CHAPTER 10
NONSTRUCTURAL SYSTEMS AND COMPONENTS

10-1. General.

a. *Component Force Transfer.* Components shall be supported or braced such that the component forces are transferred to the structure of the building. Component seismic attachment shall be bolted, welded, or otherwise positively fastened without consideration of frictional resistance produced by the effects of gravity. The design documents shall include sufficient information relating to the attachments to verify compliance with the requirements of this chapter. For buildings in Seismic Design Categories D, E, and F, if the supported weight of the nonstructural systems and components with flexible dynamic characteristics exceeds 25 percent of the weight of the building, the building shall be designed considering the interaction effects between the building and the supported items.

b. *Seismic Forces.* Seismic design of nonstructural components shall be in accordance with Chapter 6 of FEMA 302, and shall include the following considerations:

(1) Seismic forces (F_p) shall be determined in accordance with:

$$F_P = \frac{0.4 a_p S_{DS} W_p}{R_p / I_p}\left(1 + 2\frac{z}{h}\right) \quad (10\text{-}1)$$

F_p is not required to be taken as greater than:

$$F_P = 1.6 S_{DS} I_p W_p \quad (10\text{-}2)$$

nor less than

$$F_P = 0.3 S_{DS} I_p W_p \quad (10\text{-}3)$$

where:

F_P = Seismic design force centered at the component's center of gravity and distributed relative to component's mass distribution.

a_p = Component amplification factor that varies from 1.0 to 2.50 (Select appropriate value from Table 10-1 or Table 10-2.

S_{DS} = Spectral acceleration, short period, as determined from Chapter 3.

W_p = Component operating weight.

R_p = Component response modification factor that varies from 1.0 to 5.0 (select appropriate value from Table 10-1 or Table10-2.

I_p = Component importance factor that is either 1.0 or 1.5 (See Paragraph 10-1d).

z = Height in structure of highest point of attachment of component. For items at or below grade, the base, z, shall be taken as 0.

h = Average roof height of structure relative to grade elevation.

Table 10-1: Architectural Components Coefficients

Architectural Component or Element	A_p [a]	R_p [b]
Interior Nonstructural Walls and Partitions (See also Section 6.2.8 of FEMA 302)		
Plain (unreinforced) masonry walls	1.0	1.25
All other walls and partitions	1.0	2.5
Cantilever Elements (unbraced or braced to structural frame below its center of mass)		
Parapets and cantilever interior nonstructural walls	2.5	2.5
Chimneys and stacks where laterally supported by structures	2.5	2.5
Cantilever Elements (Braced to structural frame above its center of mass)		
Parapets	1.0	2.5
Chimneys and stacks	1.0	2.5
Exterior nonstructural walls	1.0 [c]	2.5
Exterior Nonstructural Wall Elements and Connections (see also Section 6.2.4 of FEMA 302)		
Wall element	1.0	2.5
Body of wall panel connections	1.0	2.5
Fasteners of the connecting system	1.25	1
Veneer		
High deformability elements and attachments	1.0	2.5
Low deformability elements and attachments	1.0	1.25
Penthouses (except when framed by an extension of the building frame)	2.5	3.5
Ceilings (see also Section 6.2.6 of FEMA 302)		
All	1.0	2.5
Cabinets		
Storage cabinets and laboratory equipment	1.0	2.5
Access floors (see also Section 6.2.7 of FEMA 302)		
Special access floors (designed in accordance with Section 6.2.7.2 of FEMA 302)	1.0	2.5
All other	1.0	1.25
Appendages and Ornamentation	2.5	2.5
Signs and Billboards	2.5	2.5
Other Rigid Components		
High deformability elements and attachments	1.0	3.5
Limited deformability elements and attachments	1.0	2.5
Low deformability elements and attachments	1.0	1.25
Other flexible components		
High deformability elements and attachments	2.5	3.5
Limited deformability elements and attachments	2.5	2.5
Low deformability elements and attachments	2.5	1.25

a A lower value for a_p may be justified by detailed dynamic analysis. The value for a_p shall not be less than 1.00. The value of a_p = 1 is for equipment generally regarded as rigid and rigidly attached. The value of a_p = 2.5 is for flexible components or flexibly attached components. See Chapter 2 of FEMA 302 for definitions of rigid components and flexible components, including attachments.

b R_p= 1.25 for anchorage design when component anchorage is provided by expansion anchor bolts, shallow chemical anchors, or shallow (nonductile) cast-in-place anchors, or when the component is constructed of nonductile materials. Powder-actuated fasteners (shot pins) shall not be used for component anchorage in tension applications in Seismic Design Categories D, E, or F. Shallow anchors are those with an embedment length-to-diameter ratio of less than 8.

c Where flexible diaphragms provide lateral support for walls and partitions, the design forces for anchorage to the diaphragm shall be as specified in Section 5.2.5.4.4 of FEMA 302.

Table 10-2: Mechanical and Electrical Components Coefficients

Mechanical and Electrical Component or Element[c]	a_p [a]	R_p [b]
General Mechanical		
Boilers and furnaces	1.0	2.5
Pressure vessels on skirts and free-standing	2.5	2.5
Stacks	2.5	2.5
Cantilevered chimneys	2.5	2.5
Other	1.0	2.5
Manufacturing and Process Machinery		
General	1.0	2.5
Conveyors (nonpersonnel)	2.5	2.5
Piping Systems		
High deformability elements and attachments	1.0	3.5
Limited deformability elements and attachments	1.0	2.5
Low deformability elements and attachments	1.0	1.25
HVAC System Equipment		
Vibration isolated	2.5	2.5
Non-vibration isolated	1.0	2.5
Mounted in-line with ductwork	1.0	2.5
Other	1.0	2.5
Elevator Components	1.0	2.5
Escalator Components	1.0	2.5
Trussed Towers (free-standing or guyed)	2.5	2.5
General Electrical		
Distributed systems (bus ducts, conduit, cable tray)	1.0	3.5
Equipment	1.0	2.5
Lighting Fixtures	1.0	1.25

a A lower value for a_p is permitted provided a detailed dynamic analysis is performed which justifies a lower limit. The value for a_p shall not be less than 1.00. The value of $a_p = 1$ is for equipment generally regarded as rigid or rigidly attached. The value of $a_p = 2.5$ is for flexible components or flexibly attached components. See Chapter 2 of FEMA 302 for definitions of rigid components and flexible components, including attachments.

b $R_p = 1.25$ for anchorage design when component anchorage is provided by expansion anchor bolts, shallow chemical anchors, or shallow low deformability cast-in-place anchors or when the component is constructed of nonductile materials. Powder-actuated fasteners (shot pins) shall not be used for component anchorage in Seismic Design Categories D, E, or F. Shallow anchors are those with an embedment length-to-diameter ratio of less than 8.

c Components mounted on vibration isolation systems shall have a bumper restraint or snubber in each horizontal direction. The design force shall be taken as $2F_P$.

The force, F_p, shall be applied independently longitudinally and laterally in combination with service loads associated with the components. Horizontal and vertical load effects shall be combined as indicated in ASCE 7, substituting F_p for the term Q_E. The reliability/redundancy factor, *D*, in FEMA 302 shall be taken as equal to 1.0. When positive and negative wind loads exceed F_p for nonstructural exterior walls, these wind loads shall govern the design. Similarly, when building code horizontal loads exceed F_p for interior partitions, the specified building code loads shall govern the design.

c. *Seismic Relative Displacement.* Relative structural displacements that may affect the design of nonstructural systems and components shall be calculated in accordance with Section 6.1.4 of FEMA 302.

d.. *Component Importance Factor.* Compliance with the provisions in Chapter 6 of FEMA 302 with Component Importance Factor, I_p, equal to 1.0 satisfies the acceptance criteria for Performance Objective 1A (Life Safety). For buildings with enhanced performance objectives, a Component Importance Factor of 1.5 will be assigned to selected nonstructural components as follows:

I_p = 1.5 Life safety component is required to function after an earthquake.

I_p = 1.5 Component contains or can damage hazardous contents.

I_p = 1.5 Storage racks in occupancies with general access (e.g., warehouses or retail stores).

I_p = 1.5 Components needed for continued operation of an essential facility (Seismic Use Groups IIIE).

I_p = 1.0 All other components.

10-2. Architectural Components.

a. *Introduction.* This paragraph defines architectural components, discusses their participation and importance in relation to the seismic design of the structural system, and prescribes the criteria for their design to resist damage from seismic lateral forces. The fundamental principle and underlying criterion of this paragraph are that the design of architectural components will be such that they will not collapse and cause personal injury due to the accelerations and displacements induced by severe seismic disturbances, and that the architectural components will withstand more frequent but less severe seismic disturbance without excessive damage and economic loss.

b. *Definition*. Architectural components are elements such as partitions, stairways, windows, suspended ceilings, parapets, building ornamentation and appendages, and storage racks. They are called architectural because they are not part of the vertical-or lateral-load-carrying systems of the building, nor part of the mechanical or electrical systems. Although they are usually shown on the architectural drawings, they often have a structural aspect. The architect will consult with the structural, mechanical, and electrical engineers when dealing with these elements. Examples of architectural components that have a structural aspect follow.

(1) Nonstructural walls. A wall is considered “architectural” or “nonstructural” when it does not participate in the resistance to lateral forces. This is the case if the wall is isolated; that is, not connected to the structure at the top and the ends, or if it is very flexible relative to the structural wall frames. Note that an isolated wall must be capable of acting as a cantilever from the floor, or be braced laterally.

(2) Curtain walls and filler walls. A curtain wall is an exterior wall, usually of masonry, that lies outside of, and usually conceals, the structural frame. A filler wall is an infill, usually of masonry, within the members of a frame. These are often considered architectural if they are designed and detailed by the architect, but they can act as structural shear walls. If they are connected to the frame, they will be subjected to the deflections of the frame and will participate with the frame in resisting lateral forces. Curtain walls and infill walls in buildings governed by this document will be designed so as not to restrict the deformations of the structural framing under lateral loads. Lateral supports and bracing for these walls will be provided as prescribed in the following paragraphs.

