4.8 Procedures for Nonstructural Components

This section provides Tier 2 Evaluation Procedures that apply to nonstructural components.

Commentary:

Nonstructural Components

"Nonstructural" is the name given by design professionals to those architectural, mechanical and electrical components that are delineated on the construction documents, and where additional guidance may be requested from another design professional with expertise in the design of structural components.

Investigation of nonstructural components can be very time consuming because they usually are not well detailed on plans and because they often are concealed. It is essential, however, to investigate these items because their seismic support may have been given little attention in the past and they are potentially dangerous. Of particular importance in nonstructural component evaluation efforts are site visits to identify the present status of nonstructural items.

For nonstructural component evaluation in general, the key issue is generally whether the component or piece of equipment is braced or anchored. This is generally immediately visible, and is part of the Tier 1 evaluation. If the component is braced or anchored a Tier 2 evaluation may be necessary (based on the design professional's judgment) to establish the capacity of the components. Evaluation of cladding, exterior veneers, back-up materials and glazing requires more careful investigation, because the critical components, such as connections and framing, will often be concealed. In some cases it will be necessary to remove materials in order to conduct the evaluation. In addition, some calculations may be necessary to establish capacity to accommodate estimated seismic forces.

Several different types of deficiencies may be identified by the design professional in the Tier 1 evaluation. Some of these, such as the non existence of anchorage or bracing are clearly non-complying and any further evaluation is not necessary. In other cases, where some bracing or anchorage is provided, or material is deteriorated or corroded, further evaluation and judgment is necessary to ascertain the extent of the deficiency and the consequences of failure. Some simple calculations of weights, dimensional ratios and forces are used in this Tier of evaluation. A few critical components, such as heavy cladding, may justify a complete analysis (a Tier 3 evaluation) for ability to withstand forces and drifts and achievement of the desired performance level

Hazards

Nonstructural elements can pose significant hazards to life safety under certain circumstances. In addition, certain types of building contents can pose hazards (e.g., toxic chemicals) and should be given attention during the evaluation. Special consideration also is warranted for nonstructural elements in essential facilities (e.g., hospitals, police and fire stations) and other facilities that must remain operational after an earthquake.

Unintended Structural Effects

Any element with rigidity will be a part of the lateral-force resisting system until it fails. All walls have some rigidity, and they will participate in resisting lateral forces in proportion to their relative rigidity. Walls of gypsum board or plaster have considerable rigidity. If connected at top and bottom, they can take a significant portion of the lateral load at low force levels; at some higher level they crack and lose strength and the main system then takes all of the lateral load.

4.8.1 Partitions

4.8.1.1 UNREINFORCED MASONRY: Unreinforced masonry or hollow clay tile partitions shall be braced at a spacing of equal to or less than 10 feet in regions of low and moderate seismicity and 6 feet in regions of high seismicity.

Tier 2 Evaluation Procedure: The adequacy of the bracing to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Hollow clay tile units are brittle and subject to shattering. Unreinforced masonry units may have cracks, loose blocks, or weak mortar. Bracing is needed to prevent portions of the unreinforced masonry from dislodging due to out-of-plane seismic forces. Door openings often create localized weaknesses due to inadequate support for the block masonry or clay tile at the head and at the sides of the opening.

If bracing is non-existent, mitigation with elements or connections needed to brace the partitions is necessary to achieve the selected performance level.

4.8.1.2 DRIFT: The drift ratio for masonry partitions shall be limited to 0.005.

Second Tier 2 Evaluation Procedure: The adequacy of masonry partitions to resist expected levels of drift calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Full-height partitions may fail due to lack of provision for building drift. Masonry partitions should be detailed to provide adequate space for the structure to drift without racking the masonry walls, while retaining out-of-plane support. In addition, if not separated from the structure at the top and sides, the masonry walls may alter the response of the building.

4.8.1.3 STRUCTURAL SEPARATIONS: Partitions at structural separations shall have seismic or control joints.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for partitions at structural separations without seismic or control joints.

Commentary:

Seismic and control joints are necessary to permit differential structural movement at building separations. If localized cracking of the partition will not lead to out-of-plane failure of the wall, the costs of a difficult rehabilitation process may not be justified.

4.8.1.4 TOPS: The tops of framed or panelized partitions that extend only to the ceiling line shall have lateral bracing to the building structure at a spacing of equal to or less than 6 feet.

Tier 2 Evaluation Procedure: The adequacy of the lateral bracing to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Partitions extending only to suspended ceilings may fall out-of-plane due to lack of bracing. Movement of the partition may damage the ceiling. Crosswalls that may frame into the wall will have a beneficial impact on preventing excessive out-of-plane movement and should be considered in the evaluation process.

If lateral bracing is non-existent, mitigation with elements or connections needed to brace the partitions is necessary to achieve the selected performance level.

4.8.2 Ceiling Systems

4.8.2.1 INTEGRATED CEILINGS: Integrated suspended ceilings at exitways and corridors or weighing more than 2 lb/ft^2 shall be laterally restrained with a minimum of 4 diagonal wires or rigid members attached to the structure above at a spacing of equal to or less than 12 ft.

