LECTURE # 3

In this lecture you will learn about:

Four Series Configuration Conditions

1. Soft Stories.
2. Discontinuous Shear Walls.
3. Variation In Perimeter Strength & Stiffness
4. Re-entrant Corners

Course Name

"Introduction To Earthquake Engineering"

Course Code: CT-634

Credit Hours: 3

Semester: 6^{TH}

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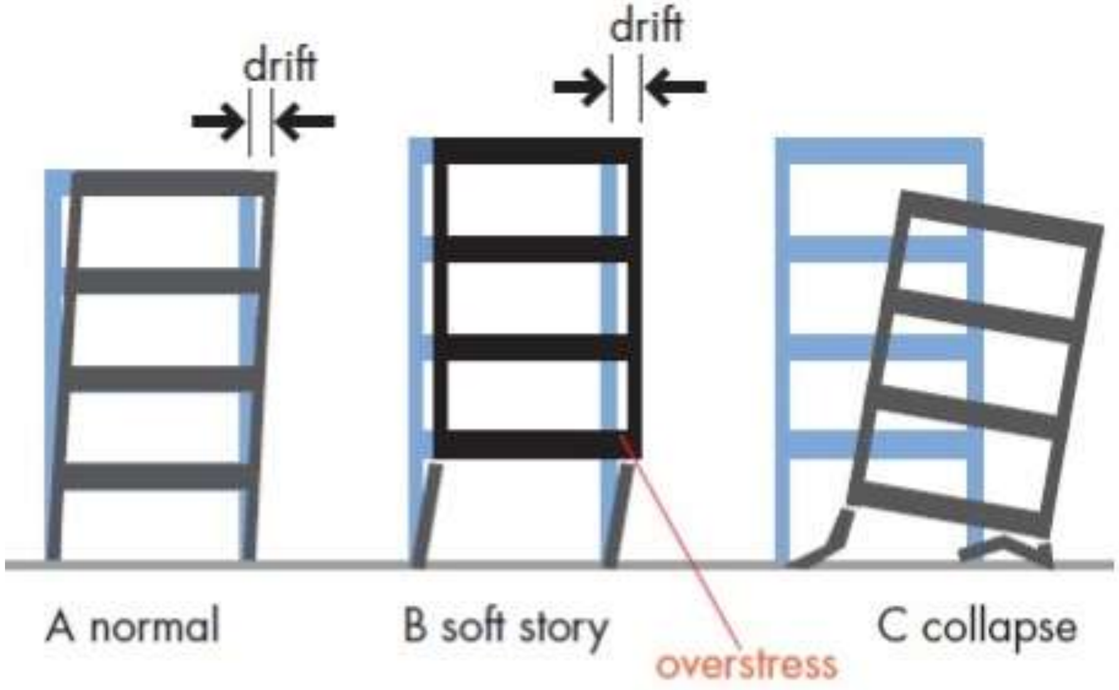
FOUR SERIES CONFIGURATION CONDITION

Four configuration conditions (two vertical and two in plan) that originate in the architectural design and that have the potential to seriously impact seismic performance are:

1. Soft stories
2. Discontinuous shear walls
3. Variations in perimeter strength and stiffness
4. Re-entrant corners.

SOFT-STOREY EFFECT

The most prominent of the problems caused by severe stress concentration is that of the “soft” story.



The soft first story failure mechanism.

