



# How to Align Architectural Form with Seismic Design Requirements N ONLY

An Online Continuing Education Course for Engineers

**Course Number: BD-3010**

**Credit: 3 Hours / 3 PDH / 3 CPD**

# How to Align Architectural Form With Seismic Design Requirements

## INTRODUCTION

This course explains how architectural design decisions influence a building's likelihood to suffer damage when subjected to earthquake ground motion. The critical design decisions are those that create the building configuration (defined as the building's size and three dimensional shape) and those that introduce detailed complexities into the structure, in ways that will be discussed later.

## THE BASIC SEISMIC STRUCTURAL SYSTEMS

A building's structural system is directly related to its architectural configuration, which largely determines the size and location of structural elements such as walls, columns, horizontal beams, floors, and roof structure. Here, the term structural/architectural configuration is used to represent this relationship.

### *The Vertical Lateral Resistance Systems*

Seismic designers have the choice of three basic alternative types of vertical lateral force-resisting systems. The system must be selected at the outset of the architectural design process. Here, the intent is to demonstrate an optimum architectural/structural configuration for each of the three basic systems. The three alternatives are illustrated in Figure 1.

These basic systems have a number of variations, mainly related to the structural materials used and the ways in which the members are connected.

- Shear walls

Shear walls are designed to receive lateral forces from diaphragms and transmit them to the ground. The forces in these walls are predominantly shear forces in which the material fibers within the wall try to slide past one another. To be effective, shear walls must run from the top of the building to the foundation with no offsets and a minimum of openings.

- Braced frames

Braced frames act in the same way as shear walls; however, they generally provide less resistance but better ductility depending on their detailed design. They provide more architectural design freedom than shear walls.

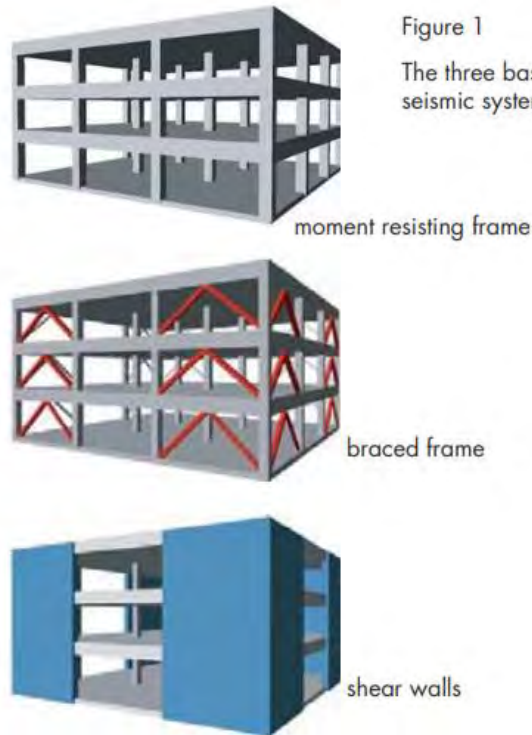


Figure 1  
The three basic vertical seismic system alternatives.

There are two general types of braced frame: conventional concentric and eccentric. In the concentric frame, the center lines of the bracing members meet the horizontal beam at a single point.

In the eccentric braced frame, the braces are deliberately designed to meet the beam some distance apart from one another: the short piece of beam between the ends of the braces is called a link beam. The purpose of the link beam is to provide ductility to the system: under heavy seismic forces, the link beam will distort and dissipate the energy of the earthquake in a controlled way, thus protecting the remainder of the structure (Figure 2).