Tier 2 Evaluation Procedure: The adequacy of the bracing to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Without bracing, integrated ceiling systems are susceptible to vertical and lateral movement which can damage fire sprinkler piping and other elements that penetrate the ceiling grid. Lightweight suspended ceilings may not pose a life safety hazard unless special conditions apply in the judgment of the design professional, such as a large area of ceiling, poor quality construction, vulnerable occupancy, or egress route.

If bracing is non-existent, mitigation with elements or connections needed to brace the ceilings is necessary to achieve the selected performance level.

4.8.2.2 LAY-IN TILES: Lay-in tiles used in ceiling panels located at exitways and corridors shall be secured with clips.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for non-compliant lay-in tiles.

Commentary:

Lay-in board or tile ceilings may drop out of the grid and depending on their location and weight could cause injury. In egress areas, falling tile represents a hazard because it may pile up on the floor and slow evacuations. Clips can reduce the likelihood of tiles falling, but depending on the type of ceiling, the likelihood of failure may vary; the design professional should use judgment in assessing the risk.

4.8.2.3 SUPPORT: The integrated suspended ceiling system shall not be used to laterally support the tops of gypsum board, masonry, or hollow clay tile partitions.

Tier 2 Evaluation Procedure: The adequacy of integrated ceiling systems used to laterally support the tops of gypsum board, masonry, or hollow clay tile partitions to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Integrated suspended ceilings braced with diagonal wires will move laterally when subjected to seismic forces. The ability of the gypsum board, masonry or hollow clay tile partitions to accommodate such movement without collapse should be considered by the design professional.

4.8.2.4 SUSPENDED LATH AND PLASTER: Ceilings consisting of suspended lath and plaster shall be anchored for every 10 square feet of area.

Tier 2 Evaluation Procedure: The adequacy of the anchorage to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Suspended plaster ceilings may behave like structural diaphragms and resist in-plane seismic forces. If the strength of the plaster is exceeded, cracking and spalling of portions of the ceiling are possible. Large areas of suspended plaster may separate from the suspension system and fall if not properly fastened. The interconnection of the plaster to the lath and lath to the support framing should also be specifically assessed.

If anchorage is non-existent, mitigation with elements or connections needed to brace the ceilings is necessary to achieve the selected performance level.

4.8.2.5 EDGES: The edges of integrated suspended ceilings shall be separated from enclosing walls by a minimum of 1/2 inch.

Tier 2 Evaluation Procedure: The adequacy of integrated suspended ceilings to resist expected levels of drift calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

This provision relates especially to large suspended grid ceilings, but may also apply to other forms of hung ceilings. The intent is to ensure that the ceiling is sufficiently detached from the surrounding structural walls that it can tolerate out-of-plane drift without suffering distortion and damage.

4.8.2.6 SEISMIC JOINT: The ceiling system shall not extend continuously across any seismic joint.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for ceiling systems that extend continuously across any seismic joint.

Commentary:

Localized damage to ceilings is expected where seismic separations are not provided in the ceiling framing. Seismic or control joints should be provided based on a consideration of the consequences of local ceiling damage. If the damage is unlikely to create a falling hazard or prevent safe egress, the costs of a difficult rehabilitation process may not be justified.

4.8.3 Light Fixtures

4.8.3.1 INDEPENDENT SUPPORT: Light fixtures in suspended grid ceilings shall be supported independently of the ceiling suspension system by a minimum of two wires at diagonally opposite corners of the fixtures.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for light fixtures not independently supported.

Commentary:

With lay-in fluorescent lighting systems, ceiling movement can cause fixtures to separate and fall from suspension systems. These fixtures perform satisfactorily when they are supported separately from the ceiling system or have back-up support that is independent of the ceiling system. If the fixtures are independently supported by methods other than that described, design professional should exercise judgment as to its efficacy.

If independent support is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.3.2 EMERGENCY LIGHTING: Emergency lighting shall be anchored or braced to prevent falling or swaying during an earthquake.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for emergency lighting that is not braced or anchored.

Commentary:

Emergency lighting should be provided with positive anchorage and/or bracing to prevent falling hazards and to enhance the reliabilty of post-earthquake performance.

If bracing or anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.3.3 PENDANT SUPPORTS: Light fixtures on pendant supports shall be attached at a spacing of equal to or less than 6 ft. and, if rigidly supported, shall be free to move without damaging adjoining materials.

Tier 2 Evaluation Procedure: The adequacy of the anchorage to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

With stem-hung incandescent or fluorescent fixtures, the fixtures are usually suspended from stems or chains that allow them to sway. This swaying may cause the light and/or fixture to break after encountering other building components. The stem or chain connection may fail. Long rows of fluorescent fixtures placed end to end have sometimes fallen due to poor support, and their weight makes them hazardous. Long-stem fixtures, which may swing considerably, tend to suffer more damage than short-stem items.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.3.4 LENS COVERS: Lens covers on fluorescent light fixtures shall be attached or shall be supplied with safety devices.