SOFT-STOREY EFFECT

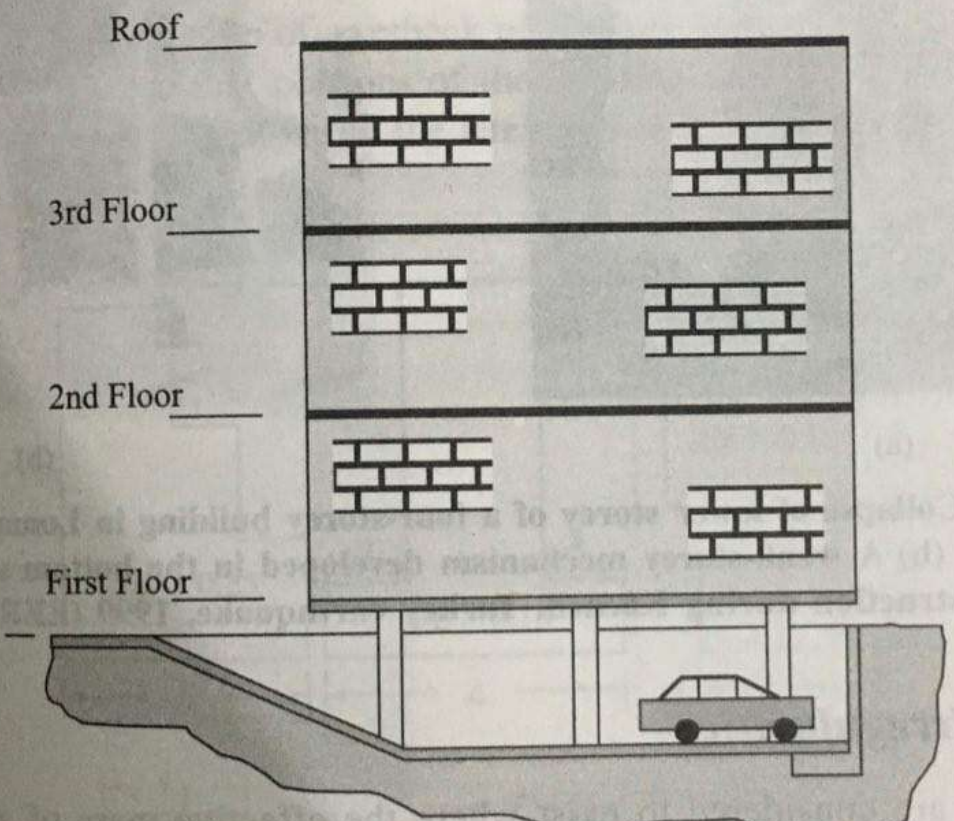


