Degenkolb

STEELCASE POST AND BEAM

Modular Space Division Product

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1.0 Introduction

The Steelcase Post and Beam product line is a modular space division system. The system is composed of aluminum beam and post extrusions and associated connection hardware. The system can be a self-supporting freestanding installation or can attach to the building structure as well as other Steelcase product lines. The purpose of this report is to provide structural calculations for various configurations of the Post and Beam system to obtain an International Conference of Building Officials Evaluation Report allowing installation of the product in seismic zones.

The report is structured as follows; section two gives a brief description of the Post and Beam system. The description includes material properties, components of the system and a summary of how the components are assembled. Appendix A of this report contains the Application Guidelines, developed by IDEO, which gives a detailed description of the Post and Beam assembly including restrictions on its use. Section three gives a detailed explanation of the analysis and evaluation (structural calculations) that was conducted for the various configurations. Structural Calculations are included in Appendix B of this report. Section four summarizes the findings of the detailed structural calculations and presents the allowable configurations of the Post and Beam system for installation in different regions of seismicity.

2.0 Post and Beam System

The Steelcase Post and Beam product line is a modular space division system. The system is composed of aluminum beam and post extrusions and associated connection hardware. The system can be a self-supporting freestanding installation or can attach to the building structure as well as other Steelcase product lines. This section gives a brief summary of the system including the basic elements, the materials of construction and a cursory review of assembly.

2.1 Components

The basic components of the system are aluminum posts and beams extrusions. Beams are approximately 8.5 inches deep and come in lengths varying from 4 feet up to 16 feet. There are two types of post extrusions (X and Y), each manufactured in length of 91.5", 39" and 31.5", allowing different shaped configurations to be constructed. The X Post allows connection of up to four beams, all at 90-degree angles to the adjacent beams (measured in plan). The Y Post allows connection of up to three beams, all at 120-degree angles to the adjacent beams. Both post sections have a hollow core, which allows a smaller extension extrusion to be inserted within. Both the X Foot Extension and the Y Foot Extension allow connection of the posts to base plates.

The beam-post connection is composed of five pieces. The T Connector slides in a vertical slot on the post. A 5/16 inch diameter bolt is attached to the T Connector at one end and the Anchor Block on the other end. The Anchor Block fits within the Beam section and is attached by two #10 screws and a backing plate to a horizontal web in the beam. The Anchor Block has two cylindrical lugs, which fit into two holes on the horizontal beam web.

The beam start plate allows connection of a beam to a building wall or other elements providing adequate support (see Section 4.1 for detailed requirements).

2.2 Materials

The aluminum extrusions (X Post, Y Post, X Foot Extension, Y Foot Extension and Beam) are all manufactured using 6063-T6 aluminum. Mechanical properties for the purpose of structural calculations are taken from Table 20-II-A of the 1997 Uniform Building Code (UBC).

The beam-post connection hardware is made of various materials. The T Connector is made from an iron-nickle alloy, FN-0705-T AS, the Anchor Block is made from AISI 4130 steel and the backing plate is made from AISI 1020 steel. The 5/16 inch diameter bolt which attaches the beam to the post is a Society of Automotive Engineers (SAE) J429, Grade 8. The screws which secure the Anchor Block to the backing plate are SAE J429, Grade 2.

The base plates are made from a zinc-aluminum alloy, Zinc ZA-8. Material properties for design were obtained from an online data base (www.matweb.com). Bolts used to connect the foot extensions to the base plate are 5/16-inch diameter Grade 8. Anchor bolts, which connect the base plate to the building structure are 3/8" diameter (three per base plate) and shall be specified by the project engineer (see Section 4.1 for detailed requirements).

2.3 Assembly

The Post and Beam system can be configured in many different layouts. The Beam extrusion has two functions; when located at the top of a post (92.5 inches above the floor) it is called a beam and when located at approximately 33 inches above the floor it is called a fence. Figure 1 shows a possible configuration of the Post and Beam system and identifies the key components. A beam can vary in length from 4 feet to 16 feet, and is used to support hanging accessories weighing up to 100 pounds total per beam. A fence can vary in length from 4 feet to 10 feet and is used to support shelves and tables weighing up to 1000 pounds total. Beams, fences and columns may not be spliced. Each end of a beam or fence must be supported by a post or attached to the building structure or other support using a beam start plate.

The beam and fence elements are attached to the posts using two 5/16-inch diameter bolts, two T Connectors, two Anchor Blocks and two backing plates (nut plate). The connection relies on friction between the T Connector and the post to support the beam as well as bearing between the beam and the T Connector. Figure 2 shows a three-dimensional rendering of the connection.

Beams can be attached to the existing building structure or other elements providing adequate structural support using the beam start plate. Whenever a beam start plate is used to support a beam end, the project engineer shall evaluate those elements supporting the beam under all imposed loads and shall design the attachment of the beam start plate, see Section 4.1 for detailed requirements. The beam start plate accepts the same connection hardware as the beam-post connection. The beam start plate is mounted to existing structural elements with four fasteners. The existing structure as well as the connection of the beam start plate to the structure shall be designed by the project engineer. The T Connectors engage the beam start plate and the remainder of the connection is as for the post-beam connection described above. Figure 3 shows how the beam-beam start plate connection assembles.

The post sections are attached to the base plate by inserting a foot extension (12 inches long) within the post section and bolting the foot extension to the base plate using three or four (depending on post shape) 5/16-inch diameter bolts, which are secured through the bottom of the base plate up into the foot extension. The foot extension is attached to the post section by a ¼-inch diameter set screw on each leg of the post. Figures 4 and 5 show details of the post to base plate connection. The base plate is anchored to the building slab using three 3/8" diameter anchors. The base plate anchorage shall be designed by the project engineer.

