5. Buildings

5.1. Introduction

This chapter presents guidance for setting performance goals for buildings in a community resilience plan. Building stock within a community varies widely, in terms of use, occupancy, ownership, age, construction type and condition. The variability in occupancy and use leads to different performance goals between buildings; variability in age and condition results in different performance levels, even within the same class of building; and variability in ownership, such as public or private, can present challenges in implementing minimum performance goals, particularly for existing buildings. This chapter discusses the various classes and uses of buildings, performance goals, and past and current codes and standards that support community resilience.

5.1.1. Social Needs and Systems Performance Goals

Buildings fulfill a multitude of social needs from the most basic, such as providing shelter, to housing necessary services like medical care and food. Many buildings also house goods or businesses that can be closed following a hazard event; but such buildings will hopefully require only modest repairs. Therefore, performance goals for buildings depend specifically on what each individual building houses or the function it serves. Some buildings must be functional immediately, or soon after, the disaster, while other buldings need to be stable so they do not collapse or place the life safety of the occupants at risk. Because buildings fulfill a wide variety of social needs, the recovery time and sequence of recovery must be evaluated at the community level. Section 5.2 discusses building classes and uses; Section 5.3 provides guidance for developing performance goals based on the methodology in Chapter 3.

5.1.2. Reliability v. Resilience

Buildings are an integrated set of systems – structural, architectural, utilities, etc. – that perform together to serve the intended function of the building. When discussing building performance, each of these systems must perform adequately because each system supports the building function in different ways. Structural systems provide a stable system that carries gravity loads based on building construction and contents and must resist forces imposed by hazard events. Architectural systems supply protection from outside elements through the cladding systems (e.g., roof, exterior walls or panels, doors, windows, etc.) and interior finishes. Utility systems deliver needed services that support the building function.

Buildings designs focus on the building’s intended purpose and on occupant safety for fires and natural hazard events. Building designs are based on provisions in building codes and standards, though some designs are performance-based and allow alternative solutions. Structural systems for buildings are typically designed for a minimum required level of hazard intensity, based on a target reliability level for building performance. For buildings, structural reliability refers to the probability that a structural member or system will not fail. For gravity, wind, snow, and flood loads, structures are designed for member reliability, with a low probability of failure, so that structural members are not expected to fail during a design event. For seismic events, structures are designed for system reliability conditional on the design seismic event, where the structural system is not expected to fail or collapse, but individual members may fail. Thus, for wind, snow, and flood events, the structural system is expected to sustain little or no damage under a design hazard event. For seismic hazard events, the structure is expected to afford life safety to the occupants, such that while structural damage may occur, the building will not collapse. Therefore, while a building is expected to protect its occupants during a seismic event, it may not be functional afterwards and may even need to be demolished.

Wind, floods and winter storm events may also disrupt services, such as water supply, and create power outages, which also affect building functionality. If water pressure cannot be maintained, then fire hydrants and fire suppression systems are out of service, and buildings cannot be occupied. If fuel for generators is depleted during long term power outages, buildings are not functional.

While structural reliability is important, it is not synonymous with resilience. If a building has sustained damage such that, following a hazard event, it cannot perform its pre-disaster function, that may negatively affect a community's resilience. An example is a fire station where the building itself has sustained little or no structural damage, but the doors cannot open, preventing fire trucks from exiting to fight fires. Some buildings may need to be functional sooner than others. Providing a minimum level of reliability ensures buildings do not collapse, but does not ensure they will remain functional after a design-level hazard event.

Designing a resilient building requires understanding the functions that building supports in the community, and the performance required to ensure those functions during or after a hazard event. Some requirements may actually exceed those required by model building codes and standards.

5.1.3. Interdependencies

A community's resilience depends on the performance of its buildings. The functionality of most buildings depends, in turn, on the utilities that supply power, communication, water/wastewater, and the local transportation system. Alternatively, some buildings support the utility systems. Buildings and supporting infrastructure systems must have compatible performance goals to support community resilience. Refer to other chapters of this framework for infrastructure system resilience recommendations.

In many instances, infrastructure systems are unavailable immediately after a hazard event to support specific buildings when they must be operational. For example, emergency operation centers and hospitals must function immediately after a hazard event. However, power and water infrastructure systems may be damaged. Therefore, during short-term recovery, critical facilities should plan to operate without external power and water until those services are expected to be recovered.

In many instances, the functionality of specific buildings depends on the occupants as well as the physical building. First responders need to reach the buildings where equipment is housed to provide emergency services. Therefore, community resilience requires the buildings and supporting infrastructure systems consider dependencies that must be addressed to be functional.

5.2. Buildings Classes and Uses

5.2.1. Government

In most communities, the emergency operations centers, first responder facilities, airports, penitentiaries, and water and wastewater treatment facilities are government-owned buildings. These buildings provide essential services and shelter occupants and equipment that must remain operational during and after a major disaster event. Therefore, essential buildings should remain operational, as defined by Category A (safe and operational) in Chapter 3 and Table 5-1.

Other government buildings may not need to be functional immediately following a hazard event (e.g., City Hall or county administrative building, public schools, mass transit stations and garages, judicial courts, and community centers). However, these buildings may be needed during the intermediate recovery phase following the hazard event. A performance goal for these types of buildings might be either Category A or Category B, safe and usable during repair, depending on their role in the community recovery plan.

Categories C and D are provided to help communities evaluate the anticipated performance of their existing buildings for a hazard event. Older construction that is poorly maintained, or has features known to be prone to failure, such as unreinforced masonry walls and a lack of continuous load path to the foundation, need to be documented as part of the community resilience plan.

Typically, buildings are designed according to risk categories in the *American Society of Civil Engineers Standard 7* (ASCE 7) and *International Building Code*. Risk categories relate the criteria for design loads or resulting deformations to the consequence of failure for the structure and its occupants. Risk categories are distinct from *occupancy category*, which relates primarily to issues associated with fire and life safety protection, as opposed to risks associated with structural failure. Risk categories rank building performance with a progression of the anticipated seriousness of the consequence of failure from lowest risk to human life (Risk Category I) to the highest (Risk Category IV).

Essential buildings fall under Risk Category IV, which has the highest level of reliability, and provisions for seismic events that require nonstructural systems to remain operable. Some buildings that may be deemed essential are classified as Risk Category III, which includes buildings and structures that house a large number of people in one place or those having limited mobility or ability to escape to a safe haven in the event of failure, including elementary schools, prisons, and healthcare facilities. This category has also includes structures associated with utilities required to protect the health and safety of a community, including power-generating stations and water treatment and sewage treatment plants. Risk Category III requires a higher level of reliability than a typical building associated with Risk Category II, but there are fewer nonstructural system requirements for seismic events than a Risk Category IV building.