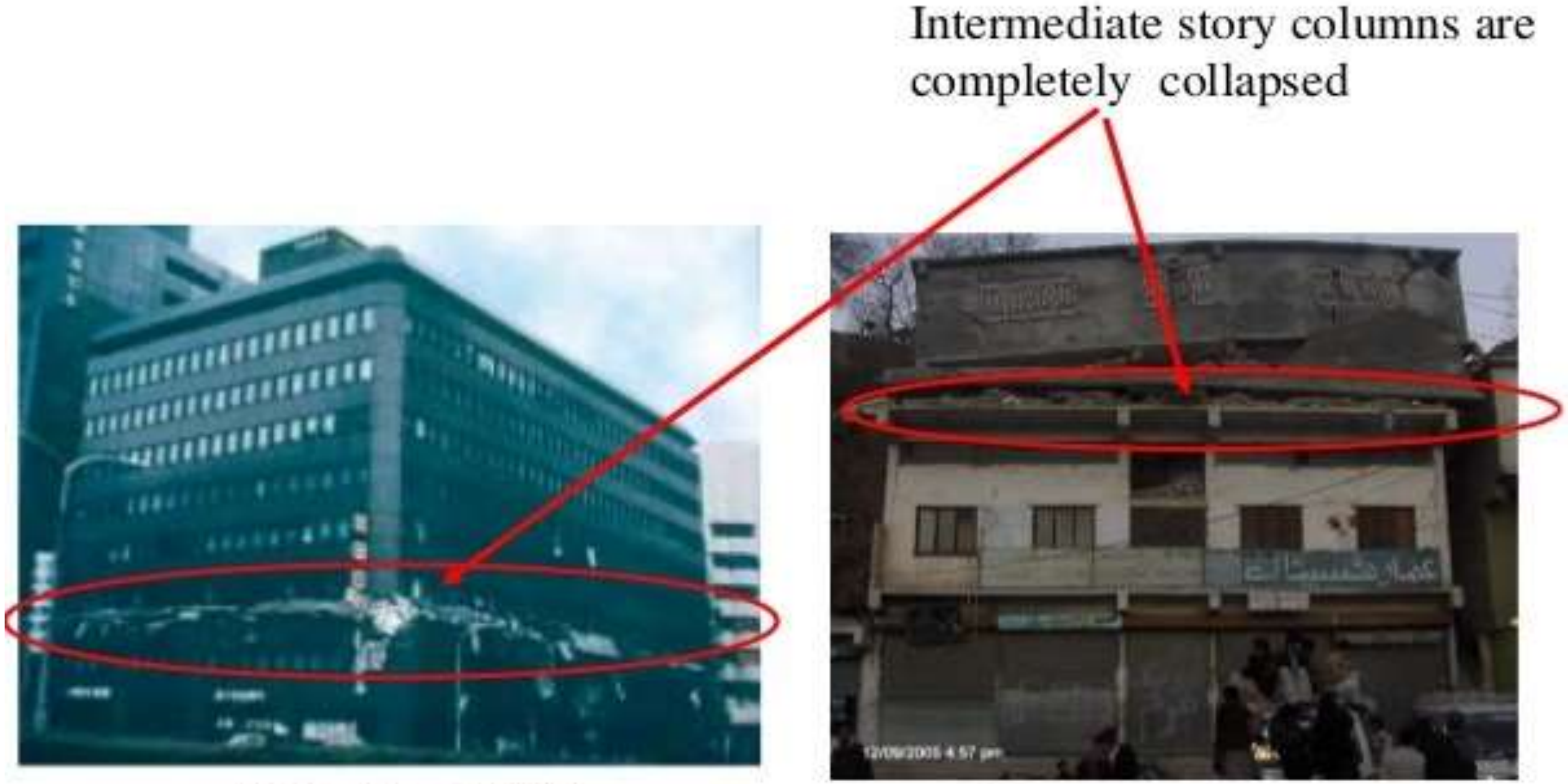
FIGURE 14.6 Soft stories type construction (Vukazich, 1998).

