16.11 SEISMIC RETROFIT USING STEEL COLUMN CASING

16.11.1 GENERAL

This BDM provides guidance for designing and detailing of steel column casings for seismic retrofit of existing concrete bridge columns. Steel column casing is an effective means of increasing column shear capacity, flexural ductility, and column confinement. They are also effective in preventing the slippage of lap splices commonly found at the base of columns constructed prior to 1971.

16.11.2 DEFINITIONS

Confinement – The use of reinforcing steel bars, steel casing, composite fiber wrapping, or similar devices to produce lateral and/or circumferential pressures that prevent the disintegration of concrete in a structural member subjected to deformation.

Plastic Hinge – The region of a structural member that undergoes flexural yielding and plastic rotation while retaining flexural strength.

16.11.3 NOTATION

a	=	one half of the casing cross-section dimension, measured to the midpoint of the casing along the major axis (in.)
b	=	one half of the casing cross-section dimension, measured to the midpoint of the casing along the minor axis (in.)
E_s	=	modulus of elasticity of steel casing (psi)
ε_s	=	strain in steel casing
f_s	=	circumferential stress in steel casing (psi)
f_{LONG}	=	longitudinal stress (psi)
f_{TRAN}	=	circumferential (transverse) stress (psi)
R_{LONG}	=	casing longitudinal radius (ft)
R_{TRAN}	=	casing transverse radius measured to the centerline of the casing (in.)
p	=	internal pressure (psi)
t	=	thickness of steel casing (in.)
tf_s	=	resultant circumferential force in a steel casing
METS	=	Caltrans Materials Engineering and Testing Services
t_{LS}	=	casing thickness when longitudinal reinforcement is lapped (in.)
t_{CR}	=	casing thickness when longitudinal reinforcement is continuous (in.)

X	=	distance between column edge and the midpoint of casing measured along the major axis (in.)
Y	=	distance between column edge and midpoint of casing measured along the minor axis (in.)

16.11.4 TYPES OF CASING

Caltrans uses two types of steel column casing retrofit, Type F and Type P/F (Caltrans 2016). The choice of casing to be used for a retrofit depends on several factors, such as:

- the primary reason for the retrofit (i.e., increase in shear, flexural ductility, or confinement),
- the existing boundary condition at the ends of the column and the desired boundary condition after casing retrofit, and
- whether the column is in a single or multi-column bent.

For both types of casing, a minimum 2-inch gap should be provided between the casing ends and the bent cap soffit or the top of the footing. The gap prevents the casing from bearing on the attached member. The bearing would increase the effects of the plastic moment and, thus, the demand in the footing or bent cap.

16.11.4.1 Type F Casing

For Type F casing, the space between the casing and the column is filled with grout, potentially enhancing, maintaining, or achieving fixity conditions at the end of the column. Type F casing will prevent slippage of lap splices at the base of columns by providing increased confinement to promote ductile behavior.

Type F casing may be used for columns in single and multi-column bents. For multi-column bents pinned at the base, footing retrofit is typically not necessary. For multi-column bents fixed at the base, footing retrofit may be necessary to ensure a plastic hinge forms at the base of the columns. For single-column bents, footings should be evaluated and retrofitted as necessary to ensure that plastic hinges form at the base of the columns.

16.11.4.2 Type P/F Casing

Type P/F casing is typically used to retrofit columns in multi-column bents with column starter bars lap-spliced to the longitudinal bars or column bases pinned at the footing.

For P/F casing, polyethylene is placed around the pinned or lap-spliced end of the column before grout is placed in the space between the polyethylene and the casing. Thus, direct contact between the casing and the column is prevented, allowing the lap splice to slip.

Type P/F casing should not be used for columns in single-column bents.