Table 5-1. Building Performance Categories

Category	Performance Standard
A. Safe and operational	These are facilities that suffer only minor damage and have the ability to function without interruption. Essential facilities such as hospitals and emergency operations centers need to have this level of function.
B. Safe and usable during repair	These are facilities that experience moderate damage to their finishes, contents and support systems. They will receive green tags when inspected and will be safe to occupy after the hazard event. This level of performance is suitable for shelter-in-place residential buildings, neighborhood businesses and services, and other businesses or services deemed important to community recovery.
C. Safe and not usable	These facilities meet the minimum safety goals, but a significant number will remain closed until they are repaired. These facilities will receive yellow tags. This performance may be suitable for some of the facilities that support the community’s economy. Demand for business and market factors will determine when they should be repaired or replaced.
D. Unsafe – partial or complete collapse	These facilities are dangerous because the extent of damage may lead to casualties.

5.2.2. Healthcare

Emergency medical facilities are critical to response and recovery efforts following a major disaster. Therefore hospitals, essential healthcare facilities, and their supporting infrastructure, must be functional (Category A) during and following a hazard event. This does not mean the entire facility has to be fully operational, but critical functions, such as the emergency room and life support systems, should be operational until other functions can be restored. Currently, hospitals are designed to Risk Category IV requirements, with some local communities or federal agencies imposing additional requirements. For example, California requires that all hospital designs, regardless of location or ownership (municipal or private), be reviewed and construction overseen by a state agency.

Nursing homes and residential treatment facilities that house patients who cannot care for themselves may also need to be immediately functional after a hazard event. Other healthcare facilities, such as doctors’ offices, pharmacies, and outpatient clinics, may not all need to be immediately available. Communities should determine if a subset of these buildings will be needed shortly after the event. Medical office buildings and pharmacies may need to be designed to suffer limited damage that can be repaired in a reasonable period of time, either Category A or Category B, depending on their role in community recovery and resilience. In most cases, buildings for these types of medical offices are currently designed as Risk Category II buildings.

5.2.3. Schools and Daycare Centers

Many communities have primary (K-12) schools that are designed to a higher performance level (Risk Category III) because they have large assemblies of children. Often, school gymnasiums or entire school buildings are designated to serve as emergency shelters during the hazard event and as emergency staging areas after the event. Additionally, the research that went into the SPUR Resilience City Initiative found a perception that when children can return to school, things are returning to normal and parents can return to work. Thus, expeditious resumption of function is important for primary schools across a community.

There can be a dichotomy of performance requirements for a school. On the one hand, providing enhanced performance and returning to operation quickly places a school in Category B, stable with moderate damage. However, if the school or some portion of the school is used as an emergency shelter, that requires Category A, stable with minor damage. Depending on the hazard, the Risk Category III provisions to which most primary schools are designed may provide Category A or B performance. Therefore, any school that will be designated as an emergency shelter should be evaluated to determine its intended role in the community and that it is appropriately designed for Category A or B performance. Evaluation would determine which schools are anticipated to perform adequately and which may need to be upgraded to a higher performance level.

Higher education facilities are generally regulated as business or assembly occupancies with exceptions for specific uses, such as laboratory and other research uses. Research universities are also often concerned with protecting their research facilities, long-term experiments, associated specimens and data.

Daycare centers house young children that require mobility assistance and are unable to make decisions; but daycare populations may not meet assembly requirements. Therefore, such centers may be located in buildings that meet either Risk Category II or III performance requirements and code requirements for these types of facilities vary. In some cases there are heightened requirements; and in other instances there are few constraints beyond basic code requirements for Risk Category II buildings. Communities may require daycare centers to be designed to a higher level of performance, similar to school buildings.

5.2.4. Religious and Spiritual Centers

Religious and spiritual centers play a special role in many communities. They can offer a safe haven for people with emotional distress following a hazard event. Logistically, these buildings are often critical nodes in the post-disaster recovery network. Many religious organizations operate charity networks that provide supplies to people following a hazard event. In past disasters, many religious institutions opened their doors to provide temporary housing. In most cases, however, these buildings are designed as typical Risk Category II buildings. Compounding the issue, these buildings are often among the oldest in a community and are built with materials and construction methods that perform poorly in hazard events.

If these facilities fill an important role in the community recovery plan, Category B would be a desired performance. However, a number of factors could influence a community to accept a lesser performance goal. First, most of these institutions are nonprofit entities, with little funding for infrastructure improvement. Second, many historic buildings would have to be modified, unacceptably disrupting their historic fabric to meet this higher performance category. Therefore, a community should understand the anticipated performance of its churches and spiritual centers and their role in community recovery.

5.2.5. Residential and Hospitality

Communities should consider whether residential buildings and neighborhoods will shelter a significant portion of the population following a hazard event. Houses, apartment buildings, and condominiums need not be fully functional, like a hospital or emergency operation center, but they should safely house occupants to support recovery and re-opening of businesses and schools. Not being fully functional could mean that a house or apartment is without power or water for a reasonable period of time, but can safely shelter its inhabitants. The significant destruction of housing stock led to the migration of a significant portion of the population following Hurricane Katrina’s impact on New Orleans. Such a shelter-in-place performance level is - key to the SPUR Resilient City initiative and prompted the City of San Francisco to mandate a retrofit ordinance for vulnerable multi-family housing.

Currently multi-unit residential structures are designed to Risk Category II provisions, except where the number of occupants is quite large (e.g., > 5,000 people); then they designs meet Risk Category III criteria. For multi-family residential structures, there are two dominant construction types: light frame (wood and cold formed steel light frame) construction and steel or reinforced concrete construction. Light frame residential structures have different performance issues than steel or reinforced concrete structures, which are typically larger.

Most one and two-family dwellings are constructed based on pre-engineered standards using the prescriptive requirements of the *International Residential Code*. There has been debate as to whether the IRC provides comparable performance to the *International Building Code*. In some cases, such as the Loma Prieta and Northridge earthquakes, one and two-family dwellings performed as well as or better than engineered buildings. Further investigation regarding a possible discrepancy in requirements between the IBC and the IRC is essential, because of the importance of residential housing.

In addition, an effective response to most hazard events may require supplemental first responders and personnel from outside the community. If most residential buildings are not functional or safe to occupy, demand for temporary shelter may compete with the need to temporarily house response and recovery workers. Hotels and motels can support response and recovery efforts if they are back in operation shortly after the event. Typically these buildings are designed to meet Risk Category II criteria, like multi-family residential structures.

