Annex#3: Causes of Non-Structural damage

Earthquake ground shaking has three primary effects on non-structural elements in buildings. These are inertial or shaking effects on the non-structural elements themselves, distortion imposed on non-structural components when building structures sways back and forth or the effect of structural on non-structural components, and the pounding effects at the interface between adjacent structures.

1. Direct Effect

When a building is shaken during an earthquake, the base of the building moves in harmony with the ground, but the entire building and the building contents above the base will experience inertial forces. These inertial forces can be explained by using the analogy of a passenger in a moving vehicle. As a passenger, you experience inertial forces whenever the vehicle is accelerating or decelerating rapidly. If the vehicle is accelerating, you may feel yourself pushed backward against the seat, since the inertial force on your body acts in the direction opposite that of the acceleration. If the vehicle is decelerating or breaking, you may be thrown forward in your seat. Although the engineering aspects of inertial forces are more complex than a simple principle of physics, the law first formulated by Sir Isaac Newton, F=ma, or force is equal to the mass times acceleration, is the basic principle involved. In general, the earthquake inertial forces are greater if the building or object within the building weighs more or if the acceleration or severity of the shaking is greater.

File cabinets, emergency-power generating equipment, freestanding bookshelves, office equipment, water tanks, flower pots and items stored on shelves or racks can all the damaged because of inertial forces. When an earthquake shakes unstrained items, inertial forces may cause them to slide, swing, strike other objects, or overturn. Items may slide off shelves and fall to the floor. One misconception is that large, heavy objects are stable and not as vulnerable to earthquake damage as lighter objects, perhaps because we may have difficulty moving them. In fact, since inertial forces during an earthquake are proportional to the mass of the object, heavy objects are more likely to overturn than *lighter ones with the same dimensions.*

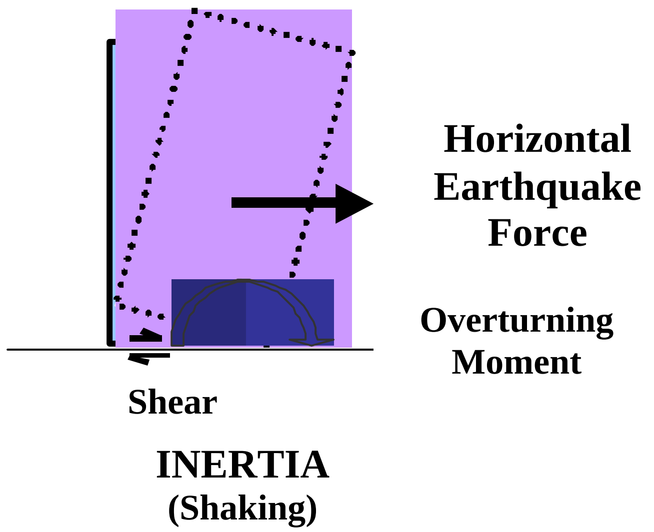


Fig A3-1: Direct Effect on Non-Structural Elements.

2. Effect of Structure to Non-Structural Components

During an earthquake, building structures distort, or bend, side to side in response to the earthquake forces. For example, the top of a tall building may incline a feet in each direction during an earthquake. The distortion over the height of each story, known as the story drift, might range from ¼ inches to several inches, depending on the size of the earthquake and the characteristics of the particular building structure. Windows, partitions and other items that are tightly locked into the structure are forced to go along for the ride. As the columns or walls distort and become slightly out of square, if only for an instant, any tightly confined windows or partitions must also distort the same amount. The more space there is around a pane of glass where it is mounted between stops or moulding strips, the more distortion the glazing assembly can accommodate before the glass itself is subjected to earthquake forces. Brittle materials like glass, plaster and masonry infill cannot tolerate any distortion and will crack when the perimeter gaps close and the building structure pushes directly on the brittle elements. Most architectural components such as glass panes, partitions and veneer are damaged because of this type of building distortion, not because they themselves are shaken or damaged by inertial forces.

There have also been notable causes of structural – non-structural interaction in past earthquakes, when rigid non-structural components have been the cause of structural damage or collapse. These causes have generally involved rigid, strong architectural components such as masonry infill that inhibit the movement or the distortion of the structural framing and cause premature failure of column or beam elements. While this is a serious concern for structural designers, the focus of this report is on earthquake damage to non-structural components.

