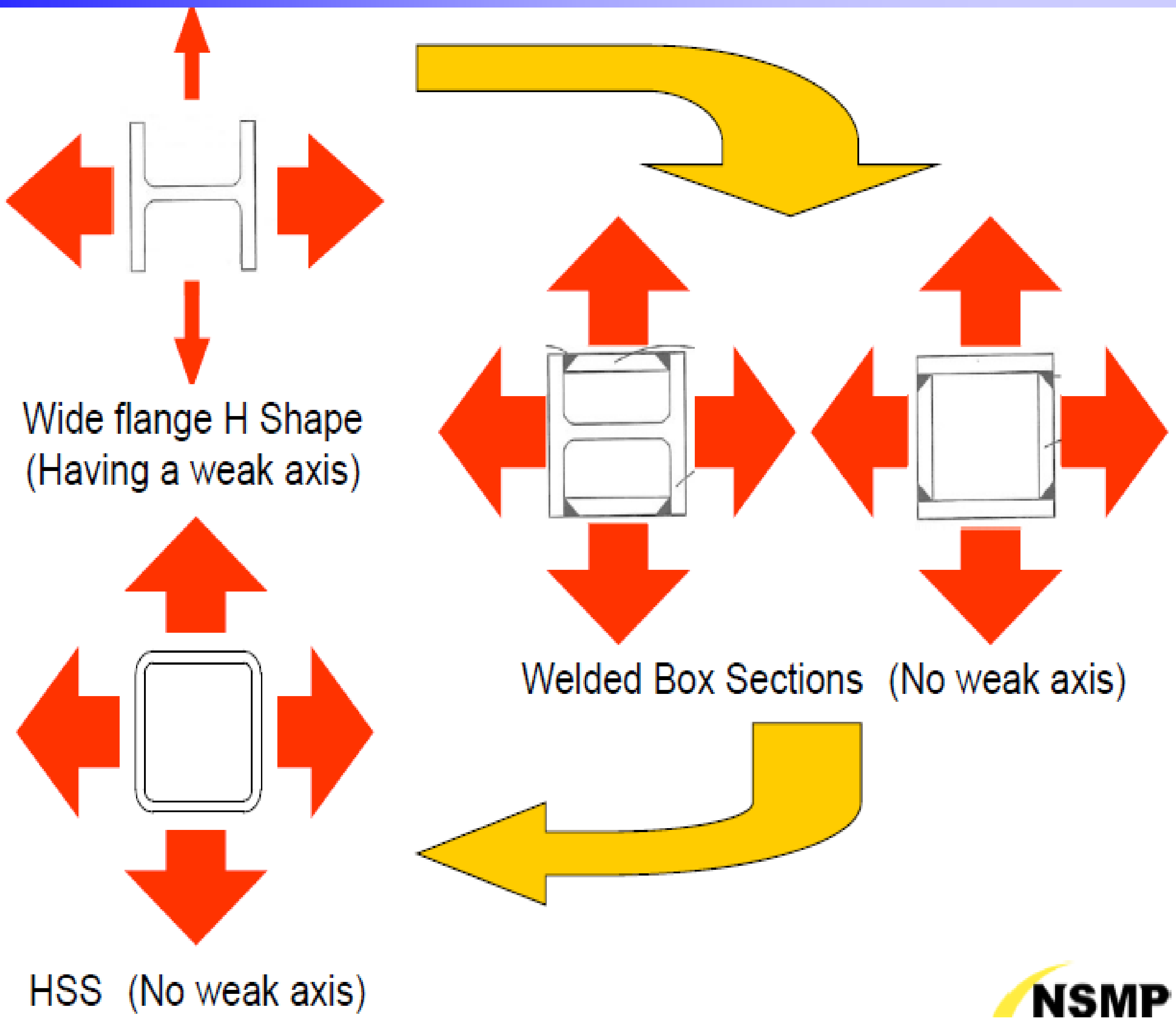
4b. Filled Composite Members

Where required, steel anchors transferring the required longitudinal shear force shall be distributed within the *load introduction length*, which shall not exceed a distance of two times the minimum transverse dimension of a rectangular steel member or two times the diameter of a round steel member both above and below the *load* transfer region. Steel anchor spacing within the load introduction length shall conform to Section I8.3e.



تیر فولادی
هسته بتنی
ورقهای پیوستگی
فضای انتقالی بتن
ستون
فولادی

History of Structural Steel for Column in Japan



Advantages of HSS vs WFB

1. Open space without brace

⇒ More flexibility for designing

2. Light weight structure

⇒ Less cost including for Civil construction

HSS

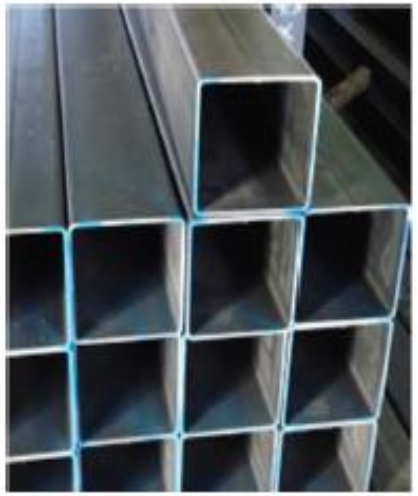
WFB

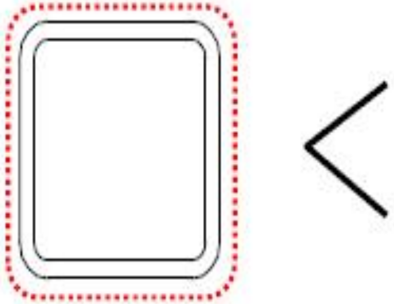
Advantages of HSS vs WFB

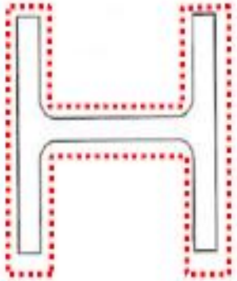
3. Less Surface Area

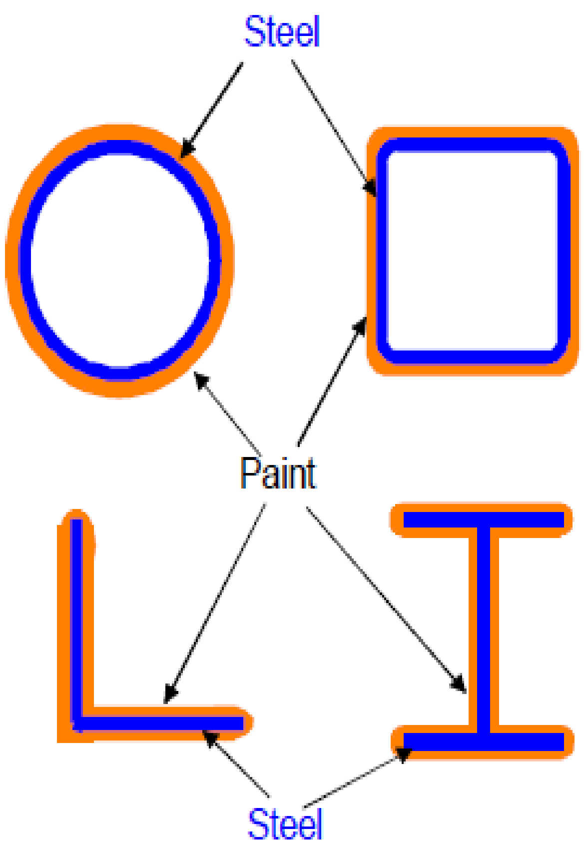
= Less election cost (Painting, Surface treatment)

4. High Anti-seismic performance









Paint surface for hollow sections vs open sections

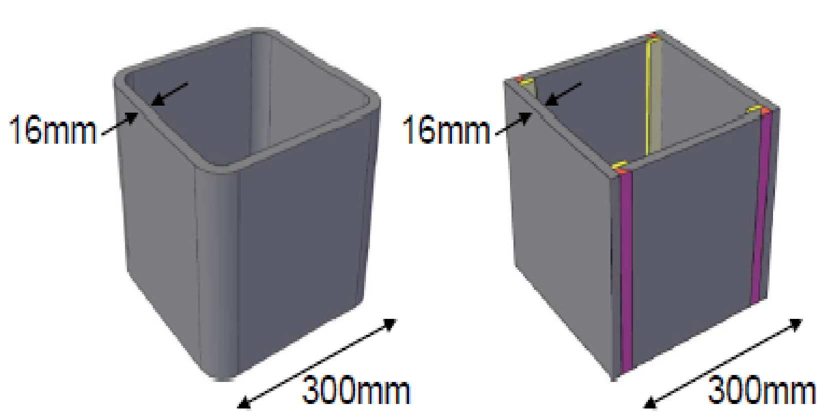
HSS Column vs WFB Column (Weight and Surface Area)

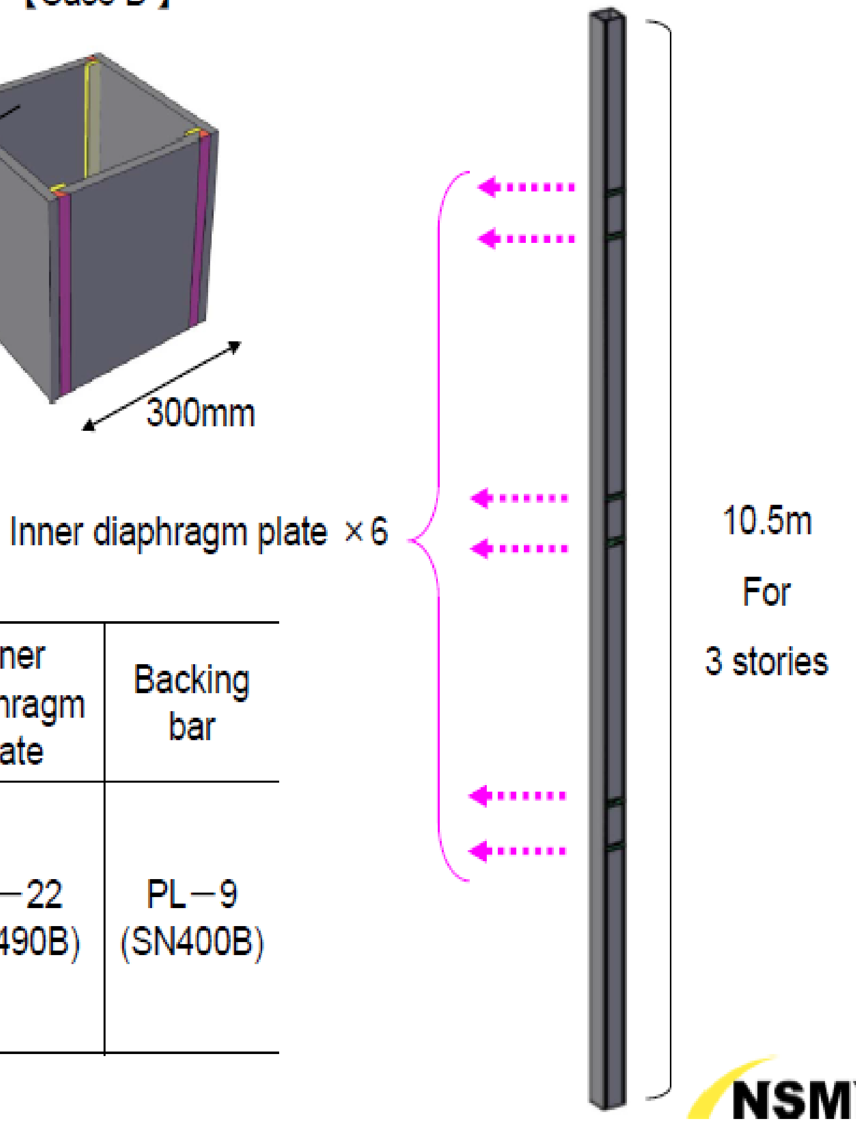
HSS : ASTM A500 GradeB Fy=317N/mm2

H-Shape : ASTMA992 Fy=345N/mm2

	case-1		case-2	
	HSS	H-shape	HSS	H-shape
	10×10×1/2	W10×77 10-5/8×10-1/4	16×16×1/2	W14×145 14-3/4×15-1/2
Effective Length	6(m)		9(m)	
Available Strength in Axial Compression	589(KN)	546(KN)	1,020(KN)	1,060(KN)
Nominal Weight (kg/m)	92.9(81%)	115(100%)	164(76%)	216(100%)
Surface Area (m2/m)	0.89(57%)	1.55(100%)	1.50(66%)	2.29(100%)

The cost comparison between HSS and Welded Box Sections in Japan



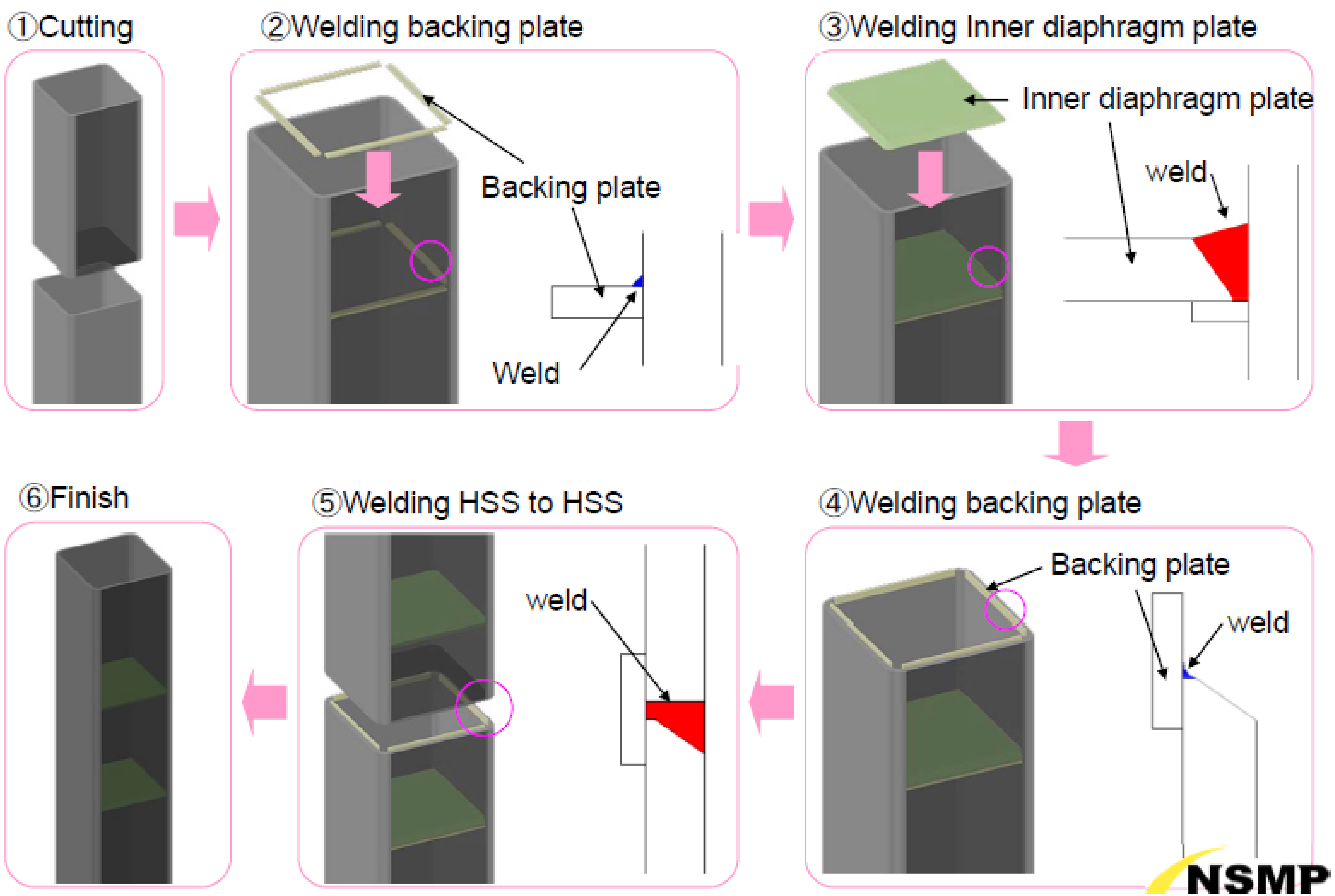


◆Steel list

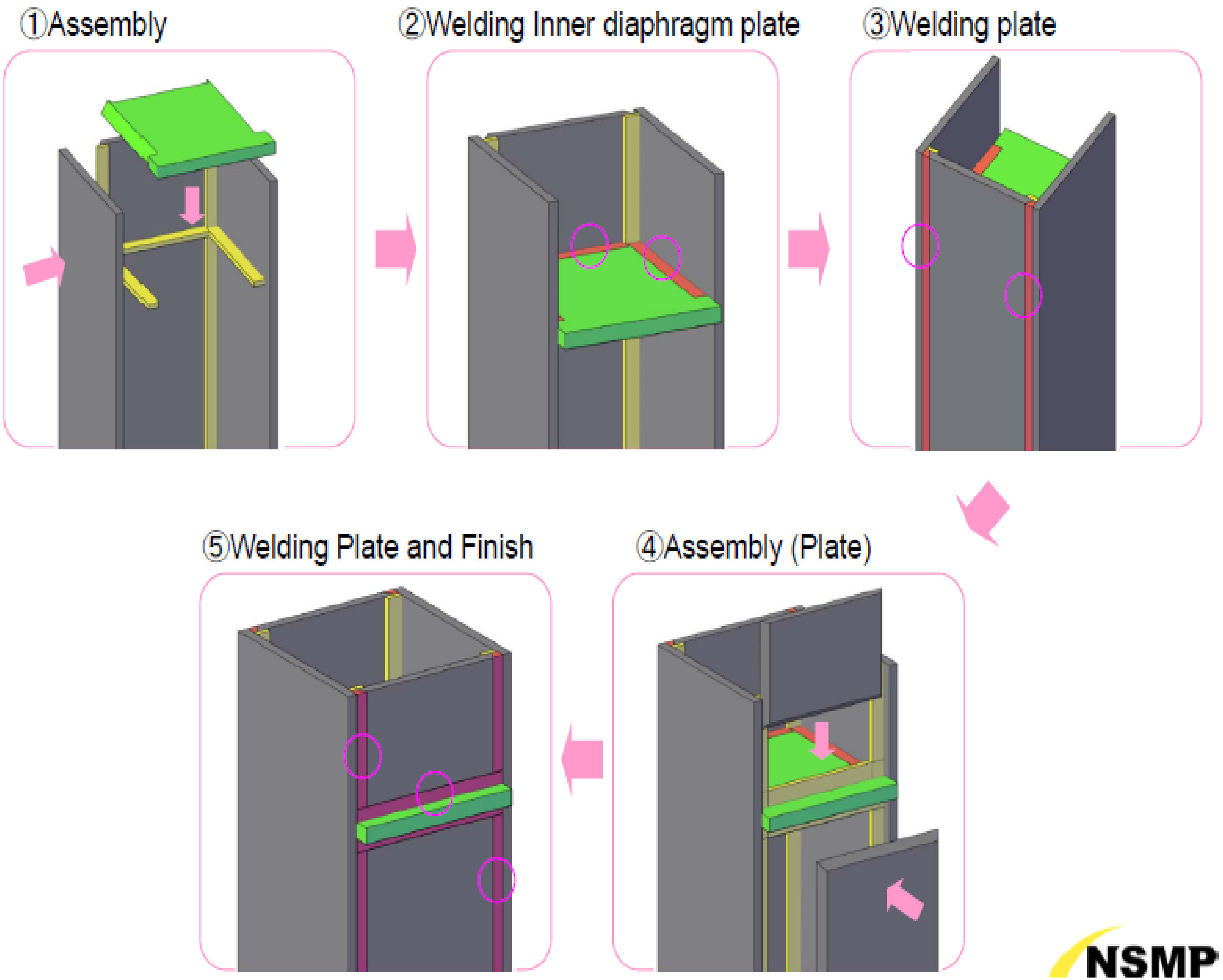
	Column	Inner diaphragm plate	Backing bar
HSS	□300×300×16 (BCR295)	PL－22 (SN490B)	PL－9 (SN400B)
Welded Box Sections	PL－16 (SN400B)		

