14-2 STEEL COLUMN CASING DESIGN AND DETAILS

Steel column casings are the most common column retrofit method used in California. They are effective for enhancing shear capacity, confinement, and preventing slipping of lap splices commonly found at the base of columns constructed prior to 1971.

Upon completion of the diagnostic analysis of the As-built structure as described in Memo to Designers (MTD) 20-4, the engineer must determine if column casings are required and the type to use. There are two types of casings, Type F and Type P/F. The Type F casing provides fixed end conditions, while the Type P/F casing provides a fixed condition at the top of the column and a pinned condition at the bottom. The pin for the Type P/F casing is detailed by placing polystyrene around the bottom of the column and allowing the lap splice to slip thus forming a pin. For both the Type F and P/F column casings, it is necessary to provide a minimum of 2-inch clearance between the casing ends and the bent cap soffit and/or footings. The gap prevents the casing from bearing on the attached member. Bearing would increase the effects of the plastic moment and thus the demand in the footing or bent cap.

Charts have been developed to give casing dimensions and thicknesses for common sizes of rectangular columns. These charts (Figures 3 and 4) give curve data used to produce the most efficient casing around the given column. The curve data should not be listed on the contract plans. This information is for design, detailing and estimation purposes only. The only dimensions that should be listed on the contract plans are the "x" and "y" dimensions as well as the casing thickness.

When determining casing thickness requirements, Type F casings can be read directly from the charts shown in Figures 3 and 4. Note that casing thicknesses may not exceed 1-inch. If the casing thickness required exceeds 1 inch the engineer is referred to Note 5 on Figure 2. The column casing thicknesses for Type F shells were developed using thin wall pressure element theory shown on Figure 1. The required shell thickness is directly related to the radius. For rectangular columns, the shell is made up of partial circles using two different radii. The engineer may use the average of the two radii to determine the casing thickness.

The engineer may encounter a situation where the charts are not applicable. For example, the engineer may need to provide more clearance or a shorter radius to reduce shell thickness requirements. In these situations, the engineer may use the design formula for an ellipse given on Figure 2. The casing is then made from partial circular shapes that will most closely match the design ellipse. For the casing thickness, the engineer should use the formula on Figure 1. The engineer should coordinate with the specification engineer on the following:

a. When the minimum spacing between the column and the casing is equal to or greater than ¾-inch, the grout mix should contain pea gravel.

b. If a pea gravel grout is used for elliptical shells, injection ports may be needed on four sides due to restricted clearances at column corners. A similar detail may apply if elliptical jackets are used for rectangular columns with round ends and tight clearances.

c. For Type P/F shells, the polystyrene insert should have a 1-foot gap at the vertical seam of the casings. This is to prevent the polystyrene from burning during the welding process.

d. For tall casings, measures should be taken to prevent the casing from bulging due to large hydrostatic head during the grouting operation. One solution is to pump the grout in lifts, allowing each preceding lift to set, in order to reduce the hydrostatic head. Another solution is to add temporary stiffeners around the casing to provide extra confinement and strength while placing the grout.

The column casing design aids attached (Figures 1 to 4), together with the column casing Standard Detail Sheet XS7-010, should apply to most situations where steel casings are needed. For columns with non-standard shapes or any situation where the design charts do not apply, the engineer should develop project specific design criteria per MTD 20-11.

References:

1. California Department of Transportation, *Bridge Memo to Designers* 20-4 and 20-11

2. California Department of Transportation, *Bridge Standard Detail Sheets* XS7-010

3. UCSD SSRP-91/06 "*Flexural Retrofit of Circular Reinforced Concrete Bridge Columns by Steel Jacketing*"

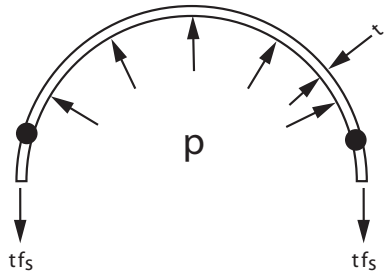
CASING THICKNESS:

TWO CONTROLLING CRITERIA:

A) Thin Walled Pressure Element (TWPE)

B) University of California San Diego Tests (UCSD Test)

A) FROM TWPE:



$$\frac{f_{LONG}}{R_{LONG}} + \frac{f_{TRAN}}{R_{TRAN}} = \frac{p}{t}$$

NOTES:

f_{LONG} = Sigma (stress) Longitudinally
f_{TRAN} = Sigma (stress) Transversely
R_{LONG} = Radius Longitudinally
R_{TRAN} = Radius Transversely
p = Internal Pressure
t = Thickness of Material
tf_s = Thickness x Steel stress

FOR COLUMN CASING: $R_{LONG} \longrightarrow \infty$

$$\frac{f_{TRAN}}{R_{TRAN}} = \frac{p}{t}$$

B) FROM UCSD TEST:[1]

At the point when a plastic hinge formed in the lap splice region, the strain in the steel casing was equal to 0.001 inch. The steel casing must be designed such that it produces 300 psi of confining pressure at this measured strain.

