A.7.4.6 Bearing Connections. *Where bearing connections are used, there is a minimum of two bearing connections for each cladding panel.*

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 nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.4.7 Inserts. *Where concrete cladding components use inserts, the inserts have positive anchorage or are anchored to reinforcing steel.*

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

A.7.4.8 Glazing. *Glazing panes of any size in curtain walls and individual interior or exterior panes more than 16 ft^2 (1.5 m^2) in area are laminated annealed or laminated heat-strengthened glass and are detailed to remain in the frame when glass is cracked.*

Laminated glass remains in the frame after cracking or shattering, providing a temporary weather barrier and allowing for Immediate Occupancy after an earthquake.

A.7.4.9 Threaded Rods. *Threaded rods for panel connections detailed to accommodate drift by bending of the rod have a length-to-diameter ratio greater than 0.06 times the story height in inches (millimeters) for Life Safety in moderate seismicity and 0.12 times the story height in inches (millimeters) for Life Safety in high seismicity and Position Retention in any seismicity.*

The limits on length-to-diameter ratios are needed to ensure proper connection performance. Longer rods in sliding connections will bind if there is significant bending and rotation in the rod, which may lead to a brittle failure. For rods that accommodate drift by flexure, longer rods reduce inelastic bending demands and provide better performance. Since anchor rods used in sliding and bending may undergo inelastic action, the use of mild steel improves ductility.

A.7.5 Masonry Veneer

A.7.5.1 Ties. *Masonry veneer is connected to the backup with corrosion-resistant ties. There is a minimum of one tie for every 2-2/3 ft^2 (0.25 m^2), and the ties have spacing no greater than the following: for Life Safety in low or moderate seismicity, 36 in. (914 mm); for Life Safety in high seismicity and for Position Retention in any seismicity, 24 in. (610 mm).*

Inadequately fastened masonry veneer can pose a falling hazard if it peels away from its backing. Judgment may be needed to assess the adequacy of various attachments that may be used. For levels of lower seismicity, it may be easier to show compliance for a larger tie spacing and larger tie area.

Ordinary shop-galvanized wire ties are not very corrosion resistant and are likely to become heavily corroded within 15 years, if the environment is marine or causes continued wetting and drying cycles to the ties, such as at a windward or southern exposure. To be corrosion resistant, the ties should be stainless steel.

If anchorage is nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.5.2 Shelf Angles. *Masonry veneer is supported by shelf angles or other elements at each floor above the ground floor.*

Inadequately fastened masonry veneer can pose a falling hazard 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 nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.5.3 Weakened Planes. *Masonry veneer is anchored to the backup adjacent to weakened planes, such as at the locations of flashing.*

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 moderate and high seismicity, masonry veneer should be anchored to the backup system immediately above the weakened plane.

If anchorage is nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.5.4 Masonry Veneer Deterioration. *There is no evidence of deterioration, damage, or corrosion in any of the connection elements.*

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.

Water leakage into and through exterior walls is a common building problem. Damage caused by 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. Wall spaces should be probed if necessary, and signs of water leakage should be sought at vulnerable locations (e.g., at windows and at floor areas). Particular attention should be paid to elements that tie cladding to the backup structure and that tie the backup 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. Exterior walls should be checked for cracking caused by thermal movements.

A.7.5.5 Mortar. *The mortar in masonry veneer cannot be easily scraped away from the joints by hand with a metal tool, and there are not significant areas of eroded mortar.*

Inadequate mortar affects the veneer's ability to withstand seismic motions and maintain attachment to the backup system.

If mortar is noncompliant, mitigation is necessary to achieve the selected Performance Level.

A.7.5.6 Weep Holes. *In veneer anchored to stud walls, the veneer has functioning weep holes and base flashing.*

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

If weep holes are noncompliant, mitigation is necessary to achieve the selected Performance Level.

A.7.5.7 Stone Cracks. *There are no visible cracks or signs of visible distortion in the stone.*

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

Veins in the stone can create weak points and potential for future cracking and deterioration.

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A.7.6 Metal Stud Backup Systems

A.7.6.1 Stud Tracks. *For veneer with metal stud backup, stud tracks are fastened to the structural framing at a spacing equal to or less than 24 in. (610 mm) on center.*

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

A.7.6.2 Openings. *For veneer with metal stud backup, steel studs frame window and door openings.*

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.

A.7.7 Concrete Block and Masonry Backup Systems

A.7.7.1 Anchorage. *For veneer with concrete block or masonry backup, the backup is positively anchored to the structure at a horizontal spacing equal to or less than 4 ft (1.2 m) along the floors and roof.*

Backup is the system that supports veneer for out-of-plane forces. Inadequate anchorage of the backup wall may affect the whole assembly's ability to withstand seismic motions and maintain attachment to backup.

A.7.7.2 Unreinforced Masonry Backup. *There is not an unreinforced masonry backup.*

Unreinforced masonry (URM) backup 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 backup and necessary remedial measures. Testing may be necessary to determine the strength of the URM backup.