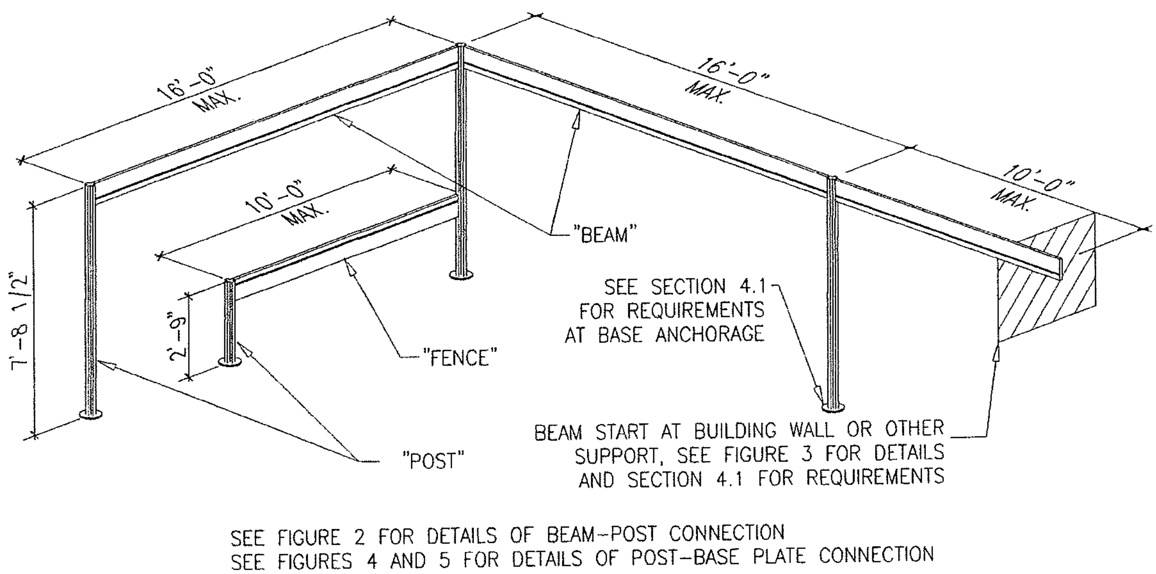


Figure 1 – Post And Beam System

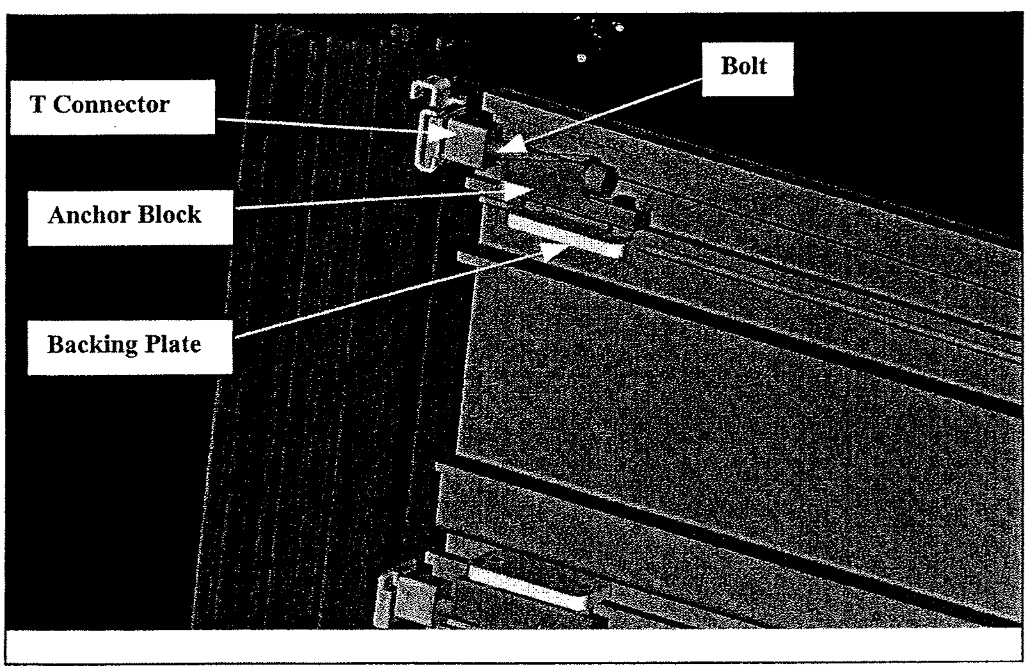


Figure 2—Beam-Post Connection (Cutaway)