Tier 2 Evaluation Procedure: The adequacy of lens covers on fluorescent light fixtures to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Devices or detailing to prevent lens covers from falling from the fixture are a necessary safety feature.

4.8.4 Cladding and Glazing

4.8.4.1 CLADDING ANCHORS: Cladding components weighing more than 10 psf shall be anchored to the exterior wall framing at a spacing equal to or less than 6 ft. for Life Safety and 4 ft. for Immediate Occupancy.

Tier 2 Evaluation Procedure: The adequacy of the anchorage to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated. The adequacy of cladding components to resist expected levels of drift calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Exterior cladding components, which are often heavy, can fail if their connections to the building frames have insufficient strength and/or ductility. The design professional should assess the consequences of failure, in particular the location of the panels in relation to building occupants and passers-by.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.4.2 CLADDING ISOLATION: For moment frame buildings of steel or concrete, panel connections shall be detailed to accommodate a drift ratio of 0.02 for Life Safety and 0.01 for Immediate Occupancy.

Tier 2 Evaluation Procedure: The adequacy of panel connections to resist expected levels of drift calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:
High levels of drift and deformation may occur in moment frames. If cladding connections are not detailed to accomodate the drift, failure of connections can result and panels can become dislodged.

4.8.4.3 MULTISTORY PANELS: For multistory panels attached at each floor level, the panels and connections shall be able to accommodate a drift ratio of 0.02 for Life Safety and 0.01 for Immediate Occupancy.

Tier 2 Evaluation Procedure: The adequacy of the panels and connections to resist expected levels of drift calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:
The design professional should determine whether the panels themselves and/or their connections to the structure will deform to accommodate the interstory drift. If the connectors are expected to deform, they should be capable of doing so without loss of structural support for the panel. If the panels are expected to rack, they should be capable of deforming without becoming unstable and without loss of support for other interconnected systems such as glazing.

4.8.4.4 BEARING CONNECTIONS: Where bearing connections are required, there shall be a minimum of two bearing connections for each wall panel.

Tier 2 Evaluation Procedure: The adequacy of the connection to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:
A single bearing connection can result in a dangerous lack of redundancy. The adequacy of single point bearing connections should be evaluated for resistance to in-plane overturning forces including all eccentricities. Small panels such as some column covers may have a single bearing connection, and still provide adequate safety against failure.

If connections are non-existent, mitigation is necessary to achieve the selected performance level.

4.8.4.5 INSERTS: Where inserts are used in concrete connections, the inserts shall be anchored to reinforcing steel.

Tier 2 Evaluation Procedure: The adequacy of inserts used in concrete connections to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:
Out-of-plane panel connections which do not engage panel reinforcement are susceptible to pulling out when subjected to seismic forces.

4.8.4.6 PANEL CONNECTIONS: Exterior cladding panels shall be anchored out-of-plane with a minimum of 2 connections for each wall panel for Life Safety and 4 connections for Immediate Occupancy.

Tier 2 Evaluation Procedure: The adequacy of the connections to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:
A minimum of two connections are generally required for stability in resisting out-of-plane earthquake forces. Evaluation of connection adequacy should include consideration of all connection eccentricities.

If connections are non-existent, mitigation is necessary to achieve the selected performance level.

4.8.4.7 DETERIORATION: There shall be no evidence of deterioration or corroding in any of the connection elements.

Tier 2 Evaluation Procedure: The adequacy of the remaining undeteriorated or undamaged connections to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Corrosion can reduce the strength of connections and lead to deterioration of the adjoining materials. The extent of corrosion and its impact on the wall cladding and structure should be considered in the evaluation.

4.8.4.8 DAMAGE: There shall be no damage to exterior wall cladding.

Tier 2 Evaluation Procedure: The extent and consequences of damage to exterior wall cladding shall be evaluated.

Commentary:

Water leakage into and through exterior walls is a common building problem. Damage due to corrosion, rotting, freezing, or erosion can be concealed in wall spaces. Substantial deterioration can lead to loss of cladding elements or panels.

Exterior walls should be checked for deterioration. Probe into wall spaces if necessary and look for signs of water leakage at vulnerable locations (e.g., at windows and at floor areas). Pay particular attention to element that tie cladding to the back-up structure and that tie the back-up structure to the floor and roof slabs.

Extremes of temperature can cause substantial structural damage to exterior walls. The resulting weakness may be brought out in a seismic event. Check exterior walls for cracking due to thermal movements.

4.8.4.9 GLAZING: Glazing in curtain walls and individual panes over 16 square feet in area, located up to a height of 10 feet above an exterior walking surface, shall be laminated annealed or heat strengthened safety glass that will remain in the frame when cracked.

Tier 2 Evaluation Procedure: Glazing in curtain walls and individual panes over 16 square feet in area shall be shown by analysis or dynamic racking testing to be detailed to accommodate expected levels of drift calculated in accordance with Section 4.2.7.