(3) Partial infill wall. A partial infill wall is one that has a strip of windows between the top of the solid infill and the bottom of the floor above, or has a vertical strip of window between one or both ends of the infill and a column. Such walls require special treatment: if they are not properly isolated from the structural system they will act as shear walls. The wall with windows along the top is of particular concern because of its potential effect on the adjacent columns. The columns are fully braced where there is an adjacent infill, but are unbraced in the zone between the windows. The upper, unbraced part of the column is a “short column,” and its greater rigidity (compared with other unbraced columns in the system) must be accounted for in the design. As indicated above, all infills in buildings governed by this document will be considered to be nonstructural components, and will be designed so as not to restrict the deformation of the structural framing under lateral loads.

(4) Precast panels. Exterior walls that have precast panels attached to the frame are a special case. The general design of the walls is usually shown on the architectural drawings, while the structural details of the panels are usually shown on the structural drawings. Often, the structural design is assigned to the General Contractor so as to allow maximum use of the special expertise of the selected panel subcontractor. In such cases, the structural drawings will include design criteria and representative details in order to show what is expected. The design criteria will include the required design forces and the frame deflections that must be accommodated by the panels and their connections.

c. Design Criteria. Architectural elements must safely resist horizontal forces prescribed by Equation 10-1, and must be capable of conforming (accommodating) to the lateral deflections that they will be subjected to during the lateral deformations of the structure.

(1) Lateral force coefficients. Coefficients for Equation 10-1 applicable to architectural components are provided in Table 10-1.

(2) Displacements. Allowable story drift for structures is prescribed in Table 6-1. Determination of relative displacement applicable to architectural components is prescribed in Section 6.1.4 of FEMA 302.

d. Detailed Requirements

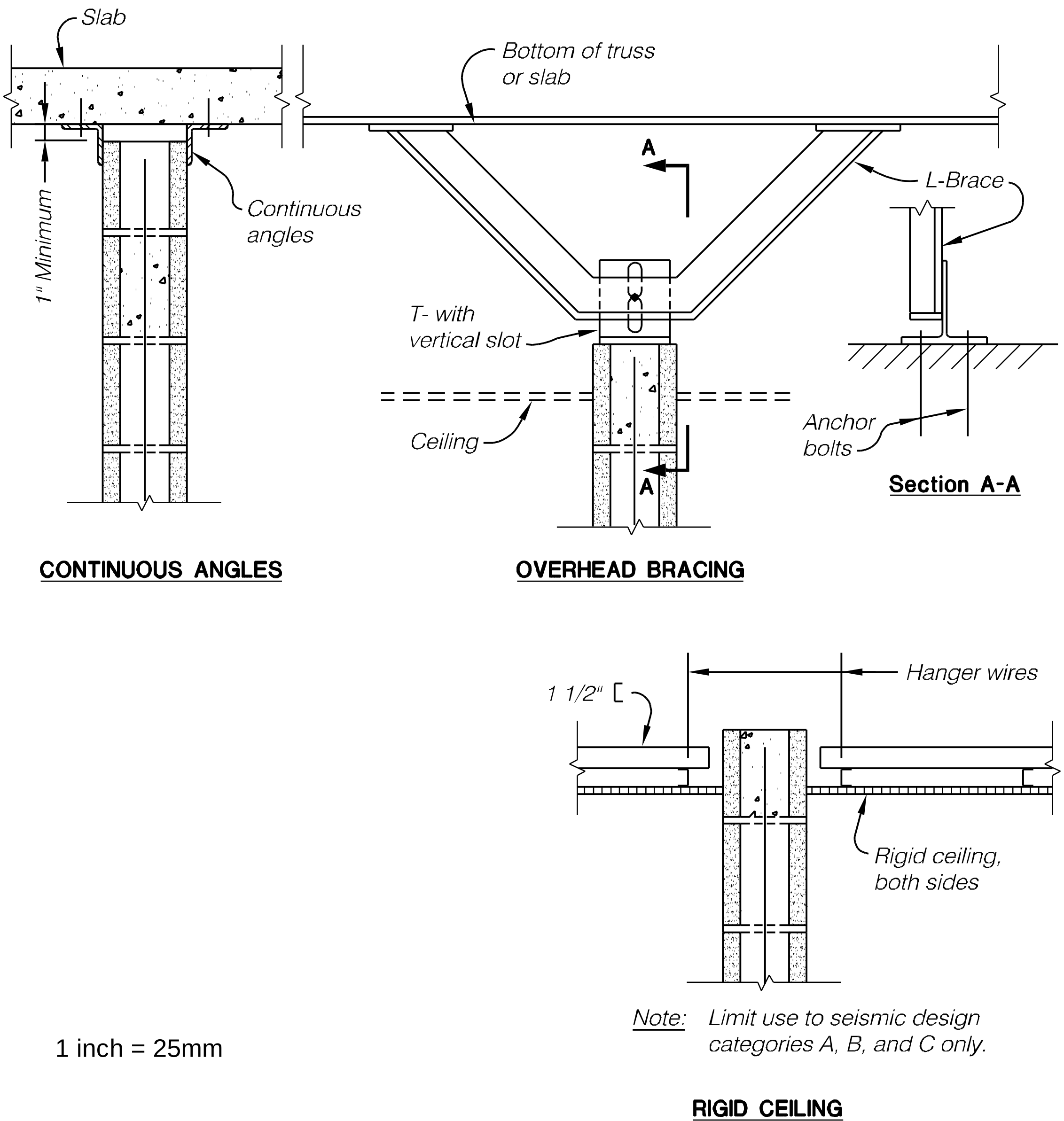
(1) Partitions. Partitions are classified into two general categories: rigid and nonrigid.

(a) Rigid partitions. This category generally refers to nonstructural masonry walls. Walls will be isolated where they are unable to resist in-plane lateral forces to which they are subjected, based on relative rigidities. Typical details for isolation of these walls are shown in Figure 10-1. These walls will be designed for the prescribed forces normal to their plane.

(b) Nonrigid partitions. This category generally refers to nonstructural partitions such as stud and drywall, stud and plaster, and movable partitions. When constructed according to standard recommended practice, it is assumed that the partitions can withstand the design in-plane drift of .005 times the story height (i.e., 1/16 inch per foot (5.2mm per meter) of height) without damage. Therefore, if the structure is designed to control drift within the prescribed limits, these partitions do not require special isolation details. They will be designed for the prescribed seismic force acting normal to flat surfaces; however, wind or the usual 5 pounds per square foot partition load will usually govern. If the structural design drift is not controlled within the prescribed limits, isolation of partitions will be required for reduction of nonstructural damage. Economic justification between potential damage and costs of isolation will be considered. A decision has to be made for each project as to the role, if any, such partitions will contribute to damping and response of the structure, and the effect of seismic forces parallel to the partition resulting from the structural system as a whole. Usually it may be assumed that this type of partition is subject to future alterations in layout location. The structural role of partitions may be controlled by height of partitions and method of support.

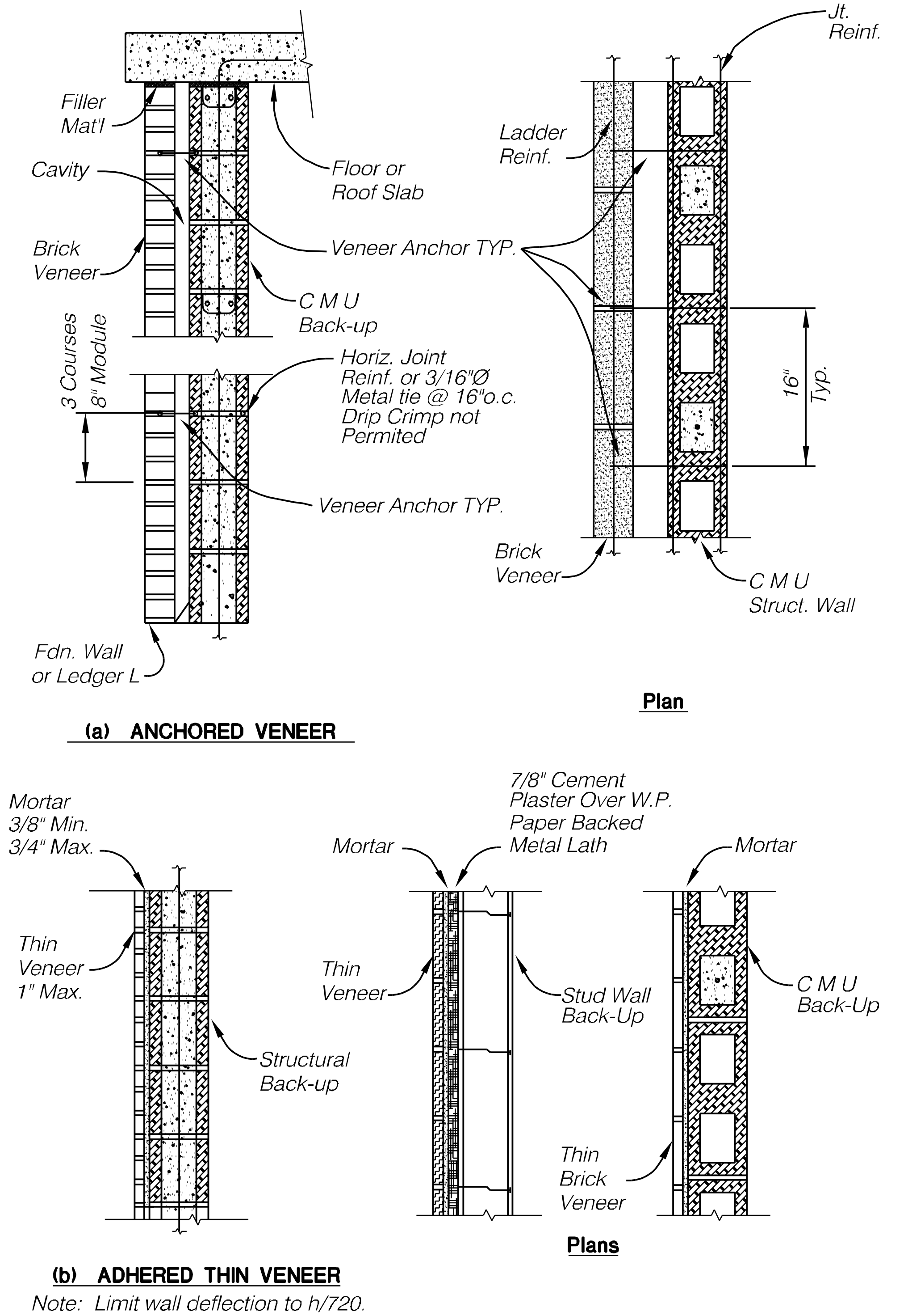
(2) Veneered walls. There are two methods for attaching veneer to a backup structural wall (see Figure 10-2).