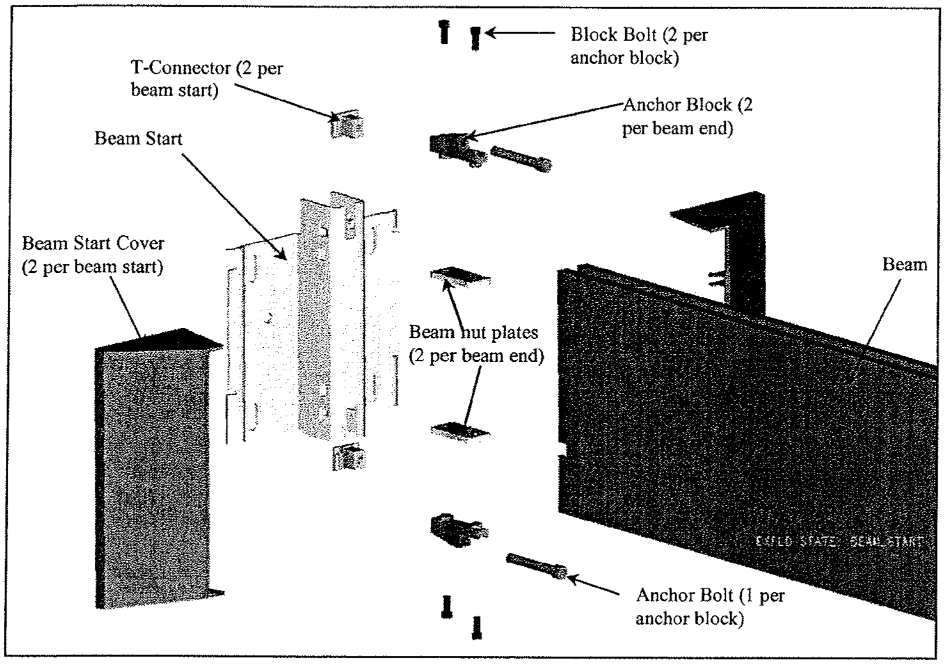


Figure 3 – Beam-to-Beam Start Plate Connection

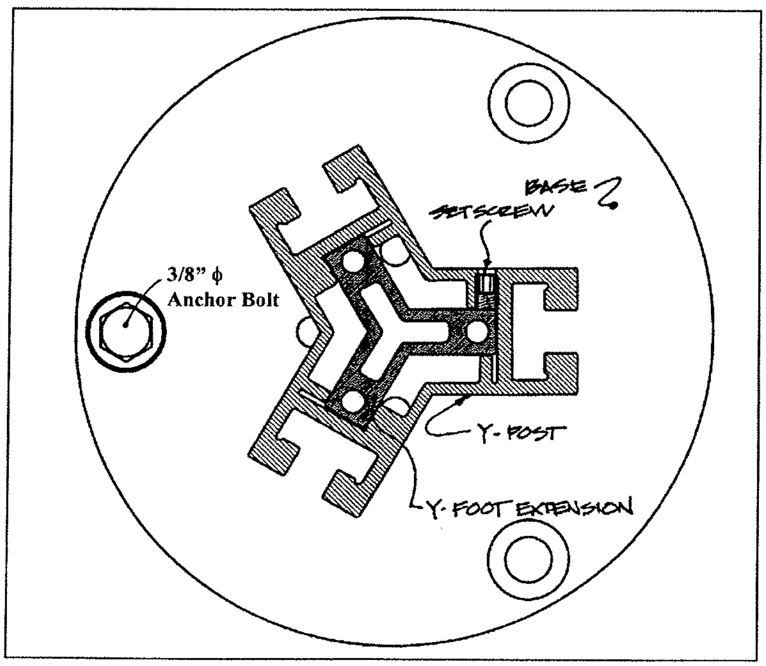


Figure 4 – Plan View Of Post-Base Plate Connection

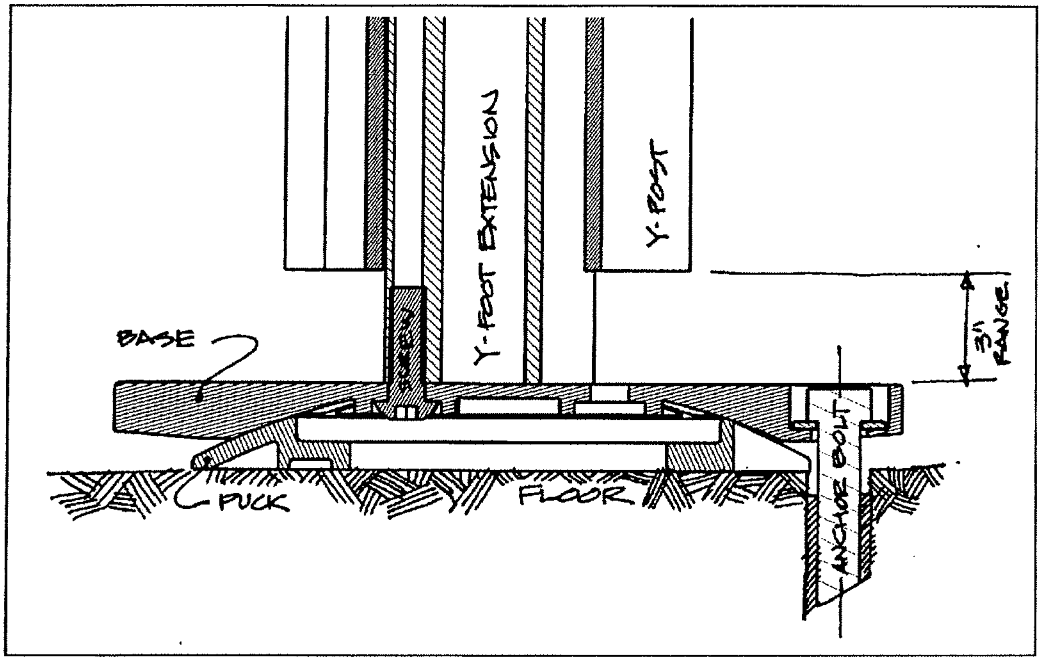


Figure 5 – Section Of Post-Base Plate Connection

3.0 Evaluation

The Post and Beam system was analyzed under vertical and lateral loading (seismic) to verify its use in regions of high seismicity. The evaluation was conducted using provisions from the 1997 Uniform Building Code. This section presents a summary of the evaluation and verification process including design loads, member and connection capacities and three dimensional mathematical modeling. For complete calculations and detailed results, see Appendix A – Structural Calculations.

3.1 Design Loads

Design vertical loads include the self weight of the Post and Beam components as well as the following loads: 1000 pounds on each fence (10 feet long x 100 pound per foot) and a 100 pound concentrated load on each beam (at mid span). The 1000 pound distributed load is the maximum load that can be placed on a fence as specified by IDEO/Steelcase. This load represents bookshelves and or desks suspended from the fence. The 1998 California Building Code (1997 Uniform Building Code with California amendments) requires that shelves and their supports be designed for a vertical load of 33 psf (Table 16-B). The fences of the Post and Beam system can support a desk and book shelves on each side for which the total load would be approximately 132 pounds per foot (2 levels x 2 sides x 1 foot x 1foot x 33 psf), which exceeds the 1000 pounds distributed over 10 feet (100 pounds per foot). Therefore, the 1000 pound load limits the total load which can be placed on the system. The 100 pound point load on the beams represents Steelcase accessories, which can be hung from a beam.

Lateral forces were calculated using equation 32-2 from the 1997 UBC and equation 16-67 from the 2000 International Building Code. Design lateral forces due to seismic loading were calculated for each seismic zone and for five different locations (height of installation relative to roof height) within the building. The five locations evaluated were at grade (hx/hr = 0), first quarter (hx/hr = 0.25), second quarter (hx/hr = 0.5), third quarter (hx/hr = 0.75) and fourth quarter (hx/hr = 1.0), see Figure 6 for a graphical representation of the different quarters.

The variables used in equation 32-2 of the 1997 UBC (Fp = (ap Ca Ip) / Rp (1 + 3 hx/hr)Wp) are as follows.

ap = 2.5, flexible components with ductile materials and attachment
Rp = 3.0, flexible components with ductile materials and attachment
Ip = 1.0, standard occupancy structures
hx/hr = varies by location in building, see Figure 6
Ca = varies by seismic zone.

Soil type S_D was used for all seismic zones. Two sets of values are presented for Zone 4. The first set (Zone 4 – Near Fault) were calculated using a Near Source Factor (Na) of 1.5 (Type A fault less than 2 km from site) and are to be used for installations within 10 km of a Type A fault or within 5 km of a Type B fault. The second set of values (Zone 4) were calculated using a Near Source Factor of 1.0 and should be used for installations 10 km or more from a type A seismic source, 5 km or more from a type B seismic source or a type C seismic source at any distance. A summary of the lateral design forces by zone and installation height is shown in Table 1.

Seismic Zone	Height in Building				
	At Grade	**First Quarter**	**Second Quarter**	**Third Quarter**	**Fourth Quarter**
4 - Near Fault	0.55	0.96	1.38	1.79	2.20
4	0.37	0.64	0.92	1.19	1.47
3	0.30	0.53	0.75	0.98	1.20
2B	0.23	0.41	0.58	0.76	0.93
2A	0.18	0.32	0.46	0.60	0.73
0 and 1	0.10	0.18	0.25	0.33	0.40

Table 1 – Seismic Lateral Force Fp By Seismic Zone And Location In Building, 1997 UBC

The variables used in equation 16-67 of the 2000 IBC (Fp = (0.4 ap Sds Ip) / Rp (1 + 2 z/h)Wp) are as follows.

ap = 2.5, flexible components with limited deformability elements and attachments
Rp = 2.5, flexible components with limited deformability elements and attachments
Ip = 1.0, standard occupancy structures
z/h = varies by location in building, see Figure 6
Sds = varies based on seismic hazard maps

For calculations in accordance with the 2000 IBC site class D was assumed. Table 2 shows the seismic design lateral forces calculated for various Ss (mapped short period acceleration values) and installation heights.