5.2.6. Business and Services

While it would be ideal to have all community businesses open shortly after a hazard event, such an outcome is not economically practicable. Many business offices, retail stores, and manufacturing plants are located in older buildings that may not perform well during a hazard event or, if constructed more recently, are designed to Risk Category II criteria. Not all commercial buildings are designed to the code minimum requirements, and they may have higher performance capabilities.

Each community should select design and recovery performance goals for its businesses and services, depending on their role in the community during recovery. Certain types of commercial buildings may be critical to the recovery effort. The community needs to designate businesses and their buildings that are critical retail and able to meet a higher performance level. Some businesses and services are commonly essential to recovery:

- ***Grocery stores and pharmacies.*** People need food, water, medication, and first aid supplies following a hazard event. Regional or national grocery stores and pharmacies typically have robust distribution networks outside the affected area that can bring supplies immediately after the hazard event. Although the common preparedness recommendation is for people to have 72 hours of food and water on hand, the potential for disruption beyond the first three days should be evaluated for a community’s hazards. For example, the Oregon Resilience Plan recommends two weeks of food and water for a Cascadia earthquake event.
- ***Banks or financial institutions.*** Banks or structures that house automated teller machines provide access to money.
- ***Hardware and home improvement stores.*** These businesses provide building materials for repairs, reconstruction, and emergency shoring of damaged buildings.
- ***Gas stations and petroleum refineries.*** Many communities are arranged so residents need automobiles to carryout basic functions, like shopping and commuting to work. A disruptive event may impact fuel delivery systems and gasoline may be difficult to obtain for a period of time.
- ***Buildings that house industrial and hazardous materials or processes.*** Buildings and other structures containing toxic, highly toxic, or explosive substances may be classified as Risk Category II structures if it can be demonstrated that the risk to the public from a release of these materials is minimal. However, communities need to verify that the risk management plan address community hazards, and any potential releases that may occur during or after a hazard event.

The resilience needs of other types of businesses and the buildings that house them depend to a large extent on the business and community's tolerance for those businesses to be delayed in reopening or closed. Many professional service businesses rely on employees working remotely from home or alternate office spaces. Conversely, manufacturing businesses, retail, and food service businesses do not have that luxury. Their location is critical to the ability of the business to function. If a restaurant or store cannot serve the public or a factory is unable to manufacture its product, then the business may fail. Losing these businesses can adversely impact the community's recovery and long-term resilience because of lost jobs and other economic impacts.

5.2.7. Conference and Event Venues

Convention centers, stadiums, and other large even venues are important for the long term recovery of many communities because of the revenue that these types of events typically generate. Additionally, a venue hosting major events following a hazard event can uplift morale for a community, like hosting the Super Bowl in New Orleans following Hurricane Katrina. Typically these venues are designed to Risk Category III because of the large number of occupants, so they have a greater performance capability than typical buildings.

5.2.8. Detention and Correctional Facilities

Many communities have standalone detention and correctional facilities (prisons). Building codes typically require some higher design requirements on these types of facilities because the people housed in them cannot evacuate without supervision. The level of enhanced design requirements varies based on the facility requirements and state or local jurisdiction. Within this framework, it is suggested that these types of facilities be designed to Category A or B.

5.3. Performance Goals

The resilience matrices in Chapter 3 provide examples of performance goals for buildings and infrastructure systems at the community level for fictional community, Centerville, USA. The example matrices provide a visual method communities can use to determine their desired performance goals in

Table 5-2 through Table 5-4 address each of the three hazard levels discussed in Chapter 3 – routine, expected, and extreme – for Centerville, USA. An individual community may start with one or more of the hazard levels. Some communities may decide that for routine events the infrastructure should have little to no disruption and the extreme event is too much to plan for, so they base their planning on the expected event. However, examining the response of the physical infrastructure to three levels of a hazard can provide insight and understanding regarding system performance. One or more systems may not perform well at the routine level, and cause cascading effects. Such performance indicates that frequent repairs may be required for that system. Alternatively, if there are substantial differences between the desired and anticipated performance of one or more systems, the performance at several hazard levels may help a community prioritize retrofit or mitigation strategies.

A community first needs to identify clusters, or groupings, of buildings for which the same performance goals are desired. The cluster groups and assignment of buildings within each cluster may be unique to each community. The types of buildings selected by Centerville are listed in the left column, and are categorized under critical facilities, emergency housing, housing/neighborhoods, and community recovery. The categories also reflect the sequence of building types that need to be functional following a hazard event. Each building cluster then needs to be evaluated for its role in the community recovery. The rate of recovery is indicated by percentages, 30 %, 60%, and 90%, to show how many buildings within the cluster are recovered and functioning during the three recovery phases in the top row of the table.

The examples in Table 5-2 through Table 5-4 illustrate a large urban/suburban community. Smaller or more distributed communities may elect to create different clusters, while major metropolitan areas may create even finer clusters of buildings. The Centerville example shows that, for a routine hazard in Table

5-2, almost all buildings are desired to be functioning within one to two days, and anticipated to be fully functional within one to three days. For the expected hazard in Table 5-3, only critical buildings and emergency housing are desired to be functioning within one day of the event, but these facilities are not anticipated to be functional for more than four months to two years. For the extreme hazard in Table 5-4, only emergency operation centers and first responder facilities are desired to be functional within a day, but the anticipated performance is that they will not be functional for more than three years.

Recovery of function may not initially be full recovery of function, but a minimum or interim level necessary to perform the essential tasks of that specific building to start the recovery process. For example, a city hall that has an emergency operation center may only provide for enough power to support lighting, phones, and computers for the EOC room, but not the entire building. The building's structure and exterior cladding would also need to be stable and intact to provide a safe environment and allow the EOC to be occupied.