Complete replacement of backup is extremely expensive; depending on the state of the installation and the facing materials, alternative methods may be possible.

To qualify as reinforced masonry, the area of reinforcing steel is 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 is less than 48 in. (1219 mm); and all vertical bars extend to the top of the backup 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 in-plane cracking under seismic forces, and portions of the wall may become dislodged.

A.7.8 Parapets, Cornices, Ornamentation, and Appendages

A.7.8.1 Unreinforced Masonry Parapets or Cornices. *Laterally unsupported unreinforced masonry parapets or cornices have height-to-thickness ratios no greater than the following: for Life Safety in low or moderate seismicity, 2.5; for Life Safety in areas of high seismicity and for Position Retention in any seismicity, 1.5.*

URM parapets present a major falling hazard and potential Life Safety threat. For sloped roofs, the highest anchorage level should not be taken at the ridge but should vary with roof slope when checking height-to-thickness ratios.

If anchorage is nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.8.2 Canopies. *Canopies at building exits are anchored to the structure at a spacing no greater than the following: for Life Safety in Low or Moderate Seismicity, 10 ft (3.0 m); for Life Safety in High Seismicity and for Position Retention in any seismicity, 6 ft (1.8 m).*

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

If anchorage is nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.8.3 Concrete Parapets. *Concrete parapets with height-to-thickness ratios greater than 2.5 have vertical reinforcement.*

Inadequately reinforced parapets can be severely damaged during an earthquake.

If anchorage is nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.8.4 Appendages. *Cornices, parapets, signs, and other ornamentation or appendages that extend above the highest point of anchorage to the structure or cantilever from components are reinforced and anchored to the structural system at a spacing equal to or less than 6 ft (1.8 m). This checklist item does not apply to parapets or cornices covered by other checklist items.*

The above components may vary greatly in size, location, and attachment; the design professional should use judgment in his or her assessment. If any of these items is of insufficient strength and/or is not securely attached to the structural elements, it may break off and fall onto storefronts, streets, sidewalks, or adjacent property and become a significant Life Safety hazard.

If anchorages are nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.9 Masonry Chimneys

A.7.9.1 Unreinforced Masonry Chimneys. *Unreinforced masonry chimneys extend above the roof no more than the following: for Life Safety in Low or Moderate Seismicity, 3 times the least dimension of the chimney; for Life Safety in High Seismicity and for Position Retention in any seismicity, 2 times the least dimension of the chimney.*

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 onto a public or private walkway, creating a Life Safety hazard. Experience has shown that the costs of retrofitting masonry chimneys can sometimes exceed the costs of damage repair.

A.7.9.2 Anchorage. *Masonry chimneys are anchored at each floor level, at the topmost ceiling level, and the roof.*

Anchorage of chimneys has proven to be problematic at best, ineffective at worst in reducing chimney losses because anchorage alone does not typically account for incompatibility of deformations between the main structure and the chimney. Other retrofit strategies—such as the presence of plywood above the ceiling or on the roof to keep the falling masonry from penetrating or relocating occupant activities within a falling radius—may be more effective than anchoring chimneys.

A.7.10 Stairs

A.7.10.1 Stair Enclosures. *Hollow-clay tile or unreinforced masonry walls around stair enclosures are restrained out of plane and have height-to-thickness ratios not greater than the following: for Life Safety in low or moderate seismicity, 15-to-1; for Life Safety in high seismicity and for Position Retention in any area, 12-to-1.*

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

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The procedures in Chapter 13 are recommended for analysis of the walls for both in-plane and out-of-plane forces. If bracing is nonexistent, mitigation may be necessary to achieve the selected Performance Level.

A.7.10.2 Stair Details. *The connection between the stairs and the structure does not rely on post-installed anchors in concrete or masonry, and the stair details are capable of accommodating the drift calculated using the Quick Check procedure of Section 4.4.3.1 for moment-frame structures or 0.5 in. (13 mm) for all other structures without inducing any lateral stiffness contribution from the stairs.*

If stairs are not specially detailed to accommodate story drift, they can modify structural response by acting as struts attracting seismic force. Shallow anchors, such as expansion and sleeve anchors, rigidly connect the stairs to the structure. The connection of the stair to the structure must be capable of resisting the imposed forces without loss of gravity support for the stair.

A.7.11 Building Contents and Furnishing

A.7.11.1 Industrial Storage Racks. *Industrial storage racks or pallet racks more than 12 ft (3.6 m) high meet the requirements of ANSI/RMI MH 16.1 as modified by ASCE 7, Chapter 15.*

Storage racks are usually constructed of metal. Storage racks are generally purchased as proprietary systems installed by a tenant and are often not under the direct control of the building owner. Thus, they are usually not part of the construction contract and often have no foundation or foundation attachment. However, they are often permanently installed, and their size and loaded weight make them an important hazard to life, property, or the surrounding structure.

