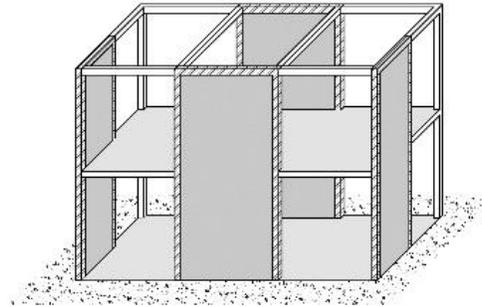


# Earthquake-safe Buildings

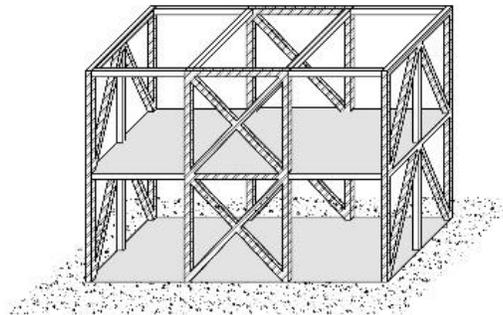
## Article 3. Three Structural Systems to Resist Earthquakes

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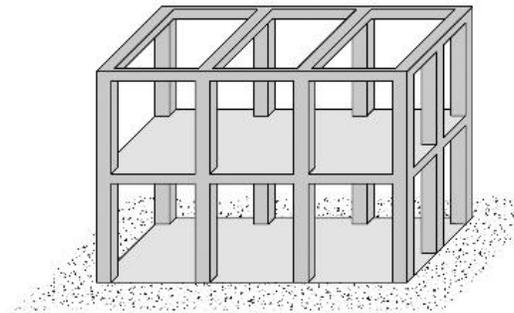
The buildings of any city are diverse. Some are low-rise while others are very tall, some are compact and others huge, like a shopping malls. Even though buildings appear radically different, there are only three common structural systems that can resist earthquake shaking. The three systems are shear walls, or structural walls; braced frames; and moment frames, as shown in Figure 1.



(a) Shear walls



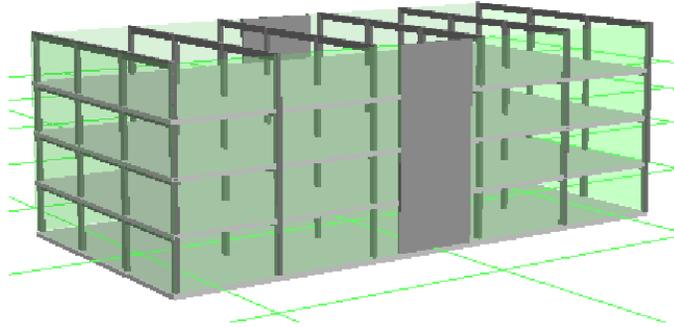
(b) Braced frames



(c) Moment frames

*Figure 1. The three common structural systems in order of their strength and ability to resist earthquakes (highest to lowest).*

When architects and civil engineers design a new building, they choose one of the three systems to resist earthquake forces. Sometimes, two systems are chosen to resist shaking in the building, one in each direction (Figure 2). Provided that one of the three systems provides strength across and along the building, the building can resist shaking from any direction.



*Figure 1. Six moment frames, each of three bays, resist shaking across the building, and two structural walls resist shaking in the direction along the length of the building. (The roof slab is not shown.)*

Each system is vertical and should rise up the building from foundation to roof. The numbers of walls, braced frames or moment frames required depend on a city's seismic risk, the size of the building and its importance to the community.

Moment frames are a popular system (Figure 3). Their columns and beams resist earthquake shaking by being connected strongly (refer Article 6). Frames offer the greatest freedom for planning interior spaces and providing windows. Unfortunately, moment frames are usually more flexible in earthquakes than the other two systems. They sway further to-and-fro and are more prone to damage. They are also more difficult to design and build properly, and are sensitive to construction errors. As for their construction materials, they are usually built of reinforced concrete or structural steel. Wooden frames can be used for low-rise buildings.



*Figure 2. The two four-bay moment frames resist earthquake forces acting along the building. Similar frames are expected to be on the other side of the building.*

Braced frames contain diagonal members that form triangles with the beams and columns (Figure 4). They are fabricated from steel members and are most commonly found in low-rise construction, like warehouses. Welding quality can be a weakness in steel connections unless there is excellent quality assurance, and steel braces can buckle under large forces.



*Figure 3. Steel braced frames resist earthquake forces acting across the building. Steel moment frames provide strength along the building.*

Shear walls or structural walls are potentially the strongest structural system against earthquake shaking (Figure 5). Internationally, they have the best track record. The longer the walls and the more walls, the stronger the building. This means less to-and-fro shaking movements causing building damage. Reinforced concrete is the most common material for high-rise structural walls. Confined masonry walls (refer Article 4) are suitable for low-rise buildings. In some earthquake-prone countries, like the USA or New Zealand, low-rise wooden construction relies on plywood or gypsum plasterboard structural walls for earthquake resistance. Engineered wood products like cross-laminated timber are also emerging for use as shear walls in mid-rise buildings.



*Figure 4. A reinforced concrete structural wall resists forces acting along the length of the building. There should be another wall on the other side of the building.*

### About this article series:

This is a series of articles about earthquakes, their effects on buildings, and how to ensure that buildings are safe against earthquakes. They are intended for potential owners of new houses and larger buildings and others involved in the building industry. The articles are written by Andrew Charleson and colleagues from the World Housing Encyclopedia (<http://www.world-housing.net/>) which is sponsored by the Earthquake Engineering Research Institute (<https://www.eeri.org/>) and the International Association of Earthquake Engineering (<http://www.iaee.or.jp/>).

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