Table 5-2. Example Building Performance Goals for Routine Event in Centerville, USA

Disturbance		
(1)	Hazard	Any
	Affected Area for Routine Event	Localized
	Disruption Level	Minor

Restoration times		
(2)	30%	Restored
	60%	Restored
	90%	Restored
(3)	X	Current

Functional Category: Cluster	**(4) Support Needed**	**(5) Target Goal**	**Routine Hazard Level**								
			Phase 1 – Short-Term			**Phase 2 -- Intermediate**			**Phase 3 – Long-Term**		
			Days			**Wks**			**Mos**		
			0	**1**	**1-3**	**1-4**	**4-8**	**8-12**	**4**	**4-24**	**24+**
Critical Facilities	**….**	**A**									
Emergency Operation Centers			90%	X							
First Responder Facilities			90%	X							
Acute Care Hospitals			90%	X							
Non-ambulatory Occupants (prisons, nursing homes, etc.)			90%	X							
Emergency Housing		**B**									
Temporary Emergency Shelters			90%		X						
Single and Multi-family Housing (Shelter in place)			90%		X						
Housing/Neighborhoods		**B**									
Critical Retail			90%		X						
Religious and Spiritual Centers			90%		X						
Single and Multi-family Housing (Full Function)			90%		X						
Schools			90%		X						
Hotels & Motels			90%		X						
Community Recovery		**C**									
Businesses - Manufacturing			60%	90%	X						
Businesses - Commodity Services			60%	90%	X						
Businesses - Service Professions			60%	90%	X						
Conference & Event Venues			60%	90%	X						

Footnotes:

1 Specify hazard being considered
Specify level – Routine, Expected, Extreme
Specify the size of the area affected – localized, community, regional
Specify severity of disruption – minor, moderate, severe

2 30% 60% 90% Restoration times relate to number of elements restored within the cluster

3 X Estimated 90% restoration time for current conditions based on design standards and current inventory
Relates to each cluster or category and represents the level of restoration of service to that cluster or category
Listing for each category should represent the full range for the related clusters
Category recovery times will be shown on the Summary Matrix
"X" represents the recovery time anticipated to achieve a 90% recovery level for the current conditions

4 Indicate levels of support anticipated by plan

R	Regional
S	State
MS	Multi-state
C	Civil Corporate Citizenship

5 Indicate minimum performance category for all new construction.
See Section 3.2.6

Table 5-3. Example Building Performance Goals for Expected Event in Centerville, USA

Disturbance		
(1)	Hazard	Any
	Affected Area for Expected Event	Community
	Disruption Level	Moderate

Restoration times		
(2)	30%	Restored
	60%	Restored
	90%	Restored
(3)	X	Current

Functional Category: Cluster	**(4) Support Needed**	**(5) Target Goal**	**Expected Hazard Level**								
			Phase 1 – Short-Term			**Phase 2 -- Intermediate**			**Phase 3 – Long-Term**		
			Days			**Wks**			**Mos**		
			0	**1**	**1-3**	**1-4**	**4-8**	**8-12**	**4**	**4-24**	**24+**
Critical Facilities	**….**	**A**									
Emergency Operation Centers			90%							X	
First Responder Facilities			90%							X	
Acute Care Hospitals			90%							X	
Non-ambulatory Occupants (prisons, nursing homes, etc.)			90%							X	
Emergency Housing		**B**									
Temporary Emergency Shelters			30%	90%							X
Single and Multi-family Housing (Shelter in place)			60%			90%					X
Housing/Neighborhoods		**B**									
Critical Retail				30%	60%	90%					X
Religious and Spiritual Centers					30%	60%	90%				X
Single and Multi-family Housing (Full Function)					30%		60%		90%		X
Schools					30%	60%	90%				X
Hotels & Motels					30%		60%	90%			X
Community Recovery		**C**									
Businesses - Manufacturing						30%	60%	90%			X
Businesses - Commodity Services						30%	60%		90%		X
Businesses - Service Professions						30%		60%		90%	X
Conference & Event Venues						30%		60%		90%	X

Footnotes: See Table 5-2, page 8.

Table 5-4. Example Building Performance Goals for Extreme Event in Centerville, USA

Disturbance		
(1)	Hazard	Any
	Affected Area for Extreme Event	Regional
	Disruption Level	Severe

Restoration times		
(2)	30%	Restored
	60%	Restored
	90%	Restored
(3)	X	Current

Functional Category: Cluster	(4) Support Needed	(5) Target Goal	Extreme Hazard Level								
			Phase 1 – Short-Term			Phase 2 -- Intermediate			Phase 3 – Long-Term		
			Days			Wks			Mos		
			0	1	1-3	1-4	4-8	8-12	4	4-36	36+
Critical Facilities	….	**A**									
Emergency Operation Centers			90%								X
First Responder Facilities			90%								X
Acute Care Hospitals			30%		60%		90%				X
Non-ambulatory Occupants (prisons, nursing homes, etc.)			30%			60%		90%			X
Emergency Housing		**B**									
Temporary Emergency Shelters			30%		60%	90%					X
Single and Multi-family Housing (Shelter in place)			30%			60%		90%			X
Housing/Neighborhoods		**B**									
Critical Retail					30%	60%	90%				X
Religious and Spiritual Centers					30%		60%	90%			X
Single and Multi-family Housing (Full Function)						30%		60%	90%		X
Schools						30%	60%	90%			X
Hotels & Motels						30%		60%	90%		X
Community Recovery		**C**									
Businesses - Manufacturing						30%		60%		90%	X
Businesses - Commodity Services						30%		60%		90%	X
Businesses - Service Professions							30%		60%	90%	X
Conference & Event Venues							30%		60%	90%	X

Footnotes: See Table 5-2, page 8.

It is difficult for designers to specifically target an amount of damage that can be repaired in a given timeframe, as there are numerous sources of uncertainty. However, it is possible to design for estimated levels of damage and based on that, assign a likelihood that the buildings within a cluster will be functional.

Communities primarily consist of existing buildings that have been designed and constructed under the building code at that time, potentially creating a range of expected performance levels for the same category of buildings. Sometimes, older buildings were designed using provisions that were later found to be inadequate, but rarely were the new provisions retroactively applied. Figure 5-1 shows a partially collapsed unreinforced masonry building following a major earthquake. This type of construction is unsafe in earthquakes, but many communities have not mandated retrofitting these types of buildings to avoid damage or collapse.

As part of developing performance goals for building clusters, the community should identify if any types of buildings or construction pose a significant safety hazard to occupants or the public. Mitigation or retrofit programs can be developed to address buildings that pose a significant safety hazard, such as unreinforced masonry building retrofit ordinances that have been adopted by many California cities, requirements for elevated construction in a flood plan, or requiring storm shelters in new homes.

When selecting recovery goals, a community must decide which performance category is appropriate for buildings within each cluster.

Category A buildings should require little repair to return to function. Often recovery is limited by outside factors such as power or water not being available, which is why onsite power and water is often required by communities for essential facilities. There may be some damage to a Category A building, but the damage can easily be cleaned up (i.e., toppled shelves or cosmetic damage to the structure) as shown in Figure 5-2.