Ss ≤	Location in Building				
	At Grade	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
2.5	0.67	1.00	1.33	1.67	2.00
1.5	0.40	0.60	0.80	1.00	1.20
1	0.29	0.44	0.59	0.73	0.88
0.75	0.24	0.36	0.48	0.60	0.72
0.5	0.19	0.28	0.37	0.47	0.56
0.25	0.11	0.16	0.21	0.27	0.32

Table 2 - Seismic Lateral Force Fp By Mapped Short Period Acceleration (Ss) And Location In Building, 2000 IBC

The assumption that the equipment is flexible was validated from a dynamic analysis of the Post and Beam system, which showed a period of 0.39 seconds for the first mode of the minimum configuration. The Post and Beam system is considered ductile based on IDEO tests, which shows significant post elastic deformation capacity, as well as the inherent ductility of aluminum (fracture strain divided by yield strain is approximately 35).

The 1997 UBC specifies that aluminum structures be designed using an allowable stress design procedure and the 2000 IBC allows either allowable stress design or load and resistance factor design. In accordance with Section 1612 of the Code, the load combination specified in equation 12-16 was used; $D + L + S + E/1.4$, where D is dead load, L is live load, S is snow load and E is earthquake load (as described above). Both L and S are taken as zero. Use of load combination 12-16 allows a 1/3 increase in the allowable stresses, as described in the following section.

3.2 Allowable Stress Design of Aluminum

Capacities of the post and beam elements were evaluated under the imposed loading using the provisions specified in Chapter 20, Divisions I and II, of the 1997 UBC. The design provisions are based on Specifications for Aluminum Structures published by the Aluminum Association. Mechanical properties are taken from Table 20-II-A and the equations used to determine the allowable stresses for various elements are taken from Table 20-I-C. As a result of the three-dimensional nature of the Post and Beam system, the members are subjected to axial, bending and shear stresses. The interaction between all three stress states was computed using the equation specified in 2009.3 of the 1997 UBC.

3.3 Three-Dimensional Modeling and Analysis

To evaluate the Post and Beam system under the combined vertical and lateral loading specified in section 3.1, three-dimensional mathematical computer models were constructed using a finite-element analysis program. The models were constructed using line elements (beam-column) whose section properties were supplied by the product development team at IDEO. Model dimensions were taken at the centerlines of the elements. Rigid offsets were used at member ends to account for actual member dimensions. The bases of the posts were modeled using a rotational spring about both plan axes; all other degrees of freedom were restrained. Spring properties were calculated using test data supplied by IDEO.

Vertical and lateral loads were applied to the models. Vertical loads were applied on the beams and fences and lateral loads were applied in the same locations as the vertical loads multiplied by the coefficient Fp (lateral loads are applied based on the distribution of mass in the system).

Member stresses, forces and deflections were calculated by the finite-element analysis program. Member stresses were imported into a spreadsheet were the stress demands were compared to the allowable stresses. Member forces at connection locations were imported into another spreadsheet to verify the connection strengths. System verification was based on member and connection interaction equations. Deflections were calculated but were not used to determine system acceptance.

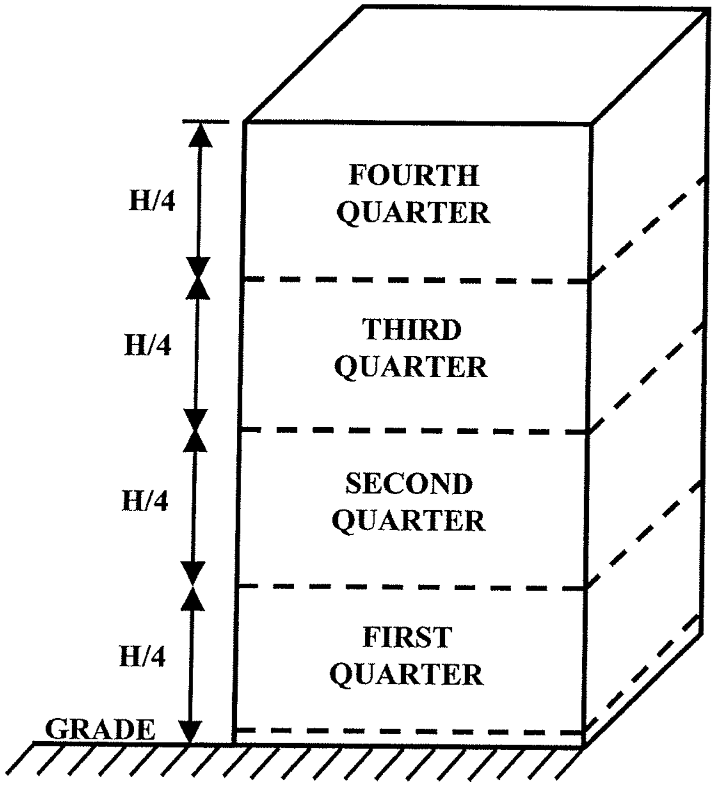


Figure 6 – Location In Building By Quarters

4.0 Configuration Constraints

Worst case configurations of the Post and Beam system were developed and analyzed to determine which cases could be used based on seismicity of the region and height of the floor on which the Post and Beam system is installed relative to the roof height. This section summarizes those findings and presents a narrative and graphical description of what configurations can be installed for different combinations of seismicity and relative height within a building.

Models of the Post and Beam system were evaluated for four different lateral load demands. Based upon these lateral force demands, four groups (Groups 1 through 4) of restrictions on the layout of the Post and Beam system were developed. Using the lateral force demands presented in Tables 1 and 2, restrictions on the layout of the Post and Beam system were assigned to the various combinations of seismicity and installation height. Table 3 shows the restrictions for use with the 1997 UBC and Table 4 shows restrictions for use with the 2000 IBC. The numbers in the fields of the Tables correspond to the Group restrictions. The following sections describe the Group restrictions and reference figures showing possible configurations.

Seismic Zone	Location in Building				
	At Grade	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
4 - Near Fault	2	1	1	1	1
4	3	3	3	2	1
3	4	3	3	2	2
2B	4	3	3	3	3
2A	4	4	3	3	3
0 and 1	4	4	4	4	4

Table 3 – Allowable Configuration Group Based Upon Seismic Zone and Location In Building, 1997 UBC

See Figure 6 for a description of Location in Building.

Ss ≤	Location in Building				
	At Grade	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
2.5	3	2	1	1	1
1.5	4	3	3	2	2
1	4	3	3	3	3
0.75	4	4	3	3	3
0.5	4	4	4	3	3
0.25	4	4	4	4	4

Table 4 - Allowable Configurations Based Upon Mapped Short Period Acceleration (Ss) and Location In Building, 2000 IBC

For all configurations maximum loads are as follows:

1. Beams – sum of all point loads shall be less than 100 pounds
2. Fences – total superimposed distributed load over the length of the fence shall not exceed 1000 pounds.

The above listed loads are in addition to the self-weight of the Post and Beam aluminum sections.