16.11.5 CASING THICKNESS FOR CIRCULAR COLUMNS

The thickness of steel column casings is obtained from the governing equation for a thin-walled pressure element subjected to internal pressure, *p* (see Figure 16.11.5-1)

$$\frac{f_{LONG}}{R_{LONG}} + \frac{f_{TRAN}}{R_{TRAN}} = \frac{p}{t} \tag{16.11.5-1}$$

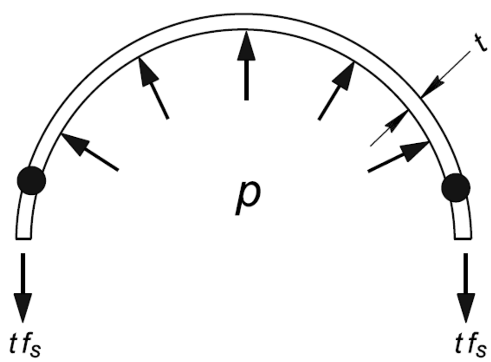

Figure 16.11.5-1 Stresses in Thin-Walled Pressure Element

For a column casing, R_{LONG} approaches infinity; therefore Equation 16.11.5-1 reduces to:

$$\frac{f_{TRAN}}{R_{TRAN}} = \frac{p}{t} \tag{16.11.5-2}$$

In the context of column retrofit by steel casing, the circumferential (transverse) stress is provided by the steel casing, i.e., $f_{TRAN} = f_{s.}$ Therefore, the thickness of a steel casing may be written as:

$$t = \frac{pR_{TRAN}}{f_s} \tag{16.11.5-3}$$

Equilibrating forces on the free body diagram of Figure 16.11.5-1, the internal pressure, *p*, acting on the casing is given by:

$$p = \frac{2tf_{TRAN}}{(2R_{TRAN} - t)} = \frac{2tf_s}{(2R_{TRAN} - t)} \tag{16.11.5-4}$$

16.11.5.1 Design Values for Confining Pressure and Circumferential Stress

Based on tests of retrofitted columns constructed with lapped starter bars using steel casing (Chai, Priestley, and Seible 1991), the strain in the steel casing at the point where a plastic hinge formed in the lap splice region, ε_s was equal to 0.001. This corresponds to circumferential stress in the steel casing, $f_s = \varepsilon_s E_s = 0.001 \times 29{,}000{,}000 = 29{,}000$ psi.

Using the test data and results by Chai, Priestley, and Seible (1991), a conservative estimate of the confining pressure developed by the steel casing when a plastic hinge forms in the lap splice region is taken as 300 psi.

For columns with continuous longitudinal bars, the circumferential stress in the steel casing cannot exceed the yield strength of the casing, $f_s = 36000$ psi.

16.11.5.2 Thickness when Column Longitudinal Reinforcement is Lap-spliced

Substituting p = 300 psi and f_s = 29000 psi into Equation 16.11.5-3, the required thickness of steel casing (in inches) for lap splice, t_{LS} is:

$$t_{LS} = \frac{R_{TRAN}}{100}(12) \qquad (16.11.5.2\text{-}1)$$

16.11.5.3 Thickness when Column Longitudinal Reinforcement is Continuous

Substituting $f_s = 36000$ psi and p = 300 psi into Equation 16.11.5-3, the required thickness of steel casing (in inches) for continuous reinforcement, t_{CR}, is:

$$t_{CR} = \frac{R_{TRAN}}{120}(12) \qquad (16.11.5.3\text{-}1)$$

16.11.6 DIMENSIONS AND DESIGN CHARTS

The required casing thickness for circular and square columns is obtained directly using Equations 16.11.5.2-1 and 16.11.5.3-1, as applicable. For a square column, R_{TRAN} should be measured from the center of the square to the midpoint of the circumscribing circular casing.

Charts have been developed for casing dimensions and thicknesses for common sizes of rectangular columns. Table 16.11.A1 of the Appendix provides data used to produce the most efficient casing around the proposed columns. For these columns, the casings are ellipses modified by stretching or shrinking along the minor axis while maintaining a 1 inch gap at the corners of the rectangular columns. The engineer should use the average of the a and b dimensions (see Table 16.11.A1 and Figure 16.11.A-1 in the appendix) to determine the casing thickness using Equation 16.11.5.2-1 or 16.11.5.3-1, as appropriate. The required thickness should be rounded up to the nearest $^1/_8$ of an inch.

