

Editorial

Towards Resilience of the Built Environment: Designing Buildings for Strength

Iftekhhar Ahmed 

School of Architecture and Built Environment, University of Newcastle, Callaghan, NSW 2308, Australia;
ifte.ahmed@newcastle.edu.au

The design and construction of buildings for strength, characterised by their durability and safety, is fundamental to the practice of built environment professionals, including architects, civil engineers, construction managers and builders. Buildings serve as homes and places of work, and they need to be sufficiently strong to be able to withstand the day-to-day forces imposed on them, as well as more powerful impacts from natural hazards. Building for strength requires competent architectural and structural design skills and the application of appropriate building materials and construction techniques. Furthermore, proper planning that considers the site, locational and environmental risks can contribute to the resilience of buildings.

Understanding the interaction of a building with the forces that act on it, such as gravitational pull, wind and seismic loads and water pressure, is central to designing for strength. To understand the building itself in terms of its loads is also important, including both the 'dead load', which is the permanent weight of a building and its components, and the 'live load', which is the variable weight from its occupancy (inhabitants, furniture, etc.) [1]. Structural engineers take into consideration both these types of loading to design safe buildings that do not fail structurally. Even accumulated snow or water on a building's roof is a kind of live load, which can affect the strength of a building. Architects also need to consider such factors when they design buildings to guide their decisions on the shape, height and configuration of the building, and the choice of materials and construction details.

The selection and combination of building materials is an important factor in designing buildings for strength. Durable materials such as concrete, steel and masonry made of brick or concrete blocks provide strength; however, structural design considerations are important when using these materials. For example, concrete resists pressure, that is, it has compressive strength but requires adequate steel reinforcement that provides balance by its tensile strength; designing the right balance of concrete and steel in reinforced concrete incorporates structural strength in a building [2]. In areas exposed to lateral seismic and/or wind forces, masonry construction also requires reinforcing with steel rods (or rebars). Well-designed steel structures without concrete can also be strong in resisting wind and seismic forces because of their tensile strength [3]. An example of a resilient building is shown in Figure 1.



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Figure 1. A house in Biloxi, USA, designed by Architect Marlon Blackwell after the 2005 Hurricane Katrina, which includes disaster-resilient features such as an elevated floor to mitigate floods and coastal storm surges, and a steel structure with bracings and metal cladding to resist wind impact (photo credit: Author).

Natural hazards present a key challenge in designing buildings to withstand and endure their impact. Damage and destruction of buildings in disasters is widespread around the world, and increasingly so because of the ferocity and frequency of disasters such as cyclones, floods and wildfires understood to be linked to climate change. In areas at risk of earthquakes, building design that is resistant to seismic forces is essential. This involves applying key techniques such as base isolation, that is, separating a building from the ground with a pad or layer that prevents collapse by allowing the building to shake [4]; reinforcement in strategic places within a building that makes it flexible to shaking, known as ‘ductility’ [5] and masonry confined within a structural frame and continuous running bands tying the building together [6,7]. Buildings with a symmetrical and regular form are more resilient, especially in earthquakes, than buildings of long and narrow shapes or irregular forms. Buildings with irregular and linear forms require expansion joints to break up the building into regular and symmetrical blocks [7].

Examples of designing for some of the other main hazards include elevated buildings with water-resistant materials in flood-prone areas; aerodynamic forms of buildings with regular configurations together with reinforced connections, bracings and ties to survive a cyclone and fire-resistant buildings in areas exposed to wildfire. While it is possible to design new buildings for strength, existing buildings that have been built without resilient designs can present a challenge, which require retrofitting to improve their strength. This is often expensive and difficult to implement, but where feasible, it should be implemented to impart strength and safety to vulnerable buildings.

Building codes in many countries provide guidance for designing buildings to withstand natural hazards and it is necessary for designers to follow them, and to have an institutional mechanism to ensure compliance. In some cases, taking into consideration local constraints such as affordability in low-income countries, codes developed in affluent countries have been adapted to the local context. For example, after the 2015 earthquakes in Nepal, minimum standard building codes were established that allow rule-of-thumb appli-

cations for a basic level of seismic safety [8]. In the Solomon Islands, building codes derived from Australian and New Zealand codes that follow modern materials and construction methods were recommended for a review to adapting to buildings in the dispersed islands that use local natural resources as building materials [9].

It is important to understand the types of disaster risk in a certain area to inform building design. For example, lightweight structures can resist earthquakes, but they can be damaged by cyclones. Designing buildings for multiple hazards that can affect the same area is a critical challenge for designers. Traditionally, people around the world built resilient buildings with natural materials known as vernacular architecture, which in the past was adapted to the local hazards and environment (an example of this is shown in Figure 2). However, with the rapidly transforming global context due to climate change, urbanisation, human conflicts and displacement, together with aspirations of modernity, new challenges have emerged that place extreme pressures on vernacular architecture, demanding new solutions. It has become necessary for designers and built environment professionals to understand and respond to these multiple risks and the complexities they present.



Figure 2. An example of vernacular architecture in Aceh, Indonesia, adapted to the local environment and floods. This type of building is generally not built anymore (photo credit: Author).

Designing buildings for strength need to be positioned within a framework of physical planning. For example, in areas facing risk from volcanoes, landslides or coastal hazards such as tsunamis and storm surges, land-use planning that avoids constructing in proximity to these hazards should be adopted. A strategic approach to land-use planning is necessary for disaster resilience of the built environment by avoiding or reducing exposure to disaster risks that can arise from building settlements, facilities and infrastructure in high-risk areas. As much as possible, locating buildings where there is exposure to natural hazards should be avoided, and open land should instead be utilised for vegetation and water bodies. This can promote nature-based solutions for resilience by protecting from strong winds and reducing flooding risks by serving as drainage and water retention areas [10].

Contemporary technological innovations can contribute towards designing strong buildings. These include architectural and structural design and analysis software such as

computer-aided design (CAD) and Building Information Modelling (BIM), which allow developing an understanding of a building's behaviour and performance before it is built, so that weak areas can be addressed. These technological tools also allow collaboration between different built environment professionals. The rapidly emerging field of Artificial Intelligence (AI) brings new possibilities for designing stronger buildings by assisting in the different stages of architectural and structural design, construction (e.g., AI robots), operation and maintenance [11].

Considerations of a building's strength also include its long-term performance and durability. Regular inspections, monitoring and maintenance are essential to ensure the building's strength over its lifetime. Prevention and remediation of cracking, corrosion, mould, weather damage and other such aspects of deterioration need to be undertaken. Use of weather-resistant materials that allow effective maintenance and repair allow buildings to continue being strong for a long time.

The construction industry and associated built environment professionals have a strong responsibility for designing buildings for strength. In addition to knowledge of technical principles, the responsibility goes beyond to include an understanding of environmental factors, the changing climate and related hazards and importantly, the needs of society to be safe, protected and resilient within the built environment.

Conflicts of Interest: The author declares that there is no conflict of interest.

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