Dimensions are not shown on the configuration figures for clarity, see Figure 1 for typical dimensions of the Post and Beam system.

4.1 Disclaimers

The guidelines presented in this section as well as the analysis presented in Appendix A only apply to the Post and Beam components. Attachment of the Post and Beam system to existing building structures or other Steelcase products, using a beam start plate must be designed by qualified professionals considering the actual installation. The existing building structure must be evaluated for and the anchorage of the beam start plate must be designed for the forces (strength design) shown in Figure 7. Base plate anchorage to the building structure must also be designed by a qualified professional. The design professional should be retained to design the attachment as well as to determine the impact of any additional loading on the existing structure or its components. Strength design loads for anchorage and evaluation of the building structure are shown in Figure 8.

4.2 Configuration Restrictions – Group 1

The configurations for this group were evaluated for a high lateral force demand equal to 2.2 times the dead load (strength design, 1.6 for allowable stress design) of the Post and Beam system plus accessories. Due to the high lateral force demand the minimum configuration requires a 90-degree return at the free end of all fences. All fences must be supported out-of-plane at each end of the fence, either by a minimum 2-foot fence return and an X Post or a full height X or Y Post and beam. Possible configurations for this group are shown in Figure 9.

4.3 Configuration Restrictions – Group 2

Configurations for this group were evaluated for a moderate lateral force demand equal to 1.2 times the dead load (strength design, 0.9 for allowable stress design) of the Post and Beam system plus accessories. Due to the moderate lateral force demand the, minimum configuration is more restrictive than zones with lower seismicity. In addition to the configurations shown in Figure 9 (Group 1) other possible are shown in Figure 10. In general, the configurations require that one end of all fences be supported by a beam/fence return of 90-degrees or 120-degrees. In addition, the end of all beams/fences not supported by a beam/fence return must be connected to an X Post

4.4 Configuration Restrictions – Group 3

These configurations were evaluated for a relatively low lateral force demand of 0.9 (strength design, 0.6 allowable stress design) times the dead weight. Although the lateral forces are much less than those for groups 1 and 2, several restrictions on the configuration of the Post and Beam system are required.

The requirements for this group are as follows. One end of each fence must be supported by either a 90-degree post and beam/fence return or a 120-degree post and beam/fence return. Figure 11 shows configurations for Group 3. All configurations shown in Figures 9 and 10 may also be used for Group 3.

4.5 Configuration Restrictions – Group 4

Post and Beam configurations for this group were evaluated for a low lateral force demand of 0.4 times the dead load (strength design, 0.29 for allowable stress design), less than 20% of the demands for Group 1. As a result, there are minimal restrictions on the configuration of the Steelcase Post and Beam system for Group 4. The first restriction is the minimum configuration. The minimum configuration consists of an "L." The minimum configuration may be composed of either two beam/fences and three posts or two beam/fences, two posts and a beam start plate attached to an element providing adequate support. The "L" may be 90 or 120 degrees. The second restriction is that no more than two beams and/or fences may be placed in a line without adding a 90 or 120 degree beam/fence return. The final restriction on the layout of the system is shown in Figure 12. The restriction requires a 2 foot long Beam and Post return where two beams in the same plane are supported by a mutual column on one end and are supported by partial height posts on the other ends. All other configurations are acceptable for use in Group 4 including those shown in Figures 9, 10 and 11.