A.7.11.2 Tall, Narrow Contents. *Contents more than 4 ft (1.4 m) high with a height-to-depth or height-to-width ratio greater than 3-to-1 are anchored to the floor slab or adjacent structural walls. A height-to-depth or height-to-width ratio of up to 4-to-1 is permitted when only the basic nonstructural component checklist is required by Table 3-2.*

Tall, narrow storage or file cabinets or racks can tip over if they are not anchored to resist overturning forces. Commercial kitchen equipment, such as freezer boxes, refrigerators, ovens, and storage racks, can be overturned if not properly fastened to adjacent structural walls and floors.

A.7.11.3 Fall-Prone Contents. *Equipment, stored items, or other contents weighing more than 20 lb (9.1 kg) whose center of mass is more than 4 ft (1.2 m) above the adjacent floor level are braced or otherwise restrained.*

Contents heavier than 20 lb (9.1 kg) that are elevated more than 4 ft (1.2 m) above the floor level can fall from where they are located and be a potential Life Safety concern in earthquakes with strong ground shaking. That is why these types of contents should be braced or restrained, such as being placed in a cabinet with doors that latch in buildings located in a region of high seismicity.

A.7.11.4 Access Floors. *Access floors more than 9 in. (229 mm) high are braced.*

Unbraced 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 nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.11.5 Equipment on Access Floors. *Equipment and computers supported on access floor systems are anchored or braced to the structure independent of the access floor.*

Tall, narrow computers and communications equipment can overturn if not properly anchored. Where overturning is not a concern because of 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 nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.11.6 Suspended Contents. *Items suspended without lateral bracing are free to swing from or move with the structure from which they are suspended without damaging themselves or adjoining components.*

Suspended contents generally do not present a hazard unless they affect something else during seismic shaking.

A.7.12 Mechanical and Electrical Equipment

A.7.12.1 Emergency Power. *Equipment used to power or control Life Safety systems is anchored or braced.*

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.

Nonemergency equipment located close to or above emergency equipment can be dislodged and fall onto, or cause piping to fail and flood out of, the emergency system.

If anchorage is nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.12.2 Hazardous Material Equipment. *Equipment mounted on vibration isolators and containing hazardous material is equipped with restraints or snubbers.*

Heating, ventilating, and air conditioning (HVAC) or other equipment containing hazardous material on vibration isolation supports that are not restrained by snubbers may release their contents during an earthquake.

A.7.12.3 Equipment Support Deterioration. *There is no evidence of deterioration, damage, or corrosion in any of the anchorage or supports of mechanical or electrical equipment.*

Damaged or corroded anchorage or supports of equipment may not have adequate capacity to resist seismic demands. Suspended or wall-mounted equipment is of more concern than floor- or roof-mounted equipment because failure of supports would create a falling hazard.

A.7.12.4 Fall-Prone Equipment. *Equipment weighing more than 20 lb (9.1 kg) whose center of mass is more than 4 ft (1.2 m) above the adjacent floor level, and which is not in-line equipment, is braced.*

Equipment located more than 4 ft (1.2 m) above the floor poses a falling hazard unless it is 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 on impact with other adjacent items.

If bracing is nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.12.5 In-Line Equipment. *Equipment installed in line with a duct or piping system, with an operating weight more than*

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75 lb (34.0 kg), is supported and laterally braced independent of the duct or piping system.

Pieces of equipment, such as large variable air volume (VAV) boxes, which are installed in line with distribution system components such as ducts or piping, can become falling hazards if they are not independently braced. It is common for these pieces of equipment to instead be supported by the piping or ducts with which they are in line and to which they are attached.

A.7.12.6 Tall, Narrow Equipment. *Equipment more than 6 ft (1.8 m) high with a height-to-depth or height-to-width ratio greater than 3-to-1 is anchored to the floor slab or adjacent structural walls.*

Tall, narrow equipment can tip over if not anchored to resist overturning forces.

A.7.12.7 Mechanical Doors. *Mechanically operated doors are detailed to operate at a story drift ratio of 0.01.*

Doors that are stuck open or closed, such as fire house garage doors, can greatly affect essential services. Most large doors are not designed to accommodate earthquake-induced transient or permanent drifts in flexible buildings. Fire trucks and ambulances can be delayed in exiting. Critical minutes of emergency response time have been lost in past earthquakes when such doors have been rendered inoperable. Energy conservation measures and vandalism concerns have resulted in an evolution in modern door system designs. Most common door designs are drift intolerant and can result in egress difficulties in flexible buildings, requiring contingency planning and in many cases retrofits. Simple visual evaluations of drift incompatibility between doors that are critical to essential services, their frames, and supporting structures can quickly identify vulnerabilities.

A.7.12.8 Suspended Equipment. *Equipment suspended without lateral bracing is free to swing from or move with the structure from which it is suspended without damaging itself or adjoining components.*

Suspended equipment generally does not present a hazard unless it impacts something else during seismic shaking.