NSMP

HSS work process

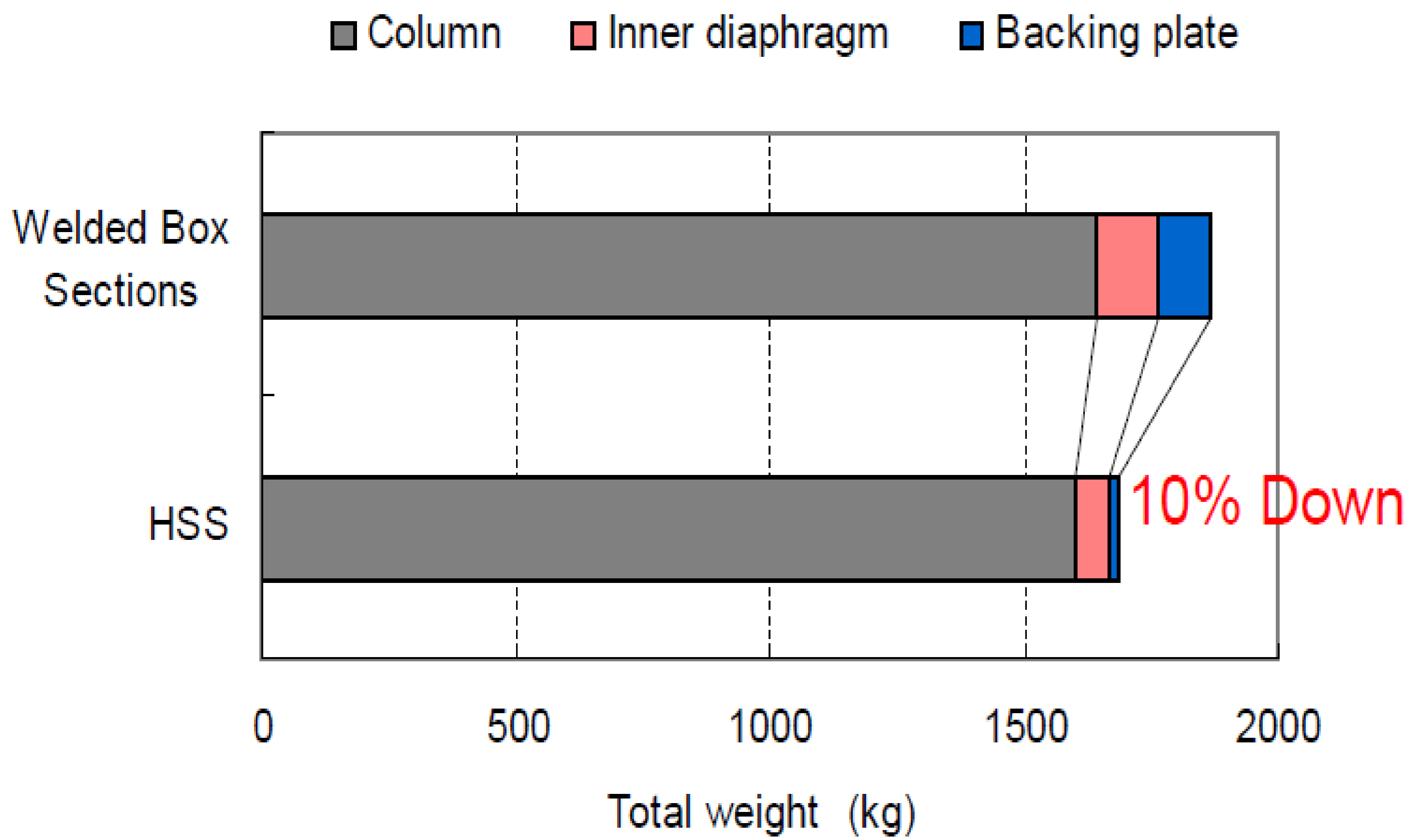


Welded Box Sections work process

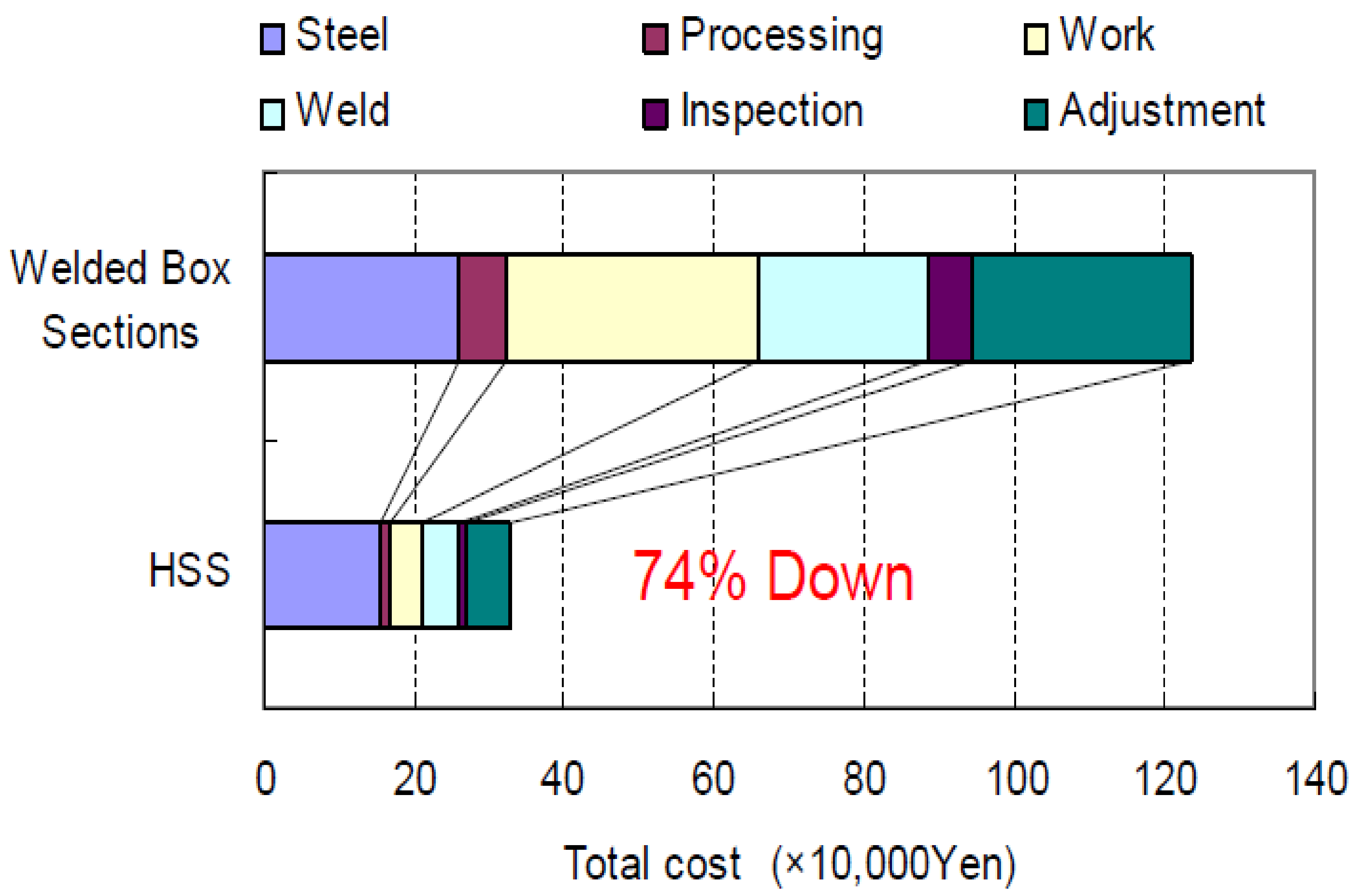


NSMP

Result (Weight)



Result (Cost)



Steel
Processing
Work
Weld
Inspection
Adjustment
Welded Box Sections
HSS
74% Down
0
20
40
60
80
100
120
140
Total cost (×10,000Yen)

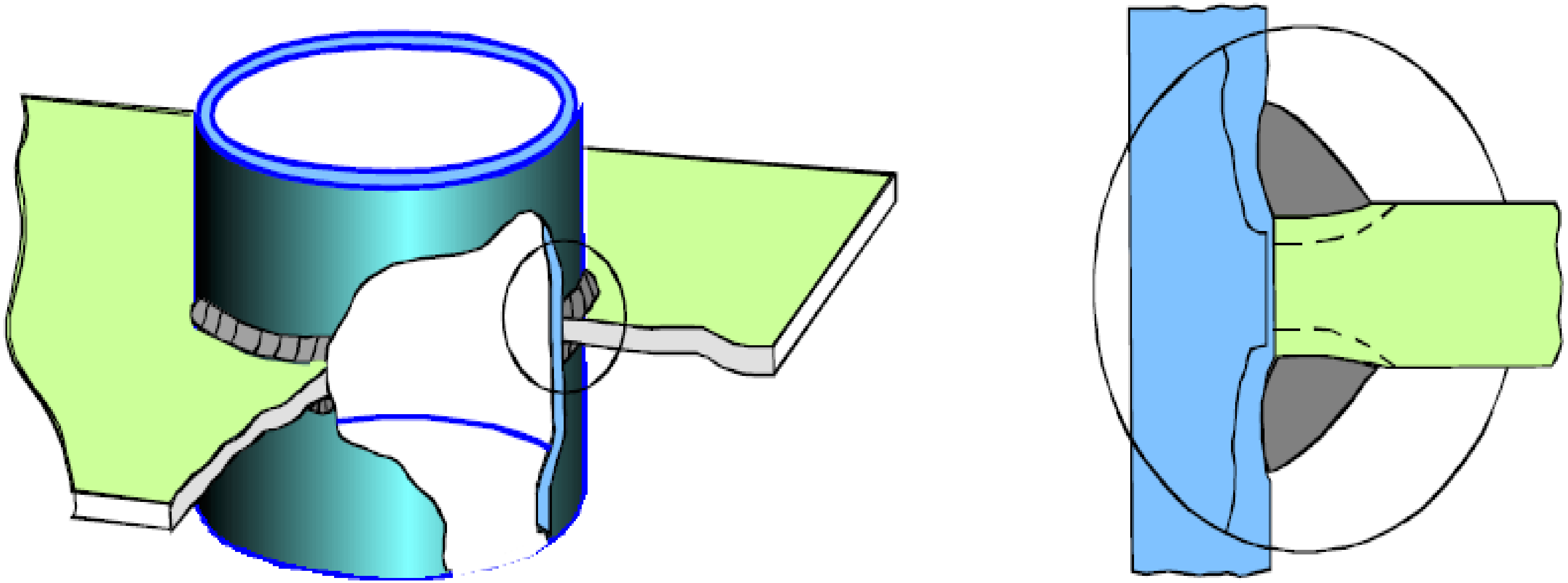


Fig. 2.1 Lamellar tearing

مزایای ستون های CFT

۱- افزایش مقاومت فشاری

۲- افزایش مقاومت خمشی

۳- افزایش شکل پذیری

۴- افزایش مقاومت در برابر آتش

۵- جلوگیری از کمانش موضعی مقطع فولادی

۶- افزایش نسبت لنگر خمشی ستون به تیر هنگام کنترل ستون قوی تیر ضعیف

۷- افزایش سختی ستون

مشکلات ستون های CFT

۱- بتن ریزی داخل مقطع توخالی

۲- افزایش وزن ساختمان

۳- ورق پیوستگی

۴- برشگیر

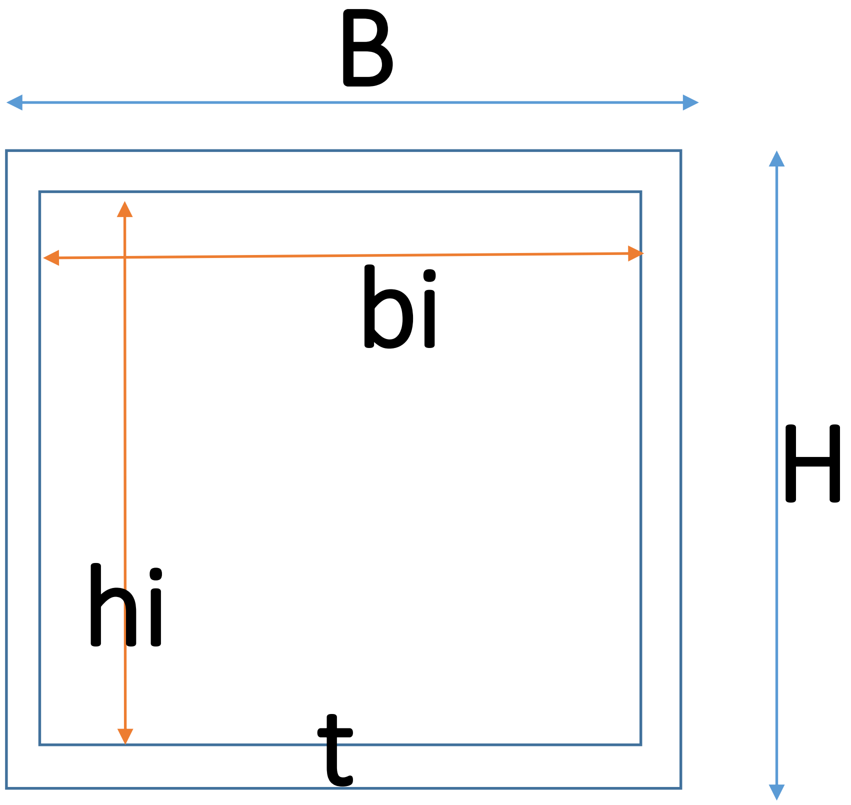
مزایای ستون های CFT

۱- افزایش مقاومت فشاری

$$P_p = F_y A_s + C_2 \left(A_c + A_{sr}\frac{E_s}{E_c}\right) f_c \qquad (۱۰-۸-۲-۱۰)$$

C_2 = ۰/۸۵ برای مقاطع فولادی توخالی مستطیلی شکل

= ۰/۹۵ برای مقاطع فولادی توخالی دایره‌ای شکل



$$B = 40\ cm$$

$$H = 40cm$$

$$t = 2cm$$

$$f_c' = 300\frac{kg}{cm2}$$

$$F_y = 2400\frac{kg}{cm2}$$

$$E_s = 2.04 \times 10^6\frac{kg}{cm2}$$

$$E_C = 2.62 \times 10^5\frac{kg}{cm2}$$

$$K = 1$$

$$L = 360\ cm$$

$$b_i = B - 2t = 40 - 4 = 36\ cm$$

$$h_i = H - 2t = 40 - 4 = 36\ cm$$

$$A_s = 40 \times 2 \times 2 + (40 - 4) \times 2 \times 2 = 304\ cm^2$$

$$A_c = b_i h_i - 0.85r^2 = 36 \times 36 = 1296\ cm^2$$

$$P_A = F_y A_s + 0.85 f_c' A_C = 2400 \times 304 + 0.85 \times 300 \times 1296 = 1060080\ kg$$

$$P_e = \frac{\pi^2 EI}{(KL)^2} = 13906680\ kg$$

$$P_n = 1060080 \times 0.658^{0.076} = 1026792\ kg$$

$$\mathbf{0.75} P_n = \mathbf{0.75} \times 1026792 = 770093.8\ kg$$ ستون کامپوزیت

$$\mathbf{0.9} P_n = 639280.43\ kg$$ ستون فلزی تنها

مزایای ستون های CFT

۲- افزایش مقاومت خمشی

$$Z_s = 40 \times 2 \times (40 - 2) + 2 \times \frac{36}{2} \times 2 \times \frac{36}{2} = 4336\ cm^3$$

$$Z_c = 11664\ cm^3$$

$$M_D = F_y Z_s + \frac{0.85 \times f_c' \times Z_c}{2} = 11893560\ kg.cm$$

$$h_n = \frac{0.85 \times f_c' \times A_c}{2[0.85 \times f_c' \times b_i + 4tF_y]} \leq \frac{h_i}{2} = 18$$

$$h_n = 5.82\ cm$$

$$Z_{sn} = 2th_n^2 = 135.6018\ cm^3$$

$$Z_{cn} = b_i h_n^2 = 1220.417\ cm^3$$

$$M_B = M_D - F_y Z_{sn} - \frac{0.85 f_c' Z_{cn}}{2} = 11412512\ kg.cm$$

ستون کامپوزیت

$$0.9M_n = \boxed{10271260\ kg.cm}$$

ستون فلزی تنها

$$M_n = 0.9ZF_y = 0.9 \times 4336 \times 2400 = \boxed{9365760\ kg.cm}$$

مزایای ستون های CFT

۶- افزایش نسبت لنگر خمشی ستون به تیر   هنگام کنترل ستون قوی تیر ضعیف

$$\sum M_{pc}^{*} = \sum Z_c(F_{yc} - P_{uc}/A_g)$$

$$A_s = 40 \times 2 \times 2 + (40 - 4) \times 2 \times 2 = 304\ cm^2$$

$$A_c = b_i h_i - 0.85r^2 = 36 \times 36 = 1296\ cm^2$$

$$Ag = As + Ac \times \frac{Ec}{Es} = 470.15\ cm2$$

در روابط فوق:

Z_c= اساس مقطع پلاستیک ستون

A_g= سطح مقطع ستون

F_y= تنش تسلیم فولاد ستون

P_{uc}= مقاومت فشاری مورد نیاز ستون حاصل از ترکیبات بار زلزلهٔ تشدیدیافته

M_{pb}= لنگر خمشی پلاستیک تیر در محل تشکیل مفصل پلاستیک

R_{yb}= نسبت تنش تسلیم مورد انتظار به حداقل تنش تسلیم تعیین شدهٔ مصالح تیر مطابق مقادیر جدول ۱۰-۳-۲-۱

C_{pr}= مطابق تعریف بند ۱۰-۳-۵-۴

مزایای ستون های CFT

۷- افزایش سختی ستون

$$I_S = \mathbf{73365.33}\ cm^4$$

$$I_C = 139968\ cm^4$$

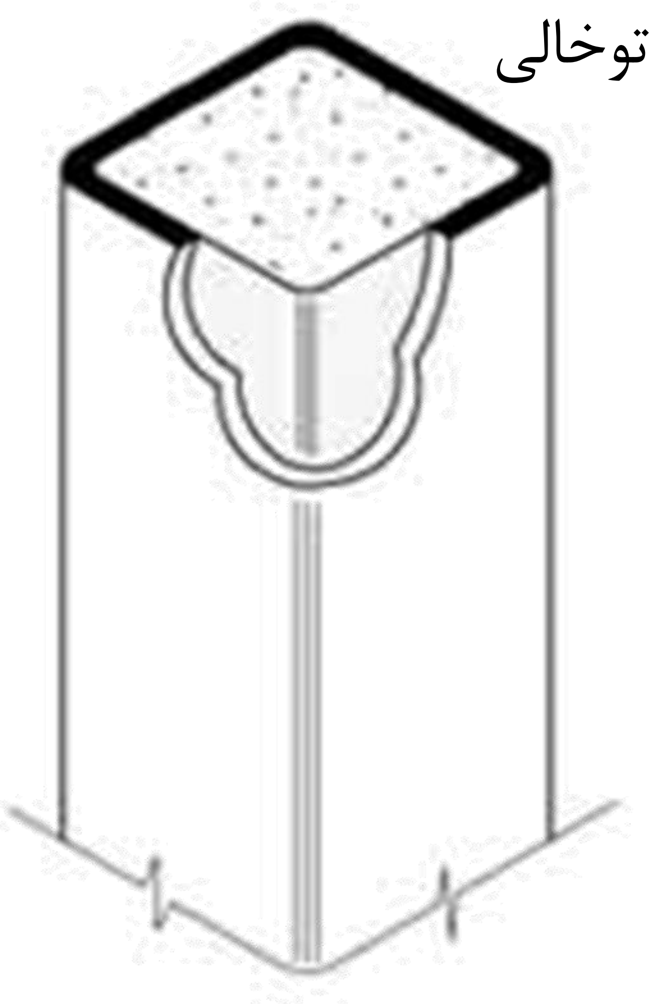
$$EI_{eff} = E_S I_S + C_3 E_C I_c = 1.82 \times 10^{11}$$