E_s = 29,000,000 psi

$f_s = \varepsilon_s E_s$ = 29,000 psi for lap-splice condition (assume 30,000 psi).

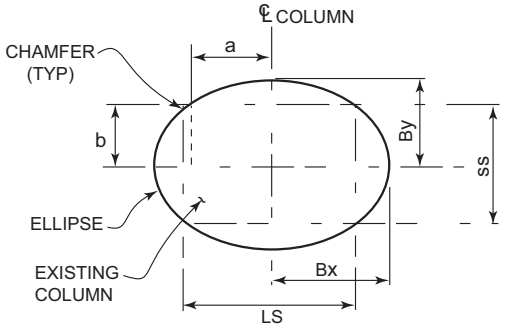
f_s = [Full Yield] = 36,000 psi for continuous reinforcement.

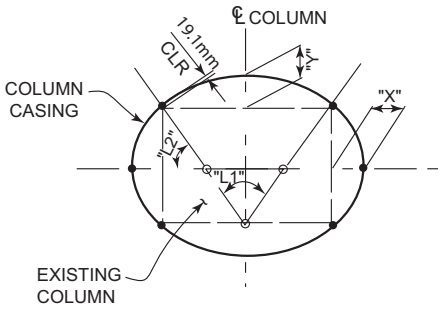
$$t_{LAP\text{-}SPLICE} = \frac{\text{Radius in feet (Average)}}{100}(12)$$ (casing thickness in inches when longitudinal reinforcement is lapped)

$$t_{CONT\ REINF} = \frac{\text{Radius in feet (Average)}}{120}(12)$$ (casing thickness in inches when longitudinal reinforcement is continuous)

Figure 1 Elliptical Steel Casing Thickness Requirement for Plastic Hinge Zones

[1] Flexural Retrofit of Circular Reinforced Concrete Bridge Columns by Steel Jacketing - UCSD SSRP-91/06





COLUMN CASING

NO SCALE

$$B_Y = \sqrt{b^2 + \frac{a^2}{(A_{SR})^2}}$$

$$B_X = B_Y \times A_{SR}$$

A_{SR} = ASPECT RATIO = $\frac{LS}{SS}$

LS = LONG SIDE

SS = SHORT SIDE

ELLIPSE GEOMETRY

NO SCALE

General Notes for Design & Analysis:

1. "X" & "Y" Dimensions are to be shown on the Contract Plans. See Figure 3 & 4 for location of "X" & "Y" dimensions.
2. Required casing thickness in the plastic hinge zone shall be the dimension shown in the tables on the following pages.
3. Type "P" casing shall be 3/8" thick unless otherwise noted on plans.
4. Maximum plate thickness shall be 1" and minimum plate thickness is 3/8".
5. If 1" maximum is exceeded, use of anchor bolts, stiffening channels, etc., must be incorporated to adequately confine the columns.
6. UCSD Tests were conducted using a 20 d_b lap length of 40 ksi yield strength rebar.
7. The Office of Bridge Architecture and Aesthetics shall be consulted to obtain a workable and aesthetically pleasing solution when different plate thicknesses are joined, exterior stiffeners are attached, or through bolts are installed.