A.7.12.9 Vibration Isolators. *Equipment mounted on vibration isolators is equipped with horizontal restraints or snubbers and with vertical restraints to resist overturning.*

Many isolation devices for vibration-isolated equipment (e.g., fans or 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.

Seismic restraints or snubbers must have proper anchors to prevent pullout. The contact surfaces on the snubbers should be resilient to prevent impact amplification.

If restraints and snubbers are nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.12.10 Heavy Equipment. *Equipment weighing more than 400 lb (181.4 kg) is anchored to the structure.*

For rigidly mounted large equipment (e.g., boilers, chillers, tanks, or 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 nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.12.11 Electrical Equipment. *Electrical equipment is laterally braced to the structure.*

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 forces. 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 nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.12.12 Conduit Couplings. *Conduit greater than 2.5 in. (64 mm). trade size that is attached to panels, cabinets, or other equipment and is subject to relative seismic displacement has flexible couplings or connections.*

Conduit rigidly attached to electrical equipment can be damaged at the junction where it attaches to the equipment because of differential movement of the conduit and the equipment. Providing a flexible coupling or connection capable of accommodating the relative displacement mitigates this issue.

A.7.13 Piping

A.7.13.1 Fire Suppression Piping. *Fire suppression piping is anchored and braced in accordance with NFPA 13.*

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 Operational Nonstructural Performance.

If anchorage and bracing are nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.13.2 Flexible Couplings. *Fluid, gas, and fire suppression piping have flexible couplings. For fire suppression piping, the couplings are in accordance with NFPA 13.*

Failures may occur in pipes that cross seismic joints because of 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. NFPA 13 is intended to provide Operational Nonstructural Performance.

If flexible couplings are nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.13.3 Sprinkler Ceiling Clearance. *Penetrations through panelized ceilings for fire suppression devices provide clearances in accordance with NFPA 13.*

A common failure of fire suppression piping is caused by the sprinkler heads impacting the ceiling where the sprinkler pokes down through. This problem can be mitigated by providing clearance around the sprinkler head or by providing flexible lines between the horizontal pipe and the sprinkler head.

A.7.13.4 Fluid and Gas Piping. *Fluid and gas piping is anchored and braced to the structure to prevent or limit spills or leaks.*

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Piping can fail at elbows, tees, and connections to supported equipment. The potential for failure is dependent on 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.

When using flexible couplings, the following limitations should be considered:

- Elastomeric flexible couplings can resist compression, tension, torsion, and bending.
- Metal flexible couplings can resist bending only.
- Ball joints can resist bending and torsion.
- Grooved couplings can resist only minimum bending and torsion.
- Some building codes permit certain configurations and size of piping without bracing or anchorage. It may be possible to demonstrate compliance by showing that the piping meets current code requirements.

If anchorage and bracing are nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.13.5 C-Clamps. *One-sided C-clamps that support piping greater than 2.5 in. (64 mm) in diameter are restrained.*

Unrestrained C-clamps (such as those connected to the bottom flange of structural steel beams) 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 noncompliant, mitigation is necessary to achieve the selected Performance Level.

A.7.13.6 Piping Crossing Seismic Joints. *Piping that crosses seismic joints or isolation planes or is connected to independent structures has couplings or other details to accommodate the relative seismic displacements.*

Because of the potential for portions of a building on either side of a seismic joint or isolation plane to move relative to each other, any piping that crosses the joint should have been detailed to accommodate whatever movement is anticipated across the joint. The same condition exists when the piping is supported by different structures that are independent of each other. If the piping does not have flexible couplings or other means to accommodate the movement, the pipe can be damaged such that it releases its contents.

A.7.14 Ducts

A.7.14.1 Stair and Smoke Ducts. *Stair pressurization and smoke control ducts are braced and have flexible connections at seismic joints.*

Because 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 nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.14.2 Duct Bracing. *Rectangular ductwork larger than 6 ft^2 (0.56 m^2) in cross-sectional area and round ducts larger than 28 in. (711 mm) in diameter, are braced. The maximum spacing of transverse bracing does not exceed 30 ft (9.2 m). The maximum spacing of longitudinal bracing does not exceed 60 ft (18.3 m).*

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 because of 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 nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.14.3 Duct Support. *Ducts are not supported by piping or electrical conduit.*

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

A.7.14.4 Ducts Crossing Seismic Joints. *Ducts that cross seismic joints or isolation planes or are connected to independent structures have couplings or other details to accommodate the relative seismic displacements.*

Because of the potential for portions of a building on either side of a seismic joint or isolation plane to move relative to each other, any ducts that cross the joint should have been detailed to accommodate whatever movement is anticipated across the joint. The same condition exists when the ducts are supported by different structures that are independent of each other. If the ducts do not have flexible couplings or other means to accommodate the movement, the ducts can be damaged to the point where they do not function.

