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Resilience: Why Material Selection Matters

Understanding how the selection of structural framing materials impacts the resilience of buildings and communities

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Resilience is the ability of an object or system to absorb and recover from an external shock, such as those caused by natural disasters (earthquakes, hurricanes, tornadoes, wildfires) or malicious acts (arson, terrorism).

While the primary purpose of building codes is to protect the health and safety of occupants during an extreme event, the design goal of a resilient structure is for it to withstand an extreme event with minimal damage. By doing so, the building will be able to maintain continuous function or be quickly repaired for a rapid return to service.

Resilience is a simple concept, yet it has complex implications for designers and builders. For some, resilience is viewed at the community level and refers to a community's ability to absorb and recover after a disaster. This could be measured by the ability to restore energy, transportation, clean water, and communication services to residents quickly after a disaster. As illustrated in the graphic below, communities become resilient by having an infrastructure, which includes buildings, that can withstand intense storms or disastrous events.

Often referred to as the "most resilient skyscraper on the West Coast," 181 Fremont in San Francisco utilizes external megabraces to resists shear demands in the office levels and standard buckling-restrained braces in the residential levels.

Rendering courtesy of Jay Paul Company

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Learning Objectives
After reading this article, you should be able to:

1. Define the architectural concept of resilience and explain its implications for occupant safety and building durability.
2. Discuss how material and framing system selection can impact resilience and health, safety, and welfare of occupants in the built environment.
3. List the attributes of framing materials that contribute to resilient framing systems and building performance.
4. Compare the durability, strength, and combustibility characteristics of structural steel and other common framing materials.

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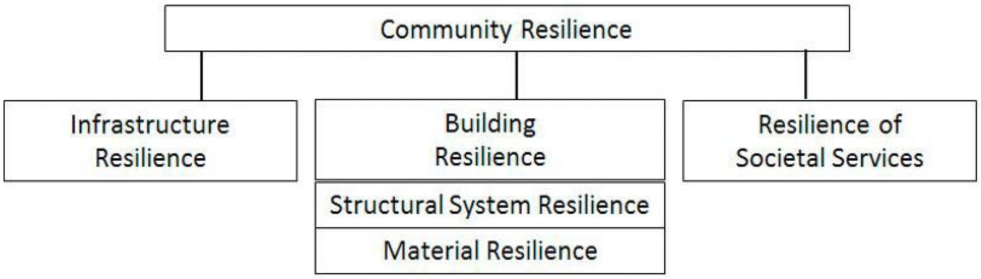
Community resilience is dependent on the resilience of multiple community assets.



Facilities such as fire, police, health care, government entities, and designated shelters or residential units are of key concern for community resilience. To enhance community resilience, key decision makers must begin by selecting structural framing materials that can efficiently and effectively be used in the design and construction of resilient framing systems for critical structures. When measured against other framing materials, structural steel clearly satisfies those requirements.

THE FOUR RS OF RESILIENCE

The resilience of a community, building, or material is often characterized by four interconnected Rs: robustness, resourcefulness, recovery, and redundancy.

Robustness at the community level refers to the ability of critical services to maintain operations during and after an extreme event. Buildings that house vital services such as health care, power management, transportation, and communications must be able to maintain operation for a community during and after a disruption. For a building to be resilient, it also must be robust and able to withstand or recover rapidly from the extreme event. The building's robustness is a function of the integrity of the structural frame and, in turn, the strength of the framing material used in that frame.

Resourcefulness is the ability to prepare for and skillfully respond to a crisis or disruption. For a community, that means not only having contingency plans in place but also identifying and providing the resources needed to implement those plans. For a building, it means having as-built building plans available for rapid reference, structural engineers identified who are prepared to provide a rapid assessment of damage to the structural frame, and sources identified for materials that may be required to implement a repair. For example, structural steel is stocked at hundreds of steel service centers throughout the country for rapid delivery to a structural steel fabricator that can quickly fabricate the members required for the repair (see MacArthur Maze sidebar).

Recovery is the restoration of key operations as quickly and efficiently as possible after a disruption with the goal of a full return to normalcy within a short timeframe. It is impossible and impractical to design a building and structural frame to handle every potential extreme event. There will be times when even the most resilient of designs are stressed beyond the point of failure. In these cases, resilience is determined by the level of loss of functionality and the time required to resume full functionality. The level of recovery and the time required to accomplish it will be in direct relationship to the robustness, redundancy, and ease of repair of the structural system, as well as the availability of resources to complete the repair.

Redundancy in the community context refers to the provision of backup resources to support key functional components of the resilient community. If a key component such as the provision of health services at a local hospital is taken offline, then a backup for that service should be identified to provide the service. For a building, redundancy can best be seen as the ability of the structural framing system and the material from which the frame is constructed to provide additional load-carrying capacity and the ability of the frame to transfer loads to alternative load paths.

Structural frames constructed using structural steel consistently receive high marks when measured using the four Rs thanks to the inherent resiliency of steel. When resiliency is required in a structure, structural steel is the ideal choice.

When developing emergency management and resilience plans, it is important to recognize that not all communities are alike. The stressors that could affect a community vary by location.

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MACARTHUR MAZE

The rapid reconstruction of the MacArthur Maze illustrates the benefits of resilient design using readily available resources

Photo courtesy of Scott Jones/Flickr

The MacArthur Maze is a large freeway interchange at the east end of the San Francisco-Oakland Bay Bridge. On April 29, 2007, a tank truck carrying 8,600 gallons of gasoline overturned and caught fire beneath one of the ramps of the interchange. The petrochemical fire weakened the steel structure supporting the roadway, resulting in the collapse of the ramp connecting I-80 east to I-580. The original cost estimate for repair of the ramp was $10 million and a schedule that required the roadway to be out of service for several months, resulting in significant out-of-pocket costs to commuters and municipal agencies that provided free transportation on the local BART system. The State of California projected that the economic impact of the road closure was $6 million per day. Contrary to the initial cost and schedule estimates, the roadway was placed back in service on May 24, less than 30 days after the original accident, at cost below original budget estimates (the actual winning bid was $876,075 with an incentive of $200,000 per day if the work was completed before June 27). This rapid recovery after an extreme event was accomplished because the material and labor resources required for completing the project were immediately available. Engineers were prepared to address the design issues on an accelerated schedule, a contractor with significant experience in rebuilding damaged expressways had an existing relationship with Caltrans, and the material (steel) and fabrication resources were readily available to the project team.