Commentary:

Glazing may shatter and fall due to lack of provision for building drift or racking. If it is safety glazing with racking capability it may shatter or crack in a manner that is unlikely to cause injury, and it may remain in the frame to provide a temporary weather barrier. Glass generally fails in earthquakes because of deformation of the frame and lack of space between the glass and frame to allow for independent movement. Special attention should be given to glazing over or close to entrance and exitways.

4.8.5 Masonry Veneer

4.8.5.1 SHELF ANGLES: Masonry veneer shall be supported by shelf angles or other elements at each floor above the first floor.

Tier 2 Evaluation Procedure: The adequacy of masonry veneer anchors to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Inadequately fastened masonry vaneer can pose a falling hazerd if it peels away from its backing. Judgment may be needed to assess the adequacy of various attachments that may be used.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.5.2 TIES: Masonry veneer shall be connected to the back-up with corrosion-resistant ties. The ties shall have a spacing of equal to or less than 36" for Life Safety and 24" for Immediate Occupancy with a minimum of one tie for every 2-2/3 square feet

Tier 2 Evaluation Procedure: The adequacy of the masonry veneer ties to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

4.8.5.3 WEAKENED PLANES: Masonry veneer shall be anchored to the back-up at weakened planes such as at the locations of flashing.

Commentary:

Inadequaetley fastened masonry vaneer can pose a falling hazerd if it peels away from its backing. Judgment may be needed to assess the adequacy of various attachments that may be used.

If ties are non-existent, mitigation is necessary to achieve the selected performance level.

Tier 2 Evaluation Procedure: The adequacy of masonry veneer anchors at weakened planes created by flashing or other discontinuities shall be evaluated. Anchors shall be evaluated for resistance to seismic forces calculated in accordance with Section 4.2.7.

Commentary:

Inadequate attachment at locations of wall discontinuities is a potential source of weakness. Such discontinuities can be created by base flashing or architectural reveals. In areas of high seismicity, masonry veneer should be anchored to the back-up system immediately above the weakened plane..

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.5.4 MORTAR: The mortar in masonry veneer shall not be easily scraped away from the joints by hand with a metal tool, and there shall not be significant areas of eroded mortar.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for non-compliant mortar.

Commentary:

Inadequate mortar will affect the veneer's ability to withstand seismic motions and maintain attachment to the back-up system.

If mortar is non-compliant, mitigation is necessary to achieve the selected performance level.

4.8.5.5 WEEP HOLES: Weep holes shall be present and base flashing shall be installed.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for non-compliant weep holes.

Commentary:

Absence of weep holes and flashing indicates an inadequately detailed veneer. Water intrusion can lead to deterioration of the veneer and/or substrate. Destructuve investigation may be needed to evaluate whether deterioration has taken place and mitigation is necessary.

If weep holes are non-compliant, mitigation is necessary to achieve the selected performance level.

4.8.5.6 CORROSION: Corrosion of veneer ties, tie screws, studs, and stud tracks shall be minimal.

Tier 2 Evaluation Procedure: The calculated tensile stresses in the veneer shall not exceed the allowable stresses for unreinforced brick as defined by ACI 530. Seismic forces shall be calculated in accordance with Section 4.2.7.

Commentary:

Corroded connections are a both a general and a seismic hazard that can cause veneer to become dislodged.

4.8.5.7 STONE PANELS: Stone panels less than 2 inches nominal thickness shall be anchored every 2 square feet of area.

Tier 2 Evaluation Procedure: The adequacy of stone panel anchors to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Stone panels are relatively heavy and may become dislodged during an earthquake if not adequately anchored.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.5.8 CRACKS: There shall be no visible cracks or weak veins in the stone.

Tier 2 Evaluation Procedure: The extent and consequences of visible cracking shall be evaluated.

Commentary:

Cracking in the panel, depending on the material, may be due to weathering, or to stresses imposed by movement of the structure or connection system. Severely cracked panels will probably require replacement.

4.8.6 Metal Stud Back-up Systems

4.8.6.1 STUD TRACKS: Stud tracks shall be fastened to the structural frame at a spacing of equal to or less than 24 inches on center.

Tier 2 Evaluation Procedure: The adequacy of stud track fasteners to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Without proper anchorage at top and bottom tracks, metal stud back-up systems are susceptible to excessive movement during an earthquake.

If fasteners are non-existent, mitigation is necessary to achieve the selected performance level.

4.8.6.2 OPENINGS: Additional steel studs shall frame window and door openings.

Tier 2 Evaluation Procedure: The adequacy of window and door framing shall be evaluated.

Commentary:

This issue is primarily one of the general framing system of the building. Absence of adequate framing around openings indicates a possible out-of-plane weakness in the framing system.

4.8.7 Concrete Block and Masonry Back-up Systems

4.8.7.1 CONCRETE BLOCK: Concrete block back-up shall qualify as reinforced masonry.

Tier 2 Evaluation Procedure: The ability of concrete block back-up that does not qualify as reinforced masonry to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

To qualify as reinforced masonry, the reinforcing steel shall be greater than 0.002 times the gross area of the wall with a minimum of 0.0007 in either of the two directions; the spacing of reinforcing steel shall be less than 48 inches; and all vertical bars shall extend to the top of the back-up walls.