- Moment-resistant frames

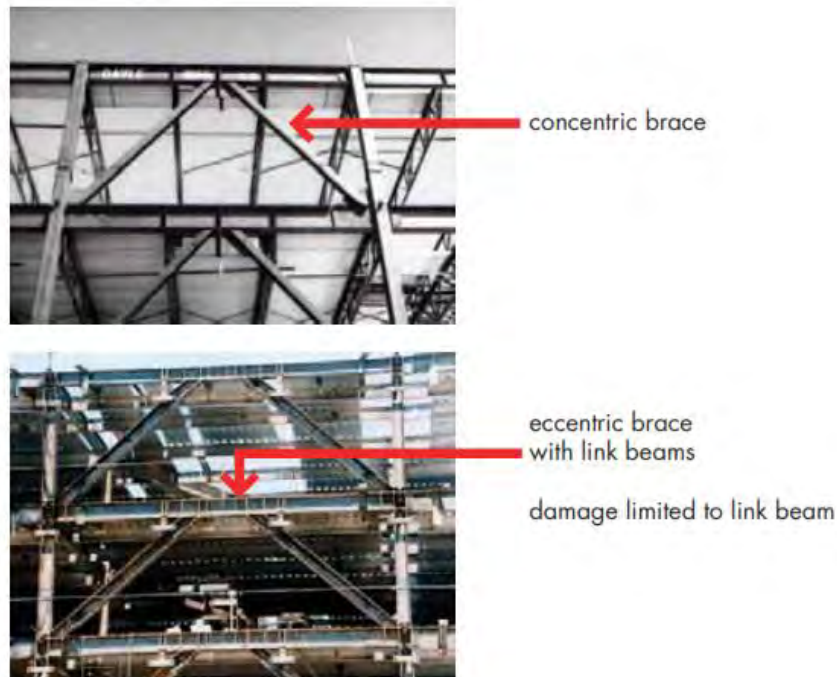
A moment resistant frame is the engineering term for a frame structure with no diagonal bracing in which the lateral forces are resisted primarily by bending in the beams and columns mobilized by strong joints between columns and beams. Moment-resistant frames provide the most architectural design freedom.

These systems are, to some extent, alternatives, although designers sometimes mix systems, using one type in one direction and another type in the other. This must be done with care, however, mainly because the different systems are of varying stiffness (shear-wall systems are much stiffer than moment-resisting frame systems, and braced systems fall in between), and it is difficult to obtain balanced resistance when they are mixed. However, for high-performance structures,) there is now increasing use of dual systems. Examples of effective

mixed systems are the use of a shear-wall core together with a perimeter moment-resistant frame or a perimeter steel-moment frame with interior eccentric-braced frames. Another variation is the use of shear walls combined with a moment-resistant frame in which the frames are designed to act as a fail-safe back-up in case of shear-wall failure.

Figure 2

Types of braced frames.



The framing system must be chosen at an early stage in the design because the different system characteristics have a considerable effect on the architectural design, both functionally and aesthetically, and because the seismic system plays the major role in determining the seismic performance of the building. For example, if shear walls are chosen as the seismic force-resisting system, the building planning must be able to accept a pattern of permanent structural walls with limited openings that run uninterrupted through every floor from roof to foundation.

### *Diaphragms: The Horizontal Resistance System*

The term "diaphragm" is used to identify horizontal-resistance members that transfer lateral forces between vertical-resistance elements (shear walls or frames). The diaphragms are generally provided by the floor and roof elements of the building; sometimes, however, horizontal bracing systems independent of the roof or floor structure serve as diaphragms. The diaphragm is an important element in the entire seismic resistance system (Figure 3).

The diaphragm can be visualized as a wide horizontal beam with components at its edges, termed chords, designed to resist tension and compression: chords are similar to the flanges of a vertical beam (Figure 3A).

A diaphragm that forms part of a resistant system may act either in a flexible or rigid manner, depending partly on its size (the area between enclosing resistance elements or stiffening beams) and also on its material. The flexibility of the diaphragm, relative to the shear walls whose forces it is transmitting, also has a major influence on the nature and magnitude of those forces. With flexible diaphragms made of wood or steel decking without concrete, walls take loads according to tributary areas (if mass is evenly distributed). With rigid diaphragms (usually concrete slabs), walls share the loads in proportion to their stiffness (figure 3B).