$$\boldsymbol{I_{eff} = 89515\ cm4}$$

$$I_t = Is + Ic \times \frac{Ec}{Es} = \mathbf{91310}\ cm4$$

مشکلات ستون های CFT

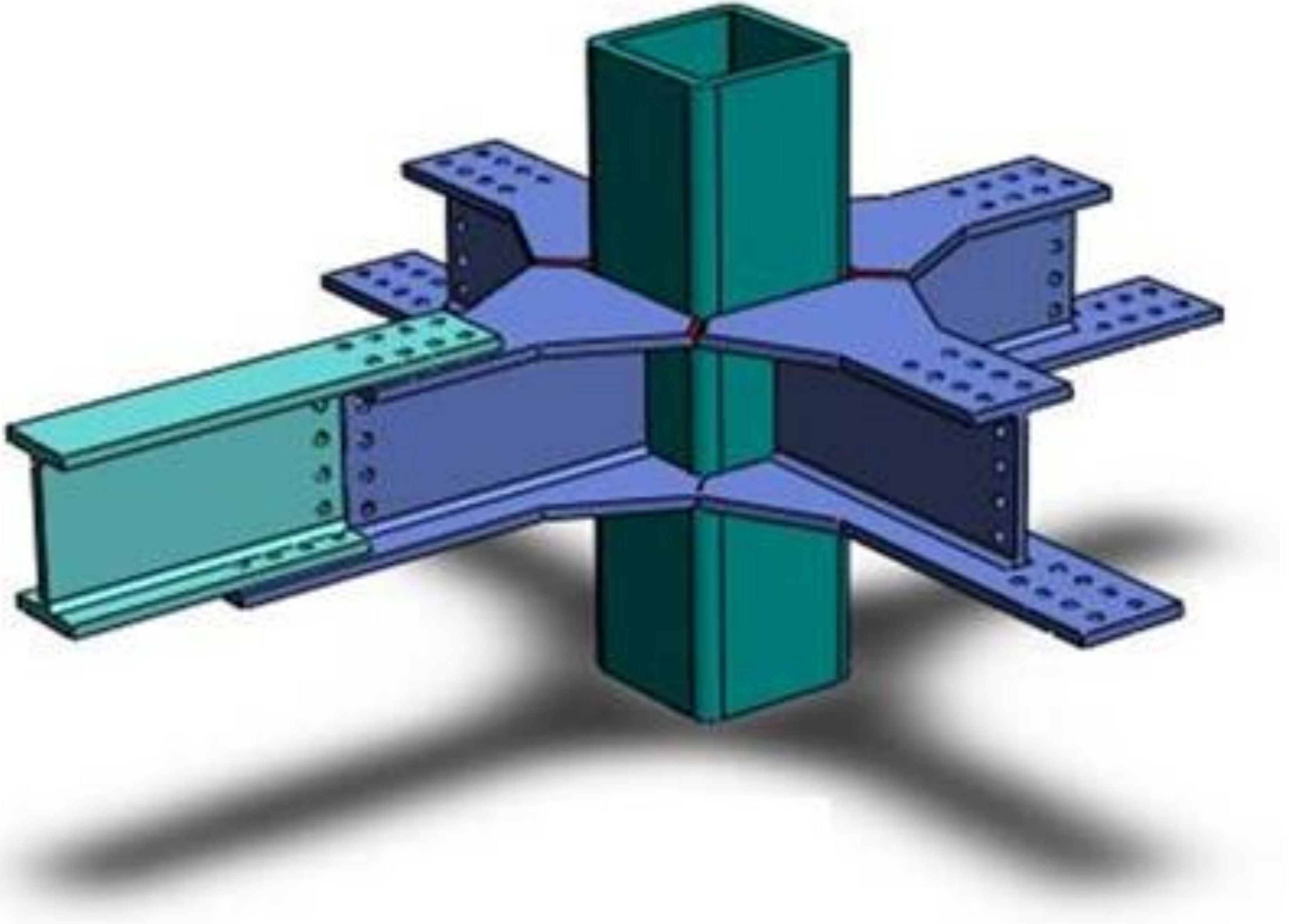
۱- بتن ریزی داخل مقطع توخالی



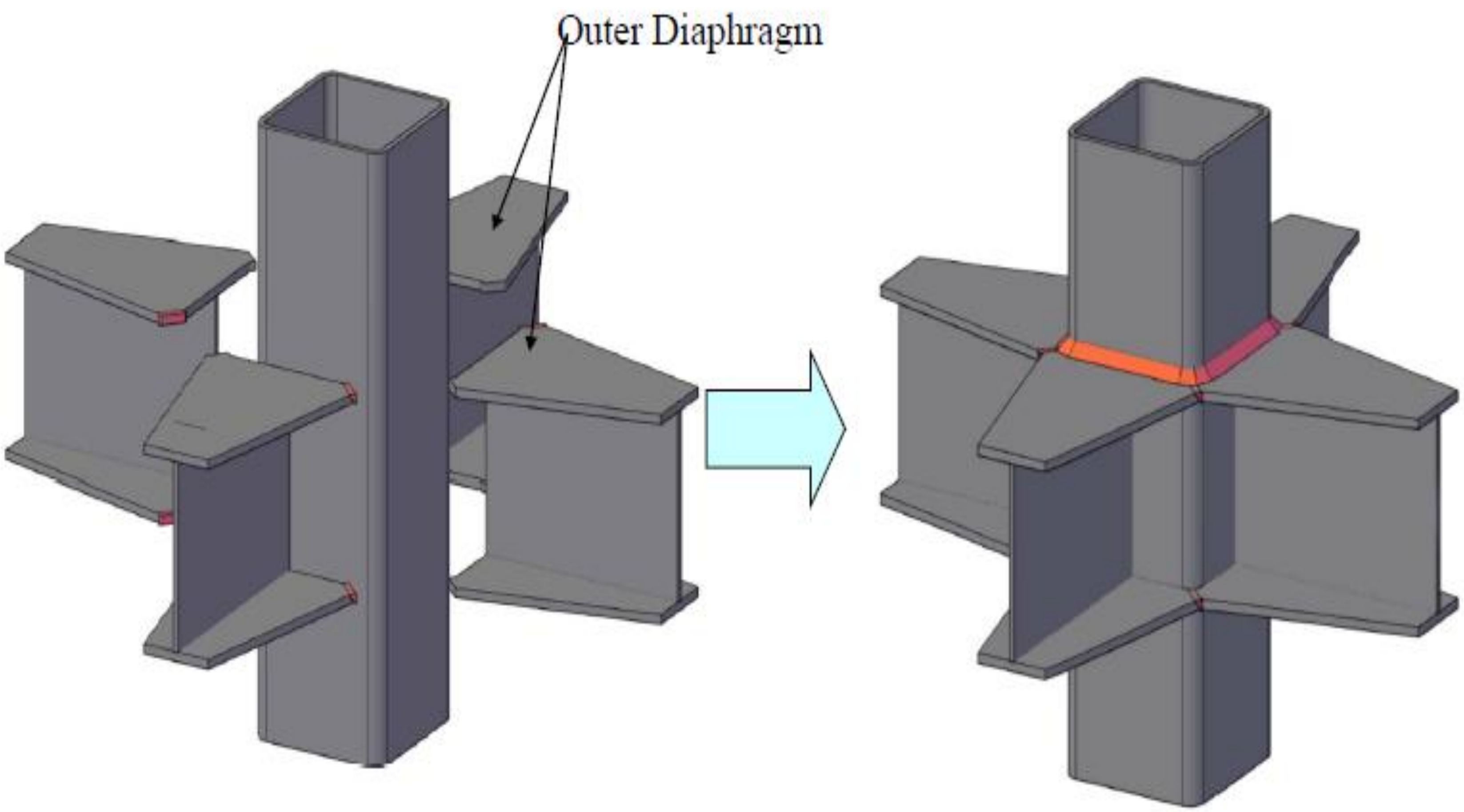

2
67


3/18

روش های مختلف اجرای ورق پیوستگی در ستون CFT

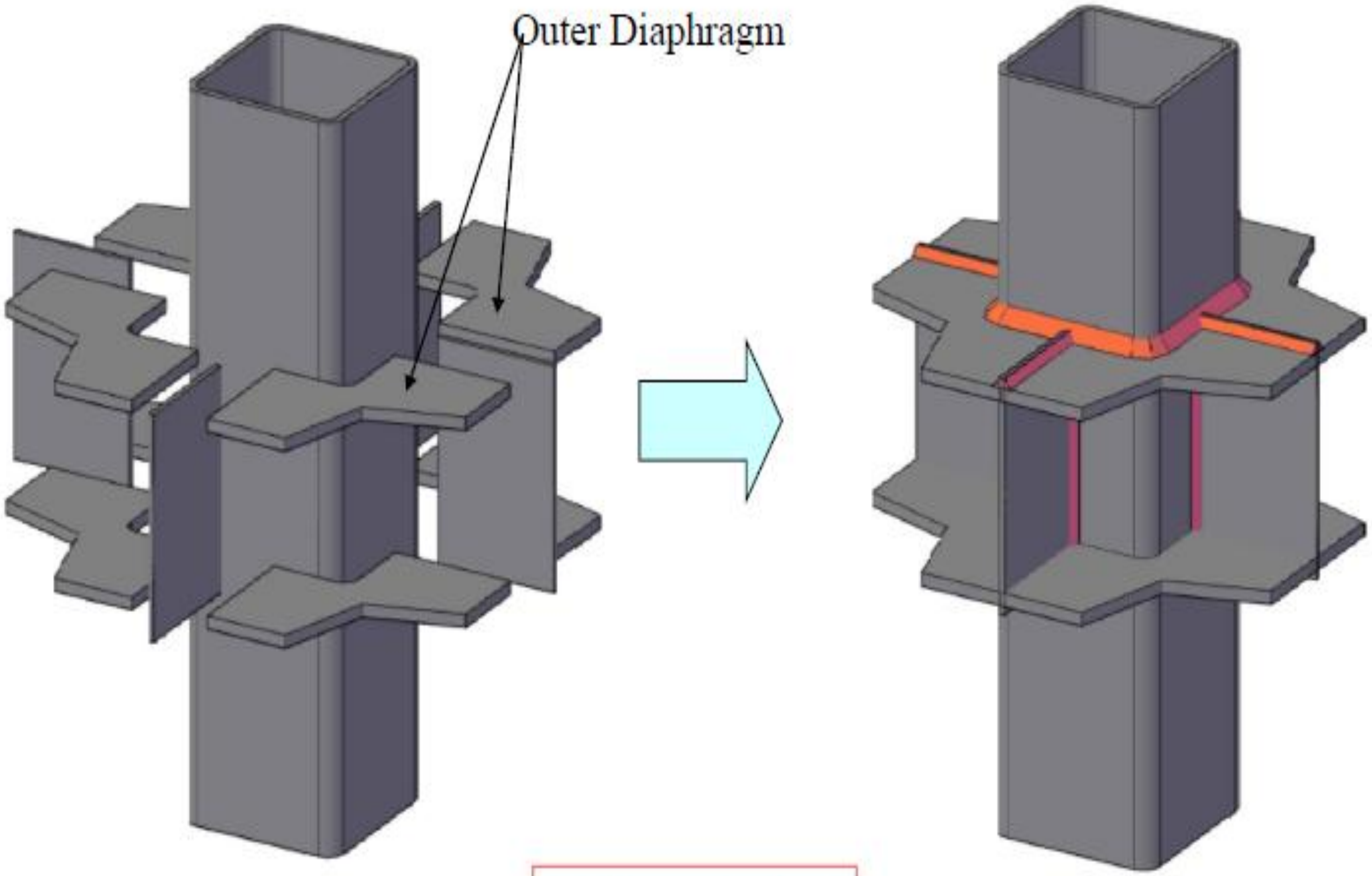


③ Outer Diaphragm-A

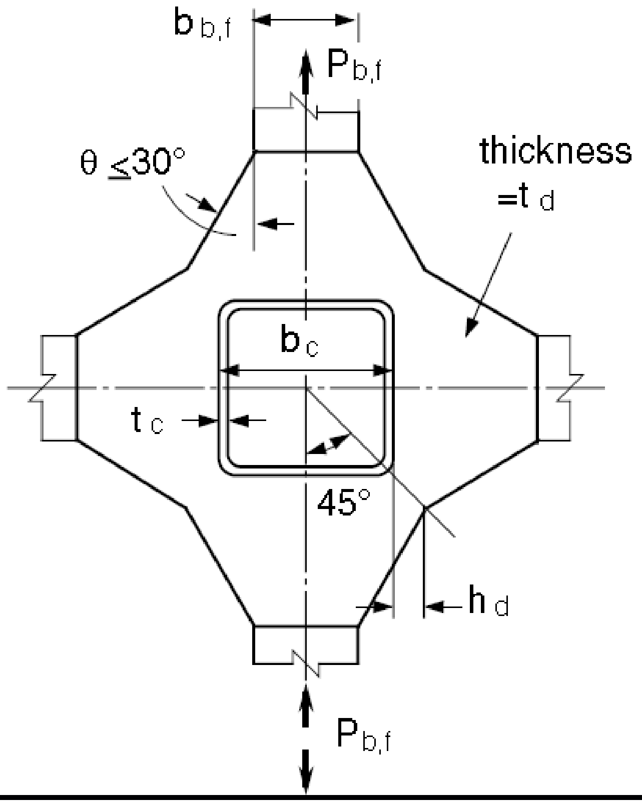


Red line : welding

④ Outer Diaphragm-B



Red lines : welding

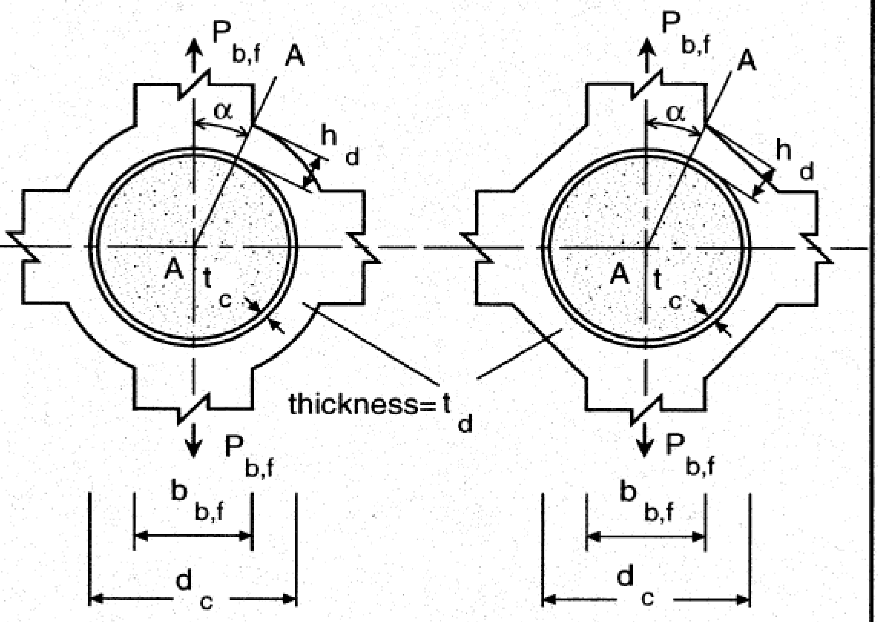
Shape of external diaphragm	Ultimate resistance equation
	$P_{b,f}{}^{*} = 3.17\left(\frac{t_c}{b_c}\right)^{2/3}\left(\frac{t_d}{b_c}\right)^{2/3}\left(\frac{t_c + h_d}{b_c}\right)^{1/3} b_c^2 f_{d,u}$ (2) where $\frac{b_c / 2 + h_d}{t_d} \leq \frac{240}{\sqrt{f_{d,y}}}$ Symbols: $f_{d,y}$ = Yield strength of diaphragm material $f_{d,u}$ = Ultimate tensile strength of diaphragm material $P_{b.f}$ = Axil load in tension or compression flange

Range of validity			
$17 \leq \frac{b_c}{t_c} \leq 67$	$0.07 \leq \frac{h_d}{b_c} \leq 0.4$	$0.75 \leq \frac{t_d}{t_c} \leq 2.0$	$\theta \leq 30°$

Note:

Symbols:	b = Width	d = diameter	h = Height	t = Thickness	θ = Slope of diaphragm
Subscript:	b = Beam	c = Column	d = Diaphragm		

Shape of external diaphragm	Ultimate strength equation



Type I Type II

$$P_{b,f}{}^{*} = 3.09 f_1(\alpha) A_1 f_{c,y} + 1.77 f_2(\alpha) A_2 f_{d,y} \qquad (1)$$

where

$$f_1(\alpha) = \sin\alpha$$

$$f_2(\alpha) = \sqrt{2\sin^2\alpha + 1}$$

$$A_1 = \left\{ \left(0.63 + 0.88\frac{b_{b,f}}{d_c}\right)\sqrt{d_c t_c} + t_d \right\} t_c$$

$$A_2 = h_d t_d$$

Symbols:

$f_{c,y}$ = Yield strength of column material

$f_{d,y}$ = Yield strength of diaphragm material

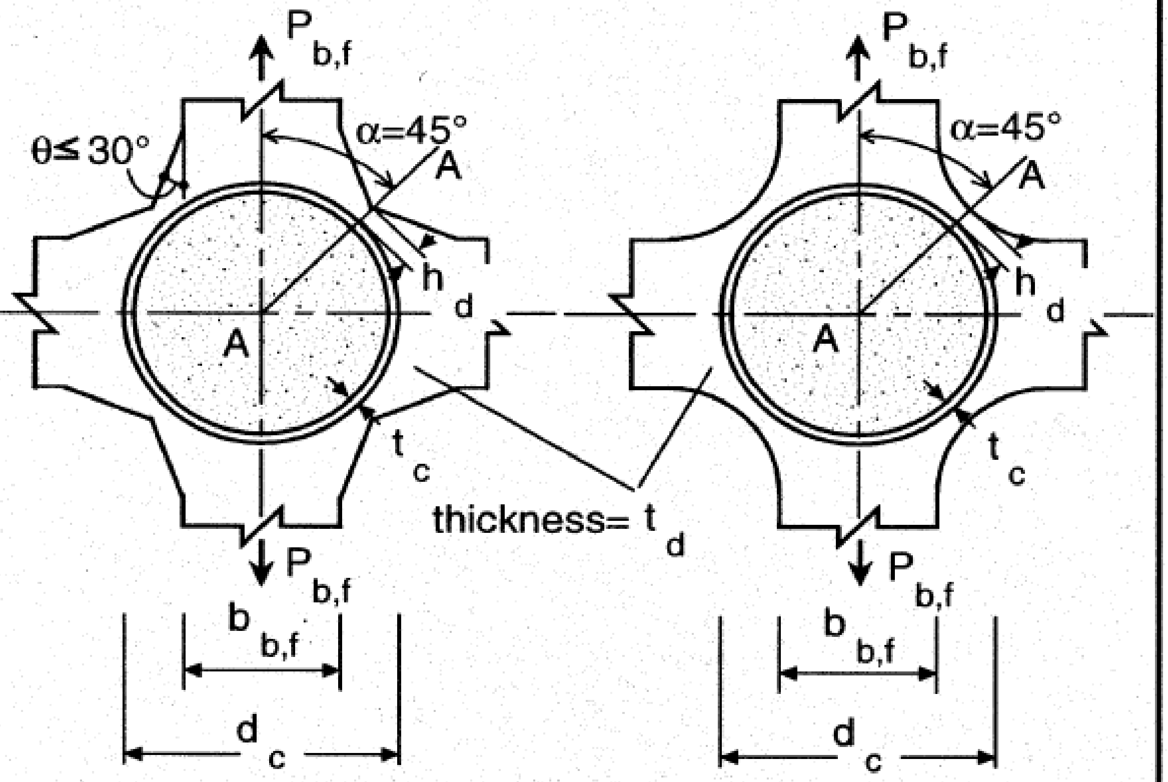
$P_{b,f}$ = Axil load in tension flange

α = Slope of critical section

Range of validity		
$20 \le d_c/t_c \le 50$	$h_d/d_c \le 0.3$	$0.25 \le b_{b,f}/d_c \le 0.75$

Note:

Symbols:	b = Width	d = Diameter	h = Height	t = Thickness	θ = Slope of diaphragm
Subscript:	b = Beam	c = Column	d = Diaphragm	f=Beam flange	



Type III Type IV

$$P_{b,f}^* = 2.19A_1 f_{c,y} + 2.53A_2 f_{d,y} \qquad (2)$$

where

$$A_1 = \left\{ \left(0.63 + 0.88\frac{b_{b,f}}{d_c}\right)\sqrt{d_c t_c} + t_d \right\} t_c$$

$$A_2 = h_d t_d$$

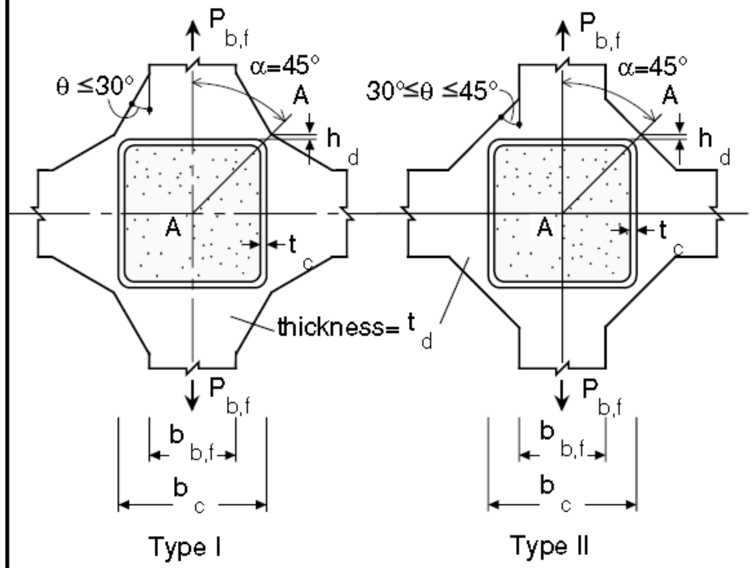
Symbols:
See above.