Judgment by the design professional must be used to evaluate the adequacy of concrete block walls not classified as "reinforced". Concrete block walls lacking the minimum reinforcement may be susceptible to excessive in-plane cracking under seismic loads and portions of the wall may become dislodged.

4.8.7.2 BACK-UP: Concrete block back-up shall be anchored to the structural frame at a spacing of equal to or less than 4 feet along the floors and roof.

Tier 2 Evaluation Procedure: The adequacy of the concrete block back-up to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

4.8.7.3 URM BACK-UP: There shall not be any unreinforced masonry back-up.

Commentary:

Inadequate anchorage of the back-up wall may affect the whole assembly's ability to withstand seismic motions and maintain attachment to back-up.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

Tier 2 Evaluation Procedure: The adequacy of unreinforced masonry to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Unreinforced masonry back-up is common in early steel framed buildings with cut stone exteriors. The design professional should use judgment in evaluating the condition and integrity of the back-up and necessary remedial measures.

Complete replacement of back-up is extremely expensive: depending on the state of the installation and the facing materials; alternative methods may be possible.

4.8.8 Parapets, Cornices, Ornamentation and Appendages

4.8.8.1 URM PARAPETS: There shall be no laterally unsupported unreinforced masonry parapets or cornices above the highest anchorage level with height-to-thickness ratios greater than 1.5 in regions of high seismicity and 2.5 in regions of low or moderate seismicity.

Tier 2 Evaluation Procedure: The adequacy of the anchorage to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

URM parapets present a major falling hazard and potential life-safety threat.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.8.2 CANOPIES: Canopies located at building exits shall be anchored at a spacing of 10 feet for Life Safety and 6 feet for Immediate Occupancy.

Tier 2 Evaluation Procedure: The adequacy of the anchorage to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Inadequately supported canopies present a life safety hazard. A common form of failure is pullout of shallow anchors from building walls.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.8.3 CONCRETE PARAPETS: Concrete parapets with height-to-thickness ratios greater than 2.5 shall have vertical reinforcement.

Tier 2 Evaluation Procedure: The adequacy of the anchorage to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Inadequately reinforced parapets can be severely damaged during an earthquake.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.8.4 APPENDAGES: Cornices, parapets, signs, and other appendages that extend above the highest anchorage level or cantilever from exterior wall faces and other exterior wall ornamentation shall be reinforced and anchored to the structural system at a spacing of equal to or less than 10 ft. for Life Safety and 6 ft. for Immediate Occupancy.

Tier 2 Evaluation Procedure: The adequacy of the anchorages to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

The above components may vary greatly in size, location and attachment; the design professional should use judgment in their assessment. If any of these items are of insufficient strength and/or are not securely attached to the structural elements, they may break off and fall onto storefronts, streets, sidewalks, or adjacent property and become significant life-safety hazards.

If anchorages are non-existent, mitigation is necessary to achieve the selected performance level.

4.8.9 Masonry Chimneys

4.8.9.1 URM: No unreinforced masonry chimney shall extend above the roof surface more than twice the least dimension of the chimney.

Tier 2 Evaluation Procedure: The adequacy of the chimney anchorage to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Unreinforced masonry chimneys are highly vulnerable to damage in earthquakes. Typically, chimneys extending above the roof more than twice the least dimension of the chimney crack just above the roof line and become dislodged. Chimneys may fall through the roof or on a public or private walkway creating a life-safety hazard. Experience has shown that the costs of rehabilitating masonry chimneys can sometimes exceed the costs of damage repair.

4.8.9.2 MASONRY: Masonry chimneys shall be anchored to the floor and roof.

Tier 2 Evaluation Procedure: The adequacy of the anchorage to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Refer to commentary associated with Section 4.8.9.1.

4.8.10 Stairs

4.8.10.1 URM WALLS: Walls around stair enclosures shall not consist of unbraced hollow clay tile or unreinforced masonry.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unbraced hollow clay tile or unreinforced masonry around stair enclosures.

Commentary:
Hollow tile or unreinforced masonry walls may fail and block stairs and corridors. Post-earthquake evacuation efforts can be severely hampered as a result.

If bracing is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.10.2 STAIR DETAILS: In moment frame structures, the connection between the stairs and the structure shall not rely on shallow anchors in concrete. Alternatively, the stair details shall be capable of accommodating the drift calculated using the Quick Check Prcedure of Section 3.5.3.1 without inducing tension in the anchors.

Tier 2 Evaluation Procedure: The adequacy of stair connections shall be evaluated when subjected to interstory drifts calculated in accordance with Section 4.2.

Commentary:
If stairs are not specially detailed to accommodate interstory drift they can modify structural response by acting as struts attracting seismic force. The connection of the stair to the structure must be capable of resisting the imposed forces without loss of gravity support for the stair.