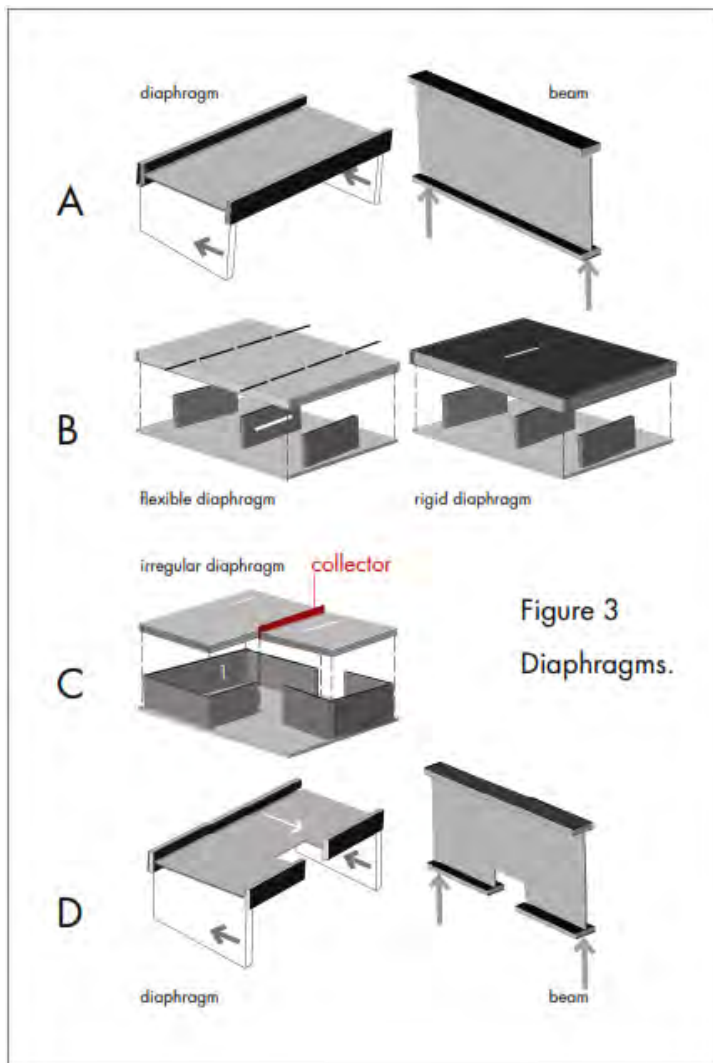


Figure 3  
Diaphragms.

Collectors, also called drag struts or ties, are diaphragm framing members that "collect" or "drag" diaphragm shear forces from laterally unsupported areas to vertical resisting elements (Figure 3C).

Floors and roofs have to be penetrated by staircases, elevator and duct shafts, skylights, and atria. The size and location of these penetrations are critical to the effectiveness of the diaphragm. The reason for this is not hard to see when the diaphragm is visualized as a beam. For example, it can be seen that openings cut in the tension flange of a beam will seriously

weaken its load carrying capacity. In a vertical load-bearing situation, a penetration through a beam flange would occur in either a tensile or compressive region. In a lateral load system, the hole would be in a region of both tension and compression, since the loading alternates rapidly in direction (Figure 3D).

### *Optimizing the Structural/Architectural Configuration*

Figure 4 shows the application of the three basic seismic systems to a model structural/architectural configuration that has been designed for near optimum seismic performance. The figure also explains the particular characteristics that are seismically desirable.

#### Building attributes

- Continuous elements and uniformity of elements and concentrations of strength
- Low height and mass  
Minimizes overturn.
- Equal floor areas  
Equalizes center of mass and stiffness, no concentration of mass.
- Symmetrical mass and stiffness  
Minimizes torsion.
- Identical resistance in both principal axes  
Eliminates eccentricity between the center of mass and resistance and provides balanced resistance in all directions, thus minimizing torsion.
- Identical vertical resistance  
No concentrations of strength or weakness.
- Uniform section and elevations  
Minimizes stress concentrations.
- Seismic resisting elements at perimeter  
Maximum torsional resistance.
- Short spans  
Low unit stress in members, multiple columns provide redundancy-loads can be redistributed if some columns are lost.

*To view the remainder of the course material and to take the quiz for PDH credit, you must purchase the course.*

*Close this window and click "Add to cart" on the product page.*

Figure 4

The optimized structural/architectural configuration.