Figure 5-1: Failure of unreinforced masonry wall during an earthquake event. (Photo courtesy of Degenkolb Engineers)

Figure 5-2: Non-structural damage to interior finishes following an earthquake event. (Photo Courtesy of Degenkolb Engineers)

Similarly, for flood events, buildings that sustain minor damage and thus fall into Category A are expected to have damage limited primarily to the exposed portions of the building exterior. If buildings are properly elevated, floodwaters may reach subflooring and building infrastructure systems but should not overtop the first floor or wet the interior. However, if the building has a basement, there could be damage to power sources, utilities and appliances located there. Buildings subject even to low flood depths may need some drying to remove residual moisture and cleaning to prevent mold growth and may not be safe for occupants until this process has occurred. Figure 5-3 shows an example of minor flood damage.

Figure 5-3: Floodwaters reached just under the first floor on this building (photo courtesy of AECOM)

Buildings that have experienced minor damage as the result of wind will generally have some roof covering damage, a limited amount of damage to openings (e.g., less than 10 % of doors and windows broken) and minimal exterior finish damage. Figure 5-4 illustrates minor damage as the result of wind.

Category B buildings are expected to sustain damage, but the damage should not affect the building’s structural stability. There may be significant nonstructural damage, but the building can be used while the repairs are made. Figure 5-5 shows pictures of significant nonstructural damage inside a building that is structurally stable following an earthquake event. In such cases, the amount of work required to clean up the fallen contents or fix the damaged to the walls may take a couple days to a couple weeks.

Figure 5-4: Damage to roof covering, vinyl siding and fascia as the result of wind (courtesy AECOM)

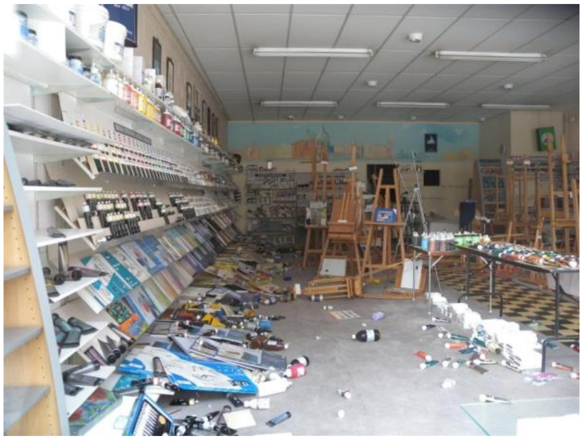

Figure 5-5: Significant nonstructural damage inside a building that is structurally stable after an earthquake event. (Photo Courtesy of Degenkolb Engineers)

Buildings that have been damaged by flooding and sustained moderate damage may experience a limited depth of flooding over the first floor; the foundation may be inundated or have minor undermining or scour; exterior and interior walls may have water stains and possible contamination that requires replacement. Subflooring and floor finishes may also require replacement along with some electrical wiring. While the building may be structurally stable, it may not be safe for habitants until properly dried and cleaned due to the potential for mold blooms and growth. Figure 5-6 show examples of moderate damage as the result of flooding.

Moderate damage sustained as the result of wind events may include moderate to major roof covering damage, some minor instances of roof sheathing failure, and some interior water damage, and damage to the exterior finish. Figure 5-7 shows moderate damage as the result of wind.

Figure 5-6: As a result of an estimated 3-4 feet of flooding, interior walls had to be replaced in this building as well as an exterior door and window (photo courtesy of FEMA) [getting a better quality version]

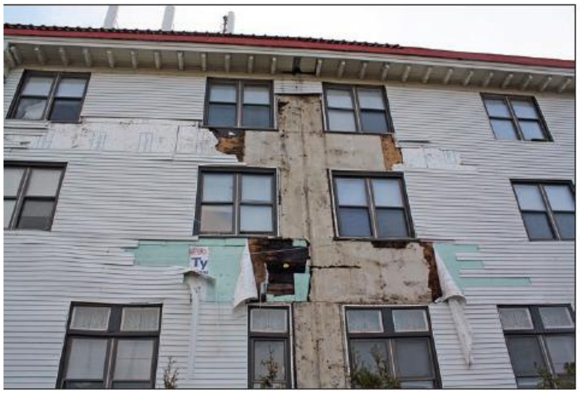

Figure 5-7: Siding loss and minor envelope damage on low-rise building from a wind event. (photo courtesy of FEMA) [getting a better quality version]

Category C buildings are expected to have significant nonstructural and some structural damage. The structural damage should not cause a loss of structural stability, but may require shoring while repairs are conducted. It is assumed that damage such as this would take weeks to months to repair. Figure 5-8 shows structural damage, but the global structure is stable. Figure 5-9 shows a fractured brace connection in a building damaged in an earthquake. There were about ten of these damaged braces on one story of a four story building and it took over three months from the disaster until the repairs were completed and the building could be reoccupied.

Figure 5-8: Apartment building with damaged structural members that is globally stable. (courtesy of Degenkolb Engineers)

Figure 5-9: Fractured brace connection in a building damaged in an earthquake (courtesy of Degenkolb Engineers)

For buildings severely damaged by flooding, flood depths will likely be several feet above the first floor and may result in foundation damage that could include settlement and severe scour and undermining.

Exterior walls may be severely damaged with large missing sections. Interior floor and wall finishes e will need replacement. Limited deformation of the structural frame may be evident. As with less severely flood damaged buildings, proper drying and cleaning is necessary prior to re-occupation of the building due to the potential for mold growth. Figure 5-10 shows severe damage as the result of flooding.

Severe damage incurred due to a wind event may include major roof sheathing loss, extensive interior water damage, and minor to major envelope damage. Additionally, roof uplift damage may be evident. In instances where significant water intrusion damage has occurred, buildings may not be safe for use until adequate drying and cleaning has occurred due to the potential for mold bloom. Figure 5-11 demonstrates severe wind damage to buildings.

Figure 5-10: Foundation wall collapse due to hydrostatic pressure from floodwaters (courtesy of FEMA) [getting a better quality version]

Figure 5-11: Wind and wind-borne debris resulted in considerable damage to glazing on this building (courtesy of FEMA) [getting a better quality version]

Category D buildings cannot be used or occupied after a hazard event. Destruction or collapse of buildings may occur because the building was not designed and constructed to withstand the severity of a particular event, or because a building was constructed to older building codes, or no codes at all, or because the codes were not properly followed or enforced. Figure 5-12 shows examples of destruction and collapse as the result of flood and wind events.