4.8.11 Building Contents and Furnishing

4.8.11.1 TALL NARROW CONTENTS: Contents with a height-to-depth ratio greater than 3 for Immediate Occupancy and 4 for Life Safety shall be anchored to the floor slab or adjacent walls.

Tier 2 Evaluation Procedure: The adequacy of tall, narrow contents to resist overturning due to seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:
Tall, narrow storage or file cabinets or racks can tip over if they are not anchored to resist overturning forces.

4.8.11.2 FILE CABINETS: File cabinets arranged in groups shall be attached to one another.

Tier 2 Evaluation Procedure: The adequacy of file cabinets to resist overturning due to seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:
File cabinets that are grouped together and attached can virtually eliminate the possibility of overturning; the attachment of these file cabinets to the floor then may not be necessary.

4.8.11.3 DRAWERS: Cabinet drawers shall have latches to keep them closed during an earthquake.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for non-compliant cabinet drawers.

Commentary:
Breakable items stored on shelves should be restrained from falling by latched doors, shelf lips, wires, or other methods. It may not be necessary for every drawer to have a safety latch.

4.8.11.4 COMPUTER ACCESS FLOORS: Computer access floors shall be braced.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unbraced computer access floors.

Commentary:

Unbraced computer access floors can collapse onto the structural slab. Small areas of unbraced floors "captured" on all sides within full-height walls may be acceptable, however, the impact of ramps and or other access openings should be considered in evaluating the adequacy of such unbraced access floors.

If bracing is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.11.5 ACCESS FLOORS: Equipment supported on access floor systems shall be either attached to the structure or fastened to a laterally braced floor system.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unattached equipment supported on access floor systems.

Commentary:

Tall, narrow computers and communications equipment can overturn if not properly anchored. Where overturning is not a concern due to the aspect ratio of the equipment and it is desirable to provide some isolation between the equipment and the structure, it may be acceptable to support the equipment on a raised floor without positive restraint. In this case the consequences of equipment movement should be considered. Tethering or some other form of restraint may be appropriate for limiting the range of movement.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.12 Mechanical and Electrical Equipment

4.8.12.1 EMERGENCY POWER: Equipment used as part of an emergency power system shall be anchored to maintain continued operation following an earthquake.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unanchored equipment used as part of an emergency power system.

Commentary:

Protection of the emergency power system is critical to post-earthquake recovery, and proper mounting of the components of the system is needed for reliable performance.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.12.2 ATTACHED EQUIPMENT: Equipment weighing over 20 pounds that is attached to ceiling, wall, or other support more than 4 feet above the floor shall be braced.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unbraced equipment weighing over 20 pounds.

Commentary:

Equipment located more than 4 feet above the floor poses a falling hazard unless properly anchored and braced. Suspended equipment is more susceptible to damage than floor-, roof-, or wall-mounted equipment. Unbraced suspended equipment can sway during an earthquake causing damage upon impact with other adjacent items.

If bracing is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.12.3 HEAVY EQUIPMENT: Equipment weighing over 100 pounds shall be anchored to the structure or foundation.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unbraced equipment weighing over 100 pounds.

Commentary:

For rigidly mounted large equipment (e.g., boilers, chillers, tanks, generators), inadequate anchorage can lead to horizontal movement. Unanchored equipment, particularly equipment with high aspect ratios such as all tanks, may overturn and/or move and damage utility connections. Performance generally is good when positive attachment to the structure is provided.

If bracing is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.12.4 VIBRATION ISOLATORS: Equipment mounted on vibration isolators shall be equipped with restraints or snubbers.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for non-compliant equipment mounted on vibration isolators.

Commentary:

Many isolation devices for vibration isolated equipment (e.g., fans, pumps,) offer no restraint against lateral movement. As a result, earthquake forces can cause the equipment to fall off its isolators, usually damaging interconnected piping. Snubbers or other restraining devices are needed to prevent horizontal movement in all directions.

If restraints and snubbers are non-existent, mitigation is necessary to achieve the selected performance level.

4.8.12.5 ELECTRICAL EQUIPMENT: Electrical equipment shall be attached to the structural system.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unattached electrical equipment.

4.8.13 Piping

4.8.13.1 FIRE SUPPRESSION PIPING: Fire suppression piping shall be anchored and braced in accordance with *NFPA-13* (NFPA, 1996).

Commentary:

Without proper connection to the structure electrical equipment can move horizontally and/or overturn. The movement can damage the equipment and may create a hazardous condition. Equipment may be mounted to the primary structural system or on walls or ceilings that are capable of resisting the applied loads. Distribution lines that cross structural separations should be investigated. If relative movement of two adjacent buildings can be accommodated by "slack" in the distribution lines, the condition may be acceptable.

If attachment is non-existent, mitigation is necessary to achieve the selected performance level.

Commentary:

Fire sprinkler piping has performed poorly in past earthquakes rendering systems unusable when most needed. Causes of fire sprinkler piping failure included: inadequate lateral bracing of sprinkler mains and cross-mains, inadequate flexibility and clearance around sprinkler piping, and impact between sprinkler pipes and other unbraced nonstructural elements. Proper pipe bracing is needed for reliable performance of the system.