A.7.15 Hazardous Materials

A.7.15.1 Hazardous Material Storage. *Breakable containers that hold hazardous material, including gas cylinders, are restrained by latched doors, shelf lips, wires, or other methods.*

Unrestrained containers are susceptible to overturning 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 nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.15.2 Shutoff Valves. *Piping containing hazardous materials has shutoff valves or other devices to prevent major spills or leaks.*

Postearthquake recovery efforts are hampered if toxic releases cannot be promptly stopped. Shutoff valves should be accessible, and training should be provided to enhance the reliability of postearthquake recovery efforts. The specifics of the materials and systems vary greatly. Federal, state, and local codes govern regarding the installation of shutoff devices.

Large spills of some nonhazardous materials, such as liquid soap or some food products, also can be environmentally damaging and can create a nuisance. Proper shutoff valves and containment structures can help to avert these problems.

If shutoff devices are nonexistent, mitigation is necessary to achieve the selected Performance Level. The need for and location of shutoff devices should be established in cooperation with local utility companies. Utility companies vary in their policies regarding the installation of shutoff devices.

A.7.15.3 Shutoff Valves. *Piping containing hazardous material, including natural gas, has shutoff valves or other devices to limit spills or leaks.*

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Postearthquake recovery efforts have been severely hampered in cases where damaged utility lines could not be expediently isolated from main distribution systems. Shutoff 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 postearthquake response.

Shutoff valves can be either manually operated or automatic. Automatic shutoff valves should conform to ASCE 25-97. Manually operated valves should conform to ASME B16.33 or ANSI Z21.15.

If shutoff devices are nonexistent, mitigation is necessary to achieve the selected Performance Level. The need for and location of shutoff devices should be established in cooperation with local utility companies. Utility companies vary in their policies regarding the installation of shutoff devices.

A.7.15.4 Flexible Couplings. *Hazardous material ductwork and piping, including natural gas piping, has flexible couplings.*

Failures may occur in pipes that cross seismic joints because of 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 nonexistent, mitigation is necessary to achieve the selected Performance Level.

A.7.16 Elevators. Elevator components are typically not dealt with by design professionals. If necessary, a design professional with experience in elevator design should be consulted.

A.7.16.1 Retainer Guards. *Sheaves and drums have cable retainer guards.*

Strong earthquake motions cause the elevator hoistway 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 possibility that the elevator can continue in service after inspection.

A.7.16.2 Retainer Plate. *A retainer plate is present at the top and bottom of both car and counterweight.*

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 in. (19 mm) from the rail.

A.7.16.3 Elevator Equipment. *Equipment, piping, and other components that are part of the elevator system are anchored.*

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.

A.7.16.4 Seismic Switch. *Elevators capable of operating at speeds of 150 ft/min (45.7 m/min) or faster are equipped with seismic switches that meet the requirements of ASME A17.1 or have trigger levels set to 20% of the acceleration of gravity at the base of the structure and 50% of the acceleration of gravity in other locations.*

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

A.7.16.5 Shaft Walls. *Elevator shaft walls are anchored and reinforced to prevent toppling into the shaft during strong shaking.*

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 caused by in-plane and out-of-plane forces and may fall into the shaft.

A.7.16.6 Counterweight Rails. *All counterweight rails and divider beams are sized in accordance with ASME A17.1.*

The typically poor performance of counterweights is caused by the size of the rails and the spacing of the rail brackets. Eight-pound [8-lb (3.6 kg)] rails have routinely shown to be insufficient and are best replaced by 15-lb (6.8 kg) rails as a minimum.

A.7.16.7 Brackets. *The brackets that tie the car rails and the counterweight rail to the building structure are sized in accordance with ASME A17.1.*

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 eccentricities that often occur within the standard bracket systems most commonly used.

A.7.16.8 Spreader Bracket. *Spreader brackets are not used to resist seismic forces.*

Spreader brackets are a useful element to maintain alignment of counterweight rails between supporting brackets. They have worked 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.

A.7.16.9 Go-Slow Elevators. *The building has a go-slow elevator system.*

The functionality of a building after an earthquake depends on the ability to move through it. However, elevators that are compliant with the code shut down after an earthquake. Therefore, even if the building has the ability to provide Immediate Occupancy after an earthquake, movement through the building is impeded until the elevators are reactivated. Go-slow elevators alleviate this problem by providing one elevator that functions at a lower speed after an earthquake.

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APPENDIX B

APPLYING ASCE 41 IN BUILDING CODES, REGULATORY POLICIES, AND MITIGATION PROGRAMS

B.1 INTRODUCTION

This appendix discusses issues related to the ASCE 41 standard that are outside the scope of its technical provisions. The specification of a performance objective sets both the expected level of seismic performance and the seismic hazard in which it is to be achieved. There may be multiple performance objectives set for an analysis that are each to be satisfied. Different contexts lead to different conclusions for each issue's resolution. The standard can be applied for evaluation and/or mitigation programs for code-specified work, or for voluntary efforts. The performance objectives can be the target for specific building types or occupancies. It is noted that in most of the country, mitigation is most commonly done either voluntarily or when triggered by the local building code or by other proposed actions. These variations call for different considerations when selecting a performance objective and applying the standard.