(a) Anchored veneer is a masonry facing secured by joint reinforcement or equivalent mechanical tie attached to the backup. All required load-carrying capacity (both vertical and lateral) will be provided by the structural backup wall. The veneer will be nonbearing and isolated on three edges to preclude it from resisting any load other than its own weight, and in no case shall it be considered part of the wall in computing required thickness of a masonry wall. The veneer will be not less than 1½ inches (38mm), nor more than 5 inches (127mm) thick. The veneer will be tied to the structural wall with joint reinforcement



LATERAL SUPPORTS - NONSTRUCTURAL PARTITION

Figure 10-1 Typical details of isolation of walls.



1 inch = 25mm

Figure 10-2 Veneered walls.

or 3/16-inch (5mm) round corrosion-resisting metal ties capable of resisting, in tension or compression, the wind load or two times the weight of veneer, whichever governs. Maximum spacing of ties is 16 inches (406mm), and a tie must be provided for each 2 square feet ($0.2m^2$) of wall area. Adjustable ties are not permitted in Seismic Design Categories D, E, and F. They may be used in Seismic Design Categories A, B, and C if the basic wind speed is less than 100 mph (160 kmph). If adjustable ties are used, they will be the double pintle-eye type, with a minimum wire size of 3/16 inch (5mm); play within the pintle will be limited to 1/16 inch (1.6mm), and the maximum vertical eccentricity will not exceed 1/2 inch (12.7mm). The maximum space between the veneer and the backing will not exceed 3 inches (75mm), unless spot mortar bedding is provided to stiffen the ties. A noncombustible, noncorrosive horizontal structural framing will be provided for vertical support of the veneer. The maximum vertical distance between horizontal supports will not exceed 25 feet (7.6m) above the adjacent ground, and 12 feet (3.7m) maximum spacing above the 25-foot (7.6m) height.

(b) Adhered veneer is masonry veneer attached to the backing with minimum 3/8-inch (9.5mm) to maximum 3/4 inch (19mm)mortar or with approved thin-set latex Portland cement mortar. The bond of the mortar to the supporting element will be capable of withstanding a shear stress of 50 psi (345 kPa). Maximum thickness of the veneer will be limited to 1 inch (25mm). Since adhered veneer is supported through adhesion to the mortar applied over a backup, consideration will be given for differential movement of supports, including that caused by temperature, shrinkage, creep, and deflection. A horizontal expansion joint in the veneer is recommend at each floor level to prevent spalling. Vertical control joints should be provided in the veneer at each control joint in the backup.

(3) Connections of Exterior Wall Panels. Precast, non-bearing, non-shear wall panels or other elements that are attached to or enclose the exterior will be designed and detailed to accommodate movements of the structure resulting from lateral forces or temperature changes. The concrete panels or other elements will be supported by means of cast-in-place concrete or by mechanical devices. Connections and panel joints will be designed to allow for the relative movement between stories, and will be designed for the forces specified in Section 6.1.6 of FEMA 302. Connections will have sufficient ductility and rotation capacity so as to preclude fracture of the concrete or brittle failures at or near welds. Inserts in concrete shall be attached to or hooked around reinforcing steel or otherwise terminated so as to effectively transfer forces to the reinforcing steel. Connections to permit movement in the plane of the panel for story drift may be properly designed sliding connections using slotted or oversized holes, or may be connections that permit movement by bending of steel components without failure. Typical design forces are shown in Figure 10-3.

(4) Suspended Ceiling Systems. Seismic design is required for structures conforming to Seismic Design Categories C, D, E, and F. Earthquake damage to suspended ceiling systems can be limited by proper support and detailing.

Suspended ceiling framing systems will be designed for forces prescribed in Section 6.2.6 of FEMA 302.

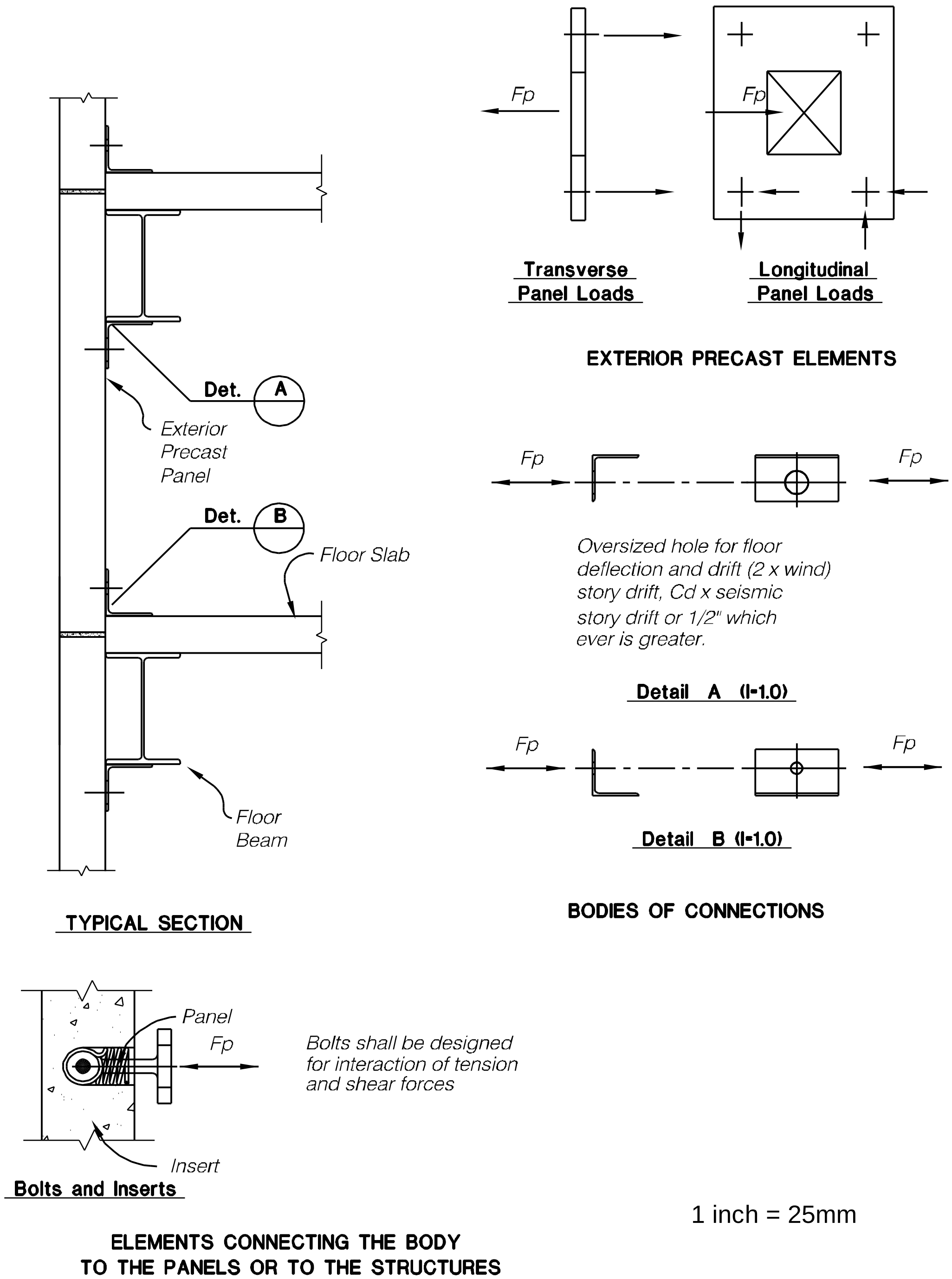


Figure 10-3 Design forces for exterior precast elements.

The ceiling weight, $W_{P,}$ will include all light fixtures and other equipment laterally supported by the ceiling. For purposes of determining the lateral force, a ceiling weight of not less than 4 pounds per square foot (0.2kPa) will be used. The support of the ceiling systems will be by positive means, such as wire or an approved seismic clip system. Typical details of suspended acoustical tile ceilings are shown in Figure 10-4.

(5) Window Frames. Window frames will be designed to accommodate deflections of the structure without imposing a load on the glass. Because glass is a brittle material, a considerable hazard of falling glass may be present. It is particularly serious if the glass is above and adjacent to a public way. This hazard can be eliminated by proper isolation between glass and its enclosing frame. It is obvious that the magnitude of isolation required depends upon the drift and the size of the individual pane or enclosing frame; thus, a pane of glass in a full-story-height frame should have an isolation or movement capability as great as the maximum possible drift (e.g., C_d times the calculated elastic story displacement in Table 6-1). The actual isolation clearance will depend on the geometry and deformation characteristics of enclosing frame, frame support, and structural system. Special care will be exercised in the field to see that such isolation is actually obtained.

(6) Stairways. Stairways tend to act like struts; therefore, the rigidity of the stairway, relative to the structure, will be considered. In some cases, the stairway will be isolated in order to prevent damage to the stair by the building frame, or to prevent the stair from imposing an unwanted constraint on the frame.

(7) Cantilever parapets, ornamentation, and appendages shall be designed with a_p and R_p equal to 2.5 in accordance with Table 10-1.

(8) Storage racks.