NFPA-13 is intended to provide a life-safety level of performance. Where a higher performance is desired, careful design and detailing of all components of the system are needed.

If anchorage and bracing are non-existent, mitigation is necessary to achieve the selected performance level.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unbraced and unanchored fire suppression piping.

Commentary:

Failures may occur in pipes that cross seismic joints due to differential movement of the two adjacent structures. Special detailing is required to accommodate the movement. Flexibility can be provided by a variety of means including special couplings and pipe bends. Flexible couplings should be evaluated for their ability to accommodate expected seismic movements in *all* directions.

If flexible couplings are non-existent, mitigation is necessary to achieve the selected performance level.

Commentary:

Piping can fail at elbows, tees, and connections to supported equipment. The potential for failure is dependent upon the rigidity, ductility, and expansion or movement capability of the piping system. Joints may separate and hangers may fail. Hanger failures can cause progressive failure of other hangers or supports. Smaller diameter pipes, which generally have greater flexibility, often perform better than larger diameter pipes but they are still subject to damage at the joints. Piping in vertical runs typically performs better than in horizontal runs if it is regularly connected to a vertical shaft.

If anchorage and bracing are non-existent, mitigation is necessary to achieve the selected performance level.

4.8.13.2 FLEXIBLE COUPLINGS: Fluid, gas and fire suppression piping shall have flexible couplings to allow for building movement at seismic separations.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for fluid, gas and fire suppression piping without flexible couplings.

Commentary:

Post earthquake recovery efforts have been severely hampered in cases where damaged utility lines could not be expediently isolated from main distribution systems. Shut-off valves are needed to allow for isolation of a building or portions of a building. The valves should be easily accessible and training should be provided for reliable post-earthquake response.

If shut-off devices are non-existent, mitigation is necessary to achieve the selected performance level. The need for and location of shut-off devices should be established in cooperation with local utility companies. Utility companies vary in their policies regarding the installation of shut-off devices.

4.8.13.3 FLUID AND GAS PIPING: Fluid and gas piping shall be anchored and braced to the building structure in accordance with *SP-58* (MSS, 1993).

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unbraced and unanchored fluid and gas piping.

Commentary:

C-clamps have proven to be unreliable during an earthquake. Pipe movement can cause the C-clamp to work itself off its support causing local loss of gravity support for the pipe. The loss of a single C-clamp can lead to progressive collapse of other supports.

If C-clamps are non-compliant, mitigation is necessary to achieve the selected performance level.

Commentary:

Large duct installations are heavy and can cause damage to other materials and may pose a hazard to occupants. Failures may occur in long runs due to large amplitude swaying. Failure usually consists of leakage rather than collapse.

When evaluating the ductwork, the function of the duct system, proximity to occupants, and other materials likely to be damaged should be considered.

If bracing is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.13.4 SHUT-OFF VALVES: Shut-off devices shall be present at building utility interfaces to shut off the flow of gas and high temperature energy in the event of earthquake-induced failure.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for non-compliant shut-off devices.

Commentary:

Since these ducts are part of the fire protection system they are more critical than normal air conditioning ducts. Depending on the duct layout and function of the building, however, the hazard may vary greatly and judgment should be exercised during the evaluation.

If bracing or flexible connections are non-existent, mitigation is necessary to achieve the selected performance level.

Commentary:
Though generally undesirable, this condition is only serious when large ducts are supported by other elements that are poorly supported and braced.

4.8.13.5 C-CLAMPS: One-sided C-clamps that support major piping shall not be unrestrained.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for non-compliant C-clamps.

4.8.14 Ducts

4.8.14.1 DUCT BRACING: Rectangular ductwork exceeding 6 square feet in cross-sectional area, and round ducts exceeding 28" in diameter shall be

Commentary:
Unrestrained containers are susceptiable to overturing and falling resulting in release of materials. Storage conditions should be evaluated in relation to the proximity to occupants, the nature of the substances involved and the possibility of a toxic condition.

If restraints are non-existent, mitigation is necessary to achieve the selected performance level.

braced. Maximum transverse bracing shall not exceed 40 feet for Life Safety and 30 feet for Immediate Occupancy. Maximum longitudinal bracing shall not exceed 80 feet for Life Safety and 60 feet for Immediate Occupancy. Intermediate supports shall not be considered part of the

Commentary:
Unrestrained gas cylinders are highly susceptible to overturning. Release and/or ignition of gas may result. Cylinders should be prevented from overturning by positive means.

If restraints are non-existent, mitigation is necessary to achieve the selected performance level.

lateral-force-resisting system.

Commentary:
Post-earthquake recoery efforts will be hampered if toxic releases can not be promptly stopped. Shut-off valcves should be accessible and traning should be provided to enhance the reliablity of post-earthuqake recovery efforts. The specifics of the materials and systems vary greatly. Federal, state and local codes will govern regarding the installation of shut-off devices.