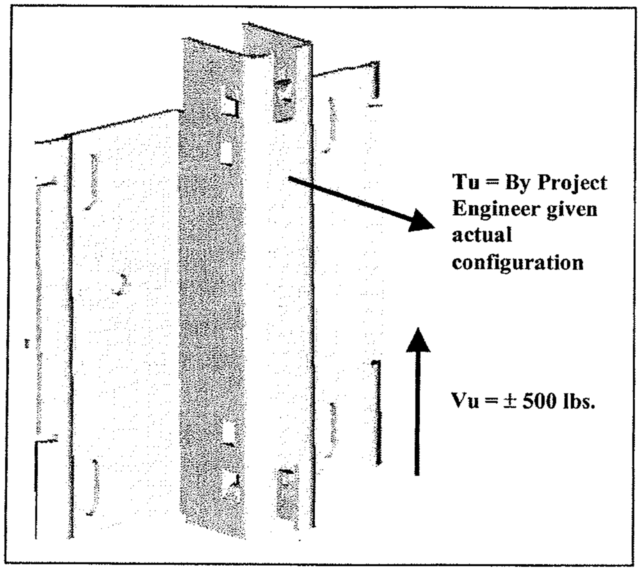


Figure 7- Strength Design Forces For Beam Start Plate

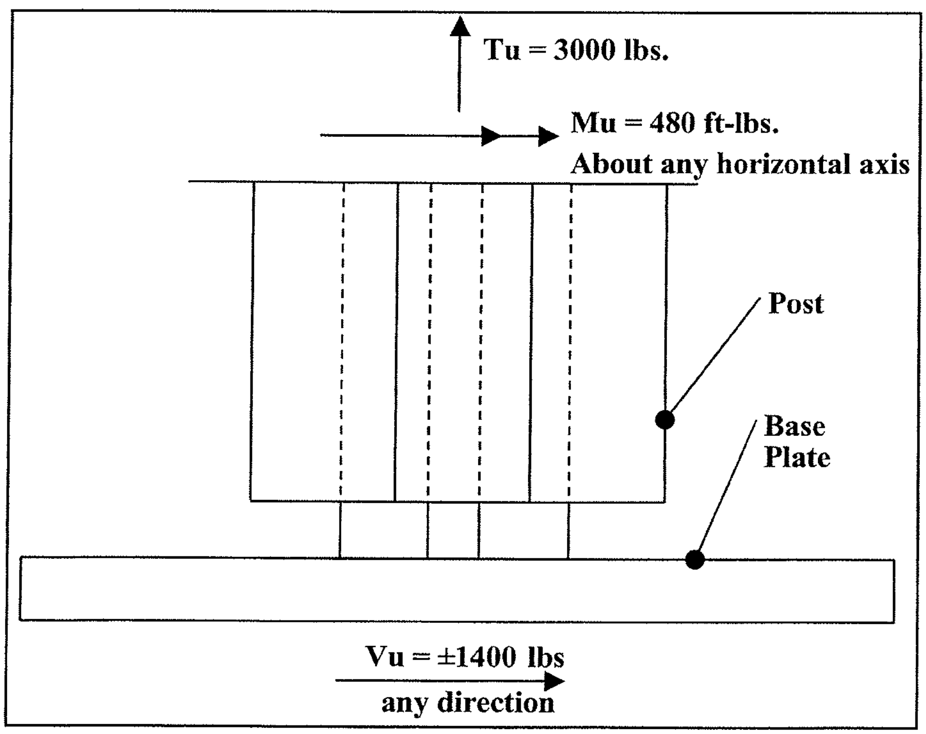
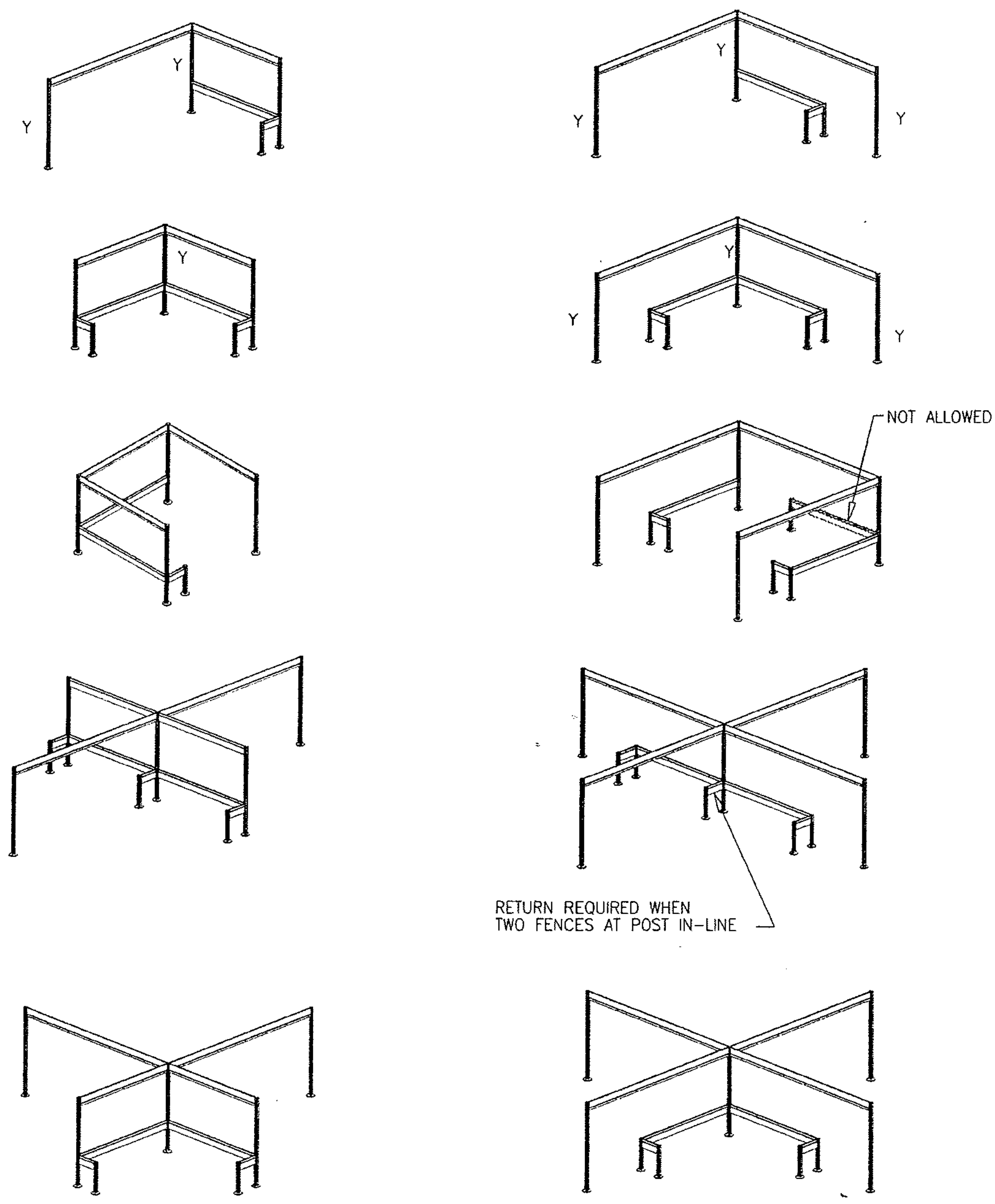
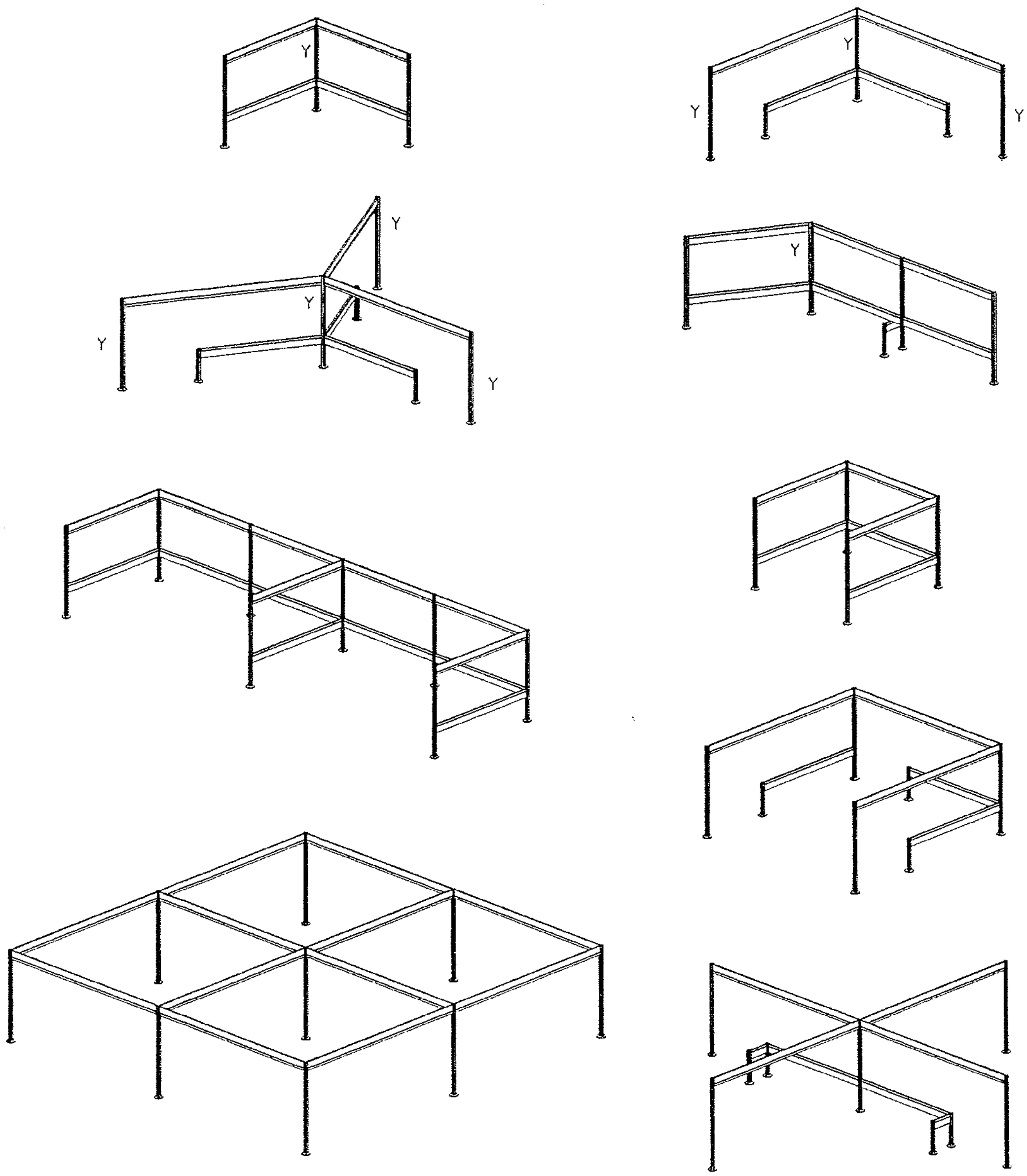