Figure 2 Ellipse Geometry

COLUMN CASING DATA								CASING THICKNESS	
COLUMN SIZE	CURVE DATA (L_1) / CURVE DATA (L_2)							PLASTIC HINGE ZONE	
	Radius	Delta	Curve Length	Tangent	Chord Length	X*	Y*	$t^{**}_{lap\ splice}$	$t^{**}_{cont\ reinf}$
2′0″ × 3′-0″	2′-1 1/2″	59° 59′ 00″	3′- 1 1/8″	1′- 8 1/2″	2′- 1 1/2″	7 3/16″	5 5/8″	3/8″	3/8″
	1′-2 7/8″	60° 00′ 30″	1′- 3 5/8″	0′- 8 5/8″	1′- 2 7/8″				
2′0″ × 4′-0″	5′- 3/4″	45° 47′ 04″	4′- 1/2″	2′-1 5/8″	3′-11 1/4″	8 3/16″	5 11/16″	3/8″	3/8″
	1′- 2″	57° 06′ 28″	1′- 4 1/2″	0′- 9 1/4″	1′-3 1/2″				
2′0″ × 5′-0″	7′-9 1/4″	36° 58′ 14″	5′- 1/8″	2′-7 1/8″	4′-11 1/8″	9 3/8″	5 13/16″	3/4″	5/8″
	1′- 1 5/8″	71° 30′ 53″	1′- 5 5/8″	0′-9 3/4″	1′- 4″				
2′0″ × 6′-0″	11′-1″	30° 59′ 00″	1′- 5 5/8″	0′-10 1/4″	1′- 4 3/8″	1′- 1 7/8″	10 1/2″	1/2″	1/2″
	1′- 1 1/2″	74° 30′ 30″	1′- 5 5/8″	0′-10 1/4″	1′- 4 3/8″				
2′0″ × 7′-0″	15′-0 ″	26° 39′ 26″	6′-11 3/4″	3′- 6 5/8″	6′- 11″	9 13/16″	5 7/8″	1″	7/8″
	1′-1 3/8″	76° 40′ 17″	1′- 5 7/8″	0′-10 5/8″	1′- 4 5/8″				
2′0″ × 8′-0″	19′-6 1/8″	23° 23′ 14″	7′-11 5/8″	4′- 1/2″	7′-10 7/8″	10″	5 13/16″	*** Use other means	1″
	1′- 1 1/4″	78° 18′ 23″	1′- 6 1/8″	0′-10 3/4″	1′- 4 3/4″				

COLUMN CASING DATA								CASING THICKNESS	
COLUMN SIZE	CURVE DATA (L_1) / CURVE DATA (L_2)							PLASTIC HINGE ZONE	
	Radius	Delta	Curve Length	Tangent	Chord Length	X*	Y*	$t^{**}_{lap\ splice}$	$t^{**}_{cont\ reinf}$
3′0″ × 4′-0″	3′-7″	67° 34′ 34″	4′- 2 3/4″	2′- 4 3/4″	3′- 1 7/8″	10 1/16″	8 1/2″	3/8″	3/8″
	1′-10 7/8″	56° 12′ 43″	1′- 10 1/2″	1′- 1/4″	1′- 9 1/2″				
3′0″ × 5′-0″	5′- 4 1/2″	54° 52′ 08″	5′- 1 3/4″	2′- 9 1/2″	4′- 11 1/2″	11 3/16″	8 1/8″	1/2″	3/8″
	1′- 9 5/16″	52° 33′ 55″	1′- 11 1/4″	1′- 1″	1′-10 1/8″				
3′0″ × 6′-0″	7′-7″	46° 07′ 38″	6′- 1 1/4″	3′- 2 3/4″	5′-11 3/8″	1′- 3/16″	8 3/16″	5/8″	1/2″
	1′-5 5/8″	55° 56′ 11″	2′- 1/8″	1′- 1 5/8″	1′-10 5/8″				
3′0″ × 7′-0″	10′-2 1/4″	39° 45′ 48″	7′- 7/8″	3′- 8 1/4″	6′-11 1/8″	1′- 15/16″	8 3/16″	3/4″	5/8″
	1′- 8 1/8″	59° 33′ 47″	2′- 5 7/8″	1′- 4 3/8″	2′- 4 1/2″				
3′0″ × 8′-0″	13′-2 1/2″	34° 55′ 50″	8′- 3/8″	4′-1 7/8″	7′- 1 1/8″	1′- 1 1/2 ″	8 5/16″	1″	3/4″
	1′-7 15/16″	72° 32′ 05″	2′- 1 1/4″	1′- 2 5/8″	1′- 1 5/8″				
3′0″ × 9′-0″	16′-7 1/2″	31° 08′ 17″	9′- 3/8″	4′- 7 5/8″	8′-11 1/8″	1′- 2″	8 3/8″	use other means***	1″
	1′- 7 13/16″	74° 25′ 51″	2′-1 3/4″	1′- 3″	2′- 0″				
3′0″ × 10′-0″	17′-5 9/16″	33° 00′ 13″	10′- 11/16″	5′- 2 1/16″	9′-11 1/16″	1′- 1 11/16″	9 9/16″	use other means***	use other means***
	2′- 2 3/4″	69° 20′ 22″	2′- 8 3/8″	1′- 6 1/2″	2′- 6 1/2″				
3′0″ × 11′-0″	24′- 8″	25° 34′ 28″	11′- 1/8″	5′- 7 1/4″	10′-11″	1′-2 13/16″	8 1/2″	use other means***	use other means***
	1′- 7 5/8″	77° 12′ 46″	2′- 2 1/2″	1′-3 5/8″	2′- 1/2″				
3′0″ × 12′-0″	29′- 3 1/4″	23° 28′ 30″	11′-11 7/8″	5′-1″	11′-10 7/8″	1′-2 7/8″	8 5/16″	use other means***	use other means***
	1′- 7 7/8″	78° 15′ 45″	2′-2 7/16″	1′- 3 3/4″	2′- 7/16″				

Notes:

* Dimensions to be shown on plans. Dimensions should be rounded up as approved by Engineer.