Figure 5-12: Collapse of 5-story building due to undermining (from flooding) of shallow foundation (courtesy of FEMA)

5.4. Regulatory Environment

Model building codes are developed at the national level for adoption across the country, and adopted by states or local jurisdictions. However, federal buildings are designed and constructed to federal government standards. In the U.S., two organizations publish model building codes for adoption by federal agencies or state and local governments. One is published by the International Code Council, which formed as a merger of three organizations that published regional model building codes. The other code is published by the National Fire Protection Association. The ICC's *International Building Code* is the most widely adopted model building codes; and the *National Fire Protection Code* is the most widely adopted model fire code in the U.S. Most federal agencies also use these codes, with agency-specific amendments, as the basis for their building requirements. These codes contain many reference standards that are typically published by not-for-profit standards development organizations, professional societies, and industry groups. Model building codes and the referenced standards are typically modified by federal, state, and local agencies for their specific purposes.

While the model building codes specify minimum requirements that are applicable throughout the country, states and local municipalities may modify the model building codes to achieve specific goals for local or regional hazards. For example, in areas of Florida, building codes were changed to require more hurricane-resilient construction following Hurricane Andrew, requiring certain types of roofing materials, stronger windows and doors, and greater inspection and enforcement.

Some states and localities adopt, but remove requirements in model building codes, to make them less stringent. Some jurisdictions only adopt the model code for government owned or specific occupancy buildings, but not for all buildings in their community. Some communities do not adopt or enforce any building code.

Enforcing building codes and construction standards is as important as adopting building codes and standards. The level of enforcement can significantly impact resilience. Even if the most up-to-date building code and standards are in effect, buildings designed and constructed in a substandard manner negatively impact community resilience. Therefore, having a properly trained building department to review designs for code conformance and inspect construction for conformance with the approved plans, is an essential component of community resilience.

5.5. Standards and Codes

The *International Building Code*, a commonly adopted model building code, was developed to provide design requirements that “safeguard public health, safety and general welfare through structural strength, means of egress facilities, stability, sanitation, adequate light and ventilation, energy conservation, safety to life and property from fire and other hazards attributed to the building environment, and to provide safety to fire fighters and emergency responders during emergency operations.”

The expected performance of each building depends upon the codes and standards in-force at the time of construction, as well as the level of enforcement and maintenance. Building codes and standards are dynamic and ever-changing. Many changes come in response to disasters, while others come from a perceived weakness to natural disasters brought about by research on the subject. The evolving nature of building codes and enforcement, combined with the degradation that occurs over time, results in a building stock with variable capacities to resist hazard events.

Building codes and standards primarily regulate new construction and are based on the current consensus of best practices and design methods at the time they are written. After a significant hazard event, the building code may be modified based on observed damage or failures. Some provisions, when changed, become retroactive or are enforced during renovations. Examples of these are egress protection, accessibility for differently abled persons, and fire suppression system requirements.

Communities primarily consist of existing buildings, and most do not conform to current code standards. The mix of building types, construction, and age can create significant challenges when developing plans for a resilient community. Construction materials, construction quality, structural configuration, architectural finishes, redundancy of the mechanical and electrical systems can all affect the resilience of one building compared to another.

5.5.1. New Construction

Design criteria for new construction form the foundation for future resilience planning. Additions to the model codes may be desired to support a community’s performance goals for resilience. Such changes typically add modest, incremental costs, whereas trying to require retrofit of existing construction after an event can be prohibitively expensive.

Building codes and standards have primarily focused on life safety of occupants during major natural hazard events, specifically in their structural design criteria. Early building codes addressed routine environmental design loads for frequent hazards such as wind and snow. The hazard design load and self-weight and occupancy live loads were used to design a structure. This approach produced structures that withstood routine, moderate hazards. However, the 1906 San Francisco Earthquake demonstrated that in particular seismic hazards induced large forces that were difficult to resist without any structural damage. This realization led to a philosophy of designing buildings for seismic hazards so buildings remained stable during the event with some structural damage, but did not collapse. The same concept applies to fire safety. By limiting fire spread with passive compartmentation, areas of the building outside the area of fire origin and adjacent buildings can often be saved from damage. Reduced fire damage allows more rapid recovery of functionality in the building.

Building codes provide design loads based on return periods for various hazards. In addition to design loads, there are often design provisions associated with the specific hazard. Table 5-5 (copied from Chapter 3) lists the various return periods for the routine, expected (design level), and extreme hazards.

Table 5-5: Design Loads for Buildings and Facilities (ASCE 7-10)

Hazard	Routine	Expected	Extreme
Ground Snow	50 year	300 to 500 year[1]	TBD
Rain	[2]	[2]	[2]
Wind – Extratropical	50 year	700 year	3,000 year[3]
Wind – Hurricane	50 to 100 year	700 year	3,000 year[3]
Wind – Tornado	[3]	[3]	[3]
Earthquake4	50 year	500 year	2,500 year
Tsunami	50 year	500 year	2,500 year
Flood	100 year	100 to 500 year	TBD
Fire – Wildfire	[4]	[4]	[4]
Fire –Urban/Manmade	[4]	[4]	[4]
Blast / Terrorism	[5]	[5]	[5]

[1] For the northeast, 1.6 (the LRFD factor on snow load) times the 50-year ground snow load is equivalent to the 300 to 500 year snow load.

[2] Rain is designed by rainfall intensity of inches per hour or mm/h, as specified by the local code.

[3] Tornado and tsunami loads are not addressed in ASCE 7-10. Tornadoes are presently classified by the EF scale. Tsunami loads are based on a proposal for ASCE 7-16.

[4] Hazards to be determined in conjunction with design professionals based on deterministic scenarios.

[5] Hazards to be determined based on deterministic scenarios. Reference UFC 03-020-01 for examples of deterministic scenarios.

Wind hazards. ASCE 7-10 prescribes design wind speeds for each Risk Category with different return periods. For Risk Category I, the mean return period is 300 years for facilities that have a low risk to human life and are typically unoccupied buildings. For Risk Category II facilities, that include typical buildings and other structures, the return period is 700 years. For Risk Category III and IV facilities, the return period is 1,300 years. The wind speeds derived from these return periods are based on extratropical winds and hurricane winds. Tornadic wind speeds are not currently addressed.

The majority of the wind design requirements are for the structural frame and the cladding. There are some requirements for attachment strength of nonstructural components. Requirements for serviceability and functionality are not explicitly codified, but are indirectly addressed through elastic design methods at specified wind speeds for desired performance levels. The International Building Code requires consideration of a drift limit under a reduced wind load (the factor used intends to approximate the 100-year return period wind). There are no explicit structural design requirements to preserve the building envelope so post-disaster function is not impacted, but there are some prescriptive requirements on the requirements of doors and windows. Nor are there requirements that exterior equipment, fire pumps, or generators must be functional following the design windstorm.

Snow hazards. Snow design uses a 50-year mean recurrence interval for ground snow loads. It is increased with an importance factor for higher Risk Category structures.