Range of validity		
$20 \le d_c/t_c \le 50$	$h_d/d_c \le 0.3$	$0.25 \le b_{b,f}/d_c \le 0.75$

Note:

Symbols: b = Width d = Diameter h = Height t = Thickness θ = Slope of diaphragm

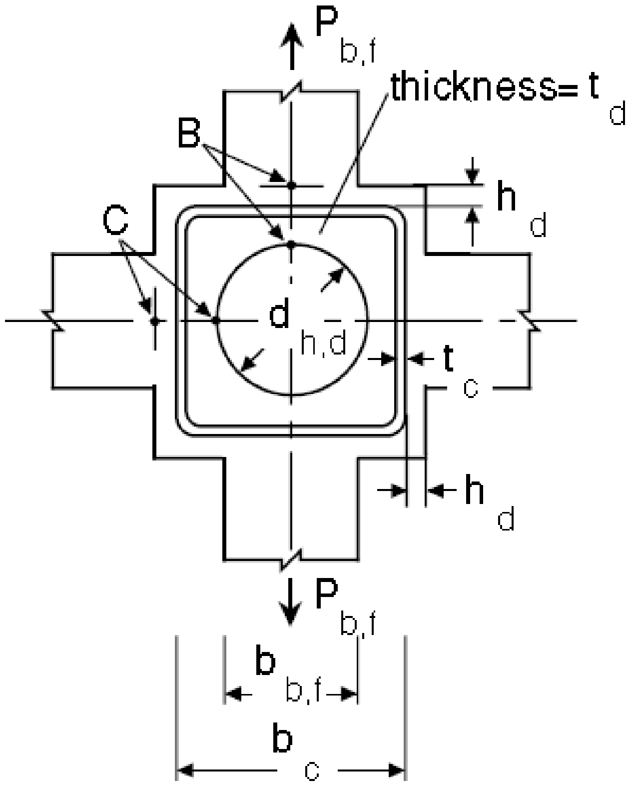
Subscript: b = Beam c = Column d = Diaphragm f=Beam flange

Shape of external diaphragm	Ultimate resistance equation
 	Type I connection: The design resistance is the larger of the values calculated by Eqs. 1 and 2. $P_{b,f}{}^{*} = 3.74\left(\frac{t_c}{b_c}\right)^{\frac{2}{3}}\left(\frac{t_d}{b_c}\right)^{\frac{2}{3}}\left(\frac{t_c + h_d}{b_c}\right)^{\frac{1}{3}} b_c^2 f_{d,u}$ (1) $P_{b,f}{}^{*} = 2.86(4t_c + t_d)t_c f_{c,y} + 3.30 h_d t_d f_{d,y}$ (2) If $f_{c,y} \geq f_{d,y}$, then calculate with $f_{c,y} = f_{d,y}$. Type II connection: The design resistance is given by Eq. 2 . Symbols: $f_{c,y}$ = Yield strength of column material $f_{d,y}$ = Yield strength of diaphragm material $f_{d,u}$ = Ultimate tensile strength of diaphragm material $P_{b,f}$ = Axial load in tension flange

Range of validity
$20 \leq b_c/t_c \leq 50$, $0.75 \leq t_d/t_c \leq 2.0$, $t_d \geq t_{b,f}$, $h_d/b_c \geq 0.1 t_{b,f}/t_d$ (Type I), $h_d/b_c \geq 0.15 t_{b,f}/t_d$ (Type II)

Note:

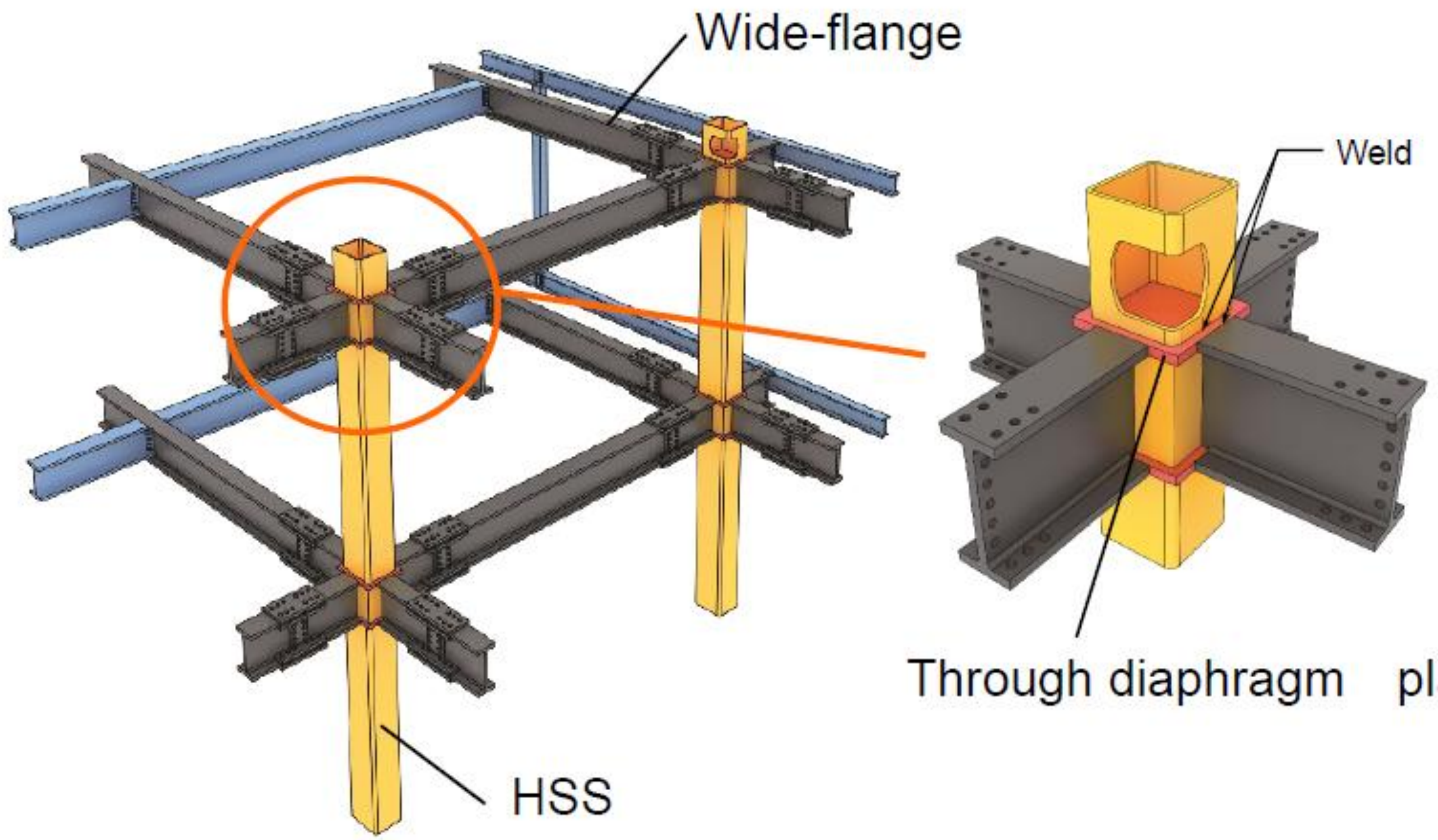
Symbols:	b = Width	d = Diameter	h = Height	t = Thickness	θ = Slope of diaphragm
Subscript:	b = Beam	c = Column	d = Diaphragm	f = Beam flange	h = hole

 Type III	Type III connection: The design resistance is the smaller of the values given by Eqs. 3 and 4. $P_{b,f}^* = 1.43(b_c + 2h_d - d_{h,d})^2 \frac{b_{b,f} t_d}{d_h^2} f_{d,y}$ (3) $P_{b,f}^* = 1.43(b_c + 2h_d - d_{h,d}) t_d f_{d,y}$ (4) Symbols: See above.
Range of validity	
$20 \le b_c/t_c \le 50$, $0.75 \le t_d/t_c \le 2.0$, $t_d \ge t_{b,f}$, $h_d/b_c \ge 0.1 t_{b,f}/t_d$ (Type I), $h_d/b_c \ge 0.15 t_{b,f}/t_d$ (Type II)	

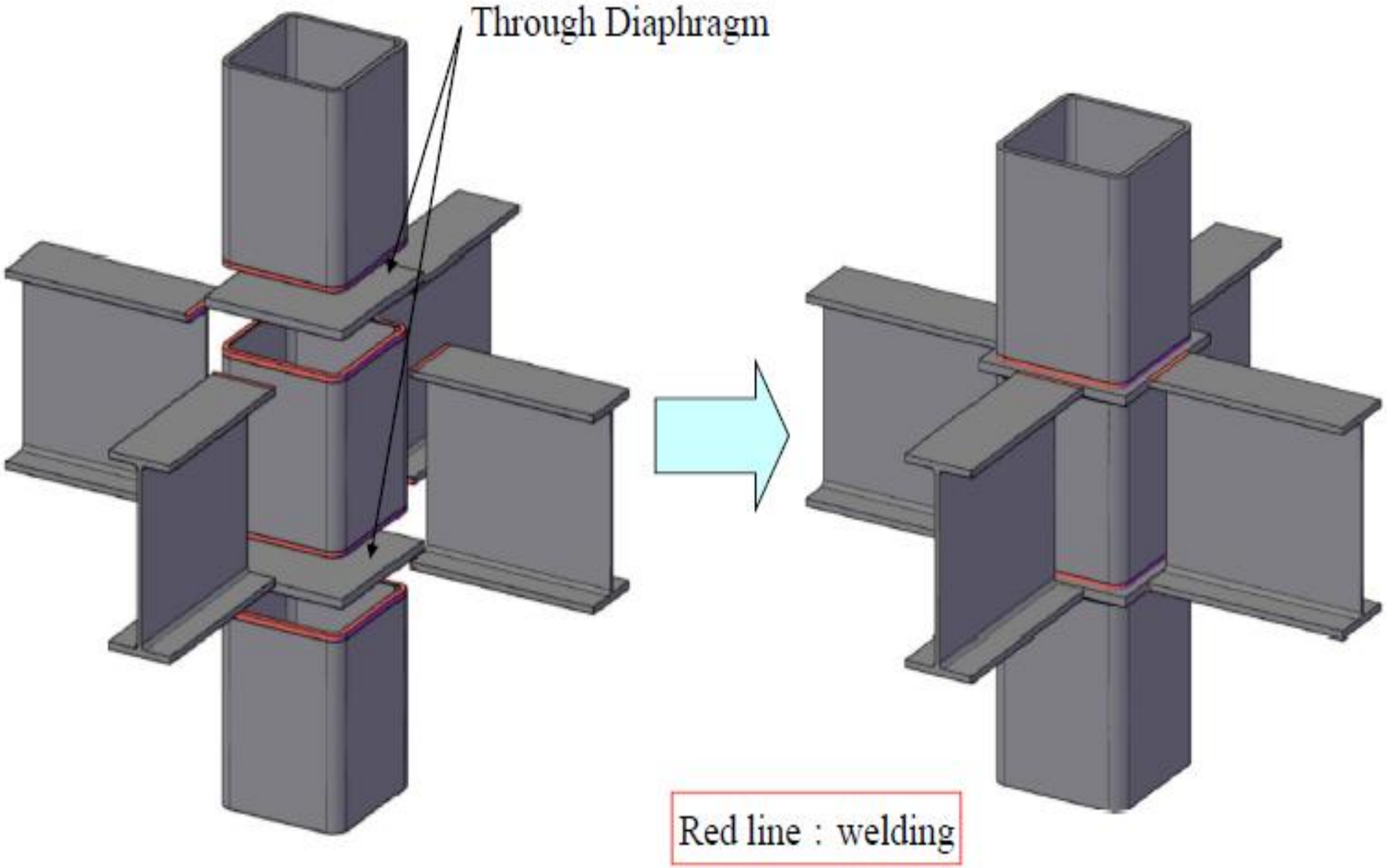
Note:

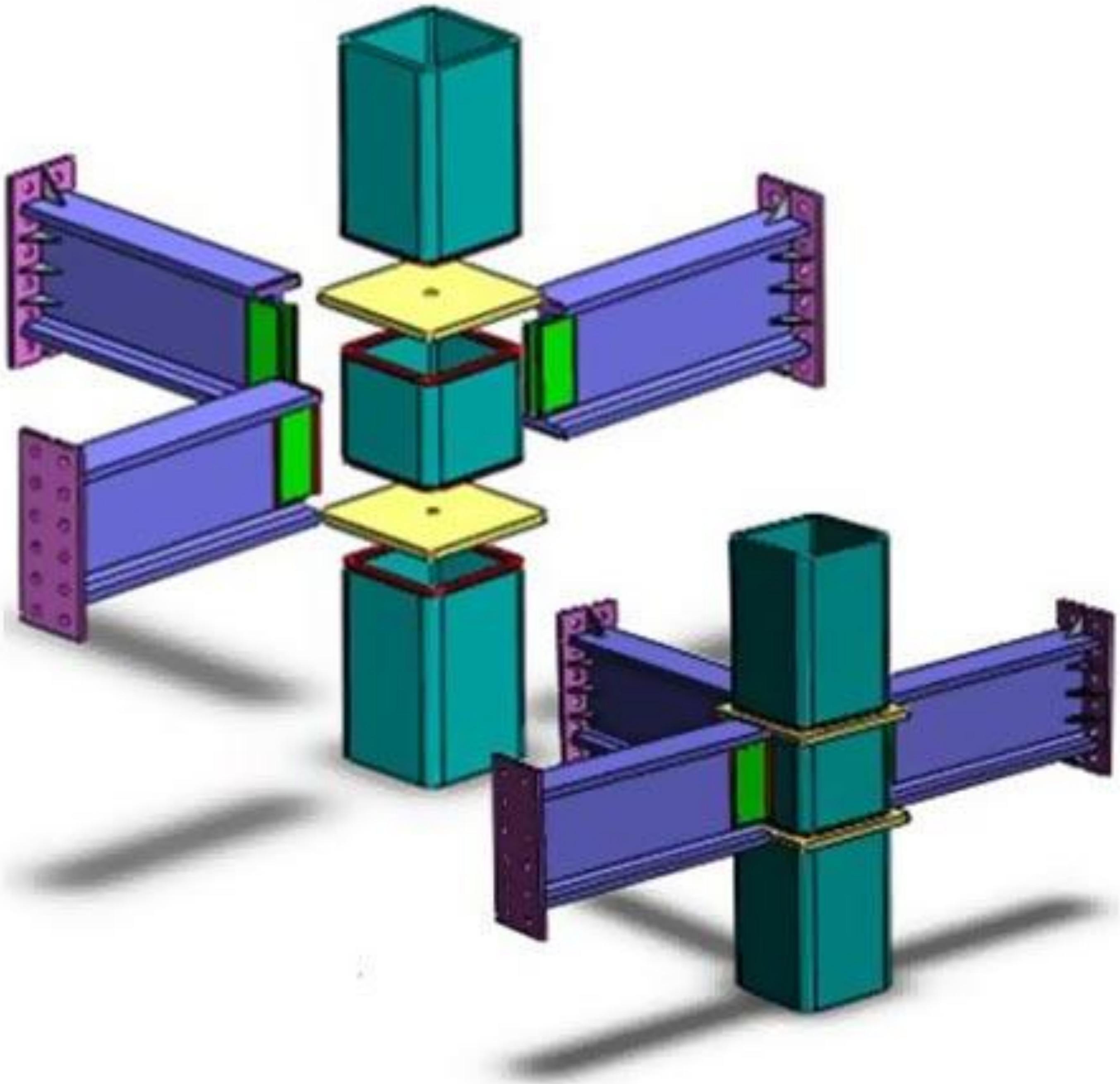
Symbols:	b = Width	d = Diameter	h = Height	t = Thickness	θ = Slope of diaphragm
Subscript:	b = Beam	c = Column	d = Diaphragm	f = Beam flange	h = hole