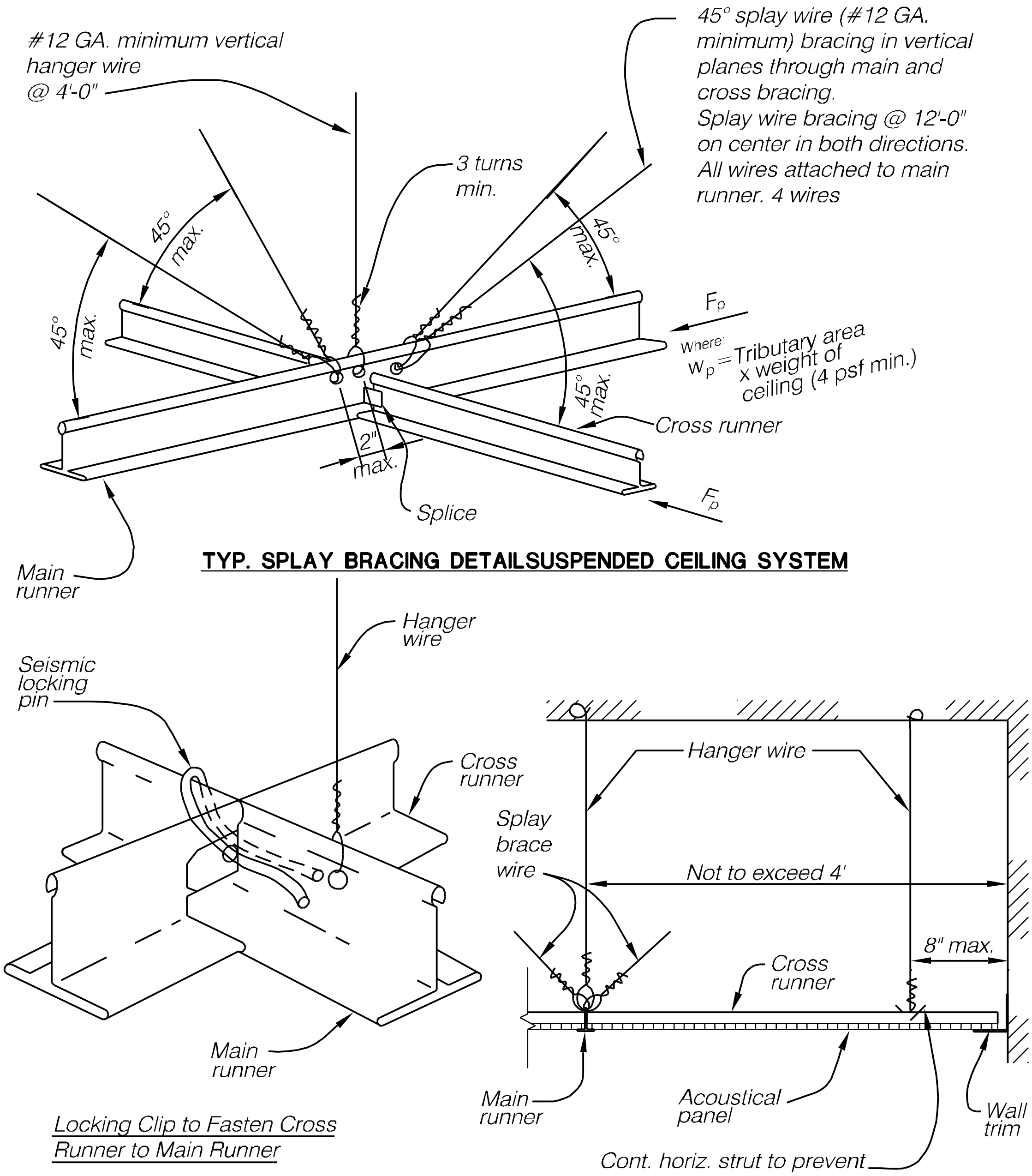
(a) Storage racks supported at grade will be treated as non-building structures in accordance with Chapter 14 of FEMA 302. The weight, *W*, will be equal to the weight of the rack plus its contents.

1. Rigid racks. Racks having periods of vibration less than 0.06 second will be governed by Section 14.2.2 of FEMA 302.

2. Flexible Rack. Racks having a period of vibration greater than 0.06 second will be governed by Section 14.3 of FEMA 302.

(b) Storage racks supported by other structures will be governed by Section 14.1.2 of FEMA 302.

e. Alternative Designs. Where an accepted national standard or approved test data provide the basis for earthquake resistance of a particular type of architectural element or rack, such standards of data may be accepted as a basis for design. Where approved standards or test data define acceptance criteria in terms of allowable stresses as opposed to strength, the design seismic forces shall be obtained from FEMA 302 and reduced by a factor of 1.4 for use with allowable stresses. Allowable stress



SUSPENDED CEILING DETAIL AT WALL

Splices and intersections of runners shall be attached with mechanical interlocking connectors such as pop rivets, screws, pins, plates with bent tabs, or other approved connectors. Design connectors for 2x design load or ultimate axial tension or compression (minimum 120 pounds).

Note:
The details in this figure apply only in seismic design categories D, E, and F

1 inch = 25mm
1 foot = 0.3m
1 pound = 4.45 N

Figure 10-4 Suspended acoustical tile ceiling.

increases used in approved standards are permitted. Detailing shall be in accordance with the approved standards.

10-3. Mechanical and Electrical Equipment.

a. Introduction. This paragraph prescribes the criteria for structural design of anchorages and supports for mechanical and electrical equipment in seismic areas.

(1) Design Goals. The goal of design is that the anchorages and supports will withstand the accelerations induced by severe seismic disturbances without collapse or excessive deflection, and withstand the accelerations induced by less severe seismic disturbances without exceeding yield stresses. The design forces are related to the inertia forces on the equipment, and are calculated on the weight of the equipment; accordingly, design provisions often speak of equipment. The design is for the supports of the equipment, however, not the equipment itself. Ordinary equipment, which is fabricated at some distance from the site and is transported by truck and/or railroad, is assumed to have adequate strength. Critical equipment, which may have to be substantiated by design or test, is beyond the scope of this manual.

(2) Earthquake loadings. The earthquake loadings applied to equipment supports are generally higher than the earthquake loadings used in the design of the building structural system. One reason is the amplification of the ground motion acceleration transmitted to elements in the elevated stories of a building due to dynamic response. Another reason is that equipment supports often lack the extra margin of safety provided by reserve strength mechanisms, such as participation of architectural elements, inelastic behavior of structural elements, and redundancy in the structural system, which are characteristics of buildings.

b. General. All equipment anchorages and supports designed under the provisions of this chapter will conform to the following requirements:

(1) Equipment supports or bracing on buildings or other structures shall be designed in accordance with Paragraph 7-1 b (5).

(2) Equipment on the ground. Mechanical and electrical equipment that is supported at or below ground level will be considered to be non-building structures, and are governed by other agency documents.

(3) Weight limitations. Equipment in buildings will be considered to be within the scope of this chapter if the maximum weight of the individual item of equipment does not exceed 10 percent of the total building weight, or 20 percent of the total weight of the floor at the equipment level. The response of equipment is dependent upon the response of the building in which it is housed. If the weight of the equipment is appreciable, relative to the weight of the building, the interaction of the equipment with the building (i.e., the coupling effect) will change the building's response characteristics. It is assumed that equipment within the above weight limitations has a negligible effect

on the response of the building. Equipment that is not within the above limitations is outside the scope of this manual, and must be designed using a more rigorous method of analysis.

(4) Rigorous analysis. No portion of this chapter will be construed to prohibit a rigorous analysis of equipment and the supporting mechanism by established principles of structural dynamics. Such an analysis will demonstrate that the fundamental principle and underlying criterion of Paragraph 10-3a are satisfied. In no case will the design result in capacities less than 80 percent of those required by Paragraph 10-1b.

(5) Securing Equipment. Friction resulting from gravity loads as a method of resisting seismic forces is not acceptable and will not be allowed. Both vertical and horizontal accelerations are possible during an earthquake. Under vertical acceleration, the gravity force required to maintain friction can be greatly diminished. This could result in a reduction or elimination of the friction force available to resist horizontal seismic loads, as simultaneous vertical and horizontal accelerations are possible. Equipment will thus be secured by bolts, embedment, or other acceptable positive means of resisting horizontal forces. Refer to Figures 10-12 and 10-13 for typical details.

(6) Special requirements. Requirements for lighting fixtures and supports, piping, stacks, bridge cranes and monorails, and elevator systems are covered in Paragraphs 10-3d through 10-3h.

c. Seismic Design Forces. Equations 10-1, 10-2, and 10-3 prescribe seismic forces for equipment that is supported by buildings or other structures. The amplification of the floor response motion in the higher level of the structure is represented by the factor $(1+z/h)$, and the amplification of the design force due to the dynamic response of the equipment and/or its supports is represented by the component amplification factor, A_p. Equation 10-1 is a simplistic, but acceptable, determination of the seismic design force for equipment supports in structures. More rigorous determinations include the use of floor response spectra together with the determination of the fundamental period of the component and its attachment to the structure.

d. Lighting Fixtures in Buildings. In addition to the requirements of the preceding paragraphs, lighting fixtures and supports will conform to the following seismic requirements in structures conforming to Seismic Design Criteria C, D, E, and F.

(1) Materials and construction.

(a) Fixture supports will employ materials that are suitable for this purpose. Cast metal parts, other than those of malleable iron, and cast or rolled threads, will be subject to special investigation to ensure structural adequacy.

(b) Loop and hook or swivel hanger assemblies for pendant fixtures will be fitted with a restraining device to hold the stem in the support position during earthquake motions. Pendant-supported fluorescent fixtures will also be provided with a flexible hanger device at the attachment to the fixture channel to preclude breaking of the support. The motion of swivels or hinged joints will not cause sharp binds in conductors or damage to insulation.

(c) Each recessed individual or continuous row of fluorescent fixtures will be supported by a seismic-resisting suspended ceiling support system, and will be fastened thereto at each corner of the fixture; or will be provided with fixture support wires attached to the building structural members using two wires for individual fixtures, and one wire per unit of continuous row fixtures. These support wires (minimum 12-gauge wire) will be capable of supporting four times the support load.

(d) A supporting assembly that is intended to be mounted on an outlet box will be designed to accommodate mounting features on 4-inch (102mm) boxes, 3-inch (76mm) plaster rings, and fixture studs.