As described in Chapter 2, ASCE 41 accommodates a number of possible performance objectives. The performance objective, together with attributes of the site and the building, determines the applicable provisions for evaluation or retrofit. Thus, the first task for the decision maker applying the standard is to select a performance objective, and the second is to select the hazard level for which the performance is to be evaluated or retrofitted.

This standard does not specify a performance objective, but it provides the means to do so by selection of the intended Structural and Nonstructural performance levels and does not establish the Seismic Hazard Levels at which the performance level(s) are to be evaluated. The commentary provides some basis for understanding the differences. The purpose of this appendix is to describe how these objectives can be set, with reference to existing programs and precedents.[1] The intent is to provide some general guidance in their selection to code developers, policy makers, building owners, and other stakeholders.

An evaluation and/or mitigation program can involve a single building, a portfolio or class of buildings, or an entire community of buildings and infrastructure. Seismic evaluation and retrofit of individual buildings, the subjects of this standard, is a key component of many programs, but a full program might also include other tasks, for example, financing, capital planning, legislation, or enforcement. These other tasks, though often essential to the success of a mitigation program, are within the scope for application of this standard and appendix.

Mitigation programs and regulations can vary in purpose, scope, duration, and in other ways. This appendix classifies them primarily by whether the mitigation is

- Mandatory, generally through a specific law or ordinance;
- Voluntary, at the discretion of one or more building stakeholders; or
- Triggered under certain conditions by a building code or by a regulation or policy of the Authority Having Jurisdiction.

The process and rationale for selecting a performance objective and applying the standard vary with the type of mitigation. Additional considerations—generally waivers or relaxed criteria—often apply to designated historic buildings, as noted briefly in the following sections. Commentary Section C1.1 discusses the application of the standard to historic buildings in more general terms.

The standard may be used for evaluations entirely separated from the enforcement of building codes or planning for structural modifications. These applications may include the following:

- Suitability for lease and/or occupancy providing a stated level of seismic performance, including for occupant safety and continuity of operations, or protection of key contents; and
- Financial decisions that are centered on understanding the expected seismic performance of the building and its sustainability of rents and revenues.

The latter applications may be triggered by ASTM E2557 or E2026 as evaluative methods for anticipating the seismic hazards and financial risks posed by the building.

B.2 MANDATORY MITIGATION

Mandatory mitigation is mitigation required by specific legislation regardless of the intentions of the building owner (or other stakeholders). Where mitigation is mandated, the ASCE 41 standard (or other engineering criteria) can be invoked by the legislation directly or by referenced regulations.

Mandatory mitigation has been used most often to target specific groups of buildings that are evaluated by the legislative body to unacceptable current extreme or urgent risks, especially where voluntary or triggered mitigation has been slow or ineffective from the perspective of public policy makers in reducing the community's seismic risk.

- In some cases, the urgency is related to safety and the likelihood of life-threatening structural collapse; the classic example is the case of unreinforced masonry buildings, or portions thereof, e.g., parapets, in California. Other similarly hazardous conditions could, in some jurisdictions, pose risks that might warrant mandatory mitigation. These conditions might include certain concrete tilt-up structures, nonductile concrete structures, or even certain nonstructural

[1] This appendix references specific codes, jurisdictions, programs, and practices for illustration purposes only. No endorsement or critique is implied.

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components such as gas-fired equipment or brick chimneys. Examples include evaluation and mitigation of nonductile concrete moment-frame buildings in Los Angeles and the Orange County requirements for assessment and retrofit of some types of concrete tilt-up structures.

- In other cases, the urgency is related to essential postearthquake services, regardless of structure type, such as those provided by hospitals, fire stations, and emergency operations centers.
- Legislation has also been proposed to target buildings that are neither historic collapse risks nor essential facilities, but which, as a group, are expected to be critical to a community's postearthquake recovery. Programs addressing soft-story, multiunit residential buildings are examples.

Almost all communities have regulations charging the building official to mitigate hazardous buildings. Often, the determination of when a building is hazardous is not clearly stated, nor are definitive means given for verifying it is hazardous. Usually this designation is determined based upon performance under gravity loads. Occasionally, a jurisdiction may want to allow voluntary structural modifications of the seismic performance of a building without invoking other code requirements. Usually, the notion is that as long as the seismic hazard is not increased from what it was before, the alterations are allowed on a voluntary basis. Thus, highly hazardous buildings can be modified as long as the seismic hazard has not been increased. ASCE 41 provides a method by which a jurisdiction could set a standard of seismic performance for a modified building to qualify for voluntary structural modifications, in which it becomes a mandatory use, not a voluntary provision. In other cases, the jurisdiction could prequalify use of ASCE 41 as acceptable, where it becomes permissive. One could be that the modified building could be determined to meet an S-5 performance level (Collapse Prevention) in a specified earthquake ground motion, say, the BSE-1E or other earthquake ground motion threat that has a risk level that the community evaluates as unacceptable. Use of ASCE 41 in this process would allow the building to be assessed easily as Compliant through successive application of the tiers until it is confirmed that the performance objectives are met, and if not, to provide a means of mitigating the hazard without invoking a full building performance evaluation. Such applications would probably be used only in High or Moderate seismic hazard locations (Table 2-5) and/or buildings not meeting the threshold ages of Table 4-7, and/or buildings well known to pose high life safety hazards in past earthquakes within the community, say URM load-bearing buildings and tilt-ups with deficient roof-to-wall connections and/or nonductile concrete-framed buildings.