Column to Beam Rigid Frame Connection



① Through Diaphragm



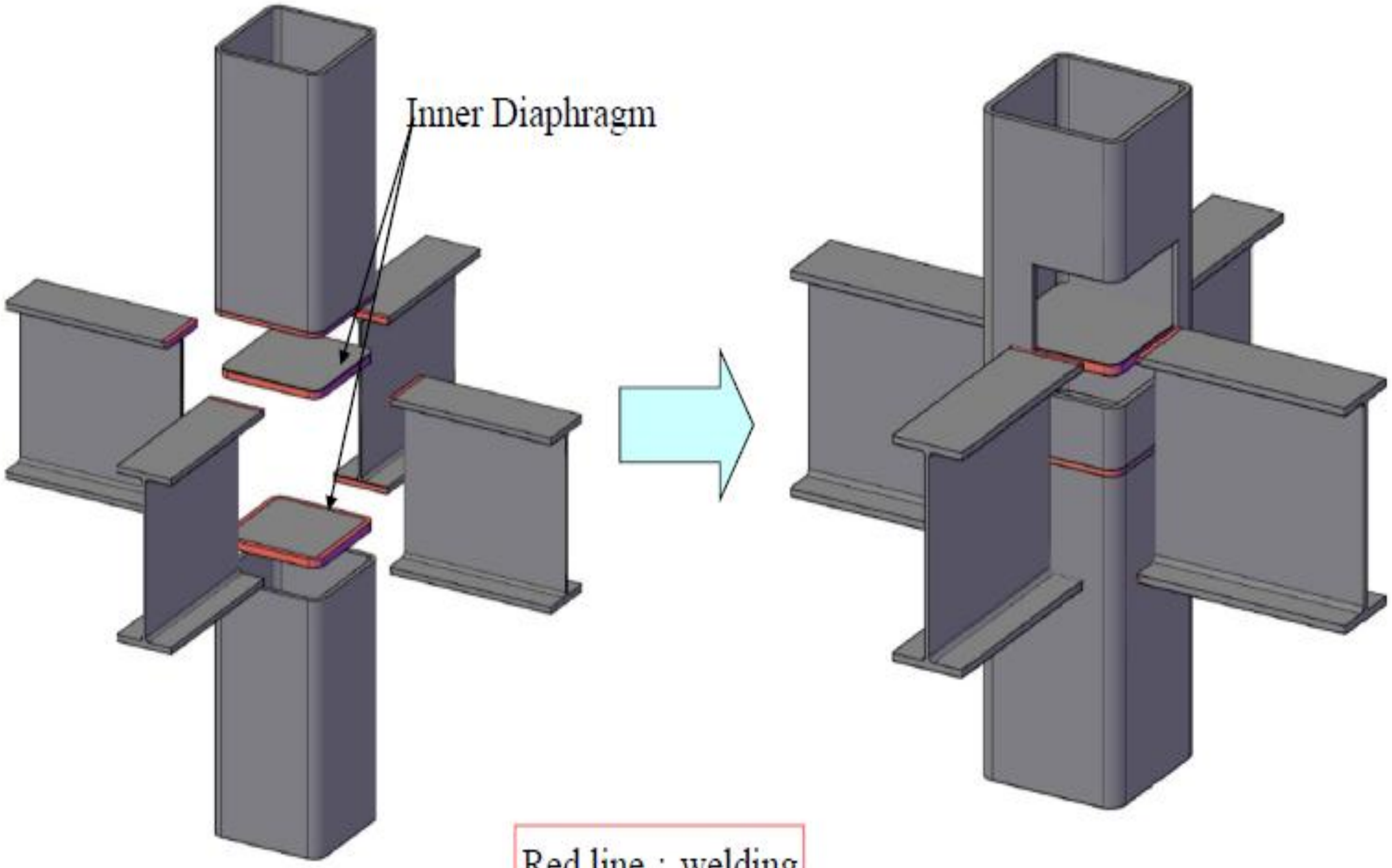



NIPPON STEEL ENGINEERING
Unbonded Brace

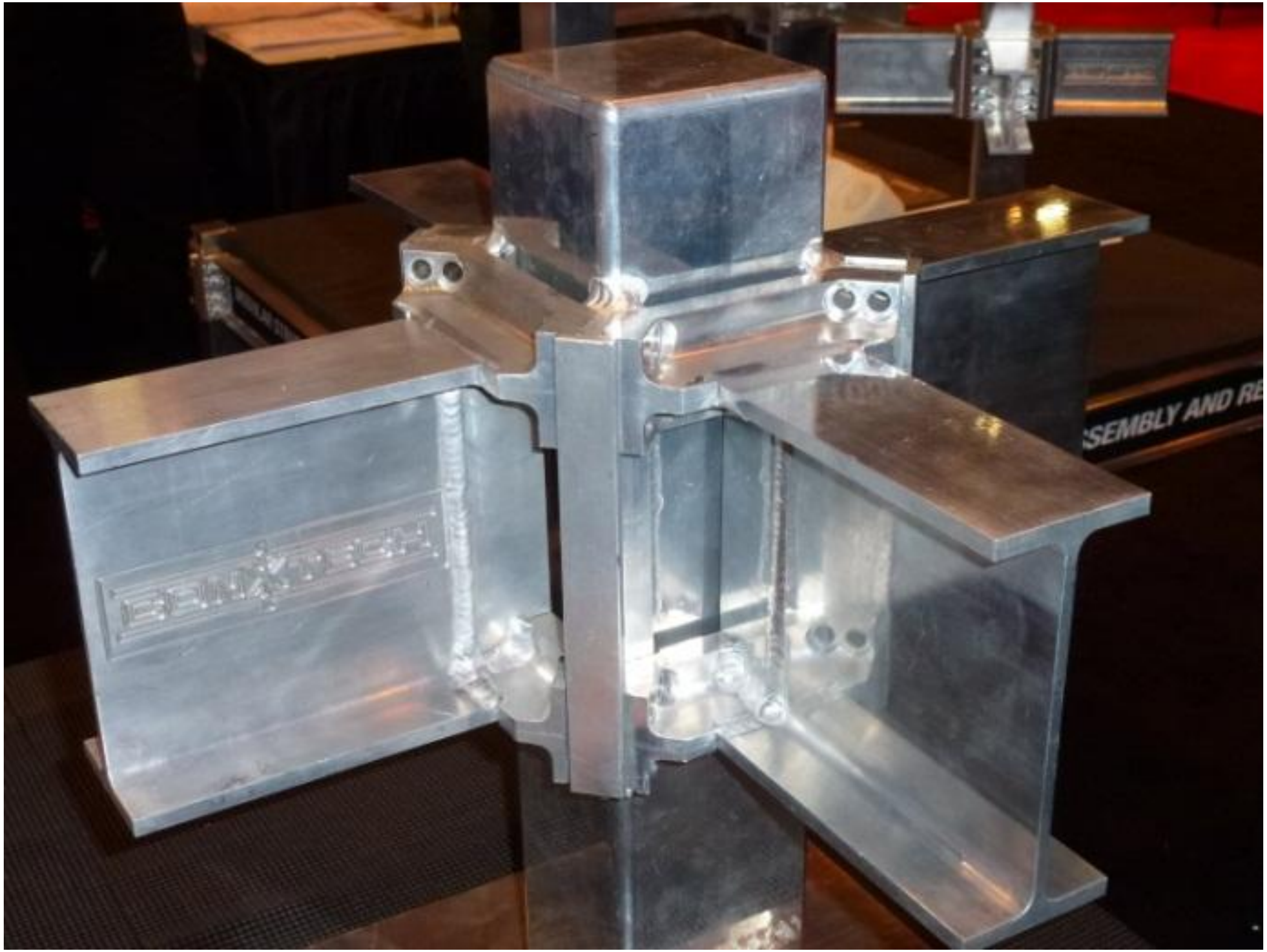
① Through Diaphragm

1. High accuracy and quality
2. Constant productivity

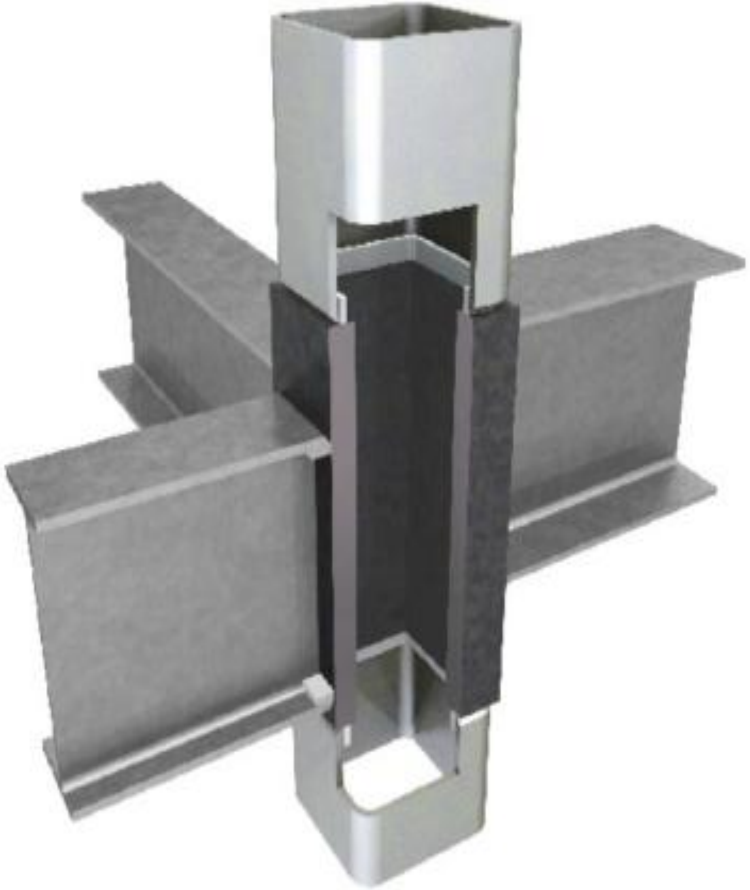
② Inner Diaphragm

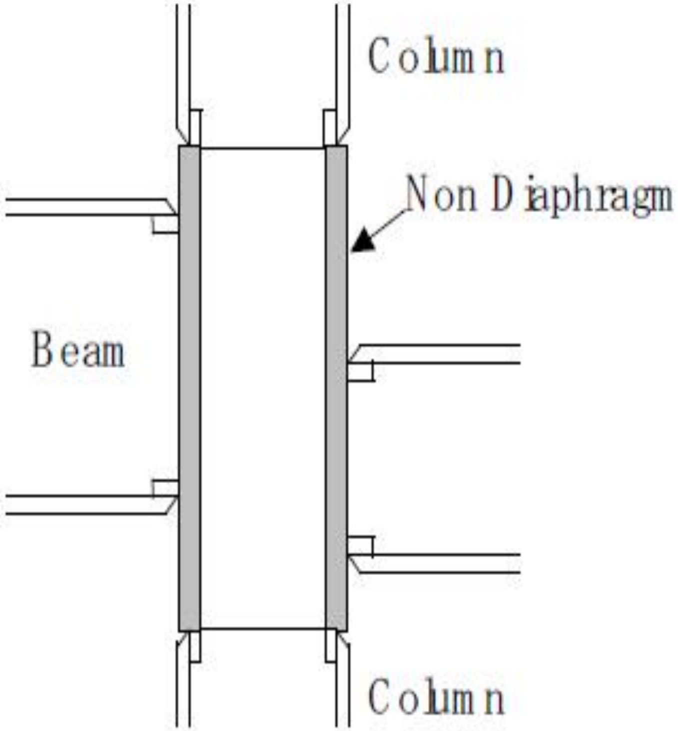


Red line : welding

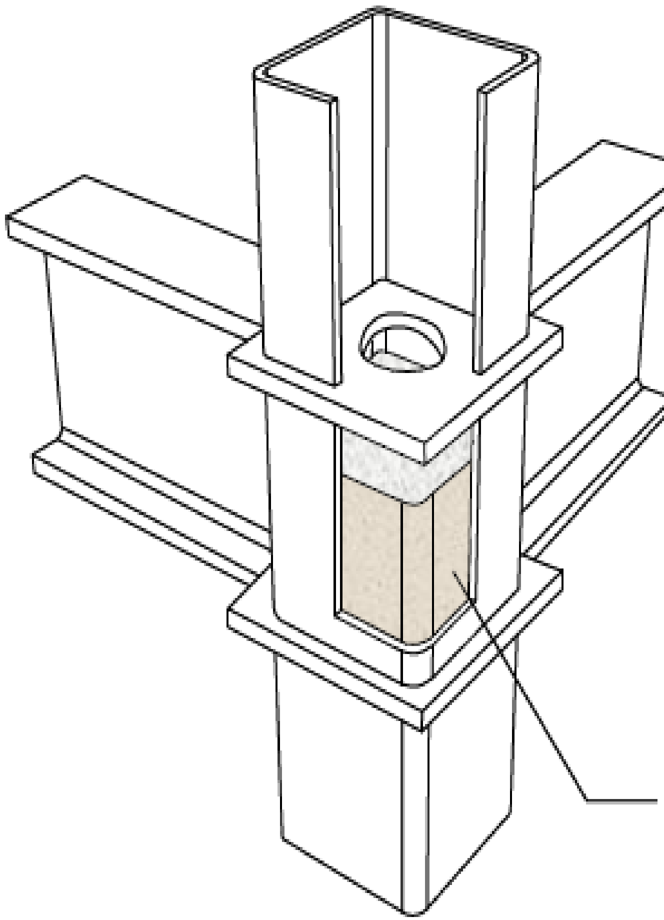


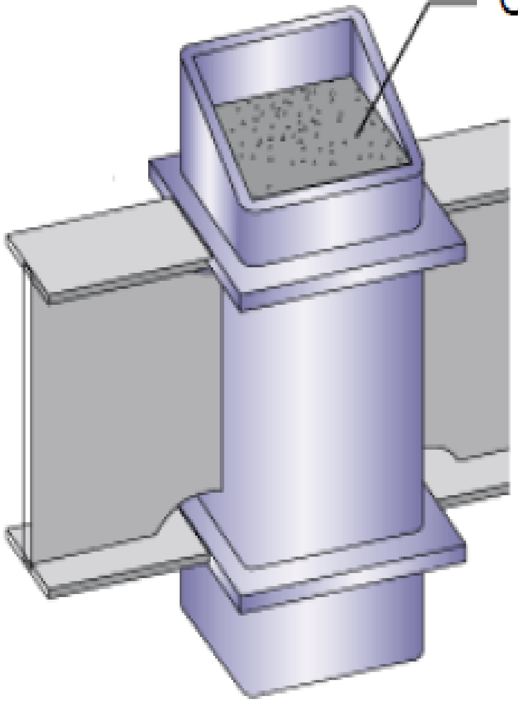
⑤ Non-Diaphragm Connection





CFT （Concrete Filled Steel Tube）





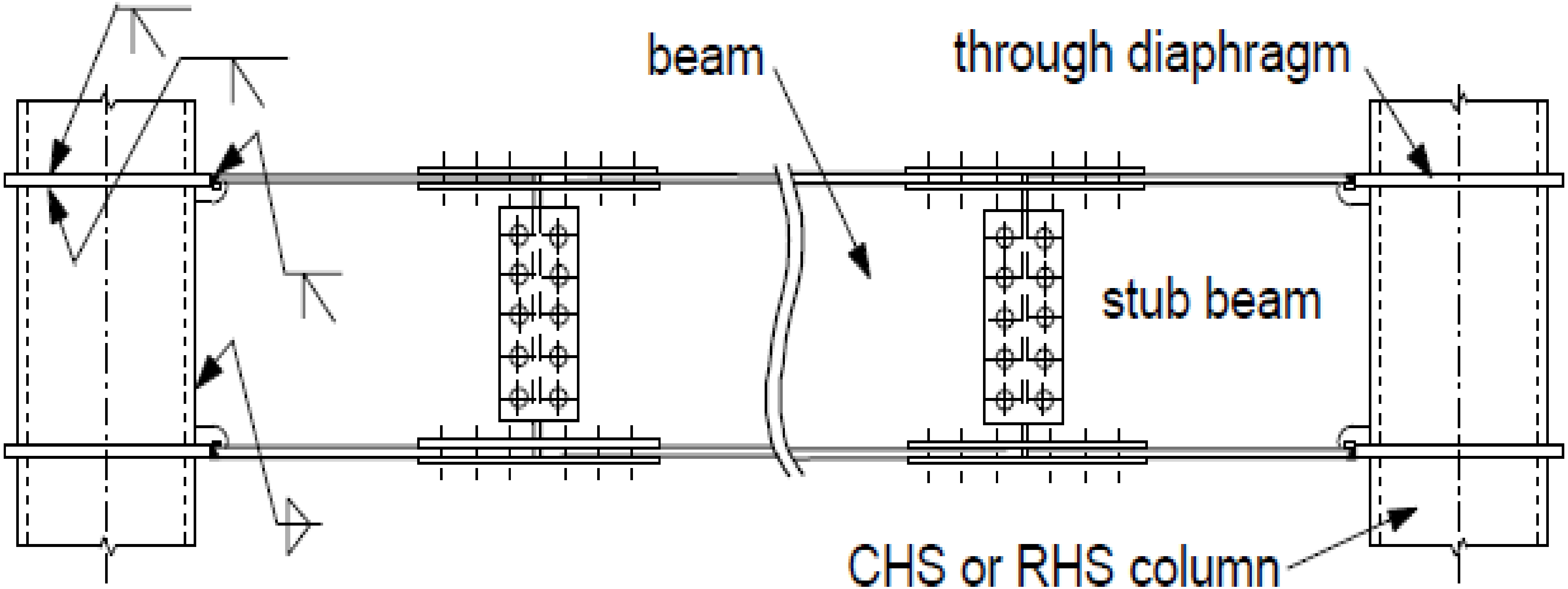


Figure 8.1 – Beam-to-column connections with through diaphragms for shop-welding

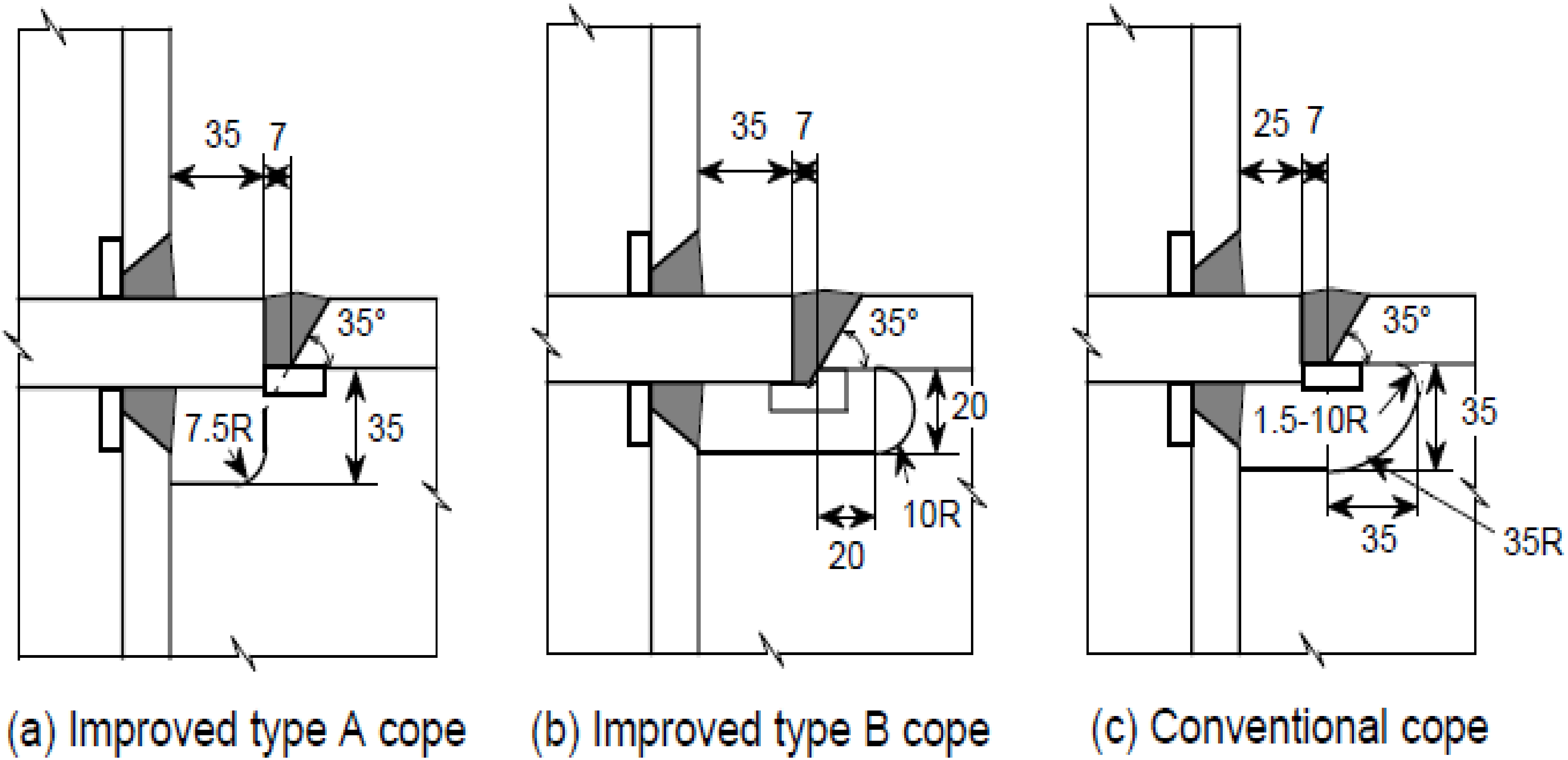


Figure 8.2 – Details of improved and conventional beam copes

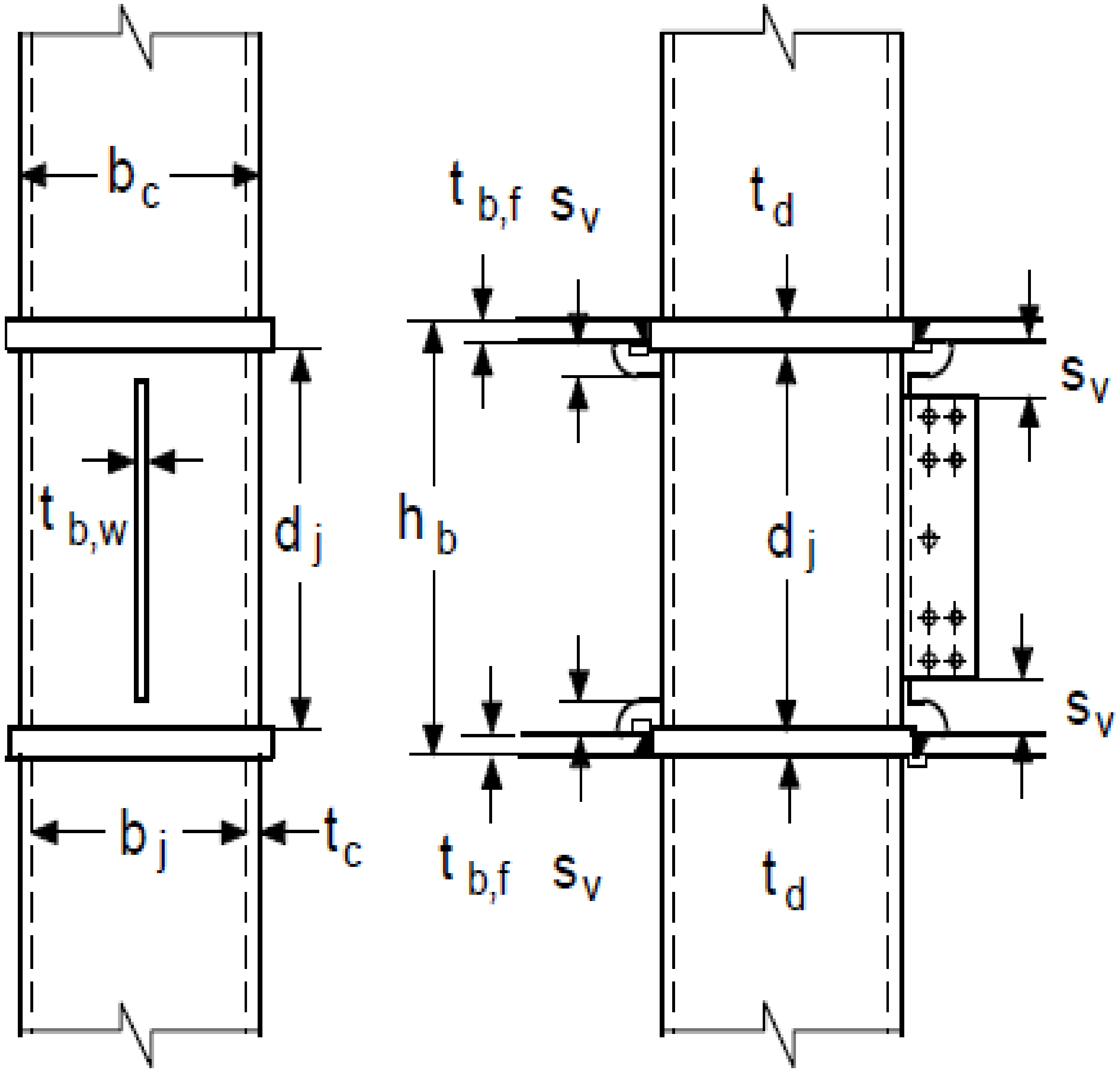


Figure 8.3 – Dimensions of welded web joint

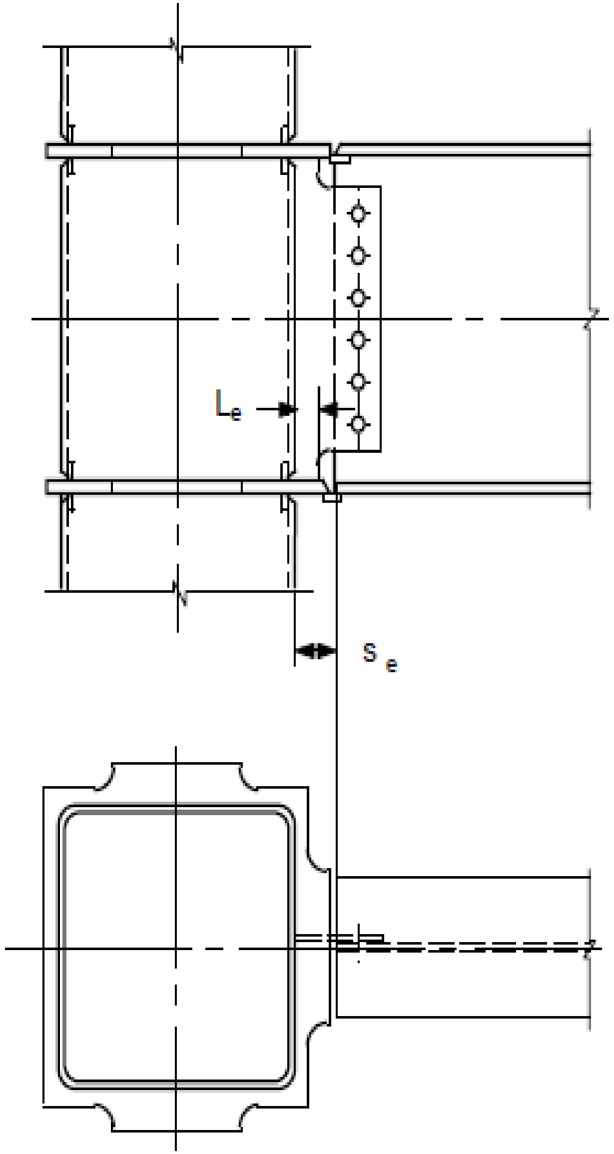


Figure 8.9 – Improved field-welded connection

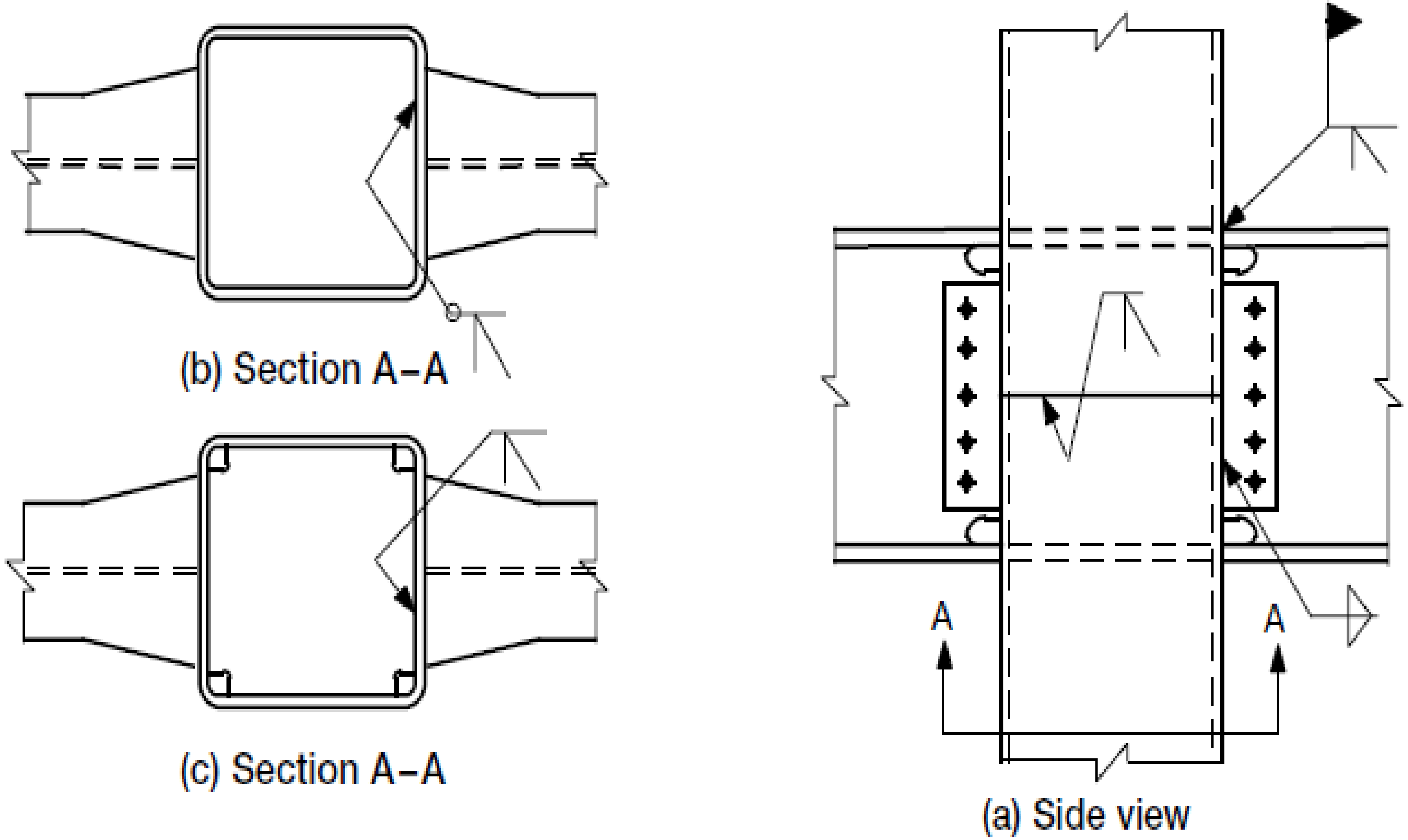


Figure 8.15 – Beam-to-column connections with internal diaphragms

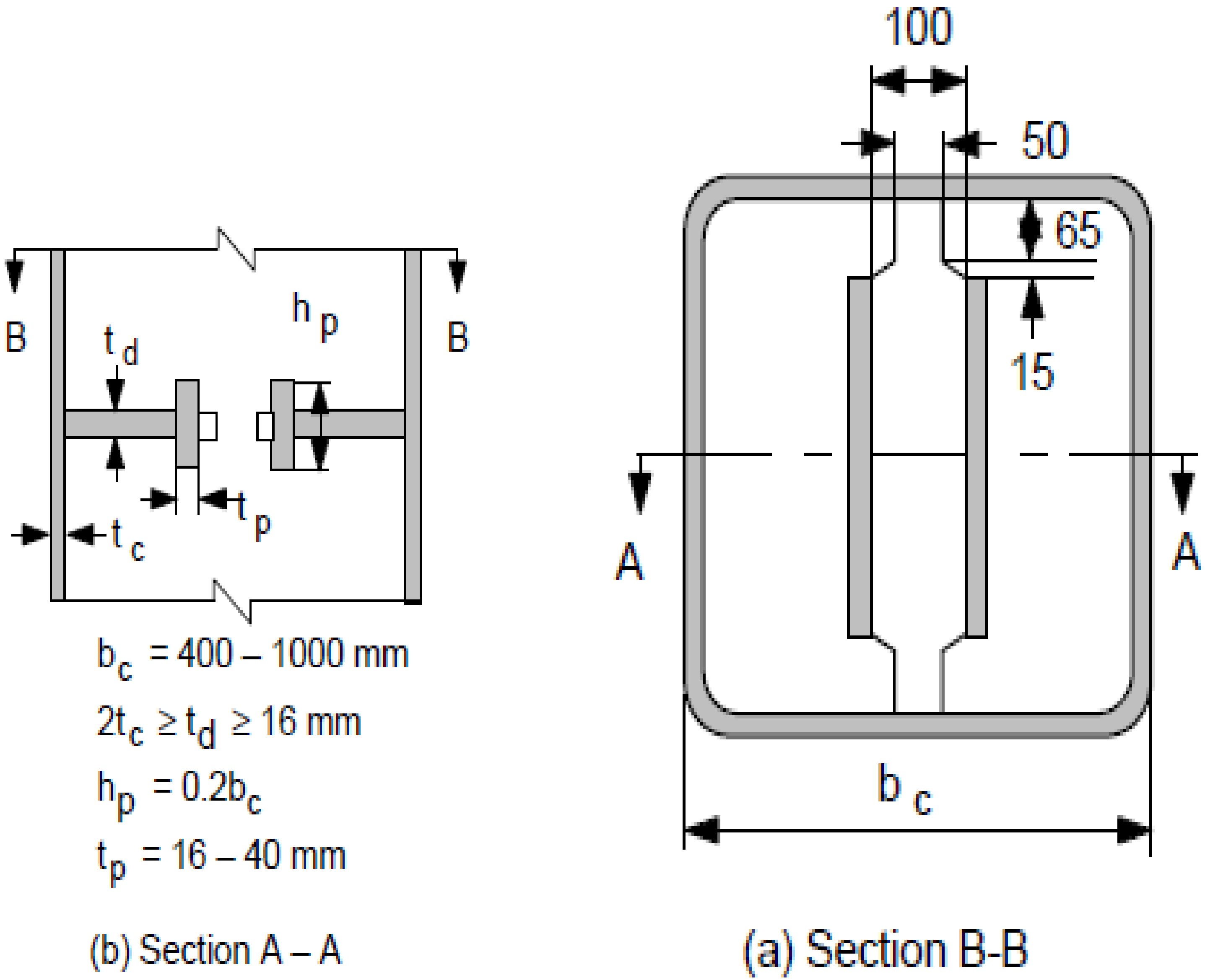


Figure 8.16 – RHS with prefabricated internal diaphragms

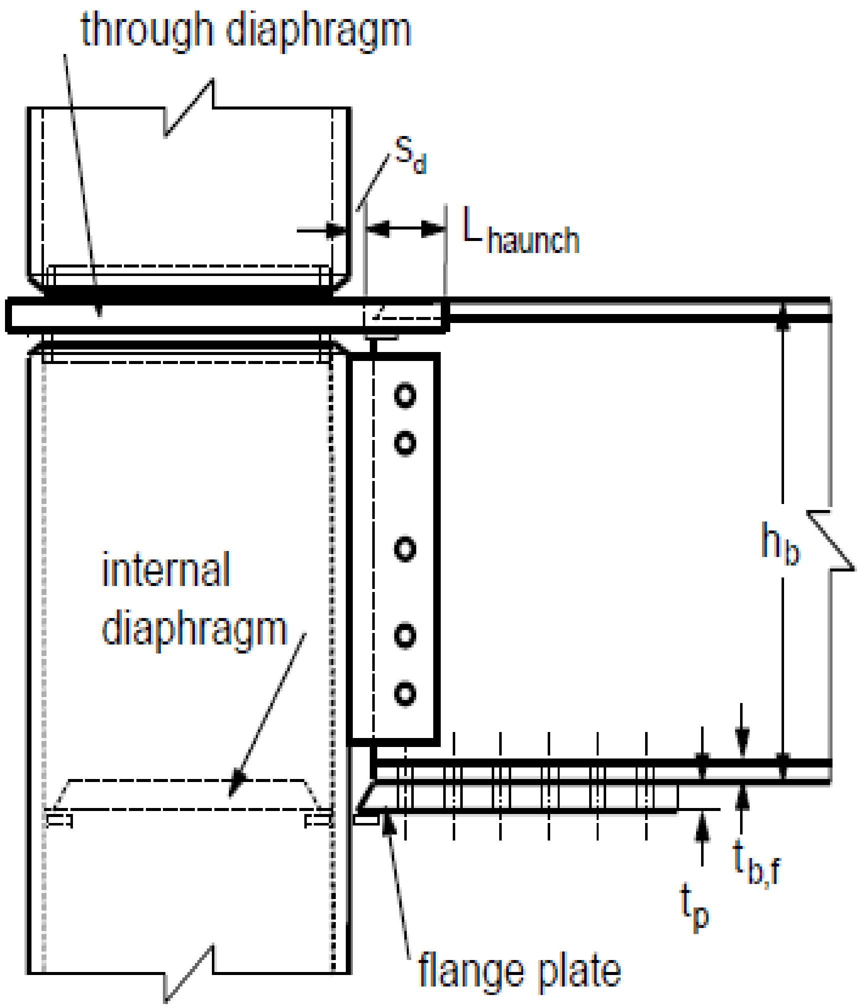
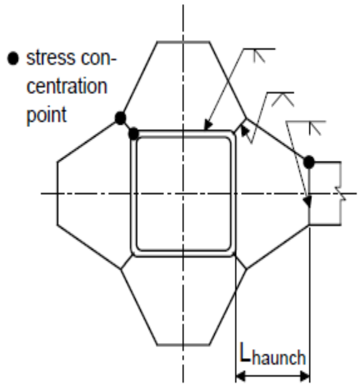
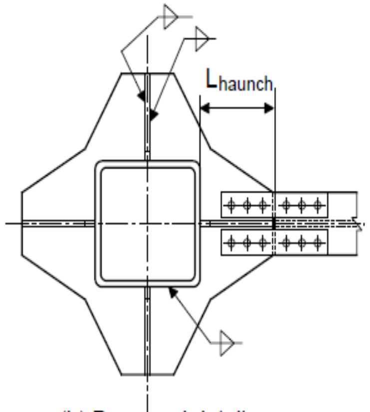


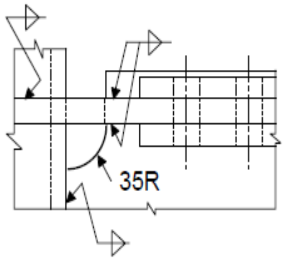
Figure 8.19 – Beam-to-column connections with combined internal and through diaphragms



(a) Recommendations by AIJ



(b) Proposed details



(c) Details of welded joints at flange centre

Figure 8.20 – Beam-to-column connections with external diaphragms

	f'c=	300	kg/cm2	f'c=	300	kg/cm2	f'c=	240	kg/cm2	f'c=	240	kg/cm2
	Fy=	2400	kg/cm2	Fy=	3500	kg/cm2	Fy=	2400	kg/cm2	Fy=	3500	kg/cm2
	Es	2040000	kg/cm2	Es	2040000	kg/cm2	Es	2040000	kg/cm2	Es	2040000	kg/cm2
	Ec	2.62E+05	kg/cm2	Ec	2.62E+05	kg/cm2	Ec	232000	kg/cm2	Ec	232000	kg/cm2
	L=	360	cm	L=	360	cm	L=	360	cm	L=	360	cm
	30x1.2 (ST37)			**30x1.2 (ST52)**			**30x1.2 (ST37)**			**30x1.2 (ST52)**		
	Composit	**Steel**	**Ratio**	**Composit**	**Steel**	**Ratio**	**Composit**	**Steel**	**Ratio**	**Composit**	**Steel**	**Ratio**
ϕPn=	372539.72	284976.59	1.31	472341.69	406791.41	1.16	346008.63	284976.59	1.21	446354.90	406791.41	1.10
ϕMn=	3601133.63	3226728.96	1.12	5130715.38	4705646.40	1.09	3550835.77	3226728.96	1.10	5067041.45	4705646.40	1.08
Pe	3840854.34	2974032.37	1.29	3840854.34	2974032.37	1.29	3742950.89	2974032.37	1.26	3742950.89	2974032.37	1.26
A	235.90	138.24	1.71	235.90	138.24	1.71	224.87	138.24	1.63	224.87	138.24	1.63
I	25343.06	19143.48	1.32	25343.06	19143.48	1.32	24642.84	19143.48	1.29	24642.84	19143.48	1.29
Ieff	24723.10	19143.48	1.29	24723.10	19143.48	1.29	24092.91	19143.48	1.26	24092.91	19143.48	1.26
	30x1.5 (ST37)			**30x1.5 (ST52)**			**30x1.5 (ST37)**			**30x1.5 (ST52)**		
	Composit	**Steel**	**Ratio**	**Composit**	**Steel**	**Ratio**	**Composit**	**Steel**	**Ratio**	**Composit**	**Steel**	**Ratio**
ϕPn=	422560.61	352179.25	1.20	545999.32	502503.91	1.09	397178.02	352179.25	1.13	521191.41	502503.91	1.04
ϕMn=	4333188.33	3951180.00	1.10	6187376.06	5762137.50	1.07	4277924.92	3951180.00	1.08	6120000.10	5762137.50	1.06
Pe	4400160.39	3606291.76	1.22	4400160.39	3606291.76	1.22	4310496.67	3606291.76	1.20	4310496.67	3606291.76	1.20
A	264.46	171.00	1.55	264.46	171.00	1.55	253.91	171.00	1.48	253.91	171.00	1.48
I	28891.06	23213.25	1.24	28891.06	23213.25	1.24	28249.78	23213.25	1.22	28249.78	23213.25	1.22
Ieff	28323.28	23213.25	1.22	28323.28	23213.25	1.22	27746.13	23213.25	1.20	27746.13	23213.25	1.20

	30x2 (ST37)			30x2 (ST52)			30x2 (ST37)			30x2 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	503198.30	460595.84	1.09	664656.25	656714.86	1.01	479695.66	460595.84	1.04	641756.25	656714.86	0.98
ϕMn=	5463751.36	5088960.00	1.07	7829078.95	7421400.00	1.05	5405018.14	5088960.00	1.06	7760528.56	7421400.00	1.05