(e) Each surface-mounted individual or continuous row of fluorescent fixtures will be attached to a seismic-resisting ceiling support system. Support devices for attaching fixtures to suspended ceilings will be a locking-type scissor clamp or a full loop band that will securely attach to the ceiling support. Fixtures attached to the underside of a structural slab will be properly anchored to the slab at each corner of the fixture.

(f) Each wall-mounted emergency light unit will be secured in a manner that will hold the unit in place during a seismic disturbance.

(g) Tests. In lieu of the requirements for equipment supports given in Paragraph 10-3c, lighting fixtures and the complete fixture-supporting assembly may be accepted of they pass shaking-table tests approved by the using agency. Such tests will be conducted by an approved and independent testing laboratory, and the results of such tests will specifically state whether or not the lighting fixture supports satisfy the requirements of the approved tests. Suspension systems for light fixtures, as installed, that are free to swing a minimum of 45° from the vertical in all directions, and will withstand, without failure, a force of not less than four times the weight they are intended to support, will be acceptable.

e. Piping in Buildings. Pipes are categorized as pipes related to the fire protection system, critical piping in essential and hazardous facilities, and all other piping.

(1) Fire protection piping. All water pipes for fire protection systems will be designed under the provisions of the current issue of the "Standard for the Installation of Sprinkler Systems" of the National Fire Protection Association (NFPA No. 13). To avoid conflict with the NFPA recommendations, the criteria in the following paragraphs are not applicable to piping expressly designed for fire protection.

(2) Critical piping in essential and hazardous facilities. Critical piping is that which is required for life-safety systems, for continued operations after an earthquake, or for safety of the general public. All critical piping in essential and hazardous

facilities located in Seismic Design Criteria C, D, E, and F will be designed using the provisions in Paragraph 10-3e(4).

(3) All other piping.

(a) Piping in Seismic Design Category A structures is not required to have seismic restraint.

(b) Piping in Seismic Design Category B structures that is not categorized as essential or hazardous is not required to have seismic restraints.

(c) Piping in all other Seismic Design Category structures that is not categorized as essential or hazardous is required to have seismic restraints designed using the provisions in Paragraph 10-3e(4). Restraints may be omitted for the following installations:

1. Gas piping of less than 1-inch (25mm) inside diameter.

2. Piping in boiler and mechanical equipment rooms of less than 1¼ (32mm) inches inside diameter.

3. All other piping of less than 2½ inches (64mm) inside diameter.

4. All electrical conduit of less than 2½ inches (64mm) inside diameter.

5. All rectangular air-handling ducts of less than 6 square feet ($0.6m^2$) in cross-sectional area.

6. All round air-handling ducts less than 28 inches (711mm) in diameter.

7. All piping suspended by individual hangers 12 inches (0.3m) or less in length from the top of pipe to the bottom of the support for the hanger.

8. All ducts suspended by hangers 12 inches or less in length from the top of the duct to the bottom of the support for the hanger.

(4) Seismic restraint provisions. Seismic restraints that are required for piping by Paragraphs 10-3e(2) and 10-3e(3) will be designed in accordance with the following provisions.

(a) General. The provisions of this paragraph apply to the following:

1. Risers. All risers and riser connections.

2. Horizontal pipe. All horizontal pipes and attached valves. For the seismic analysis of horizontal pipes, the equivalent static force will be considered to act concurrently with the full dead load of the pipe, including contents.

3. Connections. All connections and brackets for pipe will be designed to resist concurrent dead and equivalent static forces. The seismic forces will be determined from the appropriate provisions below. Supports will be provided at all pipe joints unless continuity is

maintained. See Paragraph (4) below for acceptable sway bracing details.

4. Flexible couplings and expansion joints. Flexible couplings will be provided at the bottoms of risers for pipes larger than 3½ inches (89mm) in diameter. Flexible couplings and expansion joints will be braced laterally unless such lateral bracing will interfere with the action of the flexible coupling or expansion joint. When pipes enter buildings, flexible couplings will be provided to allow for relative movement between soil and building.

5. Spreaders. Spreaders will be provided at appropriate intervals to separate adjacent pipe lines unless the pipe spans and the clear distance between pipes are sufficient to prevent contact between the pipes during an earthquake.

(b) Rigid and rigidly attached pipes will be designed in accordance with Equation 7-1, where W_P is the weight of the pipes, the contents of the pipes, and the attachments. The forces will be distributed in proportion to the weight of the pipes, contents, and attachments. A piping system is assumed rigid if the maximum period of vibration is 0.05 second (for pipes that are not rigid, see Paragraph (3) below). Figures 10-5, 10-6, and 10-7, which are based on water-filled pipes with periods equal to 0.05 second, are to be used to determine the allowable span-diameter relationship for structures conforming to Seismic Design Categories C, D, E, and F for standard (40S) pipe; extra strong (80S) pipe; types K, L, and M copper tubing; and 85 red brass or SPS copper pipe.

(c) Flexible piping systems. Piping systems that are not in accordance with the rigidity requirements of Paragraph 10-3e(4)(b) (i.e., period less than 0.05 second) will be considered to be flexible (i.e., period greater than 0.05 second). Flexible piping systems will be designed for seismic forces with consideration given to both the dynamic properties of the piping system and the building or structure in which it is placed. In lieu of a more detailed analysis, the equivalent static lateral force is given by Equation 10-1, with a_P = 2.5. The forces will be distributed in proportion to the weight of the pipes, contents, and attachments. If the weight of the attachments is greater than 10 percent of the weight of the pipe, the attachments will be separately braced, or substantiating calculations will be required. If temperature stresses are appreciable, substantiating calculations will be required.

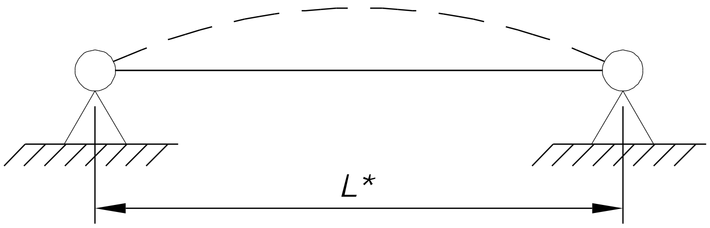
1. Separation between pipes. Separation will be a minimum of four times the calculated maximum displacement due to F_P, but not less than 4 inches (102mm) clear between parallel pipes, unless spreaders are provided.

2. Clearance. Clearance from walls or rigid elements will be a minimum of three times the calculated displacement due *to* F_P, but not less than 3 inches (76mm) clear from rigid elements.

3. Alternative method for flexible piping systems. If the provisions in the above paragraphs appear to be too severe for an economical design, alternative methods based on rational and substantial analysis may be applied to flexible piping systems.

4. Acceptable seismic details for sway bracing are shown in Figure 10-8.

f. Stacks. Stacks are actually beams with distributed mass, and as such, cannot be approximated accurately by single-mass systems.



Diameter Inches	Std. Wt. Steel Pipe 40S	Ex. Strong Steel Pipe 80S	Copper Tube Type K	Copper Tube Type L	Copper Tube Type M	85 Red Brass & SPS Copper Pipe
1	6'-6"	6'-6"	5'-0"	4'-9"	4'-6"	5'-6"
1½	7'-6"	7'-9"	5'-9"	5'-6"	5'-6"	6'-6"
2	8'-6"	8'-6"	6'-6"	6'-6"	6'-3"	7'-0"
2½	9'-3"	9'-6"	7'-3"	7'-0"	7'-0"	8'-0"
3	10'-3"	10'-6"	7'-9"	7'-6"	7'-6"	8'-9"
3½	11'-0"	11'-0"	8'-3"	8'-3"	8'-0"	9'-3"
4	11'-6"	11'-9"	9'-0"	8'-9"	8'-6"	9'-9"
5	12'-9"	13'-0"	10'-0"	9'-6"	9'-6"	10'-9"
6	13'-9"	14'-0"	10'-9"	10'-6"	10'-3"	11'-6"
8	15'-6"	16'-0"				
10	17'-0"	17'-6"				
12	18'-3"	19'-0"				

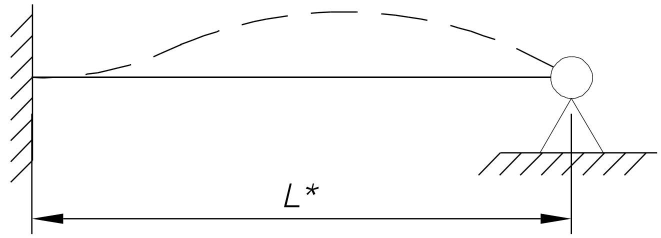
**Maximum unsupported or unbraced lengths (L) are based on water-filled pipes with period (T_a) equal to 0.05 Sec. Where*

$$L^2 = 0.50pT_a\sqrt{\frac{EIg}{w}}$$ *, in. or mm*

1 inch = 25mm
1 foot = 0.3m

E **=** *Modulus of Elasticity of Pipe, psi or MPa*
I = *Moment of Inertia of Pipe, in^4 or mm^4*
w = *Weight Per Unit Length of Pipe and Water, lbs/in. or N/mm*

Figure 10-5. Maximum span for rigid pipe pinned-pinned.