AVOID SOFT-STOREY GROUND FLOORS

Lower story columns were collapsed in a hotel at Balakot, 2005 Kashmir earthquake

Permanent plastic deformation in the ground floor of a building under construction. Soft story effect almost provoked a collapse (Friaul, Italy 1976).

AVOID SOFT-STOREY UPPER FLOORS



Kobe, Japan 1995.

Bagh, 2005 Kashmir earthquake

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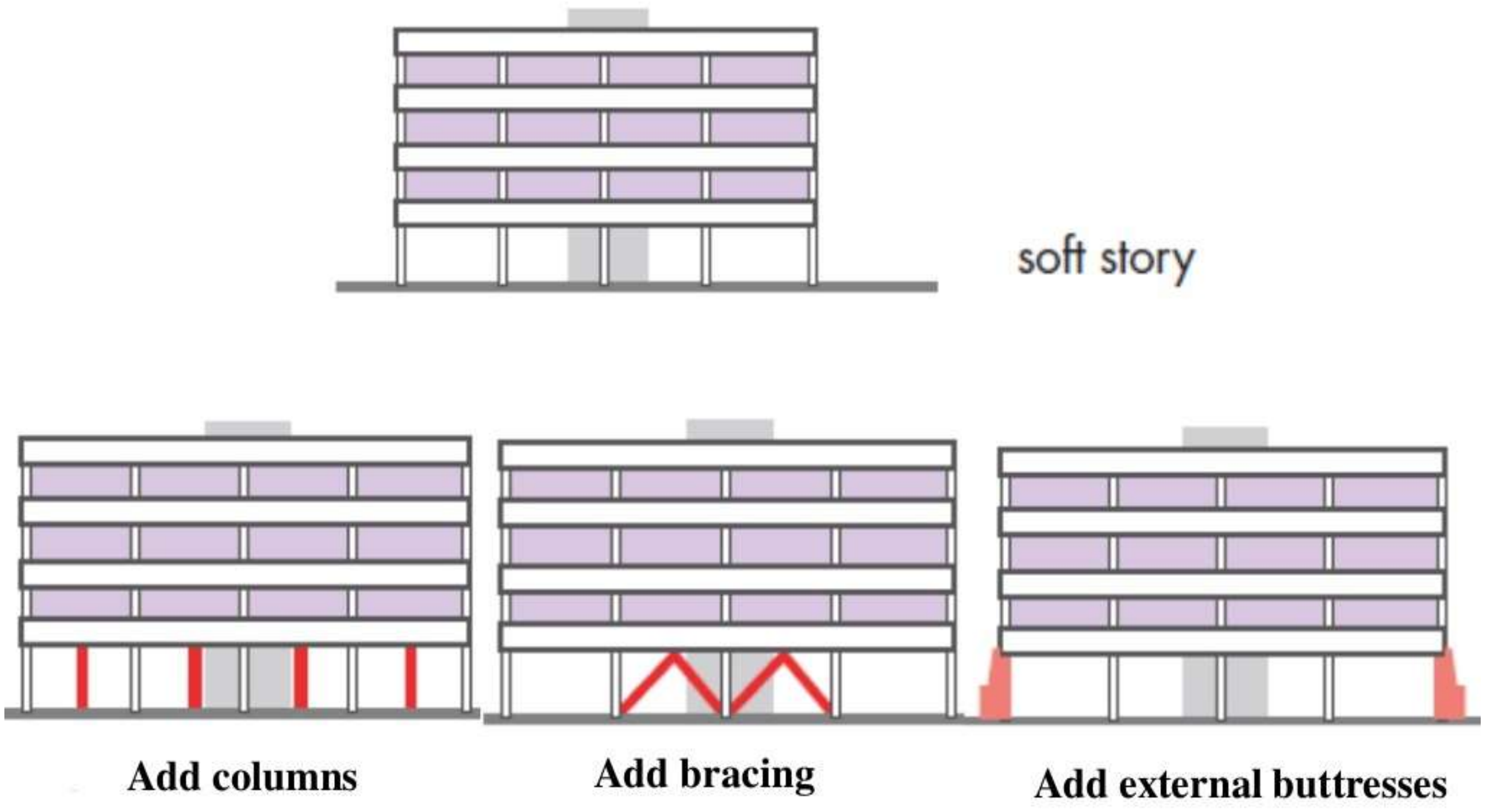
SOLUTIONS


soft story
Add columns
Add bracing
Add external buttresses

AVOID DISCONTINUOUS SHEAR WALLS

- When shear walls form the main lateral resistant elements of a structure, and there is not a continuous load path through the walls from roof to foundation, the result can be serious overstressing at the points of discontinuity. This discontinuous shear wall condition represents a special, but common, case of the “soft” first-story problem.

- The discontinuous shear wall is a fundamental design contradiction: the purpose of a shear wall is to collect diaphragm loads at each floor and transmit them as directly and efficiently as possible to the foundation. To interrupt this load path is undesirable