Pe	5252966.07	4570333.55	1.15	5252966.07	4570333.55	1.15	5175865.95	4570333.55	1.13	5175865.95	4570333.55	1.13
A	310.67	224.00	1.39	310.67	224.00	1.39	300.88	224.00	1.34	300.88	224.00	1.34
I	34300.91	29418.67	1.17	34300.91	29418.67	1.17	33749.48	29418.67	1.15	33749.48	29418.67	1.15
Ieff	33812.69	29418.67	1.15	33812.69	29418.67	1.15	33316.40	29418.67	1.13	33316.40	29418.67	1.13
	30x2.5 (ST37)			30x2.5 (ST52)			30x2.5 (ST37)			30x2.5 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	580461.58	564533.38	1.03	778198.48	804301.21	0.97	558780.34	564533.38	0.99	757130.67	804301.21	0.94
ϕMn=	6496666.67	6142500.00	1.06	9336990.18	8957812.50	1.04	6438247.42	6142500.00	1.05	9270799.56	8957812.50	1.03
Pe	6012846.68	5429329.54	1.11	6012846.68	5429329.54	1.11	5946941.17	5429329.54	1.10	5946941.17	5429329.54	1.10
A	355.13	275.00	1.29	355.13	275.00	1.29	346.08	275.00	1.26	346.08	275.00	1.26
I	39121.28	34947.92	1.12	39121.28	34947.92	1.12	38649.92	34947.92	1.11	38649.92	34947.92	1.11
Ieff	38703.94	34947.92	1.11	38703.94	34947.92	1.11	38279.72	34947.92	1.10	38279.72	34947.92	1.10
	30x3 (ST37)			30x3 (ST52)			30x3 (ST37)			30x3 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	654376.57	664000.45	0.99	886646.08	945281.70	0.94	634449.22	664000.45	0.96	867332.16	945281.70	0.92
ϕMn=	7442112.99	7115040.00	1.05	10722238.65	10376100.00	1.03	7386203.08	7115040.00	1.04	10660238.38	10376100.00	1.03
Pe	6686811.12	6191202.84	1.08	6686811.12	6191202.84	1.08	6630834.50	6191202.84	1.07	6630834.50	6191202.84	1.07
A	397.85	324.00	1.23	397.85	324.00	1.23	389.51	324.00	1.20	389.51	324.00	1.20
I	43396.63	39852.00	1.09	43396.63	39852.00	1.09	42996.28	39852.00	1.08	42996.28	39852.00	1.08
Ieff	43042.17	39852.00	1.08	43042.17	39852.00	1.08	42681.85	39852.00	1.07	42681.85	39852.00	1.07

	35x1.2 (ST37)			35x1.2 (ST52)			35x1.2 (ST37)			35x1.2 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	474434.57	338752.22	1.40	595683.84	486393.67	1.22	436529.53	338752.22	1.29	558327.42	486393.67	1.15
ϕMn=	5020983.61	4443672.96	1.13	7145256.18	6480356.40	1.10	4947780.83	4443672.96	1.11	7049988.58	6480356.40	1.09
Pe	6426561.72	4805206.60	1.34	6426561.72	4805206.60	1.34	6243437.31	4805206.60	1.30	6243437.31	4805206.60	1.30
A	298.49	162.24	1.84	298.49	162.24	1.84	283.10	162.24	1.74	283.10	162.24	1.74
I	42997.44	30930.52	1.39	42997.44	30930.52	1.39	41634.54	30930.52	1.35	41634.54	30930.52	1.35
Ieff	41366.98	30930.52	1.34	41366.98	30930.52	1.34	40188.23	30930.52	1.30	40188.23	30930.52	1.30
	35x1.5 (ST37)			35x1.5 (ST52)			35x1.5 (ST37)			35x1.5 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	534731.89	419436.69	1.27	685144.64	602082.26	1.14	498165.08	419436.69	1.19	649146.68	602082.26	1.08
ϕMn=	6057800.43	5457780.00	1.11	8636240.28	7959262.50	1.09	5975228.81	5457780.00	1.09	8532952.47	7959262.50	1.07
Pe	7418701.89	5852335.00	1.27	7418701.89	5852335.00	1.27	7241788.14	5852335.00	1.24	7241788.14	5852335.00	1.24
A	332.28	201.00	1.65	332.28	201.00	1.65	317.45	201.00	1.58	317.45	201.00	1.58
I	48873.54	37670.75	1.30	48873.54	37670.75	1.30	47608.23	37670.75	1.26	47608.23	37670.75	1.26
Ieff	47753.26	37670.75	1.27	47753.26	37670.75	1.27	46614.49	37670.75	1.24	46614.49	37670.75	1.24
	35x2 (ST37)			35x2 (ST52)			35x2 (ST37)			35x2 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	632170.71	550354.43	1.15	829634.62	789648.78	1.05	597873.06	550354.43	1.09	795941.89	789648.78	1.01
ϕMn=	7670742.14	7065360.00	1.09	10970120.43	10303650.00	1.06	7579664.43	7065360.00	1.07	10861385.01	10303650.00	1.05
Pe	8850886.33	7471327.09	1.18	8850886.33	7471327.09	1.18	8695071.63	7471327.09	1.16	8695071.63	7471327.09	1.16
A	387.21	264.00	1.47	387.21	264.00	1.47	373.29	264.00	1.41	373.29	264.00	1.41
I	57958.72	48092.00	1.21	57958.72	48092.00	1.21	56844.32	48092.00	1.18	56844.32	48092.00	1.18
Ieff	56972.05	48092.00	1.18	56972.05	48092.00	1.18	55969.09	48092.00	1.16	55969.09	48092.00	1.16

