
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 buildings 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.

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

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

57 **5.1.3. Interdependencies**

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

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

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

73 **5.2. Buildings Classes and Uses**

74 **5.2.1. Government**

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

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

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

90 Typically, buildings are designed according to risk categories in the *American Society of Civil Engineers*
91 *Standard 7 (ASCE 7)* and *International Building Code*. Risk categories relate the criteria for design loads
92 or resulting deformations to the consequence of failure for the structure and its occupants. Risk categories

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93 are distinct from *occupancy category*, which relates primarily to issues associated with fire and life safety
 94 protection, as opposed to risks associated with structural failure. Risk categories rank building
 95 performance with a progression of the anticipated seriousness of the consequence of failure from lowest
 96 risk to human life (Risk Category I) to the highest (Risk Category IV).

97 Essential buildings fall under Risk Category IV, which has the highest level of reliability, and provisions
 98 for seismic events that require nonstructural systems to remain operable. Some buildings that may be
 99 deemed essential are classified as Risk Category III, which includes buildings and structures that house a
 100 large number of people in one place or those having limited mobility or ability to escape to a safe haven
 101 in the event of failure, including elementary schools, prisons, and healthcare facilities. This category has
 102 also includes structures associated with utilities required to protect the health and safety of a community,
 103 including power-generating stations and water treatment and sewage treatment plants. Risk Category III
 104 requires a higher level of reliability than a typical building associated with Risk Category II, but there are
 105 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

107
 108 Emergency medical facilities are critical to response and recovery efforts following a major disaster.
 109 Therefore hospitals, essential healthcare facilities, and their supporting infrastructure, must be functional
 110 (Category A) during and following a hazard event. This does not mean the entire facility has to be fully
 111 operational, but critical functions, such as the emergency room and life support systems, should be
 112 operational until other functions can be restored. Currently, hospitals are designed to Risk Category IV
 113 requirements, with some local communities or federal agencies imposing additional requirements. For
 114 example, California requires that all hospital designs, regardless of location or ownership (municipal or
 115 private), be reviewed and construction overseen by a state agency.

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

5.2.3. Schools and Daycare Centers

124
 125 Many communities have primary (K-12) schools that are designed to a higher performance level (Risk
 126 Category III) because they have large assemblies of children. Often, school gymnasiums or entire school

127 buildings are designated to serve as emergency shelters during the hazard event and as emergency staging
128 areas after the event. Additionally, the research that went into the SPUR Resilience City Initiative found a
129 perception that when children can return to school, things are returning to normal and parents can return
130 to work. Thus, expeditious resumption of function is important for primary schools across a community.

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

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

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

149 **5.2.4. Religious and Spiritual Centers**

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

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

163 **5.2.5. Residential and Hospitality**

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

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

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

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

191 **5.2.6. Business and Services**

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

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

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

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

229 **5.2.7. Conference and Event Venues**

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

236 **5.2.8. Detention and Correctional Facilities**

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

242 **5.3. Performance Goals**

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

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

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

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

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267 5-2, almost all buildings are desired to be functioning within one to two days, and anticipated to be fully
268 functional within one to three days. For the expected hazard in Table 5-3, only critical buildings and
269 emergency housing are desired to be functioning within one day of the event, but these facilities are not
270 anticipated to be functional for more than four months to two years. For the extreme hazard in Table 5-4,
271 only emergency operation centers and first responder facilities are desired to be functional within a day,
272 but the anticipated performance is that they will not be functional for more than three years.

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

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

Disturbance			Restoration times		
(1)	Hazard	Any	(2)	30%	Restored
	Affected Area for Routine Event	Localized		60%	Restored
	Disruption Level	Minor		90%	Restored
			(3)	X	Current

280

Functional Category: Cluster	(4) Support Needed	(5) Target Goal	Routine Hazard Level											
			Phase 1 – Short-Term Days			Phase 2 -- Intermediate Wks			Phase 3 – Long-Term 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									

281 **Footnotes:**

- 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
- | | | |
|-----|-----|-----|
| 30% | 60% | 90% |
|-----|-----|-----|

Restoration times relate to number of elements restored within the cluster
- | |
|---|
| 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
- Indicate levels of support anticipated by plan
R Regional
S State
MS Multi-state
C Civil Corporate Citizenship
- Indicate minimum performance category for all new construction.
See Section 3.2.6

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

Disturbance			Restoration times		
(1)	Hazard	Any	(2)	30%	Restored
	Affected Area for Expected Event	Community		60%	Restored
	Disruption Level	Moderate		90%	Restored
			(3)	X	Current

284

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	

285 **Footnotes:** See Table 5-2, page 8.