AVOID DISCONTINUOUS SHEAR WALLS

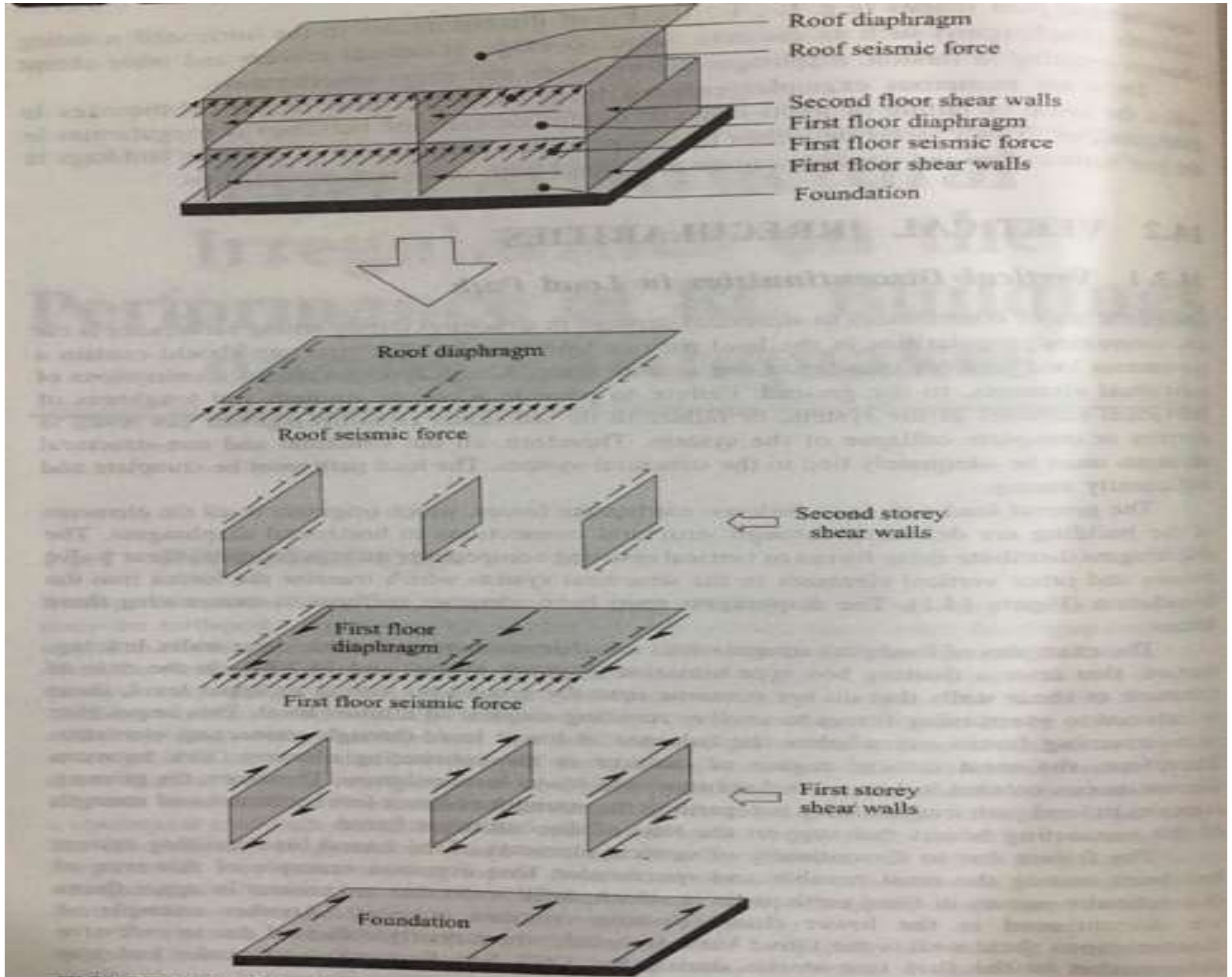


FIGURE 14.1 Seismic forces on the elements of shear wall building system (Vukazich, 1998).

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AVOID DISCONTINUOUS SHEAR WALLS