	35x2.5 (ST37)			35x2.5 (ST52)			35x2.5 (ST37)			35x2.5 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	726257.14	676829.68	1.07	969060.38	970662.11	1.00	694172.40	676829.68	1.03	937598.95	970662.11	0.97
ϕMn=	9159845.97	8572500.00	1.07	13137194.09	12501562.50	1.05	9066245.02	8572500.00	1.06	13028988.33	12501562.50	1.04
Pe	10150978.37	8940997.24	1.14	10150978.37	8940997.24	1.14	10014316.71	8940997.24	1.12	10014316.71	8940997.24	1.12
A	440.39	325.00	1.36	440.39	325.00	1.36	427.35	325.00	1.31	427.35	325.00	1.31
I	66205.97	57552.08	1.15	66205.97	57552.08	1.15	65228.55	57552.08	1.13	65228.55	57552.08	1.13
Ieff	65340.58	57552.08	1.14	65340.58	57552.08	1.14	64460.91	57552.08	1.12	64460.91	57552.08	1.12
	35x3 (ST37)			35x3 (ST52)			35x3 (ST37)			35x3 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	817014.85	798866.85	1.02	1103434.25	1145131.93	0.96	787077.38	798866.85	0.99	1074127.46	1145131.93	0.94
ϕMn=	10539152.03	9982440.00	1.06	15152637.37	14557725.00	1.04	10446783.63	9982440.00	1.05	15048345.19	14557725.00	1.03
Pe	11327361.20	10270822.10	1.10	11327361.20	10270822.10	1.10	11208030.09	10270822.10	1.09	11208030.09	10270822.10	1.09
A	491.82	384.00	1.28	491.82	384.00	1.28	479.64	384.00	1.25	479.64	384.00	1.25
I	73668.46	66112.00	1.11	73668.46	66112.00	1.11	72814.99	66112.00	1.10	72814.99	66112.00	1.10
Ieff	72912.81	66112.00	1.10	72912.81	66112.00	1.10	72144.69	66112.00	1.09	72144.69	66112.00	1.09

	40x1.2 (ST37)			40x1.2 (ST52)			40x1.2 (ST37)			40x1.2 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	585545.25	392053.60	1.49	727852.27	565037.80	1.29	534341.01	392053.60	1.36	677196.35	565037.80	1.20
ϕMn=	6687281.96	5855016.96	1.14	9509431.85	8538566.40	1.11	6587360.20	5855016.96	1.13	9376123.53	8538566.40	1.10
Pe	10029260.30	7266500.25	1.38	10029260.30	7266500.25	1.38	9717219.59	7266500.25	1.34	9717219.59	7266500.25	1.34
A	367.49	186.24	1.97	367.49	186.24	1.97	347.02	186.24	1.86	347.02	186.24	1.86
I	68127.47	46773.56	1.46	68127.47	46773.56	1.46	65715.65	46773.56	1.40	65715.65	46773.56	1.40
Ieff	64557.10	46773.56	1.38	64557.10	46773.56	1.38	62548.53	46773.56	1.34	62548.53	46773.56	1.34
	40x1.5 (ST37)			40x1.5 (ST52)			40x1.5 (ST37)			40x1.5 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	655967.29	486089.12	1.35	832810.55	700439.61	1.19	606296.50	486089.12	1.25	783702.20	700439.61	1.12
ϕMn=	8085280.33	7207380.00	1.12	11513399.82	10510762.50	1.10	7970082.91	7207380.00	1.11	11365891.17	10510762.50	1.08
Pe	11643670.13	8879036.53	1.31	11643670.13	8879036.53	1.31	11331417.81	8879036.53	1.28	11331417.81	8879036.53	1.28
A	406.51	231.00	1.76	406.51	231.00	1.76	386.69	231.00	1.67	386.69	231.00	1.67
I	77176.43	57153.25	1.35	77176.43	57153.25	1.35	74914.91	57153.25	1.31	74914.91	57153.25	1.31
Ieff	74948.85	57153.25	1.31	74948.85	57153.25	1.31	72938.92	57153.25	1.28	72938.92	57153.25	1.28
	40x2 (ST37)			40x2 (ST52)			40x2 (ST37)			40x2 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	770093.76	639280.43	1.20	1002873.87	920905.52	1.09	723066.17	639280.43	1.13	956445.93	920905.52	1.04
ϕMn=	10271261.23	9365760.00	1.10	14666372.89	13658400.00	1.07	10140266.47	9365760.00	1.08	14506666.91	13658400.00	1.06
Pe	13906679.75	11397662.86	1.22	13906679.75	11397662.86	1.22	13623298.13	11397662.86	1.20	13623298.13	11397662.86	1.20
A	470.15	304.00	1.55	470.15	304.00	1.55	451.39	304.00	1.48	451.39	304.00	1.48
I	91310.03	73365.33	1.24	91310.03	73365.33	1.24	89283.26	73365.33	1.22	89283.26	73365.33	1.22
Ieff	89515.56	73365.33	1.22	89515.56	73365.33	1.22	87691.47	73365.33	1.20	87691.47	73365.33	1.20

	40x2.5 (ST37)			40x2.5 (ST52)			40x2.5 (ST37)			40x2.5 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	880819.85	788055.22	1.12	1167806.68	1134870.43	1.03	836393.59	788055.22	1.06	1124004.29	1134870.43	0.99
ϕMn=	12304066.06	11407500.00	1.08	17615998.51	16635937.50	1.06	12165867.05	11407500.00	1.07	17453197.67	16635937.50	1.05
Pe	15956562.80	13714923.36	1.16	15956562.80	13714923.36	1.16	15703380.20	13714923.36	1.14	15703380.20	13714923.36	1.14
A	532.05	375.00	1.42	532.05	375.00	1.42	514.31	375.00	1.37	514.31	375.00	1.37
I	104313.64	88281.25	1.18	104313.64	88281.25	1.18	102502.86	88281.25	1.16	102502.86	88281.25	1.16
Ieff	102710.40	88281.25	1.16	102710.40	88281.25	1.16	101080.70	88281.25	1.14	101080.70	88281.25	1.14
	40x3 (ST37)			40x3 (ST52)			40x3 (ST37)			40x3 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	988232.00	932415.98	1.06	1327721.53	1342339.79	0.99	946342.82	932415.98	1.01	1286469.19	1342339.79	0.96
ϕMn=	14202479.04	13335840.00	1.06	20382704.44	19448100.00	1.05	14062792.42	13335840.00	1.05	20222277.00	19448100.00	1.04
Pe	17838072.14	15841848.24	1.13	17838072.14	15841848.24	1.13	17612608.07	15841848.24	1.11	17612608.07	15841848.24	1.11
A	592.21	444.00	1.33	592.21	444.00	1.33	575.47	444.00	1.30	575.47	444.00	1.30
I	116249.16	101972.00	1.14	116249.16	101972.00	1.14	114636.62	101972.00	1.12	114636.62	101972.00	1.12
Ieff	114821.44	101972.00	1.13	114821.44	101972.00	1.13	113370.16	101972.00	1.11	113370.16	101972.00	1.11

	45x1.2 (ST37)			45x1.2 (ST52)			45x1.2 (ST37)			45x1.2 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	706012.02	445033.93	1.59	869122.30	643024.62	1.35	639581.43	445033.93	1.44	803235.20	643024.62	1.25
ϕMn=	8602207.79	7460760.96	1.15	12227164.47	10880276.40	1.12	8472082.03	7460760.96	1.14	12049625.32	10880276.40	1.11
Pe	14865912.46	10451126.23	1.42	14865912.46	10451126.23	1.42	14367283.18	10451126.23	1.37	14367283.18	10451126.23	1.37
A	442.90	210.24	2.11	442.90	210.24	2.11	416.62	210.24	1.98	416.62	210.24	1.98
I	102458.16	67272.60	1.52	102458.16	67272.60	1.52	98484.12	67272.60	1.46	98484.12	67272.60	1.46
Ieff	95690.02	67272.60	1.42	95690.02	67272.60	1.42	92480.41	67272.60	1.37	92480.41	67272.60	1.37
	45x1.5 (ST37)			45x1.5 (ST52)			45x1.5 (ST37)			45x1.5 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	786340.06	552332.64	1.42	989187.97	797960.34	1.24	721667.00	552332.64	1.31	925077.57	797960.34	1.16
ϕMn=	10418847.10	9199980.00	1.13	14824186.84	13416637.50	1.10	10266011.10	9199980.00	1.12	14624250.85	13416637.50	1.09
Pe	17233109.37	12802912.51	1.35	17233109.37	12802912.51	1.35	16732739.54	12802912.51	1.31	16732739.54	12802912.51	1.31
A	487.15	261.00	1.87	487.15	261.00	1.87	461.61	261.00	1.77	461.61	261.00	1.77
I	115655.52	82410.75	1.40	115655.52	82410.75	1.40	111900.68	82410.75	1.36	111900.68	82410.75	1.36
Ieff	110927.37	82410.75	1.35	110927.37	82410.75	1.35	107706.56	82410.75	1.31	107706.56	82410.75	1.31
	45x2 (ST37)			45x2 (ST52)			45x2 (ST37)			45x2 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	917163.51	727644.86	1.26	1184777.03	1051014.65	1.13	855478.63	727644.86	1.18	1123682.56	1051014.65	1.07
ϕMn=	13270270.83	11990160.00	1.11	18925275.36	17485650.00	1.08	13091935.85	11990160.00	1.09	18703575.27	17485650.00	1.07
Pe	20725828.48	16504695.75	1.26	20725828.48	16504695.75	1.26	20249071.45	16504695.75	1.23	20249071.45	16504695.75	1.23
A	559.51	344.00	1.63	559.51	344.00	1.63	535.17	344.00	1.56	535.17	344.00	1.56
I	136428.56	106238.67	1.28	136428.56	106238.67	1.28	133018.75	106238.67	1.25	133018.75	106238.67	1.25
Ieff	133409.57	106238.67	1.26	133409.57	106238.67	1.26	130340.75	106238.67	1.23	130340.75	106238.67	1.23

	45x2.5 (ST37)			45x2.5 (ST52)			45x2.5 (ST37)			45x2.5 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	1044405.14	898559.37	1.16	1374957.99	1297606.34	1.06	985708.19	898559.37	1.10	1316880.24	1297606.34	1.01
ϕMn=	15935921.05	14647500.00	1.09	22782618.92	21360937.50	1.07	15743619.40	14647500.00	1.07	22552040.37	21360937.50	1.06
Pe	23769439.45	19945301.53	1.19	23769439.45	19945301.53	1.19	23337521.11	19945301.53	1.17	23337521.11	19945301.53	1.17
A	630.13	425.00	1.48	630.13	425.00	1.48	606.96	425.00	1.43	606.96	425.00	1.43
I	155735.97	128385.42	1.21	155735.97	128385.42	1.21	152646.85	128385.42	1.19	152646.85	128385.42	1.19
Ieff	153000.92	128385.42	1.19	153000.92	128385.42	1.19	150220.71	128385.42	1.17	150220.71	128385.42	1.17
	45x3 (ST37)			45x3 (ST52)			45x3 (ST37)			45x3 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	1168343.89	1065077.68	1.10	1560147.03	1537738.70	1.01	1112571.61	1065077.68	1.04	1505011.32	1537738.70	0.98
ϕMn=	18440160.84	17175240.00	1.07	26423141.45	25047225.00	1.05	18241936.22	17175240.00	1.06	26191783.89	25047225.00	1.05
Pe	26593140.73	23137313.60	1.15	26593140.73	23137313.60	1.15	26202821.36	23137313.60	1.13	26202821.36	23137313.60	1.13
A	699.00	504.00	1.39	699.00	504.00	1.39	676.98	504.00	1.34	676.98	504.00	1.34
I	173648.36	148932.00	1.17	173648.36	148932.00	1.17	170856.77	148932.00	1.15	170856.77	148932.00	1.15
Ieff	171176.73	148932.00	1.15	171176.73	148932.00	1.15	168664.29	148932.00	1.13	168664.29	148932.00	1.13

	50x1.2 (ST37)			50x1.2 (ST52)			50x1.2 (ST37)			50x1.2 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	835897.69	497787.55	1.68	1019627.71	720543.25	1.42	752316.98	497787.55	1.51	936582.99	720543.25	1.30
ϕMn=	10767470.44	9260904.96	1.16	15301684.90	13505486.40	1.13	10603972.49	9260904.96	1.15	15074029.83	13505486.40	1.12
Pe	21161484.24	14452297.48	1.46	21161484.24	14452297.48	1.46	20403713.26	14452297.48	1.41	20403713.26	14452297.48	1.41
A	524.72	234.24	2.24	524.72	234.24	2.24	491.91	234.24	2.10	491.91	234.24	2.10
I	147874.77	93027.64	1.59	147874.77	93027.64	1.59	141680.05	93027.64	1.52	141680.05	93027.64	1.52
Ieff	136213.83	93027.64	1.46	136213.83	93027.64	1.46	131336.16	93027.64	1.41	131336.16	93027.64	1.41
	50x1.5 (ST37)			50x1.5 (ST52)			50x1.5 (ST37)			50x1.5 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	926081.36	618287.88	1.50	1154698.55	894885.96	1.29	844482.84	618287.88	1.37	1073659.43	894885.96	1.20
ϕMn=	13061097.58	11435580.00	1.14	18573109.07	16676887.50	1.11	12865937.89	11435580.00	1.13	18312741.26	16676887.50	1.10
Pe	24485498.79	17740479.12	1.38	24485498.79	17740479.12	1.38	23723680.64	17740479.12	1.34	23723680.64	17740479.12	1.34
A	574.21	291.00	1.97	574.21	291.00	1.97	542.22	291.00	1.86	542.22	291.00	1.86
I	166326.84	114193.25	1.46	166326.84	114193.25	1.46	160438.59	114193.25	1.40	160438.59	114193.25	1.40
Ieff	157610.10	114193.25	1.38	157610.10	114193.25	1.38	152706.37	114193.25	1.34	152706.37	114193.25	1.34
	50x2 (ST37)			50x2 (ST52)			50x2 (ST37)			50x2 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	1073501.90	815614.23	1.32	1375600.66	1180308.89	1.17	995236.79	815614.23	1.22	1297914.62	1180308.89	1.10
ϕMn=	16671914.96	14938560.00	1.12	23753311.96	21785400.00	1.09	16439054.51	14938560.00	1.10	23458525.23	21785400.00	1.08
Pe	29636221.77	22947780.64	1.29	29636221.77	22947780.64	1.29	28880793.90	22947780.64	1.26	28880793.90	22947780.64	1.26
A	655.28	384.00	1.71	655.28	384.00	1.71	624.64	384.00	1.63	624.64	384.00	1.63
I	195548.29	147712.00	1.32	195548.29	147712.00	1.32	190145.41	147712.00	1.29	190145.41	147712.00	1.29
Ieff	190764.66	147712.00	1.29	190764.66	147712.00	1.29	185902.07	147712.00	1.26	185902.07	147712.00	1.26

	50x2.5 (ST37)			50x2.5 (ST52)			50x2.5 (ST37)			50x2.5 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	1217171.85	1008556.81	1.21	1590846.03	1459297.92	1.09	1142280.10	1008556.81	1.13	1516565.81	1459297.92	1.04
ϕMn=	20061057.08	18292500.00	1.10	28645259.55	26676562.50	1.07	19805207.96	18292500.00	1.08	28333333.80	26676562.50	1.06
Pe	33951854.85	27826325.33	1.22	33951854.85	27826325.33	1.22	33260005.19	27826325.33	1.20	33260005.19	27826325.33	1.20
A	734.62	475.00	1.55	734.62	475.00	1.55	705.29	475.00	1.48	705.29	475.00	1.48
I	222924.88	179114.58	1.24	222924.88	179114.58	1.24	217976.72	179114.58	1.22	217976.72	179114.58	1.22
Ieff	218543.85	179114.58	1.22	218543.85	179114.58	1.22	214090.50	179114.58	1.20	214090.50	179114.58	1.20

	50x3 (ST37)			50x3 (ST52)			50x3 (ST37)			50x3 (ST52)		
	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio	Composit	Steel	Ratio
ϕPn=	1357547.25	1197116.59	1.13	1801119.47	1731855.16	1.04	1285966.35	1197116.59	1.07	1730171.03	1731855.16	1.00
ϕMn=	23259236.22	21500640.00	1.08	33283624.46	31355100.00	1.06	22991089.40	21500640.00	1.07	32965835.59	31355100.00	1.05
Pe	37989170.83	32390250.49	1.17	37989170.83	32390250.49	1.17	37356799.19	32390250.49	1.15	37356799.19	32390250.49	1.15
A	812.21	564.00	1.44	812.21	564.00	1.44	784.17	564.00	1.39	784.17	564.00	1.39
I	248535.95	208492.00	1.19	248535.95	208492.00	1.19	244013.17	208492.00	1.17	244013.17	208492.00	1.17
Ieff	244531.55	208492.00	1.17	244531.55	208492.00	1.17	240461.05	208492.00	1.15	240461.05	208492.00	1.15

f'c=	240	kg/cm2	
Fy=	2400	kg/cm2	
Es	2040000	kg/cm2	
Ec	232000	kg/cm2	

30x1.2 (ST37)			
	Composit	Steel	Ratio
ϕPn=	346008.6348	284976.5916	1.21416511
ϕMn=	3550835.774	3226728.96	1.100444387
Pe	3742950.889	2974032.371	1.258544099
A	224.8715294	138.24	1.626674837
I	24642.84469	19143.4752	1.287271221
Ieff	24092.90774	19143.4752	1.258544099
30x1.5 (ST37)			
	Composit	Steel	Ratio
ϕPn=	397178.02	352179.25	1.127772331
ϕMn=	4277924.92	3951180.00	1.082695529
Pe	4310496.67	3606291.76	1.195271197
A	253.91	171	1.484829721
I	28249.78	23213.25	1.216967997
Ieff	27746	23213.25	1.195271197
30x2 (ST37)			
	Composit	Steel	Ratio
ϕPn=	479695.6596	460595.8418	1.04146763
ϕMn=	5405018.139	5088960	1.062106627
Pe	5175865.948	4570333.55	1.132491949
A	300.8784314	224	1.343207283
I	33749.48497	29418.66667	1.147213276
Ieff	33316.40314	29418.66667	1.132491949

f'c=	240	kg/cm2	
Fy=	3500	kg/cm2	
Es	2040000	kg/cm2	
Ec	232000	kg/cm2	

30x1.2 (ST52)			
	Composit	Steel	Ratio
ϕPn=	446354.8966	406791.4114	1.097257425
ϕMn=	5067041.45	4705646.4	1.076800299
Pe	3742950.889	2974032.371	1.258544099
A	224.8715294	138.24	1.626674837
I	24642.84469	19143.4752	1.287271221
Ieff	24092.90774	19143.4752	1.258544099
30x1.5 (ST52)			
	Composit	Steel	Ratio
ϕPn=	521191.4078	502503.9068	1.037188768
ϕMn=	6120000.102	5762137.5	1.062105877
Pe	4310496.673	3606291.763	1.195271197
A	253.9058824	171	1.484829721
I	28249.78235	23213.25	1.216967997
Ieff	27746.12912	23213.25	1.195271197
30x2 (ST52)			
	Composit	Steel	Ratio
ϕPn=	641756.247	656714.8603	0.977222058
ϕMn=	7760528.561	7421400	1.045696036
Pe	5175865.948	4570333.55	1.132491949
A	300.8784314	224	1.343207283
I	33749.48497	29418.66667	1.147213276
Ieff	33316.40314	29418.66667	1.132491949

30x2.5 (ST37)			
	Composit	Steel	Ratio
ϕPn=	558780.3351	564533.3802	0.989809203
ϕMn=	6438247.423	6142500	1.048147729
Pe	5946941.174	5429329.543	1.095336197
A	346.0784314	275	1.258467023
I	38649.9183	34947.91667	1.105929108
Ieff	38279.71814	34947.91667	1.095336197

30x3 (ST37)			
	Composit	Steel	Ratio
ϕPn=	634449.2158	664000.4539	0.955495154
ϕMn=	7386203.077	7115040	1.038111251
Pe	6630834.499	6191202.841	1.071009087
A	389.5058824	324	1.202178649
I	42996.28235	39852	1.078898985
Ieff	42681.85412	39852	1.071009087