Diameter Inches	Std. Wt. Steel Pipe 40S	Ex. Strong Steel Pipe 80S	Copper Tube Type K	Copper Tube Type L	Copper Tube Type M	85 Red Brass & SPS Copper Pipe
1	8'-0"	8'-0"	6'-0"	6'-0"	5'-9"	6'-9"
1½	9'-6"	9'-6"	7'-3"	7'-0"	7'-0"	8'-0"
2	10'-6"	10'-9"	8'-0"	8'-0"	8'-9"	9'-0"
2½	11'-9"	11'-9"	9'-0"	8'-9"	8'-6"	9'-9"
3	12'-9"	13'-0"	9'-9"	9'-6"	9'-3"	10'-9"
3½	13'-6"	14'-0"	10'-6"	10'-3"	10'-0"	11'-6"
4	14'-6"	14'-9"	11'-0"	11'-0"	10'-9"	12'-3"
5	16'-0"	16'-3"	12'-3"	12'-0"	11'-9"	13'-3"
6	17'-0"	17'-9"	13'-6"	13'-0"	12'-9"	14'-3"
8	19'-3"	20'-0"				
10	21'-3"	22'-0"				
12	23'-0"	23'-6"				

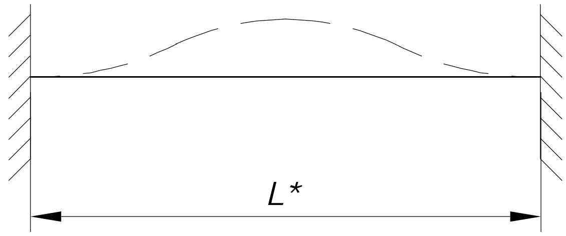
**Maximum unsupported or unbraced lengths (L) are based on water-filled pipes with period (T_a) equal to 0.05 Sec. Where*

$$L^2 = 0.78pT\sqrt{\frac{EIg}{w}}$$

1 inch = 25mm
1 foot = 0.3m

See Figure 10-5 for Notations

Figure 10-6. Maximum span for rigid pipe fixed-pinned.



Diameter Inches	Std. Wt. Steel Pipe 40S	Ex. Strong Steel Pipe 80S	Copper Tube Type K	Copper Tube Type L	Copper Tube Type M	85 Red Brass & SPS Copper Pipe
1	9'-6"	9'-6"	7'-3"	7'-3"	7'-0"	8'-0"
1½	11'-6"	11'-6"	8'-6"	8'-6"	8'-3"	9'-9"
2	12'-9"	13'-0"	9'-9"	9'-6"	9'-6"	10'-9"
2½	14'-0"	14'-3"	10'-9"	10'-6"	10'-6"	11'-9"
3	15'-6"	15'-9"	11'-9"	11'-6"	11'-3"	13'-0"
3½	16'-6"	16'-9"	12'-6"	12'-3"	12'-0"	14'-0"
4	17'-3"	17'-9"	13'-6"	13'-0"	13'-0"	14'-9"
5	19'-0"	19'-6"	15'-0"	14'-6"	14'-3"	16'-0"
6	20'-9"	21'-3"	16'-3"	15'-9"	15'-6"	17'-3"
8	23'-3"	24'-3"				
10	25'-9"	26'-6"				
12	27'-6"	28'-6"				

**Maximum unsupported or unbraced lengths (L) are based on water-filled pipes with period (T_a) equal to 0.05 Sec. Where*

$$L^2 = 1.125 p T_a \sqrt{\frac{EIg}{w}}$$

1 inch = 25mm
1 foot = 0.3m

See Figure 10-5 for Notations

Figure 10-7. Maximum span for rigid pipe fixed-fixed

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The design criteria presented herein apply to either cantilever or singly guyed stacks. All stacks designed under the provisions of this paragraph must have a constant moment of inertia. Stacks having a slightly varying moment of inertia will be treated as having a uniform moment of inertia with a value equal to the average moment of inertia.

(1). Stacks on buildings. Stacks that extend more than 15 feet (4.6m) above a rigid attachment to the building will be designed according to the criteria for cantilever stacks prescribed below. Stacks that extend less than 15 feet (4.6m) will be designed for the equivalent static lateral force prescribed in Section 6.3.11 of FEMA 302.

(a) Cantilever stacks.

1. The fundamental period of the stack will be determined from the period coefficient (i.e., C = 0.0909) provided in Figure 10-9, unless actually computed.

2. The dynamic response may be calculated from the appropriate base shear equations for the Equivalent Lateral Force procedure prescribed in Chapter 3.

(b) Guyed stacks. The analysis of guyed stacks depends on the relative rigidities of the cantilever resistance and the guy wire support system. If the wires are very flexible, the stack will respond in a manner similar to the higher modes of vibration of a cantilever, with periods and mode shapes similar to those shown on Figure 10-9. The fundamental period of vibration of the guyed system will be somewhere between the values for the fundamental and the appropriate higher mode of a similar cantilever stack. An illustration for a single-guyed stack is shown in Figure 10-10. The design of guyed stacks is beyond the scope of this manual.

1. Stacks on the ground. Where stack foundations are in contact with the ground and the stack is not supported by the building, the stack will be considered to be a non-building structure governed by other agency documents.

2. Anchor bolts. Anchor bolts for moment-resisting stack bases should be as long as possible. A great deal more strain energy can be absorbed with long anchor bolts than with short ones. The use of these long anchor bolts has been demonstrated to give stacks better earthquake performance. In some cases, a pipe sleeve is used in the upper portion of the anchor bolt to ensure a length of unbonded bolt for strain energy absorption. When this type of detail is used, provisions will be made for shear transfer (e.g., shear keys). The use of two nuts on anchor bolts is also recommended to provide an additional factor of safety.

g. Bridges, Cranes, and Monorails. In addition to the normal horizontal loads prescribed by the various other applicable government criteria, the design of bridge cranes and monorails will also include an investigation of lateral seismic forces and deformations as set forth in this paragraph.

(1) Equivalent static force. A lateral force equal to $0.5S_{DS}\ a_P$ times the weight of the bridge crane of monorail will be statically applied at the

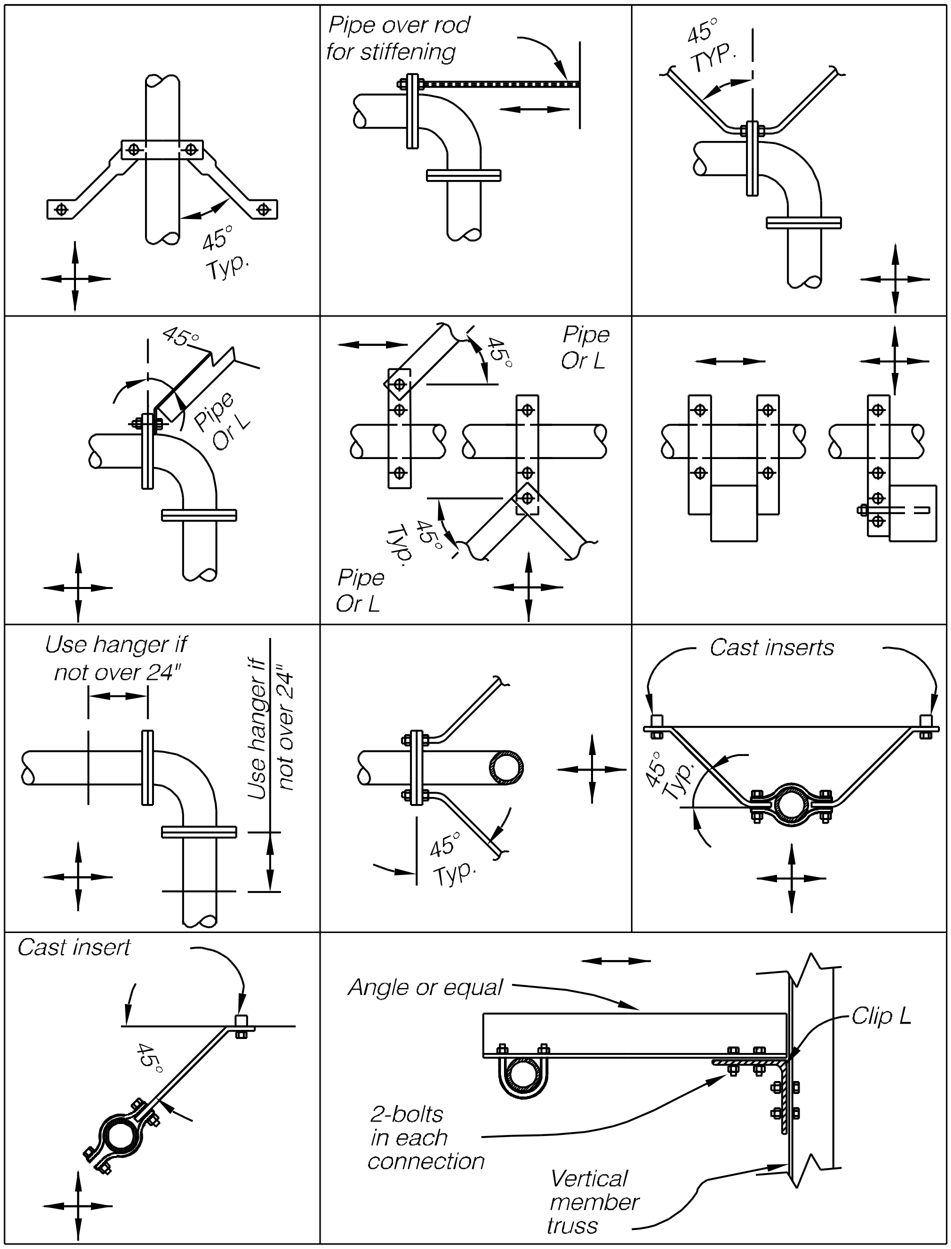
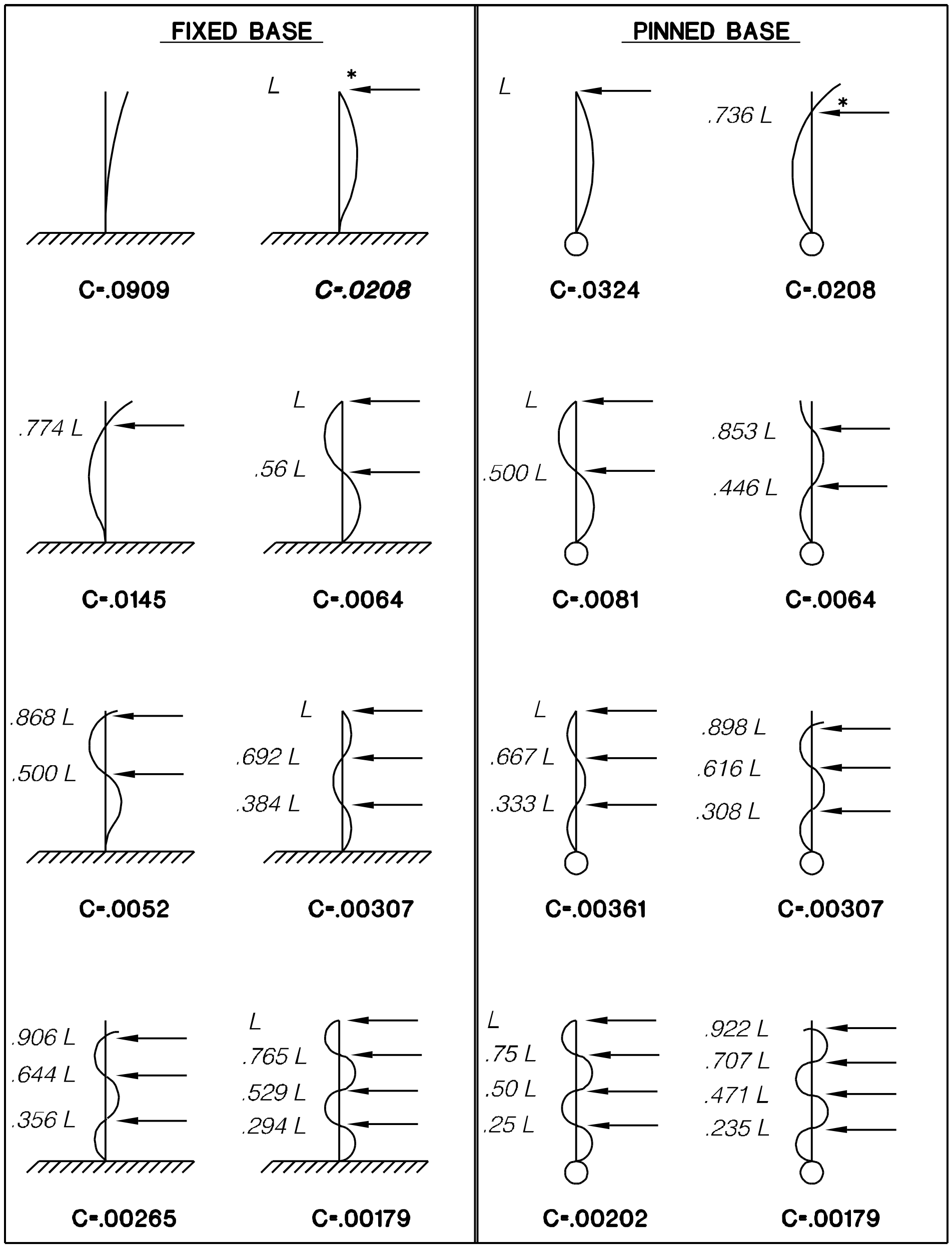


