The Soft Story Brace Company

Earthquake Resisting Columns: Information for the Design Professional

Background

Earthquake Resisting Columns (ERCs) were developed to fit in very narrow, restricted spaces in existing soft-story buildings. At the same time they provide superior ductility and reliability that allows designing with a seismic response modification coefficient, R, of 6.5.

The ERC system uses "structural fuses" to absorb earthquake energy through precisely controlled, highly ductile behavior. The column itself is sized so it will not yield even when the fuses have reached their fully-plastic capacity.

Initial stiffness is increased by using shear pins. When the load reaches approximately 2.5 times the design load, the shear pin sacrifices and full yielding of the structural fuses occurs. Ultimate capacity of the fuses has approached five times the design load during full-scale testing. Peak deflection of more than 7% was sustained for several cycles.

Benefits

Compared to cantilevered columns or special cantilevered columns, design using seismic response modification coefficient, R of 6.5 reduces seismic forces throughout the structure by 60% to 80%. This force reduction saves money from the foundation upward.

Furthermore there is no restriction on using a combination of systems along the same line of resistance or in the same loading direction. Limitations on combining structural systems can preclude the use of more popular systems, such as plywood shear walls, in the same design as a cantilevered column.

Seismic Design Parameters

The following seismic design parameters may be used in conjunction with Earthquake Resisting Columns in determining loads and deflections:

Response modification coefficient, R = 6.5;
Overstrength Factor, Ω_0 = 3;
Deflection Amplification Factor, C_d = 4

Procedure for Selecting ERC

1. Determine tributary seismic force that must be resisted by the ERC. *R* of 6.5 may be used in determining the seismic force (unless a lower value of *R* is required because the ERC is used in combination with another lateral force resisting system having a lower *R* value). Note that the load tables given in this document are based on Allowable Stress Design (ASD).

2. Using Table 1, find the ERC size that provides at least the required load determined in Step 1 in the column for the ceiling height in the project.

Limitations

The Earthquake Resisting Column is currently not approved for carrying vertical loads. Installation is limited to cases where it is subjected only to lateral loads.

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TABLE 1 ALLOWABLE LOADS & DESIGN INFORMATION ***(Figures in blue are preliminary, pending Evaluation Report)***

ERC Size	Max. Fuse Load [1]	Allowable Load (ASD) at ceiling heights [2]					Weight (lbs.) [3]	Width (in.) [4]	Stock Column Shape [5]	Column Wt./ft. (lbs.)	LTB Check [6]	
		8 ft.	9 ft.	10 ft.	11 ft.	12 ft.					H_{max}	$H_{max}/2$
A	2,250	2,550	1,875	1,600	1,375	1,200	390	8.5	W8x35	35	17'-7"	11'-11"
B	4,000	B, C, and D sizes are currently under development; testing is scheduled for June, 2018. Capacity of these sizes will be based on the test results.							W8x67			
C	8,000								W10x54			
D	12,000								W12x65	65		
E +	16,000 +	Custom sizes with higher capacity may be commercially available after further testing criteria are developed.										

1. Load at which the Structural Fuses are designed to yield, in pounds.
2. Loads that cause deflection of 0.025H for the ceiling height listed. Story height, H, is based on the assumption of 10" deep floor framing. Per ASCE 7, ρ (rho) of 1.0 was used to determine story drifts that resulted in the tabulated load values (ASCE 7, Section 12.3.4.1).
3. Weight given is for 8-foot ceiling height. For higher ceilings, added weight equals the height increase multiplied by column weight per foot.
4. Width of steel column (in listings for AISC shapes, this dimension is given as "d").
5. Unless a special order is placed for a heavier column section, the column will be fabricated from the given AISC structural shape.
6. Lateral Torsional Buckling (LTB) limitations: As a practical matter, LTB is not an issue; the column size is controlled by the stiffness requirements to stay within the allowable story drift limit (0.025H for wood-frame structures). The dimensions given in the H_{max} and $H_{max}/2$ columns are as follows:
   H_{max} is the ceiling height at which the maximum load for the Structural Fuses would exceed the bending capacity using F_{cr} as determined using the equation below for lateral torsional buckling.
   $H_{max}/2$ is the ceiling height at which the maximum load for the Structural Fuses would exceed the bending capacity using F_{cr} for lateral torsional buckling *if* L_b *in the equation below is taken as TWICE the ceiling height*. Note: there is no precedent for using 2H for L_b except a requirement in one City's ordinance governing mandatory earthquake retrofit improvements; the AISC lateral torsional buckling check would use the actual column height (essentially the story height) for L_b.