B.2.1 Performance Objectives. Because mandatory mitigation is driven by legislation, the stated purpose of the law or ordinance will usually suggest a suitable performance objective. Mandatory mitigation represents legislated public policy. As such, even though mitigation is performed through individual projects, building by building, the program's overall success is measured at the jurisdiction level. The appropriate performance objective is thus the one that, when applied to all subject buildings, results in the desired improvement for the jurisdiction as a whole. This perspective distinguishes mandatory mitigation from voluntary or triggered mitigation, which both deal primarily with individual buildings.

Where public safety is the primary concern, the standard's Life Safety Performance Level is often appropriate. The Life Safety structural and nonstructural provisions were developed to support programs focused on the safety of persons, as opposed to programs seeking to minimize repair cost or downtime. Additional considerations when selecting a safety-based performance objective include the following:

- Life Safety performance is traditionally paired with a hazard somewhat less than that required for new construction, such as the BSE-1E hazard. As discussed in Commentary Section C2.2.1, use of this lower hazard recognizes that achieving "code equivalent" performance with an obsolete structure type is often disproportionately expensive and disruptive; for mandated mitigation, this issue can affect the political viability of a proposed program. Nevertheless, if equivalence with new buildings is sought, a performance objective of Life Safety Structural Performance Level and Position Retention Nonstructural Performance Level in the BSE-1N earthquake might be more suitable (see Section 2.2.4.)
- The standard's Basic Performance Objectives for Existing Buildings Tiers 1 and 2 have a single-level required assessment (see Sections 2.2.1 and 2.2.4). Tier 3 has two levels of assessments, one of which considers performance at the BSE-2E or BSE-2N hazard level. Though use of the higher hazard level can distinguish robust performance from marginal performance at the lower BSE-1E or BSE-1N hazard level, it can also substantially increase the level of evaluation or design effort. Most mandatory mitigation programs have not used a two-part objective. This approach is consistent in principle with the standard, in which acceptable Tier 1 evaluation considering the BSE-1E hazard is deemed to comply with a corresponding performance under the BSE-2E hazard (Section 2.2.1). However, these mitigation programs may not have the same limitations as the Tier 1 procedure does; therefore, they may not provide the intended performance in the BSE-2E hazard without explicit consideration at that hazard level.
- Where the goal of the mandate is to remove the most egregious life-threatening conditions with the least expense and disruption, Collapse Prevention structural performance in the BSE-1E or BSE-1N earthquake might be appropriate. Note, however, that ASCE 41 does not provide Tier 1 evaluation criteria for Collapse Prevention performance. The standard's committee expects to develop such criteria in a future revision cycle. In the interim, Tier 1 Collapse Prevention evaluation criteria can be derived from the Life Safety criteria by extracting the checklist items and other relevant provisions that focus on the most egregious potential deficiencies.
- Where the legislation targets a specific structure type, nonstructural performance might be reasonably ignored. The standard's separate enumeration of Structural and Nonstructural Performance Levels supports such an approach. Similarly, where the targeted deficiency involves a specific nonstructural deficiency (such as an unbraced brick parapet or gas-fired equipment), an objective that ignores structural performance might be reasonable.

Where postearthquake functionality is the primary concern, the standard's Immediate Occupancy Structural Performance Level and Operational Nonstructural Performance Level might be appropriate. These Performance Levels were developed to support programs focused on maintaining building services in the immediate postearthquake period. Additional considerations are the following:

- As with safety-based mandates, functionality-based mandates often pair Immediate Occupancy performance with a reduced Seismic Hazard Level like BSE-1E

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(see Section 2.2.1). For the most essential facilities, however, the deference to practicality represented by the use of a reduced hazard might not be warranted. A performance objective involving the BSE-1N and/or the BSE-2N hazard might be more appropriate for mandating legislation that seeks equivalence with new buildings (see Section 2.2.4).
- As described in Section C2.3.2.1, the standard does not provide a full set of evaluation or retrofit criteria for Operational Nonstructural Performance, which relies in part on the performance of infrastructure and utilities external to the building. In some cases, or for some components or systems, the standard's Position Retention nonstructural criteria might be adequate. In Section 2.2.1, for example, the standard's Basic Performance Objective for Existing Buildings (BPOE) calls for Position Retention nonstructural performance in the BSE-1E earthquake even for buildings assigned to Risk Category IV. In general, however, nonstructural performance is important for functionality-based objectives and should not be ignored.