Figure 8 – Strength Design Forces For Base Anchorage



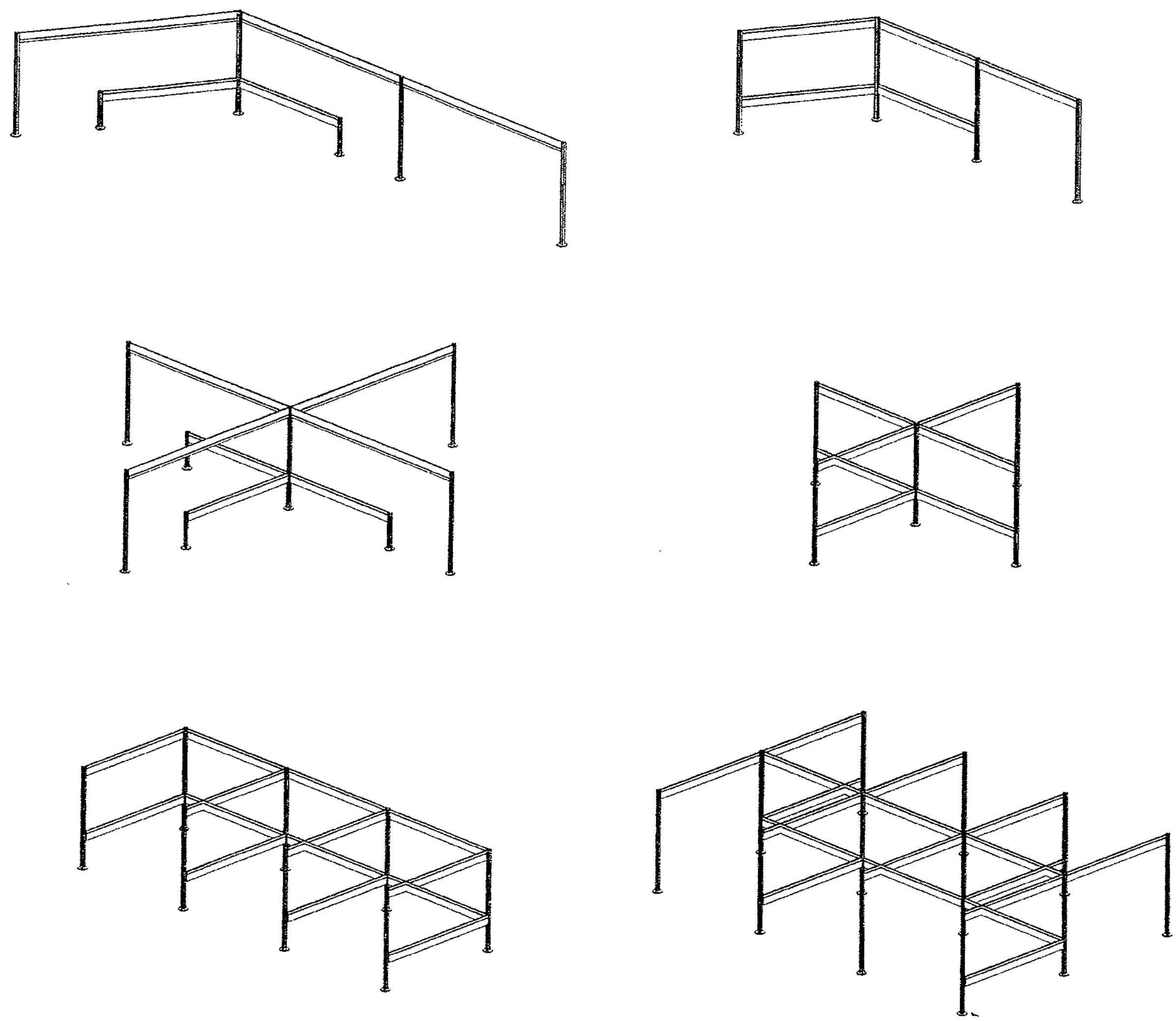
ALL POSTS ARE X-POSTS UNLESS NOTED Y, WHICH INDICATES POST CAN BE AN X-POST OR Y-POST

Figure 9 – Configuration Restrictions – Group 1



ALL POSTS ARE X–POSTS UNLESS NOTED Y, WHICH INDICATES POST CAN BE AN X–POST OR Y–POST

Figure 10 – Configuration Restrictions – Group 2



ALL POSTS CAN BE EITHER X–POST OR Y–POST (EXCEPT WHERE CONFIGURATION DICTATES SPECIFIC POST)