$$F_{cr} = [C_b\pi^2 E/(L_b/r_{ts})^2]*[1 + 0.078(J_c/S_x h_o)(L_b/r_{ts})^2]^{1/2} \quad \text{(AISC Equation F2-4)}$$

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Other Design Professional Responsibilities and Coordination

As with any prefabricated assembly, the ERC performance is tied to good design of the entire system in which it is used. Some of the design professional's responsibilities include:

1. Locating the ERC: The components that connect the ERC to the wood framing are designed on the assumption that the ERC will be centered in a joist bay. The connection brackets can accommodate a clear spacing between joists from 11-1/2" to 15-1/2".
   The ERC can also be special-ordered so that it will connect to the underside of a beam.
2. Confirming length of column, based on depth of foundation grade beam, ceiling height, and other factors. Standard column lengths are based on grade beam depths given in Table 2.
3. Designing the foundation, including provisions for base connection of ERC (see Item 7).
4. Verifying condition and capacity of floor framing: The joists to which the ERC connects must be in sound condition and adequate size to resist the design loads at appropriate levels. Size "C" and "D" ERCs must attach to doubled joists. Connections between doubled members is the Design Professional's responsibility. **Attention should be given to eliminate fastener congestion in the area where the Connector Channel fasteners will be driven into the joists.**
5. Designing collector connections needed to transfer lateral forces into the ERC.
6. Considering wood shrinkage: Wood framing in existing buildings has reached equilibrium moisture content. Any new wood that is incorporated into the structural system (such as doubled joists) should either be kiln-dried lumber (often special-order, and usually impossible to confirm in the field) or engineered lumber. Engineered lumber—especially LVL—is commonly available, and preferred.
7. Selecting the appropriate connection for base of ERC:
   a. Columns are supplied with holes in the web for rebar keying into the concrete grade beam unless a special order is placed. This is suitable for columns located far enough from the end of the grade beam that break-out is not a concern.
      Designer to provide overall column length if non-standard length is needed.
   b. The ERC can be supplied with holes in the flanges that will accept high-strength threaded rod to align with top and bottom reinforcement in the foundation. This may require a heavier column than the shape listed in Table 1. ASTM A193, Grade B7 high-strength rod, with matching high-strength nuts, is supplied with the ERC in such cases. *Designer to provide spacing between holes, and all-thread size. Hole diameter will be 1/16" greater than the all-thread diameter.*

c. Standard welded base plate; dimensions per Figure 1. High-strength anchor rods and nuts are supplied. *Designer to provide dimension from bottom of base plate to bottom of floor joists at floor above the ERC.*

d. Custom base plate. Design Professional is responsible for design of base plate (and shear lugs, if needed) and anchorage to foundation. *Designer to supply dimensioned details for base plate and connection to column, and dimension from bottom of base plate to bottom of floor joists at floor above the ERC.*

e. Plain end for customer-provided base connection, such as welded custom base plate. Design Professional is responsible for design of plate, etc. as noted in preceding item, as well as determining special inspection requirements for welding of base plate. *Designer to provide dimension from **top** of base plate to bottom of floor joists at floor above ERC.*

f. Custom column end design, if options above are not sufficient. *Designer shall provide scaled and dimensioned drawings showing all necessary information.*

TABLE 2 STANDARD COLUMN LENGTHS AND OTHER DIMENSIONS

ERC Size	Grade Bm. Depth [1]	d-d’ [2]	Total Column Length [3]	Flange Hole Size [4]	Flange Hole Dims. [5]		Web Hole Location [6]
					Top	Bottom	
A	20”	14”	8’-6¼”	13/16”	16”	2”	15”
B	24						
C	30						
D	36						

1. Grade beam depths given generally provide efficient designs. Grade beam length, width, and reinforcement shall be designed by the Design Professional.
2. d-d’ is the center-to-center distance between the top and bottom layers of grade beam reinforcement, based on 3” clear cover at the bottom, 1” clear cover at top, ½” tie diameter, and 1” main bar diameter.
3. Length for standard column with 8’-0” height from finished floor to bottom of 2nd floor framing, assuming grade beam is depressed 4” below finished floor to allow for a non-structural concrete floor slab. For finished floor to bottom of framing dimensions other than 8’-0”, column length varies by the difference between 8’-0” and measured height.
4. If needed for anchorage at end of grade beam.
5. Dimensions from bottom of column to centerline of flange holes
6. Dimension from bottom of column to centerline of holes in web