Where the mandating legislation has other goals, appropriate performance objectives can be customized from the standard's defined performance and hazard levels.

- The Structural (S-1 to S-5) and Nonstructural (N-A to N-D) Performance Levels and the freedom to specify the evaluation Seismic Hazard Levels provide a broad range of opportunities to specify performance by triples of S-, N-, and seismic hazard. At times, these may include any number of triples. For example, the owner may want (S-1, N-A) performance in a magnitude 6 earthquake on the Hayward Fault, (S-3, N-B) performance in a magnitude 7 earthquake on the San Andreas fault, and (S-4, N-C) performance in a magnitude 8 earthquake on the San Andreas Fault. ASCE 41 provides a way to systematically address such seismic performance objectives in ways that are not related to code enforcement.
- It should be noted that the standard can be used both as an acceptance standard or as a nonacceptance standard for actions outside the regulatory purview, for example, where a lease is anticipated and the occupants want to have a reasoned understanding that the seismic risks of occupancy are acceptable to them. Then an ASCE 41 evaluation that indicates a building does not achieve an S-5 (Collapse Prevention) or S-3 (Life Safety) in a prescribed seismic hazard gives clear guidance to the occupants of whether they are at risk or not in executing a lease for use of the property. The prescribed hazard could be the BSE-1R, the ground motion in a specific scenario earthquake or a ground motion with a 10% probability of exceedance in terms of the lease. Similarly, a tenant may be interested in the possibility of not being able to use the property for its intended purposes during a lease and would want an S-2, NB in a ground motion with a 10% probability of exceedance in the terms of the lease. Such could be completed at the tenant's initiative or requested of the owner as a condition of considering leasing the building. The opportunities to use the ASCE 41 performance evaluation approach for other than capital investment or public standards enforcement are only limited by the need of the user in evaluating real estate for commercial, industrial, or personal goals.

Many owners developing a new building may want seismic performance requirements that are not well achieved by setting the ASCE 7 Importance Factor, I_e, higher. In such cases, the owner could require of the design team both meeting the minimum requirements of the applicable ASCE 7-based code and then evaluating the performance using ASCE 41 stated performance objectives and, if needed, requiring design modifications to meet these performance goals. This can be particularly useful for setting higher goals for nonstructural element performance and applying it to be more inclusive of elements not regulated by the code as mandatory. ASCE 41 is a convenient manner to achieve these objectives, since it is graded in its performance measures for both structural and nonstructural elements. This hybrid approach to new development evaluation has been used for the development of several buildings by the University of California, San Francisco.

B.2.2 Implementation Issues. Because mandatory mitigation is based in legislation, the legislative language (or subsequent regulations) must account for the logistics of a whole program. Program development issues related to the use of ASCE 41 might include the following:

- Phasing: The standard's tiered methodology enables the phased approach often used in mandatory mitigation programs. The evaluation could start with a Tier 1 or Tier 2 assessment and progress through the tiers until it is found that the building performs acceptably or until a decision is made to retrofit. The standard also allows separate performance objectives for evaluation and retrofit.
- Quality assurance: Legislated mandates by their nature involve enforcement, reviews, and approvals by jurisdiction staff. This method can require the development of procedures, as well as the training of staff.

B.2.3 Historic Buildings. Whereas designated historic buildings are often afforded waivers or special consideration by building codes, some of those variances might not be appropriate in the case of mandatory mitigation. Where a public safety risk or the need for an essential facility is urgent enough to justify a legislated mandate, that urgency might be prioritized over the objectives of historic preservation. Nevertheless, where ASCE 41 is applied to historic buildings, legislation (or its implementing regulations) might allow for certain exceptions to the normal mandated compliance.

B.2.4 Example Programs. The following example programs represent the diversity of seismic mitigation mandates. They cover both private and public buildings, local and statewide scope, evaluation-only programs as well as mandated retrofit, and a variety of regulatory approaches.

- California unreinforced masonry buildings. In 1986, California required local jurisdictions in high-seismicity areas to compile inventories and adopt mitigation programs for unreinforced masonry buildings. In most of the jurisdictions, including Los Angeles and San Francisco, the resulting programs involved mandatory retrofit. The evaluation and retrofit criteria varied, but many used criteria similar to the special procedure now found in Section 15.2 of this standard. These programs were administered by the local building departments of individual jurisdictions.
- California hospitals. In 1994, California required certain hospital facilities to be replaced or retrofitted or to have acute care services relocated to other buildings. As of 2012, evaluation criteria were added to Chapter 6 of the *California Building Standards Administrative Code* reprint portions of the ASCE 31-03 Tier 1 checklists. Chapter 34A of the *California Building Code* references ASCE 41-06 and ties compliance to certain performance objectives, with an

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