Figure 10-8 Acceptable seismic details for sway bracing.



$$T_a = C\sqrt{\frac{wL^4}{EI}}$$

T_a = Fundament period (sec)
w = Weight per unit length of beam (lb/in) (N/mm)
L = Total beam length (in) (mm)
I = Moment of inertia (in^4) (mm^4)
E = Modulus of elasticity (psi) (MPa)
C = Period constant

Figure 10-9 Period coefficients for uniform beams.

center of gravity of the equipment. This equivalent static force will be considered to be applied in any direction. a_P will be equal to 1.50.

(2) Weight of equipment. The weight of such equipment, W_P, need not include any live load, and the equivalent static force so computed will be assumed to act non-concurrently with other prescribed non-seismic horizontal forces when considering the design of the crane and monorails. When considering the design of the building, the weight of the equipment will be included with the weight of the building.

h. Elevators. Power-cable-driven elevators and hydraulic elevators with lifts over 5 feet (1.5m) will be designed for lateral force set forth in this chapter.

(1) Elements of the elevator support system. All elements that are part of the elevator support system, such as the car and counterweight frames, guide rails, supporting brackets and framing, driving machinery, operating devices, and control equipment, will be investigated for the prescribed lateral seismic forces (see Figure 10-11).

(2) Equivalent static forces. The lateral seismic forces will conform to the applicable provisions of Paragraphs 10-3b and 10-3c.

(a) The car and counterweight frames, roller guide assembly, retainer plates, guide rails, and supporting brackets and framing will be designed in accordance with Section 6.3.2 of FEMA 302. The lateral forces acting on the guide rails will be assumed to be distributed one-third to the top guide rollers and two-thirds to the bottom guide rollers of elevator cars and counterweights. The elevator car and/or counterweight will be assumed to be located at its most adverse position in relation to the guide fails and support brackets. Horizontal deflections of guide rails will not exceed ½ inch (12.7mm) between supports, and horizontal deflections of the brackets will not exceed ¼ inch (6.4mm).

1. In structures conforming to Seismic Design Categories D, E, and F, a retainer plate (auxiliary guide plate) will be provided at top and bottom of both car and counterweight. The clearances between the machined faces of the rail and the retainer plate will not be more than 3/16 inch (4.8mm), and the engagement of the rail will not be less than the dimension of the machined side face of the rail. When a car safety device attached to the lower members of the car frame complies with the lateral restraint requirements, a retainer plate is not required for the bottom of the car.

2. For Seismic Design Categories D, E, and F, the maximum spacing of the counterweight rail tie brackets tied to the building structure will not exceed 16 feet (4.9m). An intermediate spreader bracket, not required to be tied to the building structure, will be provided for tie brackets spaced greater than 10 feet (3.0m), and two intermediate spreader brackets are required for tie brackets spaced greater than 14 feet (4.3m).

(b) Machinery and equipment will be designed for a_P = 1.0 in Equation 7-1, when rigid and rigidly attached. Non-rigid or flexibly mounted equipment will be designed with $a_P = 2.5$.

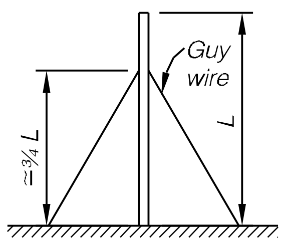
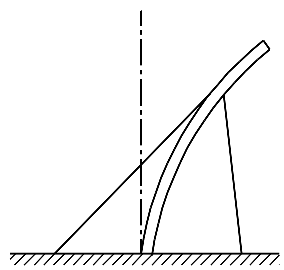
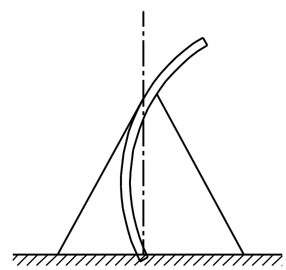
DESCRIPTION	DEFLECTED SHAPE	
	FLEXIBLE WIRE	RIGID WIRE
		

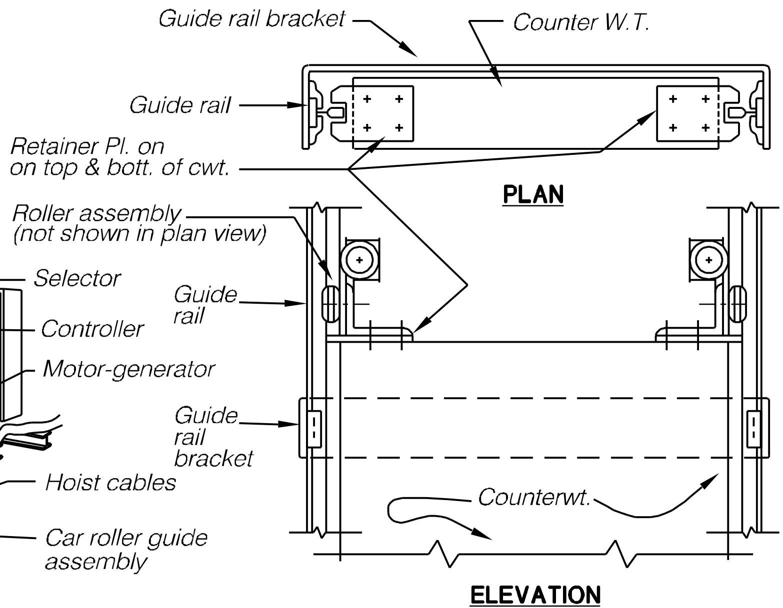
Figure 10-10 Single guyed-stack.

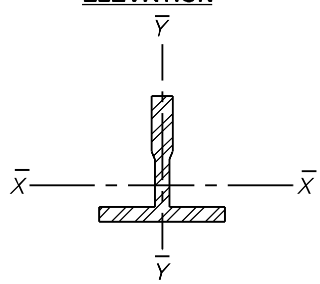
i. Typical Details for Securing Equipment. See Figures 10-12 and 10-13 for examples of seismic restraints for equipment.

10-4. Acceptance Criteria.

a. Performance Objective 1A. The acceptance criteria for nonstructural components in Performance Objective 1A is conformance with the requirements of Chapter 6 of FEMA 302, with the importance factor, I_P, equal to 1.0, and as modified by this document. The required seismic forces are represented by Equation, 10-1, 10-2, and 10-3.

b. Enhanced Performance Objective. Performance Objective 1A is the minimum requirement for all nonstructural components. Buildings that are designed for enhanced performance objective, shall identify critical nonstructural components that require enhanced performance. The enhanced performance shall be achieved by compliance with the criteria prescribed in this chapter, with *Ip* selected from Paragraph 10-1d and with S_{DS} from Ground Motion A or B, as appropriate.