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

Disturbance			Restoration times		
(1)	Hazard	Any	(2)	30%	Restored
	Affected Area for Extreme Event	Regional		60%	Restored
	Disruption Level	Severe		90%	Restored
			(3)	X	Current

287

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

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Footnotes: See Table 5-2, page 8.

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

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

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

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

307 **Category A buildings** should require little repair to return to function. Often recovery is limited by
308 outside factors such as power or water not being available, which is why onsite power and water is often
309 required by communities for essential facilities. There may be some damage to a Category A building, but
310 the damage can easily be cleaned up (i.e., toppled shelves or cosmetic damage to the structure) as shown
311 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)

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



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

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

332 **Category B buildings** are expected to sustain damage, but the damage should not affect the building's
333 structural stability. There may be significant nonstructural damage, but the building can be used while the
334 repairs are made. Figure 5-5 shows pictures of significant nonstructural damage inside a building that is
335 structurally stable following an earthquake event. In such cases, the amount of work required to clean up
336 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)

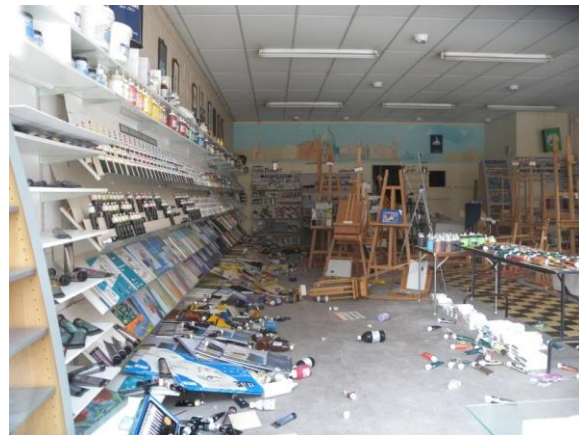


Figure 5-5: Significant nonstructural damage inside a building that is structurally stable after an earthquake event. (Photo Courtesy of Degenkolb Engineers)

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

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344 Moderate damage sustained as the result of wind events may include moderate to major roof covering
345 damage, some minor instances of roof sheathing failure, and some interior water damage, and damage to
346 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]

347 **Category C buildings** are expected to have significant nonstructural and some structural damage. The
348 structural damage should not cause a loss of structural stability, but may require shoring while repairs are
349 conducted. It is assumed that damage such as this would take weeks to months to repair. Figure 5-8 shows
350 structural damage, but the global structure is stable. Figure 5-9 shows a fractured brace connection in a
351 building damaged in an earthquake. There were about ten of these damaged braces on one story of a four
352 story building and it took over three months from the disaster until the repairs were completed and the
353 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)

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

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

360 Severe damage incurred due to a wind event may include major roof sheathing loss, extensive interior
361 water damage, and minor to major envelope damage. Additionally, roof uplift damage may be evident. In
362 instances where significant water intrusion damage has occurred, buildings may not be safe for use until
363 adequate drying and cleaning has occurred due to the potential for mold bloom. Figure 5-11 demonstrates
364 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]

365

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

376 **5.4. Regulatory Environment**

377 Model building codes are developed at the
378 national level for adoption across the country, and
379 adopted by states or local jurisdictions. However,
380 federal buildings are designed and constructed to
381 federal government standards. In the U.S., two organizations publish model building codes for adoption
382 by federal agencies or state and local governments. One is published by the International Code Council,
383 which formed as a merger of three organizations that published regional model building codes. The other
384 code is published by the National Fire Protection Association. The ICC's *International Building Code* is
385 the most widely adopted model building codes; and the *National Fire Protection Code* is the most widely
386 adopted model fire code in the U.S. Most federal agencies also use these codes, with agency-specific
387 amendments, as the basis for their building requirements. These codes contain many reference standards



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

388 that are typically published by not-for-profit standards development organizations, professional societies,
389 and industry groups. Model building codes and the referenced standards are typically modified by federal,
390 state, and local agencies for their specific purposes.

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

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

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

406 **5.5. Standards and Codes**

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

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

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

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

428 **5.5.1. New Construction**

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

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

444 Building codes provide design loads based on return periods for various hazards. In addition to design
 445 loads, there are often design provisions associated with the specific hazard. Table 5-5 (copied from
 446 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
Earthquake ⁴	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.

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

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

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

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

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

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

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

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

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

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

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

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

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

519 **5.5.2. Existing Buildings**

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

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

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

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

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

546 **5.6. Strategies for Implementing Community Resilience Plans**

547 **5.6.1. Available Guidance**

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

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

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

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

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

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

567 **5.6.2. Strategies for New/Future Construction**

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

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

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

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

584 **5.6.3. Strategies for Existing Construction**

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

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

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

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

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

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

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

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

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

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

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

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

663 **5.7. References**

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