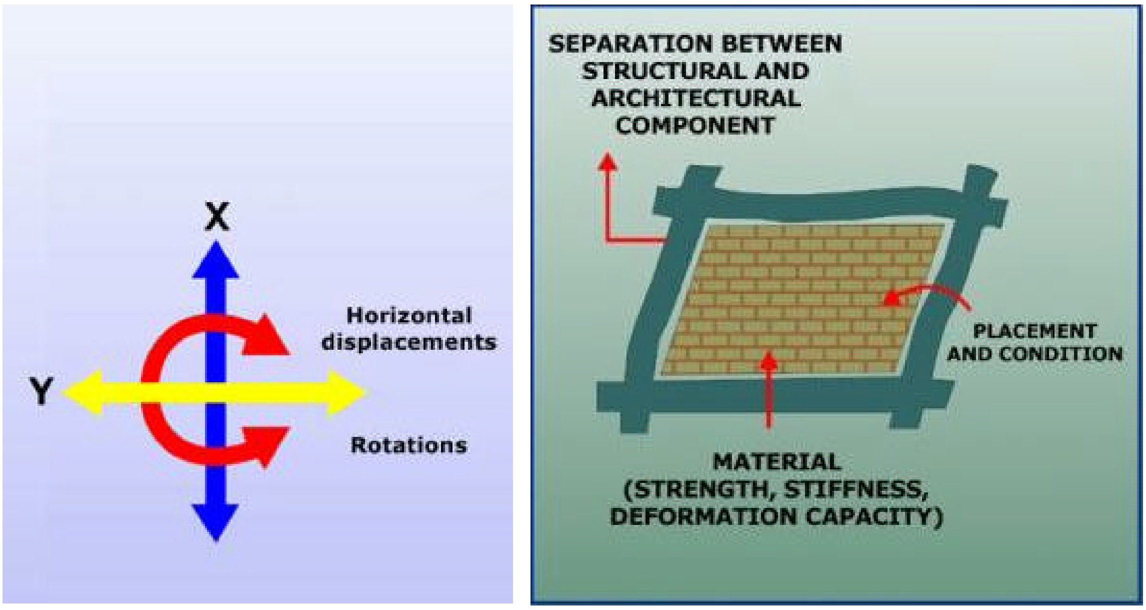
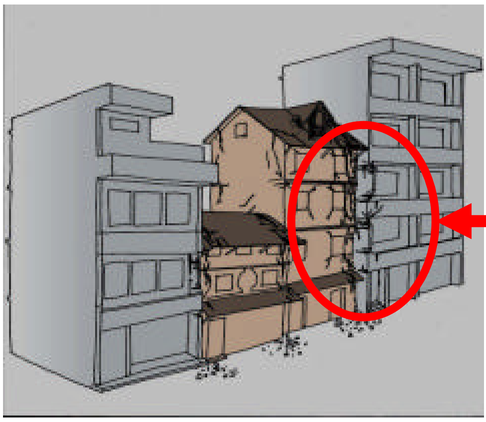


Fig A3-2: Effect of Building Deformation on Contents

3. Pounding Effect

Another source of non-structural damage involves pounding or movement across separation joints between adjacent structures. A separation joint is the distance between two different building structures - often two wings of the same facility - that allows the structures to move independently of one another.

A seismic gap is a separation joint provided to accommodate relative lateral movement during an earthquake. In order to provide functional continuity between separate wings, building utilities must often extend across these building separations, and architectural finishes must be detailed to terminate on either side. The separation joint may be only an inch or two in older constructions or as much as a foot in some newer buildings, depending on the expected horizontal movement, or seismic drift. Flashing, piping, fire sprinkler lines, HVAC ducts, partitions, and flooring all have to be detailed to accommodate the seismic movement expected at these locations when the two structures move closer together or further apart. Damage to items crossing seismic gaps is a common type of earthquake damage. If the size of the gap is insufficient, pounding between adjacent structures may result in damage to structural components such as parapets, veneer, or cornices on the facades of older buildings.



Breakage of piping or ducts may occur at seismic joints or in the joint of two buildings due to differential displacement (separa-tion and pounding).

Fig A3-3: Pounding Effect on Buildings