Figure 11 – Configuration Restrictions – Group 3

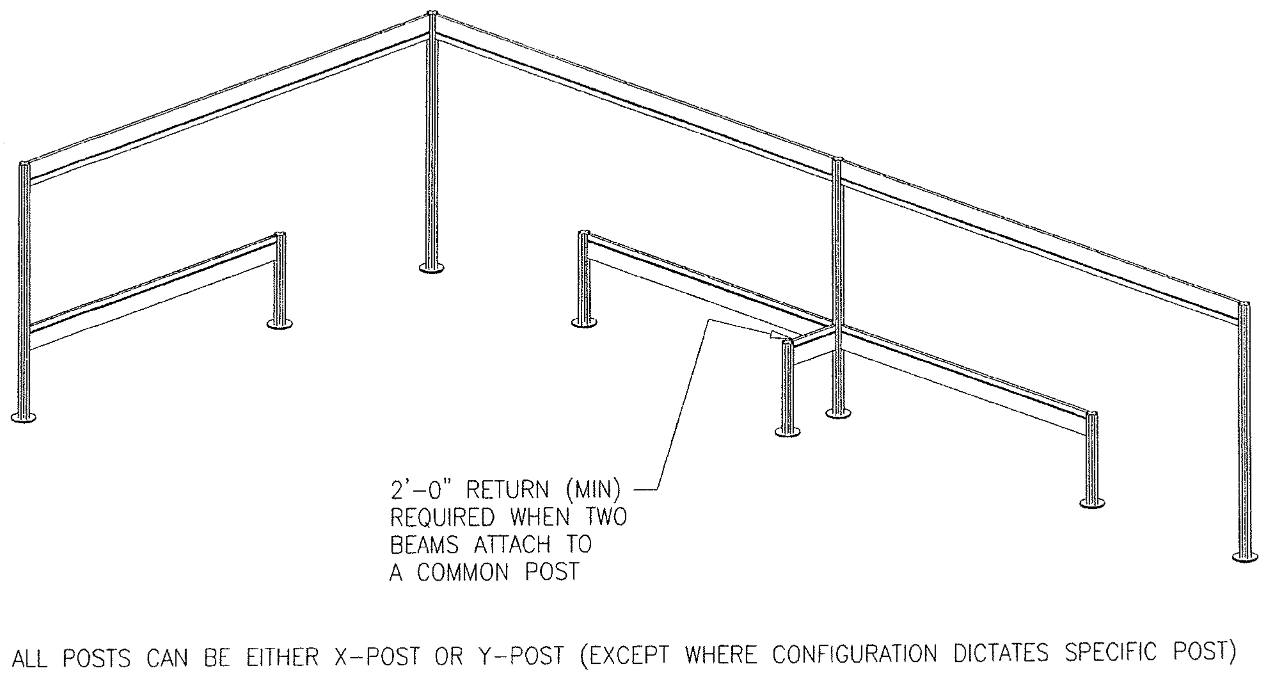


Figure 12 – Configuration Restrictions – Group 4

Appendix A— Application Guidelines

Post Base Anchoring

- Anchor bolts are 3/8 in. diameter, SAE grade 2 or better.
- Anchors will be installed with base/post in place.
- Hex head bolts are preferred to allow for cosmetic caps covering fasteners. If studs are used, the exposed stud should be trimmed off.
- Clearance holes in base plates provide clearance for 0.500 hammer drill bits.
- standard sized, hardened washers for 3/8 in. bolts should be used (.734 in. dia.)
- standard diameter (0.562 in.) socket wrenches will fit into base counterbores

Anchoring In Conventional Concrete Slabs

A number of conventional mechanical anchors and adhesive(epoxy)anchors are available whose allowable load specifications exceed the expected load for up to Z3 applications.

Refer to the assembly instructions for anchor recommendations.

Anchoring In Concrete Covered Steel Decks

The depth of concrete over the steel deck must be determined prior to installation. The minimum thickness of concrete, i.e. the thickness over the higher sections of the steel deck, must be a minimum of 125% of the depth of the anchors to be used, or 150% in order to meet ICBO standards. The Steel Deck Institute specifies a minimum "cover" of 2 inches of concrete.

If the deck is not sufficiently thick or otherwise capable of carrying the anticipated loads, anchors (threaded rod) may fully penetrate the deck and connect to supporting steel sections or tubes that distribute the loads on the lower side of the deck.

Anchoring to post-tensioned concrete slabs should be done under direction of a structural engineer.

Anchoring In Wood Floors

Anchoring to wood floors is not supported unless there is a suitable underlying concrete floor to which the Post Bases can be anchored.

Anchoring With Carpet Covered Floors

Ideally the carpeting would be installed after Post + Beam is anchored to the floor. The second most desirable option is for the carpet to be trimmed to provide appropriate openings for the base puck to rest on the concrete floor. Spacer may be used to raise the bottom of the foot plates back up to the top carpet surface.

It is not recommended that the system be mounted on top of carpeting. When the anchors are torqued down and the carpet compressed, the rigidity of the system may be unpredictable given the variation in floor coverings.

Anchoring Considerations

When posts are positioned near the edge of structural concrete slabs or decks, anchor manufacturers' guidelines for minimum spacing from the edge and derating of allowable load capacities must be observed. Attaching beams and/or fences to adjacent walls is preferable.

The levelling puck should never be omitted from the foot assembly. An inspection port has been provided in the foot plate, for post-installation verification of its presence.

Structural System

Allowable Layouts

The minimum system configuration consists of an "L." The minimum system may be composed of either two beam/fences and three posts or two beam/fences, two posts and a beam start plate attached to a wall. The "L" may be 90° or 120°.

No more than two beams and/or fences may be placed in a line, without adding a 90° or 120° return in the layout.

Beam-to-Beam connection must be made through a post that is brought to the floor. There is no provision for beam-to-beam connection without support.

Beams may not be cantilevered. They must be supported on the ends with either a post or a beam start plate.

When located at beam height, beam/fence extrusion should be oriented with the side t-slot closer to the lower edge of the extrusion.

When used as a fence, the beam/fence extrusions should be oriented with the side t-slot closer to upper edge of the extrusion.

Fences should not exceed ten feet in length.

Beam start plates must be attached either to Steelcase Denominator drywall, or to a header, in the wall, linked to building structure.

Provision has not been made to allow rigid fastening of Post and Beam to other interior systems.

Post elements may not be stacked to make a longer post.

There must be three inches of clearance between the top of the beams and ceiling.

System Restraint

When fence systems are built on carpeting in a non-seismic zone, the ending posts of the system must be bolted to the floor with at least two bolts.

System Loading

The maximum load for a beam is ~~200~~ 100 lb.

The maximum fence load is 1000 lb.

Electrical

Accessory cords should not be routed through system cable management.

If cabling is being passed from the Post and Beam system to another proximate furniture system, the two systems must be tethered together.

The maximum capacity of the cable management elements is:

- Two 5/8" X 3/8″ oval, or 3/8″ round, flexible conduits and thirty cat 5 cables
- one 5/8" X 3/8″ oval, or 3/8″ round, flexible conduit and fifty cat five cables.
- Two 3/8" round hard conduits and thirty CAT 5 cables.

For increased capacity, another parallel management element shall be added.

Hubs are not relocatable power taps. They must be anchored to the system.

Hubs should be located such that they do not constitute a trip hazard.

Flexible conduit service loops are only possible using 5/8″ X 3/8″ oval or 3/8″ round superflex conduit in the horizontal management elements.

Ceiling in-feeds shall be located directly above a post not mid-span on a beam.

In municipalities where hard wiring is required the hub shall terminate into a junction box located on a post.

The Hub is the only element where power terminates into a receptacle. Receptacles shall not be placed mid-span on any management element.

Accessories

The maximum allowable load on the accessory hook is 50 lbs.

Only two accessory hooks should be installed on any one beam.

Rigid panels should not be installed in the infill extrusions.

Shelf brackets should only be used with shelves in the DOT product line.

The maximum load per shelf is:

- 85 lbs. for 24" shelf
- 125 lbs. for 36" shelf
- 170 lbs. for 48" shelf

Adjacent shelves may be tethered near their outboard edges, using a shelf flange, to maintain visual alignment.

Table tether brackets should only be used with tables in the DOT product line.