** Shell thickness to be used in plastic hinge zones. For Type P Casing, use minimum t = 3/8″.

*** See Note 5 on Figure 2.

Figure 3 Casing Thickness and "X" and "Y" Dimension Chart 1

COLUMN CASING DATA								CASING THICKNESS	
COLUMN SIZE	CURVE DATA (L_1) / CURVE DATA (L_2)							PLASTIC HINGE ZONE	
	Radius	Delta	Curve Length	Tangent	Chord Length	X*	Y*	$t^{**}_{lap\ splice}$	$t^{**}_{cont\ reinf}$
4′ 0″ × 3′ -0″	3′ -7 ″	67° 34′ 34″	4′ - $2\frac{3}{4}$ ″	2′ - $4\frac{3}{4}$ ″	3′ - $1\frac{7}{8}$ ″	$10\frac{7}{16}$ ″	$8\frac{1}{2}$ ″	$\frac{3}{8}$ ″	$\frac{3}{8}$ ″
	1′ -$10\frac{7}{8}$ ″	56° 12′ 43″	1′ - $10\frac{1}{2}$ ″	1′ - $\frac{1}{4}$ ″	1′- $9\frac{1}{2}$ ″				
4′ 0″ × 4′ -0″	2′ -$10\frac{1}{2}$ ″	360° 00′ 00″	18′- $\frac{3}{4}$″	–	–	$10\frac{1}{2}$″	$10\frac{1}{2}$″	$\frac{3}{8}$ ″	$\frac{3}{8}$ ″
	–	–	–	–	–				
4′ 0″ × 5′ -0″	4′ -$2\frac{3}{4}$ ″	72° 06′ 38″	5′ - $3\frac{7}{8}$ ″	3′ - $\frac{7}{8}$″	4′ -$11\frac{7}{8}$ ″	1′ - $\frac{1}{2}$″	$10\frac{9}{16}$″	$\frac{1}{2}$ ″	$\frac{3}{8}$ ″
	2′ -$6\frac{3}{4}$ ″	53° 56′ 41″	2′ - $4\frac{7}{8}$″	1′ - $3\frac{5}{8}$″	2′ - $3\frac{7}{8}$″				
4′ 0″ × 6′ -0″	5′ -$10\frac{1}{2}$ ″	60° 52′ 26″	6′ - $2\frac{7}{8}$ ″	3′ - $5\frac{3}{8}$ ″	5′ -$11\frac{3}{8}$ ″	1′ - $1\frac{7}{8}$″	$10\frac{1}{2}$″	$\frac{1}{2}$ ″	$\frac{1}{2}$ ″
	2′ - $4\frac{3}{4}$ ″	59° 33′ 47″	2′ - $5\frac{7}{8}$ ″	1′ - $4\frac{3}{8}$ ″	2′ - $4\frac{1}{2}$ ″				
4′ 0″ × 7′ -0″	7′ -10 ″	52° 36′ 43″	7′ - $2\frac{1}{4}$ ″	3′ -$10\frac{1}{2}$″	6′ - $11\frac{1}{4}$″	1′ - $3\frac{1}{16}$″	$10\frac{9}{16}$″	$\frac{5}{8}$ ″	$\frac{1}{2}$ ″
	2′ -$3\frac{3}{4}$ ″	63° 41′ 38″	2′ - $6\frac{3}{4}$ ″	1′ - $5\frac{1}{4}$ ″	2′ - $5\frac{1}{4}$″				
4′ 0″ × 8′ -0″	10′ -$1\frac{1}{4}$ ″	46° 17′ 51″	8′ -2″	4′- $3\frac{7}{8}$″	7′ -$11\frac{3}{8}$ ″	1′ - $4\frac{1}{8}$ ″	$10\frac{3}{4}$″	$\frac{3}{4}$ ″	$\frac{5}{8}$ ″
	2′ - $3\frac{3}{16}$″	66° 51′ 05″	2′ - $7\frac{3}{4}$ ″	1′ - 6″	2′ - 6″				
4′ 0″ × 9′ -0″	12′ - 8″	41° 19′ 16″	9′ - $1\frac{5}{8}$″	4′ - $9\frac{1}{4}$ ″	8′ -$11\frac{1}{4}$″	1′ - $4\frac{15}{16}$″	$10\frac{13}{16}$″	1″	$\frac{3}{4}$ ″
	2′ - $2\frac{3}{4}$ ″	69° 20′ 22″	2′ - $8\frac{3}{8}$ ″	1′ - $6\frac{1}{2}$ ″	2′ - $6\frac{1}{2}$ ″				