Casing thicknesses should not exceed 1 inch. If the required casing thickness exceeds 1 inch, other means such as anchor bolts, stiffening channels, etc., should be engineered to ensure adequate confinement of the column.

For bridges in marine and corrosive environments, the designer should increase the required casing thickness based on discussions with METS.

A minimum casing thickness of $^{3}/_{8}$ inch is recommended based on previous field experience with casing installation.

A note should be placed on the contract plans directing the contractor to make field measurements prior to fabricating the casing.

Other detailing requirements for steel column casings are provided in Bridge Standard Details xs7-010.

16.11.7 CONSTRUCTION CONSIDERATIONS

The engineer should coordinate with the specification engineer on the following items:

- The minimum spacing between the column and the casing should be 1 inch. For a circular column, grout or pea gravel concrete should be used. For a rectangular column with an elliptical casing, pea gravel concrete should be used.
- If a pea gravel grout is used for elliptical casings, injection ports may be needed on four sides due to restricted clearances at column corners.
- For Type P/F casing, the polyethylene insert should have a 1 foot gap at the vertical seam of the casing to prevent the polyethylene from burning during the welding process.
- For tall casings, measures should be taken to prevent the casing from bulging due to a 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. Also, see Standard Specification 60-4.06C(3).

16.11.8 REFERENCES

1. Caltrans. (2024). *Standard Specifications*, California Department of Transportation, Sacramento, CA.
2. Caltrans. (2015). Bridge Standard Details Sheet number xs7-010 *Column Casing Steel,* California Department of Transportation, Sacramento, CA.
3. Chai, Y.H., Priestley, M.J., and Seible, F. (1991). *Flexural Retrofit of Circular Reinforced Concrete Bridge Columns by Steel Jacketing*, Report No. SSRP-91/06, Department of Applied Mechanics and Engineering Sciences, University of California, San Diego, La Jolla, CA.