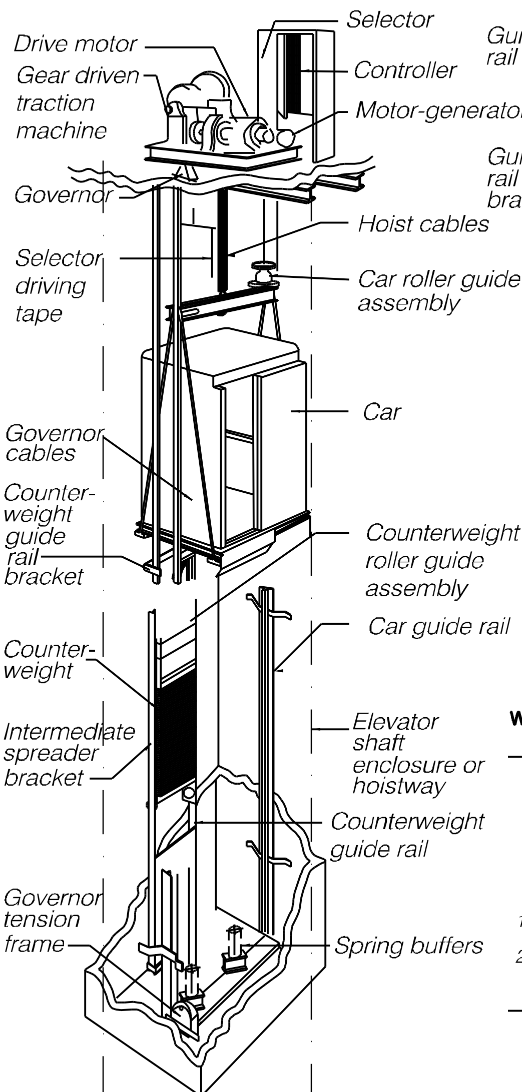


Section Properties of Elevator Guide Rails

Nom. Wt. per Foot	A	$\overline{y}$	I_x	S_x	r_x	I_y	S_y	r_y
8	2.40	0.81	1.40	0.86	0.78	1.28	0.73	0.74
11	3.24	1.12	4.29	1.80	1.15	2.67	1.19	0.90
12	3.51	1.08	4.49	1.85	1.13	3.61	1.45	1.01
15	4.41	0.97	4.78	1.89	1.04	5.51	2.21	1.12
18.5	5.44	1.26	9.67	3.23	1.33	7.45	2.71	1.17
22.5	6.73	1.38	11.17	4.20	1.28	8.64	3.10	1.13
30	8.93	1.74	24.00	7.37	1.64	11.08	4.03	1.11

A = Area (in.^{2})
$\overline{y}$ = Distance from back of rail to axis x-x (in.)
I_x = Moment of inertia about axis x-x (in.^{4})
S_x = Section modulus about axis x-x (in.^{3})
r_x = Radius of gyration about axis x-x (in.)
I_y = Moment of inertia about axis y-y (in.^{4})
S_y = Section modulus about axis y-y (in.^{3})
r_y = Radius of gyration about axis y-y (in.)

1 inch = 25mm



TRACTION TYPE ELEVATOR

Figure 10-11 Elevator Details

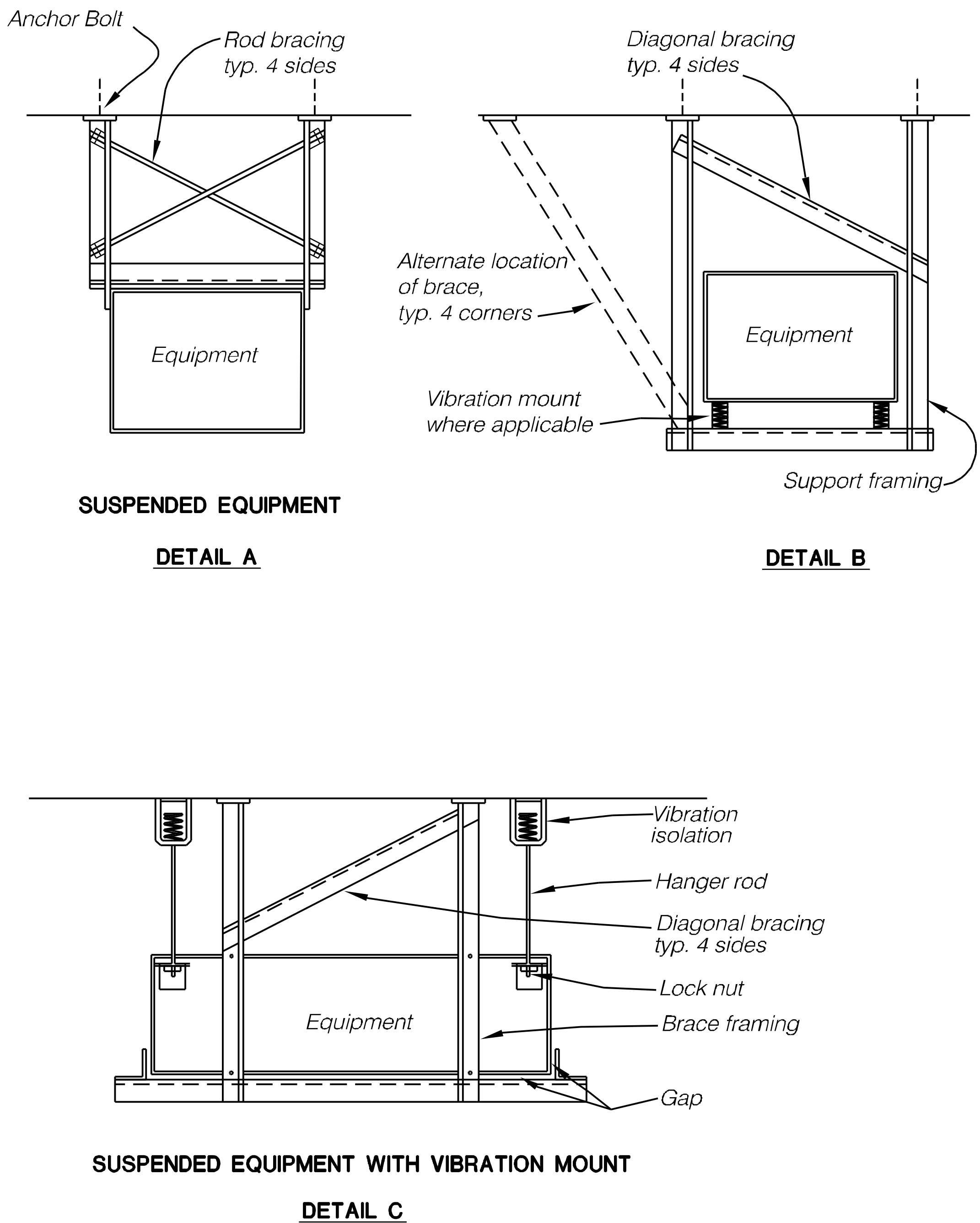
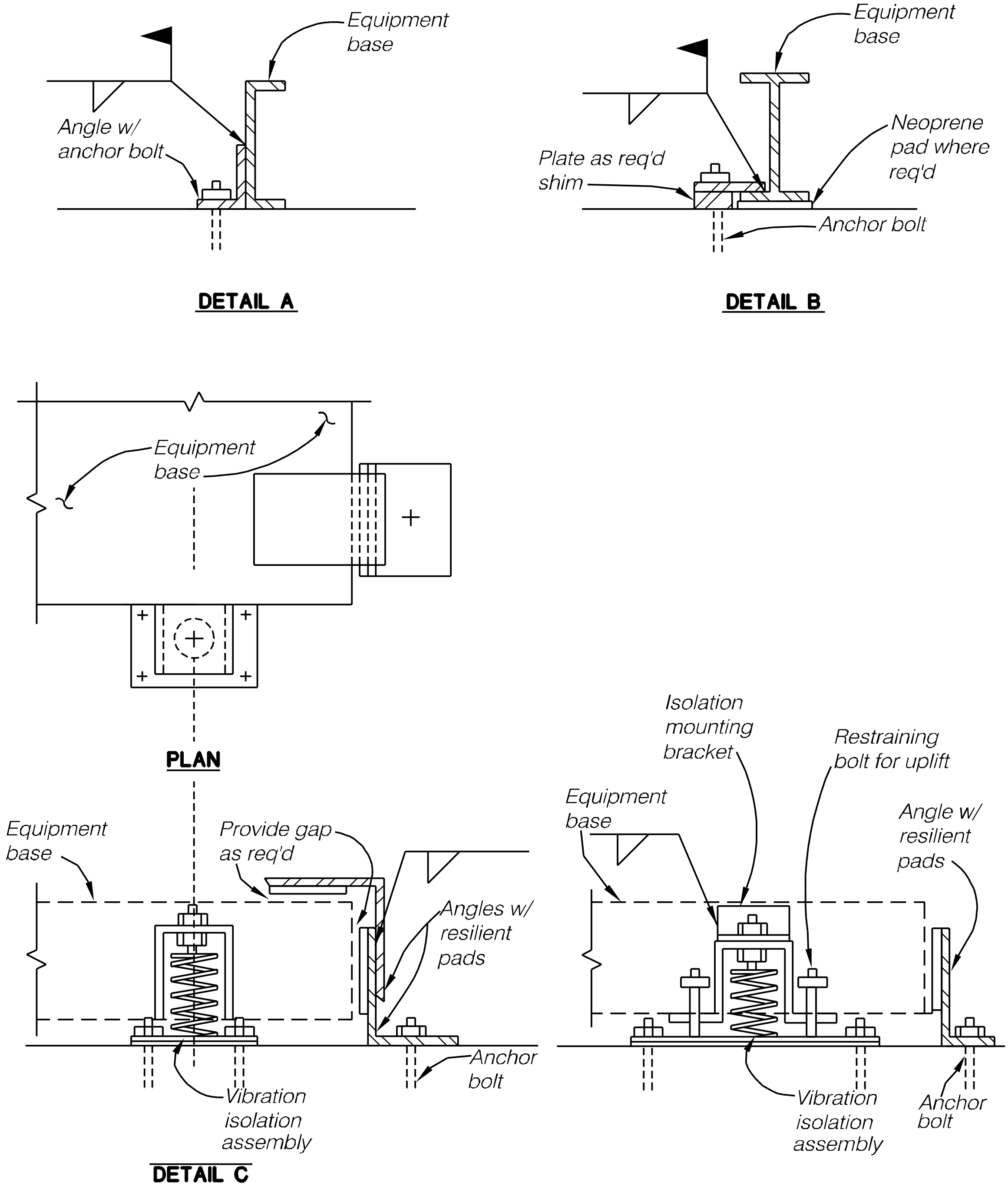


Figure 10-12 Typical seismic restraint of hanging equipment.



RESTRAINTS FOR LATERAL AND VERTICAL LOADS

Figure 10-13 Typical seismic restraint of floor-mounted equipment.