4′ 0″ × 10′ -0″	15′ -$6\frac{1}{4}$ ″	37° 18′ 08″	10′ - $1\frac{1}{4}$ ″	5′ - $7\frac{7}{8}$ ″	9′ -$11\frac{1}{8}$ ″	1′ - $5\frac{7}{16}$″	$10\frac{11}{16}$″	use other means***	1″
	2′ - $2\frac{5}{16}$″	71° 20′ 56″	2′ - $8\frac{3}{4}$ ″	1′ - 7″	2′ - $6\frac{3}{4}$ ″				
4′ 0″ × 11′ -0″	18′ - $8\frac{1}{4}$ ″	33° 59′ 24″	11′ - 1″	5′ - $8\frac{1}{2}$″	10′ -$11\frac{1}{8}$ ″	1′ - 6″	$10\frac{3}{4}$″	use other means***	use other means***
	2′ - $2\frac{1}{8}$ ″	73° 00′ 18″	2′ - $9\frac{1}{4}$ ″	1′ - $7\frac{1}{4}$ ″	2′ -$7\frac{1}{8}$ ″				
4′ 0″ × 12′ -0″	22′ - 2″	31° 12′ 54″	12′ -$\frac{7}{8}$ ″	6′ - $2\frac{3}{8}$ ″	11′ -$11\frac{1}{8}$″	1′ - $6\frac{5}{8}$″	$10\frac{15}{16}$″	use other means***	use other means***
	2′ - $2\frac{1}{8}$ ″	74° 23′ 33″	2′- 10 ″	1′- $7\frac{7}{8}$″	2′ - $7\frac{5}{8}$ ″				
4′ 0″ × 13′ -0″	25′ - 11″	28° 51′ 52″	13′ -$\frac{5}{8}$ ″	6′ - 8″	12′ - 11″	1′ - $6\frac{13}{16}$″	$10\frac{11}{16}$″	use other means***	use other means***
	2′- $1\frac{11}{16}$″	75° 34′ 04″	2′ - $9\frac{7}{8}$ ″	1′ - $7\frac{7}{8}$ ″	2′-$7\frac{1}{2}$ ″				
4′ 0″ × 14′ -0″	30′- 0″	26° 49′ 41″	14′ -$\frac{5}{8}$ ″	7′ - $1\frac{7}{8}$ ″	13′ - $1\frac{1}{8}$″	1′ - $7\frac{5}{16}$″	$10\frac{15}{16}$″	use other means***	use other means***
	2′- $1\frac{13}{16}$″	76° 35′ 10″	2′ -$10\frac{1}{2}$″	1′ - $8\frac{3}{8}$ ″	2′ - 8″				
4′ 0″ × 15′ -0″	34′- 4 $\frac{1}{4}$ ″	25° 03′ 53″	15′ -$\frac{3}{8}$″	7′ - $7\frac{5}{8}$″	14′-$10\frac{15}{16}$″	1′ - $7\frac{7}{16}$″	$10\frac{3}{4}$″	use other means***	use other means***
	2′- $1\frac{1}{2}$″	77° 28′ 03″	2′ -$10\frac{1}{2}$″	1′ -$8\frac{7}{16}$″	2′ - $7\frac{15}{16}$″				
4′ 0″ × 16′ -0″	39′- $\frac{1}{2}$″	23° 31′ 06″	16′ -$\frac{1}{4}$″	8′ - $1\frac{1}{2}$″	15′-11″	1′ - $7\frac{7}{8}$″	$10\frac{15}{16}$″	use other means***	use other means***
	2′- $1\frac{5}{8}$ ″	78° 14′ 27″	1′ - 11″	1′ - $8\frac{7}{8}$″	2′-$8\frac{3}{8}$″				

Notes:

* Dimensions to be shown on plans. Dimensions should be rounded up as approved by Engineer

** Shell thickness to be used in plastic hinge zones. For Type P Casing, use minimum t = $\frac{3}{8}$″.

*** See Note 5 on Figure 2.

Figure 4 Casing Thickness and "X" and "Y" Dimension Chart 2