If shut-off devices are non-existent, mitigation is necessary to achieve the selected performance level. The need for and location of shut-off devices should be established in cooperation with local utility companies. Utility companies vary in their policies regarding the installation of shut-off devices.

Tier 2 Evaluation Procedure: The adequacy of the bracing to resist seismic forces calculated in accordance with Section 4.2.7 in ductwork exceeding 28" in diameter shall be evaluated.

Commentary:
The successful performance of an elevator system requires that the various elements of the system remain in place, undamaged and capable of operating after inspection. As a minimum, all equipment, including hoistway doors, brackets, controllers, and motors must be anchored.

4.8.14.2 STAIR AND SMOKE DUCTS: Stair pressurization and smoke control ducts shall be braced and shall have flexible connections at seismic joints.

Commentary:
Traction elevators, unless carefully designed and constructed, are highly vulnerable to damage during strong shaking. It is very common for the counter-weights to swing out of their rails and collide with the car. Current industry practice and most elevator regulations assure that the elevator occupants will remain safe by installing seismic switches that sense when strong shaking has begun and automatically shut the system down. Seismic switches are generally located in the elevator machine room and connected directly to the controller. The design professional should verify that the switch is operational as they are often disabled due to malfunctioning.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for stair pressurization and smoke control ducts without bracing or flexible connections at seismic joints.

Commentary:
Elevator shaft walls are often unreinforced masonry construction using hollow clay tile or concrete masonry block. In the event of strong shaking, these walls may experience significant damage due to in-plane forces and fall into the shaft.

4.8.14.3 DUCT SUPPORT: Ducts shall not be supported by piping or other nonstructural elements.

Commentary:
Strong earthquake motions causes the elevator hoist way cables to whip around and often misalign on the sheaves and drums. Retainer guards are effective at reducing the number of misalignments and improving the possiblity that the elevator can continue in service after inspection.

Tier 2 Evaluation Procedure: The adequacy of piping or other nonstructural elements to resist seismic forces calculated in accordance with Section 4.2.7 and

Commentary:
Retainer plates are installed just above or below all roller guides and serve to prevent derailment. They are U-shaped, firmly attached to the roller guides and run not more than 3/4" from the rail.

gravity forces shall be evaluated.

4.8.15 Hazardous Materials

4.8.15.1 TOXIC SUBSTANCES: Toxic and

Commentary:
The typically poor performance of counterweights is due to the size of the rails and that spacing of the rail brackets. Eight-pound rails have routinely shown to be insufficient and are best replaced by fifteen-pound rails as a minimum.

hazardous substances stored in breakable containers shall be restrained from falling by latched doors, shelf lips, wires, or other methods.

Tier 2 Evaluation Procedure: No Tier 2 evaluation

Commentary:
The brackets that support the rails must be properly spaced and designed to be effective. It is common for brackets to be properly spaced but improperly designed. The design professional should be particularly aware of the eccentricites that often occur within the standard bracket systems most commonly used.

procedure is available for toxic and hazardous substnaces stored in unrestrained breakable containers.

4.8.15.2 GAS CYLINDERS: Compressed gas cylinders shall be restrained.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unrestrained compressed gas cylinders.

4.8.15.3 HAZARDOUS MATERIALS: Piping containing hazardous materials shall have shut-off valves or other devices to prevent major spills or leaks.

Commentary:
Spreader brackets are a useful element to maintain alignment of counterweight rails between supporting brackets. They have worked very successfully under normal daily operating loads. However, they do not offer any protection to the rails under seismic loading because of the large eccentricities inherent in their shape.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for non-compliant shut-off devices.

4.8.16 Elevators

Tier 2 Evaluation Procedure: To evaluate all the items specified below, the elevator installation shall be reviewed by the design professional and an elevator consultant or representative of the elevator manufacturer familiar with elevator seismic requirements. Seismic forces and expected levels of interstory drift shall be calculated in accordance with Section 4.2.7..

4.8.16.1 SUPPORT SYSTEM: All elements of the elevator system shall be anchored.

4.8.16.2 SEISMIC SWITCH: All elevators shall be equipped with seismic switches that will terminate operations when the ground motion exceeds 0.10g.

4.8.16.3 SHAFT WALLS: All elevator shaft walls shall be anchored and reinforced to prevent toppling into the shaft during strong shaking.

4.8.16.4 RETAINER GUARDS: Cable retainer guards on sheaves and drums shall be present to inhibit the displacement of cables.

4.8.16.5 RETAINER PLATE: A retainer plate shall be present at the top and bottom of both car and counterweight.

4.8.16.6 COUNTERWEIGHT RAILS: All counterweight rails shall be sized to meet current industry standards and shall be larger than eight-pound rails.

4.8.16.7 BRACKETS: The brackets that tie the counterweight rail to the building structure shall be sized to meet industry standards and shall have a spacing of 8 feet or less.

4.8.16.8 SPREADER BRACKET: Spreader brackets shall not be used to resist seismic forces