GeoHazards International

A Nonprofit Working Toward Global Earthquake Safety

An Introduction to Framed Infill

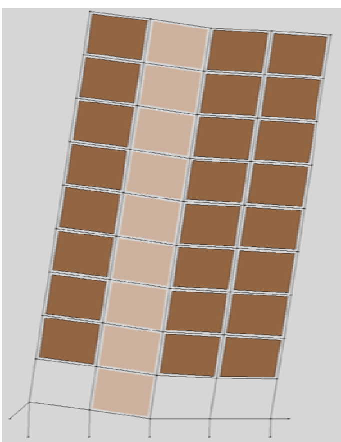
Janise Rodgers, Project Manager, GeoHazards International
Gregory G. Deierlein, Professor, Stanford University

What is Framed Infill?

Framed infill is a new approach to a very common structural system used in buildings throughout much of the world: the reinforced concrete frame, which is built first, with masonry infill walls added afterward. In a framed infill system, the masonry infill walls are intentionally designed as an integral component of the lateral force-resisting system.

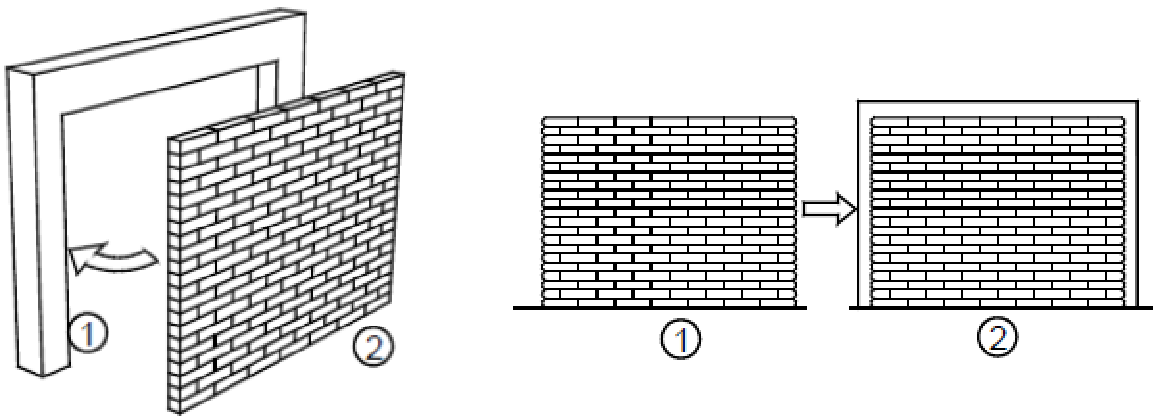
While framed infill construction looks very similar to existing reinforced concrete frames with infill walls, the two are conceptually very different. First and foremost, in framed infill buildings, the infill walls and concrete frame are designed from the outset to work integrally to resist earthquake demands. Design of these systems requires consideration of force transfer and deformation compatibility between the frame and infill. This is in contrast to existing concrete frames with infills, where the infills are typically unreinforced masonry walls that are not considered as structural elements in the design. Thus, whereas framed infill buildings are expected to ensure life safe performance under design level ground motions, existing infill buildings are often seismically deficient. Even where existing concrete frames are designed to be ductile, the common practice of ignoring the infill walls during structural design can create weak stories, torsion irregularities, and captive columns that lead to non-ductile behavior.

The developers of the framed infill concept envision that in addition to new safer buildings, existing frames with infills can be retrofitted using framed infill solutions. Whether new construction or retrofit, the underlying design concepts are the same, though the implementation may vary. The design philosophy behind framed infill views infill walls as positive contributors to the building's seismic performance, rather than as problems to be mitigated.



A framed infill rocking spine concept (left, courtesy David Mar, Tipping Mar) and existing infill (right)

Framed infill and existing infill also differ from confined masonry. The simplest way to explain the differences is in terms of construction sequence. In framed infill, the frame is built first, followed by the walls. In confined masonry, the walls are built first, followed by the frame. The structural detailing practices differ between the systems.



Construction sequence for infill (left) and confined masonry (right); Images courtesy Confined Masonry Network

Where are Existing Infill Buildings Found?

Cities located in zones of high seismic hazard in both industrialized and developing countries throughout the world contain large numbers of existing concrete frame with infill buildings. The type of masonry used as infill varies from region to region based on locally available materials and local construction practices. In many urban and urbanizing regions in the developing world, infill buildings are currently being constructed in ever-increasing numbers. For example, in South Asia, there is an unmistakable trend toward infill buildings as population densities increase, even in areas where unreinforced masonry construction or traditional construction was practiced almost exclusively in the past.

Concrete frame buildings with infill dominate this view of a suburb in Kathmandu, Nepal

In developing countries, existing infill buildings are most prevalent in areas that have experienced rapid recent growth, such as areas surrounding historic city centers, suburban areas, and suburban or peri-urban areas. Infill buildings are often mixed use buildings with commercial space on the ground floor, but they can be purely residential (either single- or multi-family), commercial, government, educational, health or other uses as well.

In industrialized countries, existing infill buildings are often found in areas with buildings dating from the early- to mid-twentieth century. These buildings tend to be institutional, industrial, commercial, or multi-family residential; single-family residential infill buildings are rare.


Mixed use and multifamily residential infill buildings in Karachi, Pakistan (left, photo by Greg Deierlein); a new single family infill residence rises above traditional construction in Agartala, India (right)

How Can Framed Infill Help Reduce Global Earthquake Risk?

Collapses of concrete frames with infill walls during earthquakes have killed tens of thousands of people in the last decade. Despite this, concrete frames with infill will continue to be built for the foreseeable future in many emerging-country cities because such frames can be built inexpensively with familiar techniques and readily available materials. In a number of countries, frames with infill are currently the ***only*** type of concrete buildings that engineers know how to design and builders know how to construct, with rare exceptions. Strategies to improve the performance of frames with infill must take this reality into account.

One strategy to improve the performance of concrete frames with infill is to change the structural system, which is a good strategy for low-rise buildings. Much better performance can be obtained by making the relatively minor changes in construction practice needed to build these buildings as confined masonry buildings. However, this strategy is problematic for taller buildings, because the recommended alternative system – reinforced concrete shear walls – may be viewed as an unacceptably radical change from the current design and construction practices in many places. For engineers and builders that are familiar with frames and not familiar with shear walls, a framed infill system will be much closer to what they know and are comfortable with. Barriers to adoption will be lower.

In addition, there are many good engineers who design frames to the American Concrete Institute (ACI) code or other ductile detailing codes, but fail to consider the infill walls. Without realizing they are doing so, they may design buildings that present a substantial collapse risk due to soft stories, captive columns, or severe torsion irregularities. Design provisions specifying how to properly include infill walls in the structural system would greatly improve the safety of the buildings these engineers design. The Framed Infill Network would help these engineers first. Initial efforts would focus on new buildings in an effort to reduce the number of new, dangerous buildings that are built. In the future, the Framed Infill Network would also address the risks posed by existing infill buildings, both in the developing world and in industrialized countries.