Rain hazards. Rain design uses a 100-year rain storm as the design hazard, with loads increased by 60% to account for uncertainty in predicting rainfall in a major event. However, the majority of rain design provisions relate to providing proper drainage and stiffness to the roof to prevent ponding. There are no code requirements in a design rain event that the building envelope must maintain its ability to keep water out. In many instances this is accomplished without explicit code requirements because of the liability seen with water intrusion and its adverse effects, such as mold.

Flood hazards. Flood design provisions for all buildings are typically based on a 100-year mean recurrence interval for flood elevation, though 500-year flood elevations are recommended for design of critical facilities. Recommended practice is to locate buildings out of the 100-year flood zone. If they must be within this flood zone, floodplain management provisions and building codes require that they be elevated to or above the design flood elevation which is, at a minimum, the elevation of the 100-year flood. Buildings with nonresidential uses may also be dry flood-proofed up to the design flood elevation if they are not subject to coastal flood forces or high velocity flooding. For structures subject to flood forces, the current provisions provide methods to avoid or resist flood forces, but are not necessarily meant to preserve functionality of the building during a flood event. Evacuation of flood prone areas during flood events is expected especially with days or even weeks of warning.

Flood design provisions are neither fully prescriptive or performance based. Instead, they are a mixture of the two. Elevation requirements are considered prescriptive because they elevation is mandated by flood maps and local codes. Other requirements that require design and vary between structures are considered performance based, such as building designs that resist flotation, collapse, and lateral movement.

Seismic hazards. Since the beginning of earthquake design, it has been recognized that designing for the hazard in the same way as other hazards would not be practical or economical. Therefore, the approach adopted prescribes forces and design requirements that allow buildings to be damaged, but not collapse. Following the 1971 San Fernando earthquake, hospitals were required to be designed to a higher standard, significantly improving their likelihood of remaining functional following the design earthquake.

The emphasis placed on the design of nonstructural systems is a very important distinction between seismic design provisions and design provisions for other hazards. All nonstructural systems have bracing requirements. In addition to the bracing requirements, nonstructural systems in essential facilities or those systems that relate to the life-safety system of the facility are required to maintain function or return to function following the design earthquake shaking hazard. The design earthquake shaking level is currently defined as 67% of the Risk Targeted Maximum Considered Earthquake shaking level.

Fire hazards. The performance of new and existing buildings during fires is addressed specifically through fire codes and in a complementary manner by building codes. Typically, fire prevention officers within local fire departments enforce the fire code, in conjunction with building inspectors. A fire code is primarily intended for preventing and containing fires and making certain that necessary training and equipment is on hand if a fire occurs. Fire codes also address inspection and maintenance requirements of passive and active fire protection systems.

The codes originated as life safety documents; but after the WTC disaster, many requirements establish additional redundancy, robustness and resilience. The (IBC) building code has been expanded to include protection for emergency responders following a major event.

Another key requirement is for automatic sprinkler systems in residential, healthcare, and assembly buildings as well as most other types of structures. Sprinklers limit the fire to the area of origin and can significantly reduce the level of smoke and fire damage.

There are currently very few, if any, code requirements for design of buildings in wild fire hazard areas. Some methods of construction could provide greater resilience than conventional construction in those regions, but nothing has been mandated.

Man-made hazards. Codes and standards do not have explicit structural design requirements for man-made hazards (e.g., arson, explosions or impact events), although some nominal provisions attempt to provide robustness to arrest the spread of damage so disproportionate collapse does not occur. Many requirements in the IBC require facility layout and hazard mitigation measures to prevent explosions of building contents. Guidelines for design of man-made hazards do exist for specific classes of buildings, like federal buildings and industrial facilities. Often these guidelines are restricted because they contain proprietary or security-sensitive information.

5.5.2. Existing Buildings

Existing buildings pose an even greater challenge than new buildings. For new buildings, codes can be amended or re-written. Although construction costs may increase, new buildings would be designed for the state-of-the-practice. Retrofit of existing buildings to the state-of-the-practice level of resilience, in contrast, can require significant financial commitment and necessitate major disruption to the building’s function, which tends to dissuade building owners from retrofit.

The cost and disruption associated with retrofit has made mandating retrofit measures a politically unpopular decision. In California, only the class of building deemed most prone to collapse in an earthquake – Unreinforced Masonry Buildings – has had widespread, albeit not universal, acceptance as something that should be mandated for retrofit.

For buildings constructed prior to development of flood provisions or a community’s adoption of flood provisions, there is a trigger for requiring that they be retrofit to meet current flood provisions. Buildings within designated flood hazard areas (generally the 100-year floodplain) that sustain damage of any origin, for which the cost to repair the building to its pre-damage conditions equals or exceeds 50 percent of the market value of the building, must be brought into compliance with current flood provisions. The same is true for improvements or rehabilitation of buildings when the cost equals or exceeds this threshold. However, enforcement of this requirement can be challenging, particularly in a post-disaster environment when communities are anxious to support building owners in reconstruction.

When existing buildings are evaluated for expected performance relative to resilience goals and required retrofit actions, standards for new construction are typically applied to the structural design. This application often leads to excessive requirements for improvements to obtain the desired performance. However, recent advancement in performance-based engineering has led to development of specific standards for existing buildings with regards to evaluation and retrofit.

One of the biggest impediments to retrofit of existing buildings lies in the conservatism embedded in current engineering codes and standards. Under-predicting a building’s performance in a given hazard because the standards are conservative can lead to significant retrofit requirements. Those requirements can make the retrofit economically unappealing to building owners.

5.6. Strategies for Implementing Community Resilience Plans

5.6.1. Available Guidance

Current engineering standards provide tools to support assessment of the structural safety of buildings. ASCE 41, the existing building seismic standard, provides a methodology to assess the performance of buildings for both safety and the ability to be reoccupied following an earthquake. ATC 45 provides an assessment methodology for flood and wind events. Similar standards do not exist for other hazards.

Building code provisions can be used to determine whether a building has sufficient fire resistance, egress, and other occupant safety-related issues. These methodologies are useful for individual buildings safety, but do not address damage versus recovery time to function.

HAZUS provides a platform for communities to assess vulnerabilities to earthquakes, hurricanes, and other hazards. HAZUS is useful for assessing effects of a disaster on a community. However, the existing building stock must be adequately reflected in the model, which can require significant data gathering.

Several existing resources exist for property owners, designers and communities to use to better understand best practices for flood resistant design and construction including:

- FEMA P-55 (Volume I and II), Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas
- FEMA P-499, Home Builder's Guide to Coastal Construction: Technical Fact Sheet Series
- FEMA P-550, Recommended Residential Construction for Coastal Areas: Building on Strong and Safe Foundations

Existing resources addressing wind include the ATC Design Guide 2, Basic Wind Engineering for Low-Rise Buildings.