30x2.5 (ST52)			
	Composit	Steel	Ratio
ϕPn=	757130.6703	804301.207	0.94135215
ϕMn=	9270799.564	8957812.5	1.034940122
Pe	5946941.174	5429329.543	1.095336197
A	346.0784314	275	1.258467023
I	38649.9183	34947.91667	1.105929108
Ieff	38279.71814	34947.91667	1.095336197

30x3 (ST52)			
	Composit	Steel	Ratio
ϕPn=	867332.1649	945281.7045	0.917538297
ϕMn=	10660238.38	10376100	1.027383929
Pe	6630834.499	6191202.841	1.071009087
A	389.5058824	324	1.202178649
I	42996.28235	39852	1.078898985
Ieff	42681.85412	39852	1.071009087

f'c=	240	kg/cm2	
Fy=	2400	kg/cm2	
Es	2040000	kg/cm2	
Ec	232000	kg/cm2	

f'c=	240	kg/cm2	
Fy=	3500	kg/cm2	
Es	2040000	kg/cm2	
Ec	232000	kg/cm2	

35x1.2 (ST37)			
	Composit	Steel	Ratio
ϕPn=	436529.53	338752.22	1.288639598
ϕMn=	4947780.83	4443672.96	1.113443964
Pe	6243437.31	4805206.60	1.299306737
A	283.10	162.24	1.744963646
I	41634.54	30930.5152	1.346066705
Ieff	40188	30930.5152	1.299306737
35x1.5 (ST37)			
	Composit	Steel	Ratio
ϕPn=	498165.0773	419436.6892	1.18770029
ϕMn=	5975228.807	5457780	1.094809393
Pe	7241788.143	5852335	1.237418593
A	317.454902	201	1.579377622
I	47608.23497	37670.75	1.263798437
Ieff	46614.48647	37670.75	1.237418593
35x2 (ST37)			
	Composit	Steel	Ratio
ϕPn=	597873.0612	550354.4322	1.086341867
ϕMn=	7579664.429	7065360	1.072792388
Pe	8695071.627	7471327.086	1.163792125
A	373.2901961	264	1.413978015
I	56844.3232	48092	1.18199125
Ieff	55969.09088	48092	1.163792125

35x1.2 (ST52)			
	Composit	Steel	Ratio
ϕPn=	558327.4198	486393.6706	1.147892034
ϕMn=	7049988.581	6480356.4	1.087901366
Pe	6243437.311	4805206.604	1.299306737
A	283.102902	162.24	1.744963646
I	41634.53667	30930.5152	1.346066705
Ieff	40188.22677	30930.5152	1.299306737
35x1.5 (ST52)			
	Composit	Steel	Ratio
ϕPn=	649146.677	602082.2602	1.078169413
ϕMn=	8532952.474	7959262.5	1.072078283
Pe	7241788.143	5852335	1.237418593
A	317.454902	201	1.579377622
I	47608.23497	37670.75	1.263798437
Ieff	46614.48647	37670.75	1.237418593
35x2 (ST52)			
	Composit	Steel	Ratio
ϕPn=	795941.8852	789648.776	1.007969504
ϕMn=	10861385.01	10303650	1.054129848
Pe	8695071.627	7471327.086	1.163792125
A	373.2901961	264	1.413978015
I	56844.3232	48092	1.18199125
Ieff	55969.09088	48092	1.163792125

35x2.5 (ST37)			
	Composit	Steel	Ratio
ϕPn=	694172.4007	676829.6805	1.025623463
ϕMn=	9066245.02	8572500	1.057596386
Pe	10014316.71	8940997.235	1.120044717
A	427.3529412	325	1.314932127
I	65228.55392	57552.08333	1.133383018
Ieff	64460.90686	57552.08333	1.120044717
35x3 (ST37)			
	Composit	Steel	Ratio
ϕPn=	787077.3757	798866.8507	0.985242253
ϕMn=	10446783.63	9982440	1.046516045
Pe	11208030.09	10270822.1	1.09124956
A	479.6431373	384	1.24907067
I	72814.98987	66112	1.1013884
Ieff	72144.69088	66112	1.09124956

35x2.5 (ST52)			
	Composit	Steel	Ratio
ϕPn=	937598.95	970662.11	0.965937513
ϕMn=	13028988.33	12501562.50	1.042188793
Pe	10014316.71	8940997.24	1.120044717
A	427.35	325	1.314932127
I	65228.55	57552.08333	1.133383018
Ieff	64461	57552.08333	1.120044717
35x3 (ST52)			
	Composit	Steel	Ratio
ϕPn=	1074127.46	1145131.925	0.937994511
ϕMn=	15048345.19	14557725	1.033701708
Pe	11208030.09	10270822.1	1.09124956
A	479.6431373	384	1.24907067
I	72814.98987	66112	1.1013884
Ieff	72144.69088	66112	1.09124956

f'c=	240	kg/cm2	
Fy=	2400	kg/cm2	
Es	2040000	kg/cm2	
Ec	232000	kg/cm2	

40x1.2 (ST37)			
	Composit	Steel	Ratio
ϕPn=	534341.01	392053.60	1.362928462
ϕMn=	6587360.20	5855016.96	1.12507961
Pe	9717219.59	7266500.25	1.33726268
A	347.02	186.24	1.863297621
I	65715.65	46773.5552	1.404974399
Ieff	62549	46773.5552	1.33726268
40x1.5 (ST37)			
	Composit	Steel	Ratio
ϕPn=	606296.5027	486089.1194	1.247294947
ϕMn=	7970082.909	7207380	1.105822491
Pe	11331417.81	8879036.529	1.276199031
A	386.6901961	231	1.673983533
I	74914.90654	57153.25	1.310772468
Ieff	72938.92225	57153.25	1.276199031
40x2 (ST37)			
	Composit	Steel	Ratio
ϕPn=	723066.1695	639280.4251	1.131062584
ϕMn=	10140266.47	9365760	1.082695529
Pe	13623298.13	11397662.86	1.195271197
A	451.3882353	304	1.484829721
I	89283.26275	73365.33333	1.216967997
Ieff	87691.4698	73365.33333	1.195271197

f'c=	240	kg/cm2	
Fy=	3500	kg/cm2	
Es	2040000	kg/cm2	
Ec	232000	kg/cm2	

40x1.2 (ST52)			
	Composit	Steel	Ratio
ϕPn=	677196.3518	565037.8044	1.198497422
ϕMn=	9376123.526	8538566.4	1.098091071
Pe	9717219.591	7266500.247	1.33726268
A	347.020549	186.24	1.863297621
I	65715.64762	46773.5552	1.404974399
Ieff	62548.52976	46773.5552	1.33726268
40x1.5 (ST52)			
	Composit	Steel	Ratio
ϕPn=	783702.1987	700439.6087	1.118871904
ϕMn=	11365891.17	10510762.5	1.081357435
Pe	11331417.81	8879036.529	1.276199031
A	386.6901961	231	1.673983533
I	74914.90654	57153.25	1.310772468
Ieff	72938.92225	57153.25	1.276199031
40x2 (ST52)			
	Composit	Steel	Ratio
ϕPn=	956445.9309	920905.5181	1.038592898
ϕMn=	14506666.91	13658400	1.062105877
Pe	13623298.13	11397662.86	1.195271197
A	451.3882353	304	1.484829721
I	89283.26275	73365.33333	1.216967997
Ieff	87691.4698	73365.33333	1.195271197

40x2.5 (ST37)			
	Composit	Steel	Ratio
ϕPn=	836393.5925	788055.2157	1.06133882
ϕMn=	12165867.05	11407500	1.066479689
Pe	15703380.2	13714923.36	1.144984904
A	514.3137255	375	1.371503268
I	102502.8595	88281.25	1.161094337
Ieff	101080.6985	88281.25	1.144984904

40x2.5 (ST52)			
	Composit	Steel	Ratio
ϕPn=	1124004.292	1134870.43	0.990425217
ϕMn=	17453197.67	16635937.5	1.049126187
Pe	15703380.2	13714923.36	1.144984904
A	514.3137255	375	1.371503268
I	102502.8595	88281.25	1.161094337
Ieff	101080.6985	88281.25	1.144984904

40x3 (ST37)			
	Composit	Steel	Ratio
ϕPn=	946342.8236	932415.9802	1.014936299
ϕMn=	14062792.42	13335840	1.054511184
Pe	17612608.07	15841848.24	1.111777351
A	575.4666667	444	1.296096096
I	114636.6222	101972	1.124197056
Ieff	113370.16	101972	1.111777351

40x3 (ST52)			
	Composit	Steel	Ratio
ϕPn=	1286469.186	1342339.787	0.958378198
ϕMn=	20222277	19448100	1.039807333
Pe	17612608.07	15841848.24	1.111777351
A	575.4666667	444	1.296096096
I	114636.6222	101972	1.124197056
Ieff	113370.16	101972	1.111777351

f'c=	240	kg/cm2	
Fy=	2400	kg/cm2	
Es	2040000	kg/cm2	
Ec	232000	kg/cm2	

45x1.2 (ST37)			
	Composit	Steel	Ratio
ϕPn=	639581.43	445033.93	1.437152065
ϕMn=	8472082.03	7460760.96	1.135552001
Pe	14367283.18	10451126.23	1.374711478
A	416.62	210.24	1.981661295
I	98484.12	67272.5952	1.46395599
Ieff	92480	67272.5952	1.374711478
45x1.5 (ST37)			
	Composit	Steel	Ratio
ϕPn=	721667.0025	552332.6441	1.306580392
ϕMn=	10266011.1	9199980	1.115873197
Pe	16732739.54	12802912.51	1.306947894
A	461.6117647	261	1.768627451
I	111900.6794	82410.75	1.357840809
Ieff	107706.5561	82410.75	1.306947894
45x2 (ST37)			
	Composit	Steel	Ratio
ϕPn=	855478.6284	727644.8604	1.175681538
ϕMn=	13091935.85	11990160	1.091890004
Pe	20249071.45	16504695.75	1.226867297
A	535.172549	344	1.555734154
I	133018.7546	106238.6667	1.252074774
Ieff	130340.7458	106238.6667	1.226867297

f'c=	240	kg/cm2	
Fy=	3500	kg/cm2	
Es	2040000	kg/cm2	
Ec	232000	kg/cm2	

45x1.2 (ST52)			
	Composit	Steel	Ratio
ϕPn=	803235.2008	643024.619	1.249151552
ϕMn=	12049625.32	10880276.4	1.107474192
Pe	14367283.18	10451126.23	1.374711478
A	416.6244706	210.24	1.981661295
I	98484.11869	67272.5952	1.46395599
Ieff	92480.40875	67272.5952	1.374711478
45x1.5 (ST52)			
	Composit	Steel	Ratio
ϕPn=	925077.57	797960.34	1.159302699
ϕMn=	14624250.85	13416637.50	1.090008644
Pe	16732739.54	12802912.51	1.306947894
A	461.61	261	1.768627451
I	111900.68	82410.75	1.357840809
Ieff	107707	82410.75	1.306947894
45x2 (ST52)			
	Composit	Steel	Ratio
ϕPn=	1123682.564	1051014.648	1.069140727
ϕMn=	18703575.27	17485650	1.069652845
Pe	20249071.45	16504695.75	1.226867297
A	535.172549	344	1.555734154
I	133018.7546	106238.6667	1.252074774
Ieff	130340.7458	106238.6667	1.226867297

45x2.5 (ST37)			
	Composit	Steel	Ratio
ϕPn=	985708.186	898559.3719	1.096987263
ϕMn=	15743619.4	14647500	1.074833207
Pe	23337521.11	19945301.53	1.170076125
A	606.9607843	425	1.428143022
I	152646.8546	128385.4167	1.188973472
Ieff	150220.7108	128385.4167	1.170076125
45x3 (ST37)			
	Composit	Steel	Ratio
ϕPn=	1112571.609	1065077.683	1.044591984
ϕMn=	18241936.22	17175240	1.062106627
Pe	26202821.36	23137313.6	1.132491949
A	676.9764706	504	1.343207283
I	170856.7676	148932	1.147213276
Ieff	168664.2909	148932	1.132491949

45x2.5 (ST52)			
	Composit	Steel	Ratio
ϕPn=	1316880.238	1297606.339	1.014853425
ϕMn=	22552040.37	21360937.5	1.055760796
Pe	23337521.11	19945301.53	1.170076125
A	606.9607843	425	1.428143022
I	152646.8546	128385.4167	1.188973472
Ieff	150220.7108	128385.4167	1.170076125
45x3 (ST52)			
	Composit	Steel	Ratio
ϕPn=	1505011.319	1537738.7	0.978717203
ϕMn=	26191783.89	25047225	1.045696036
Pe	26202821.36	23137313.6	1.132491949
A	676.9764706	504	1.343207283
I	170856.7676	148932	1.147213276
Ieff	168664.2909	148932	1.132491949

f'c=	240	kg/cm2	
Fy=	2400	kg/cm2	
Es	2040000	kg/cm2	
Ec	232000	kg/cm2	

50x1.2 (ST37)			
	Composit	Steel	Ratio
ϕPn=	752316.98	497787.55	1.511321412
ϕMn=	10603972.49	9260904.96	1.145025517
Pe	20403713.26	14452297.48	1.411797209
A	491.91	234.24	2.100045537
I	141680.05	93027.6352	1.522988815
Ieff	131336	93027.6352	1.411797209
50x1.5 (ST37)			
	Composit	Steel	Ratio
ϕPn=	844482.836	618287.8763	1.365840846
ϕMn=	12865937.89	11435580	1.12507961
Pe	23723680.64	17740479.12	1.33726268
A	542.2196078	291	1.863297621
I	160438.5928	114193.25	1.404974399
Ieff	152706.3715	114193.25	1.33726268
50x2 (ST37)			
	Composit	Steel	Ratio
ϕPn=	995236.7949	815614.2252	1.220229815
ϕMn=	16439054.51	14938560	1.100444387
Pe	28880793.9	22947780.64	1.258544099
A	624.6431373	384	1.626674837
I	190145.4065	147712	1.287271221
Ieff	185902.0659	147712	1.258544099

f'c=	240	kg/cm2	
Fy=	3500	kg/cm2	
Es	2040000	kg/cm2	
Ec	232000	kg/cm2	

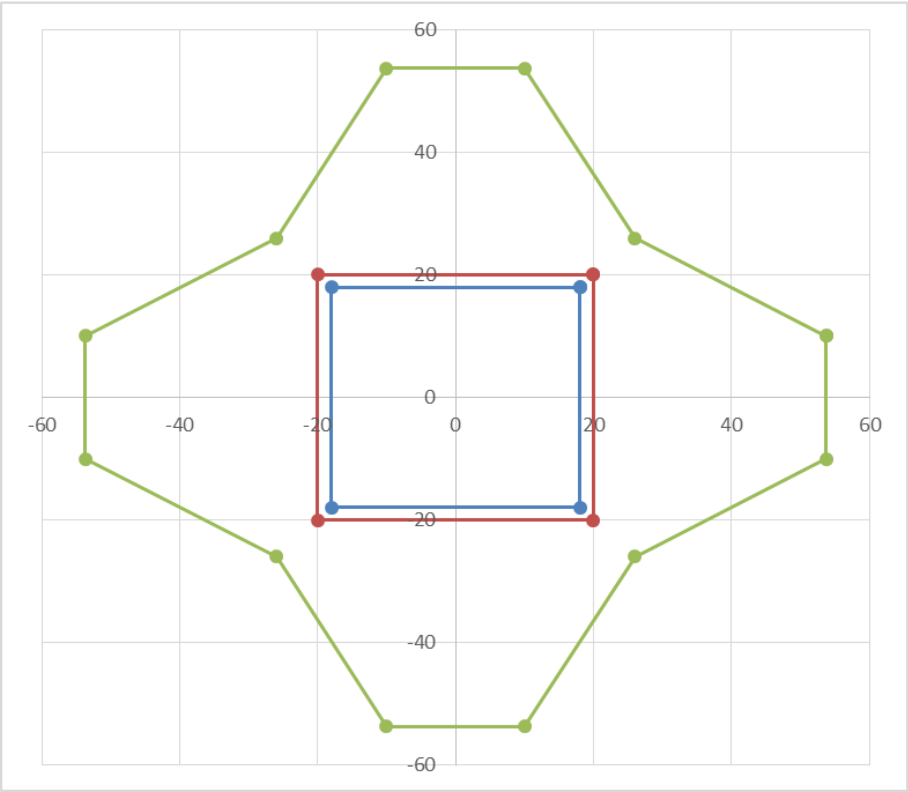
50x1.2 (ST52)			
	Composit	Steel	Ratio
ϕPn=	936582.9926	720543.2541	1.299828965
ϕMn=	15074029.83	13505486.4	1.116141203
Pe	20403713.26	14452297.48	1.411797209
A	491.9146667	234.24	2.100045537
I	141680.0479	93027.6352	1.522988815
Ieff	131336.1558	93027.6352	1.411797209
50x1.5 (ST52)			
	Composit	Steel	Ratio
ϕPn=	1073659.428	894885.9626	1.199772343
ϕMn=	18312741.26	16676887.5	1.098091071
Pe	23723680.64	17740479.12	1.33726268
A	542.2196078	291	1.863297621
I	160438.5928	114193.25	1.404974399
Ieff	152706.3715	114193.25	1.33726268
50x2 (ST52)			
	Composit	Steel	Ratio
ϕPn=	1297914.616	1180308.886	1.09963979
ϕMn=	23458525.23	21785400	1.076800299
Pe	28880793.9	22947780.64	1.258544099
A	624.6431373	384	1.626674837
I	190145.4065	147712	1.287271221
Ieff	185902.0659	147712	1.258544099

50x2.5 (ST37)			
	Composit	Steel	Ratio
ϕPn=	1142280.097	1008556.811	1.132588749
ϕMn=	19805207.96	18292500	1.082695529
Pe	33260005.19	27826325.33	1.195271197
A	705.2941176	475	1.484829721
I	217976.7157	179114.5833	1.216967997
Ieff	214090.5025	179114.5833	1.195271197

50x3 (ST37)			
	Composit	Steel	Ratio
ϕPn=	1285966.35	1197116.595	1.074219801
ϕMn=	22991089.4	21500640	1.069321165
Pe	37356799.19	32390250.49	1.15333468
A	784.172549	564	1.39037686
I	244013.1712	208492	1.170371867
Ieff	240461.0541	208492	1.15333468

50x2.5 (ST52)			
	Composit	Steel	Ratio
ϕPn=	1516565.811	1459297.921	1.039243453
ϕMn=	28333333.8	26676562.5	1.062105877
Pe	33260005.19	27826325.33	1.195271197
A	705.2941176	475	1.484829721
I	217976.7157	179114.5833	1.216967997
Ieff	214090.5025	179114.5833	1.195271197

50x3 (ST52)			
	Composit	Steel	Ratio
ϕPn=	1730171.026	1731855.162	0.999027554
ϕMn=	32965835.59	31355100	1.051370769
Pe	37356799.19	32390250.49	1.15333468
A	784.172549	564	1.39037686
I	244013.1712	208492	1.170371867
Ieff	240461.0541	208492	1.15333468



$$P_{bf} = ۲۰۲ \quad Ton$$

$$۲۰ \leq \frac{b_c}{t_c} \leq ۵۰$$ OK

$$۳۰ \leq \theta \leq ۴۵$$ ok

$$t_d \geq t_{bf}$$ OK

$$\frac{۰/۱۵ t_{bf}}{t_d} \leq \frac{h_d}{b_c}$$ OK

$$۰/۷۵ \leq \frac{t_d}{t_c} \leq ۲$$ OK

bc	40	cm
tc	2	cm
hd	6	cm
bb	20	cm
teta	30	degree
td	1.5	cm

fdu=	3600	kg/cm2
fdy=	2400	kg/cm2
fcy=	2400	kg/cm2
tbf=	1.5	cm

نتیجه

هر چه ضخامت ورق ستون بیشتر شود مقاومت فشاری ستون CFT کاهش می یابد.

هر چه ابعاد ستون قوطی کمتر شود مقاومت فشاری ستون CFT کاهش می یابد.

هر چه مقاومت فشاری بتن کمتر شود مقاومت فشاری ستون CFT کاهش می یابد.

هر چه مقاومت فولاد بیشتر شود مقاومت فشاری ستون CFT کاهش می یابد.

5. Stiffness for Calculation of Required Strengths

For the direct analysis method of design, the required strengths of encased composite members and filled composite members shall be determined using the provisions of Section C2 and the following requirements:

(1) The nominal flexural stiffness of members subject to net compression shall be taken as the effective stiffness of the composite section, EI_{eff}, as defined in Section I2.

(2) The nominal axial stiffness of members subject to net compression shall be taken as the summation of the elastic axial stiffnesses of each component.

(3) Stiffness of members subject to net tension shall be taken as the stiffness of the bare steel members in accordance with Chapter C.

(4) The stiffness reduction parameter, τ_b, shall be taken as 0.8.

> **User Note**: Taken together, the stiffness reduction factors require the use of $0.64EI_{eff}$ for the flexural stiffness and 0.8 times the nominal axial stiffness of encased composite members and filled composite members subject to net compression in the analysis.
>
> Stiffness values appropriate for the calculation of deflections and for use with the effective length method are discussed in the Commentary.

با تشکر