Briefing Paper 1

Building Safety and Earthquakes

Part C: Earthquake Resisting Systems

Introduction

This Briefing Paper 1, *Building Safety and Earthquakes*, consists of four parts describing earthquakes and their effects on buildings. Parts A and B describe the causes of earthquakes and resulting ground motions and explain how earthquake motions create various forces acting on a building. This Part C describes the types of structural systems and lateral-force-resisting elements used in buildings and how they can be used in combinations. Part D discusses the "load path" of earthquake forces within buildings.

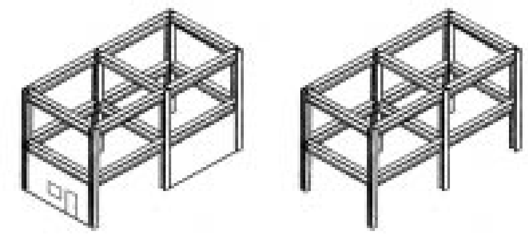

Figure 1. Building frame systems.

Structural Systems Defined

The *Uniform Building Code* (UBC) earthquake provisions define three basic types of building structural systems: bearing wall systems, building frame systems, and moment-resisting frame systems.

Bearing wall systems consist of vertical load-carrying walls located along exterior wall lines and at interior locations as necessary. Many of these bearing walls are also used to resist lateral forces and are then called shear walls. Bearing wall systems do not contain complete vertical-load-carrying space frames but may use some columns to support floor and roof vertical loads. This type of system is very common and includes wood-frame buildings, concrete tilt-up buildings and masonry wall buildings.

Building frame systems use a complete three-dimensional space frame to support vertical loads, but use either shear walls or braced frames to resist lateral forces. Examples of these include buildings with steel frames or concrete frames along the perimeter and at intervals throughout the interior supporting vertical loads from floors and roof. Building frame systems typically use steel braced frames or concrete or masonry shear walls to resist lateral forces. A building frame system with shear walls is shown in Figure 1(a).

Moment-resisting frame systems can be steel, concrete, or masonry construction. They provide a complete space frame throughout the building to carry vertical loads, and they use some of those same frame elements to resist lateral forces. Shear walls (and braced frames) are not used in this system, as shown in Figure 1(b).

Occasionally buildings are defined as dual systems when they have a complete space frame that supports vertical loads and combine moment-resisting frames with either shear walls or braced frames to resist lateral loads.

Lateral-Force-Resisting Elements

Lateral-force-resisting elements must be provided in every structure to brace it against wind and seismic forces. The three principal types of resisting elements are shear walls, braced frames, and moment-resisting frames. Shear walls can be made of sheathed wood-frame walls, reinforced masonry, or reinforced concrete. Steel braced frames are often used in combination with concrete shear walls or masonry shear walls. Braced frames are essentially vertical, cantilevered trusses and may be either concentric or eccentric in configuration. Concentric frames have diagonal braces located so that the lateral forces act along the direction of their longitudinal axis. Eccentric braced frames use both axial loading of braces and bending of sections of horizontal beams to resist the forces. Figure 2 shows typical braced frame configurations.

Moment-resisting frames can be constructed of steel, concrete, or masonry. Moment frames consist of beams and columns in which bending of these members provides the resistance to lateral forces. There are two primary types of moment frames, ordinary and special. Special moment-resisting frames are detailed to ensure ductile behavior of the beam-to-column joints and are normally used in zones of higher seismicity.

Because of damage observed following the 1994 Northridge earthquake, steel moment-resisting frames have been under intensive study and testing. The goal is to determine the causes of the damage and to recommend changes in steel moment-resisting frame design and construction to ensure ductile behavior of the joints. Additional information on that subject is available from the SAC Joint Venture. Contact the Applied Technology Council (see box).

The selection of the type of lateral-force-resisting elements to use in a building is often based on economics. A single type of resisting element is commonly used in most building types, such as in houses where wood-framed shear walls are used, or in concrete tilt-up buildings where concrete shear walls are used. However, other types of buildings may need to use combinations of more than one type of seismic element.

The building code allows combinations to be used but they are also subject to very specific structural design rules. For example, if concrete shear walls that are also bearing walls are combined with braced frame elements along one axis and ordinary moment-resisting frames are used along the other axis, the braced frame elements need to be designed using slightly larger forces than if they were the only type of resisting element used along that axis. On the other axis, the moment-frame elements also need to be designed for forces larger than if they were the only type of resisting element in the building. These adjustments in design forces are required to account for the differences in strength, stiffness, and ductility among the three types of resisting elements when used in combination.

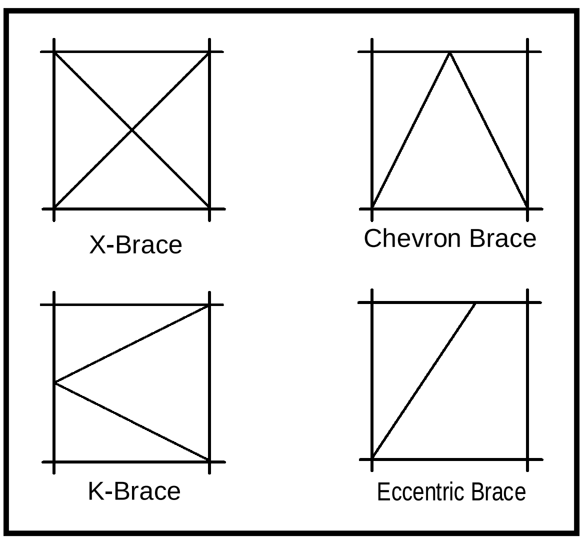

Figure 2. Types of braced frame elements.

References

ICBO, 1997, *Uniform Building Code*, International Conference of Building Officials, Whittier, California.

About this Briefing Paper Series

Briefing papers in this series are concise, easy-to-read summary overviews of important issues and topics that facilitate the improvement of earthquake-resistant building design and construction quality.

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ATC/SEAOC Joint Venture
c/o Applied Technology Council
555 Twin Dolphin Drive, Suite 550
Redwood City, California 94065