5.6.2. Strategies for New/Future Construction

For new and future construction, desired performance goals and anticipated performance for adopted building codes needs to be evaluated to determine if additional local requirements are required. Risk categories currently in the building codes can support the desired levels of performance and resilience goals. By clearly defining the desired building performance for a hazard event in terms of performance and recovery time for return of function, communities can tailor local building codes and standards to support specific resilience goals.

For flood-resistant design and construction, best practices exist for communities or individuals to implement in addition to code minimum requirements. One basic but effective practice is locating all new construction outside of flood zones. Additionally, using additional height, or freeboard, in building design is also effective.

Stronger design and construction practices for wind resistance are encouraged through a variety of existing resources with primary goals of improving continuous load path connections, strengthening building envelopes, and protecting openings.

For fire hazards, sole reliance on active fire protection through automatic extinguishing systems (AES) to provide property protection in combustible construction is not appropriate for communities with hazards that compromise the performance of the AES, such as seismic events.

5.6.3. Strategies for Existing Construction

Building codes and standards evolve, but little retroactive compliance is required. This is a major issue in communities because the cost of retrofit exceeds, by orders of magnitude, the cost of adding resilience to a new building. A strong resistance to building retrofit because of cost, inconvenience to the building occupants, and disruption of operations creates a significant challenge for community resilience planning.

A strategy to prioritize retrofit requirements is to identify the most significant hazards posed by potential failures by various types of buildings and to mandate retrofit or demolition of those buildings. There have also been programs specifically aimed at critical facilities (e.g., hospitals and fire stations), where those buildings must be retrofit or replaced.

Given the aforementioned challenges with existing construction, community resilience planning should take a long-term view to achieve resilience. For example, the City of Los Angeles just instituted an ordinance requiring older concrete buildings that present significant collapse hazard in major earthquake be retrofit within the next 30 years.

The risk associated with existing flood-prone construction can be addressed primarily through retrofitting:

- ***Elevation* –** Elevation is one of the most common flood retrofitting techniques because it provides a high level of protection and does not require the owner to relocate. Elevation involves raising an existing building so the lowest floor or lowest horizontal structural member is at or above the regulated flood level. Common elevation techniques include elevation on piles, piers or columns, and elevation on extended foundation walls. Other elevation techniques involve leaving the home in place and building a new elevated floor system within the building or adding a new upper story and wet floodproofing the ground level.
- ***Relocation* –** Relocation offers the greatest security from flooding. It involves moving an existing building to an area that is less vulnerable to flooding or completely outside the floodplain. The building owner usually selects the new site, often in consultation with a designer to ensure factors such as accessibility, utility service, cost, and owner preferences meet engineering and local regulatory requirements. Relocation includes lifting a building off its foundation, placing it on heavy-duty moving dollies, hauling it to a new site, and lowering it onto a pre-constructed foundation.
- ***Floodproofing* –** There are two types of floodproofing: wet floodproofing and dry floodproofing. Wet floodproofing allows floodwaters to enter the building and quickly reach the same level as the floodwaters on the building exterior. Equalizing the water level greatly reduces the effects of hydrostatic pressure and buoyancy. Wet floodproofing is generally used to limit damage to enclosures below elevated buildings, basements, crawlspaces, or garages. Wet floodproofing is not practical for areas used as habitable space. Dry floodproofing involves completely sealing the exterior of a building to prevent entry of floodwaters. All openings below the flood level are sealed and the walls of the building are relied on to keep water out. Internal drainage systems, such as sump pumps, remove any seepage. Due to large hydrostatic pressures, dry floodproofing is practical only for buildings with reinforced concrete or masonry walls; it is typically not practical for residential buildings or for buildings where flood depths exceed 2 to 3 feet.

Additional information on these techniques is found in FEMA P-259, Engineering Principles and Practices for Retrofitting Flood-Prone Residential Structures and FEMA P-936, Floodproofing Non-Residential Buildings.

For buildings subject to a wind hazard, the following strategies are widely accepted as among the most effective to address potential damage.

- ***Improving roof and wall coverings* –** Roof and wall coverings are important components of the building envelope. If the building envelope is breached during a storm, wind pressures can drastically increase internal pressures and fail the structural system of the building. Wind driven rain may cause extensive water damage to interior contents. Improving roof coverings may involve reinforcing the roof deck or removing the existing covering, securing the roof deck, and installing a new roof covering. Improving wall coverings may involve installing moisture barriers and ensuring proper fastener spacing is used or removing the existing covering and installing a new wall covering that is rated for high winds.
- ***Protecting openings* –** Openings (e.g., windows, doors, skylights, soffits, and vents) are an important component of the building envelope. Glazed openings, such as windows, are often vulnerable to debris impact and wind driven rain intrusion. Protecting openings usually involves installing an impact-resistant covering (such as a storm shutter) over an existing unprotected opening or installing impact-resistant products (such as a new window or door assembly).
- ***Continuous load path* –** The term “continuous load path” refers to the structural condition required to resist all loads – such as lateral and uplift wind pressures – applied to a building. A continuous load path starts at the point or surface where loads are applied, moves through the building, continues through the foundation, and terminates where the loads are transferred to the soils that support the building. To be effective, each link in the load path – from the roof to the foundation – must be strong enough to transfer loads without breaking. An existing building may be retrofitted if load paths are incomplete or if the load path connections are not adequate. Continuous load path design or retrofit

considerations typically involve several connections such as the roof sheathing to roof framing; roof framing to wall; wall to floor; and floor to foundation.

In some states, existing programs reward wind retrofit measures via homeowners' insurance discounts. FEMA P-804, Wind Retrofit Guide for Residential Buildings provides additional information on specific techniques for wind retrofitting residential buildings. Additionally, the Insurance Institute for Business and Home Safety developed a program called "Fortified" that encourages wind retrofits for both new and existing construction.

Many resources are available that describe seismic retrofit methods and performance-based methods. Examples are:

- **ASCE 41-13:** Seismic Evaluation and Retrofit of Existing Buildings. This is a consensus standard that allows users to perform and evaluation and retrofit using performance-based provisions which match a selected earthquake shaking intensity with a specific performance level. It is referenced by many building codes and jurisdictions.
- **FEMA 549:** Techniques for Seismic Retrofit. This publication provides examples of methods to seismically retrofit various types of construction materials and structural configurations. It contains example retrofit strategies and details to address identified deficiencies based on structural material.

5.7. References

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