APPENDIX

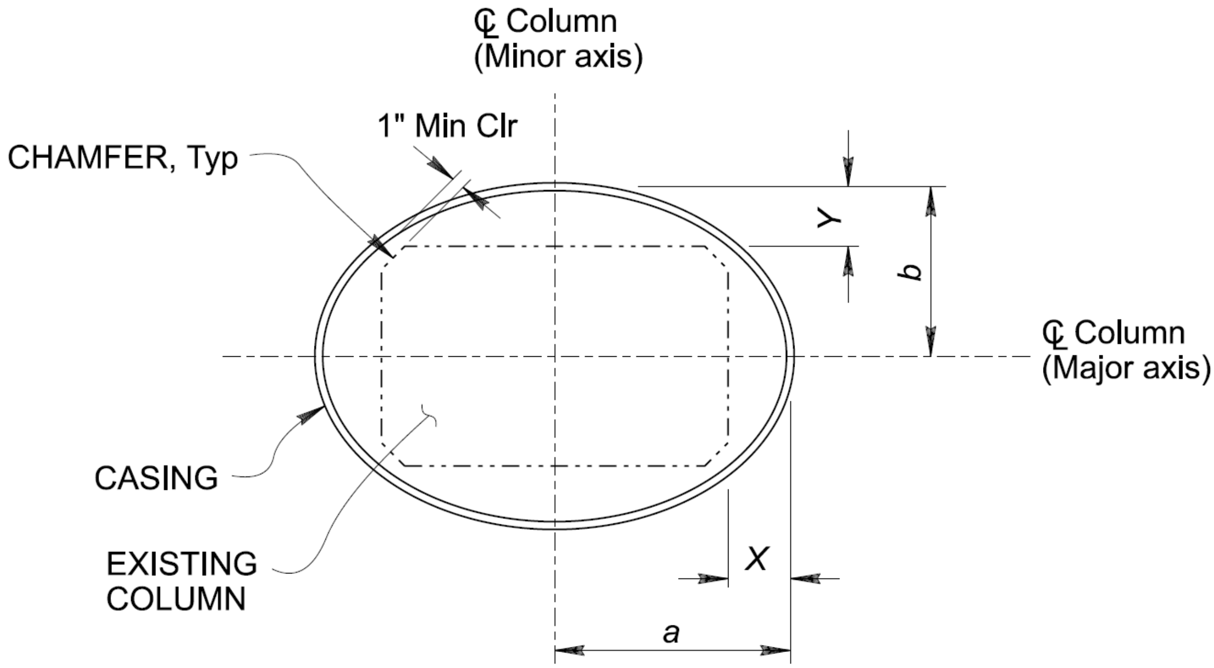

Figure 16.11.A-1 Casing Geometry

Notes:

1. The casing dimensions *a* and *b,* as well as dimensions *X* & *Y,* should be shown on the Contract Plans.
2. The design engineer should consult with the architect to ensure a workable and aesthetically pleasing finished product if different thicknesses of casing are used, exterior stiffeners are attached, or through bolts are installed.

Table 16.11.A1 Casing Thickness for Rectangular Columns

COLUMN SIZE (ft)	CASING DIMENSIONS				CASING THICKNESS	
	a (in.)	*b* (in.)	*X* (in.)	*Y* (in.)	t_{LS} (in.)	t_{CR} (in.)
2 × 3	24 ½	18 ½	6 ½	6 ½	3/8	3/8
2 x 4	32	19	8	7	3/8	3/8
2 x 5	39	19 ¾	9	7 ¾	3/8	3/8
2 x 6	49 ½	18 ½	13 ½	6 ½	3/8	3/8
2 x 7	52	21 ½	10	9 ½	3/8	3/8
2 x 8	58 ¼	22 ¼	10 ¼	10 ¼	1/2	3/8
3 x 4	34 ¼	26	10 ¼	8	3/8	3/8
3 x 5	41 ¾	26 ¾	11 ¾	8 ¾	3/8	3/8
3 x 6	49 ¼	27 ¼	13 ¼	9 ¼	1/2	3/8
3 x 7	55	28 ¾	13	10 ¾	1/2	3/8
3 x 8	62 ¼	29 ¼	14 ¼	11 ¼	1/2	1/2
3 x 9	68 ¼	30 ½	14 ¼	12 ½	1/2	1/2
3 x 10	74	31 ¾	14	13 ¾	5/8	1/2
3 x 11	81 ¼	32	15 ¼	14	5/8	1/2
3 x 12	87 ¼	33	15 ¼	15	5/8	1/2

Table 16.11.A1 Casing Thickness for Rectangular Columns (contd.)

COLUMN SIZE (ft)	CASING DIMENSIONS				CASING THICKNESS	
	a (in.)	*b* (in.)	*X* (in.)	*Y* (in.)	t_{LS} (in.)	t_{CR} (in.)
4 x 5	43	34 ¼	13	10 ¼	1/2	3/8
4 x 6	50 ¼	35 ¼	14 ¼	11 ¼	1/2	3/8
4 x 7	58	35 ¾	16	11 ¾	1/2	1/2
4 x 8	64 ¾	36 ¾	16 ¾	12 ¾	1/2	1/2
4 x 9	71 ¼	37 ¾	17 ¼	13 ¾	5/8	1/2
4 x 10	77 ¾	38 ¾	17 ¾	14 ¾	5/8	1/2
4 x 11	84 ½	39 ½	18 ½	15 ½	5/8	5/8
4 x 12	91 ½	40	19 ½	16	3/4	5/8
4 x 13	97 ¼	41 ¼	19 ¼	17 ¼	3/4	5/8
4 x 14	104	41 ¾	20	17 ¾	3/4	5/8
4 x 15	110 ¼	42 ¾	20 ¼	18 ¾	7/8	3/4
4 x 16	116	44	20	20	7/8	3/4

Notes:

1. The required casing thicknesses have been rounded up to the nearest 1/8 of an inch.
2. If the casing dimensions are such that the casing encroaches on an adjacent roadway, the engineer should make necessary adjustments to the dimensions.