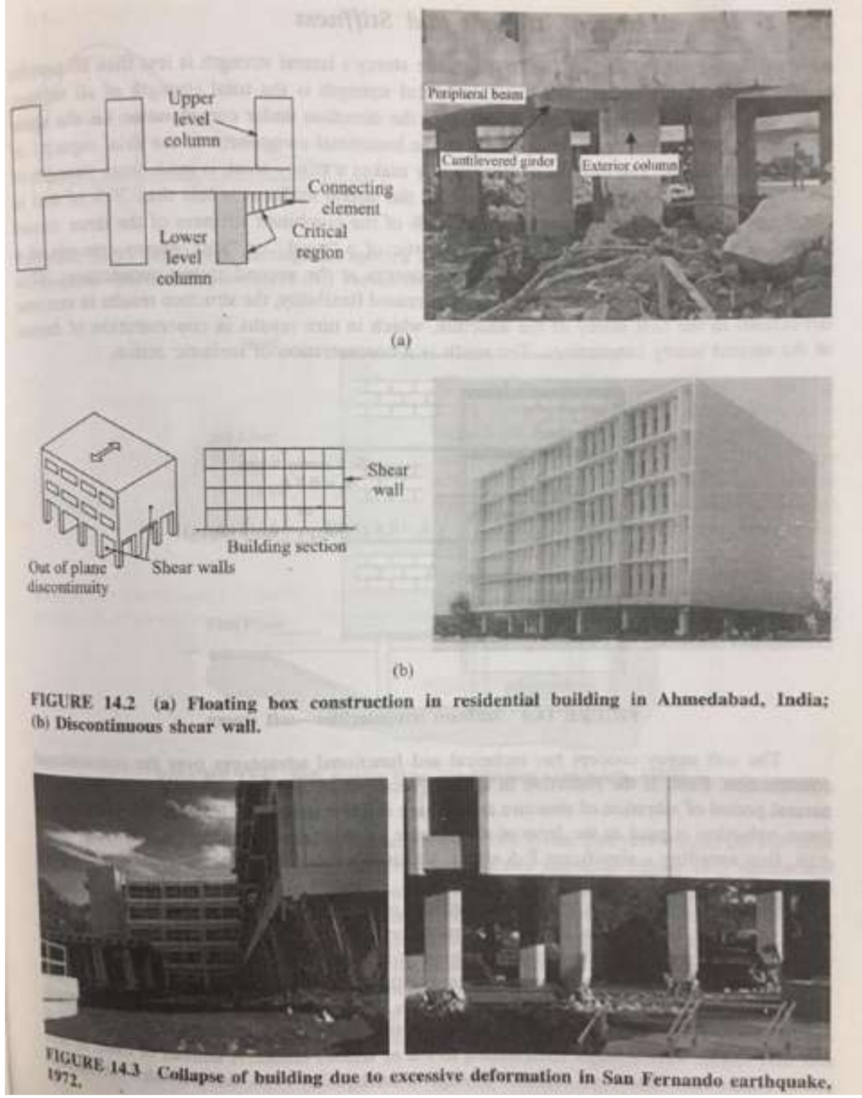
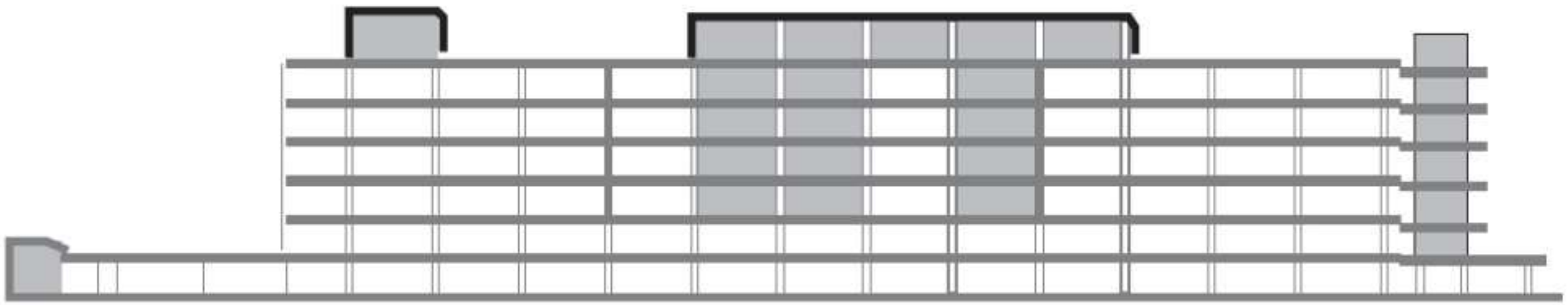


FIGURE 14.2 (a) Floating box construction in residential building in Ahmedabad, India; (b) Discontinuous shear wall.

FIGURE 14.3 Collapse of building due to excessive deformation in San Fernando earthquake, 1972.

AVOID DISCONTINUOUS SHEAR WALLS



Long section, Olive View Hospital. Note that the shear walls stop at the third floor.

Cross section, Olive View hospital, showing the second-floor plaza and the discontinuous shear wall.

AVOID DISCONTINUOUS SHEAR WALLS

Olive View hospital, San Fernando earthquake, 1971, showing the extreme deformation of the columns above the plaza level.

SOLUTIONS

- The solution to the problem of the discontinuous shear wall is to eliminate the shear walls.

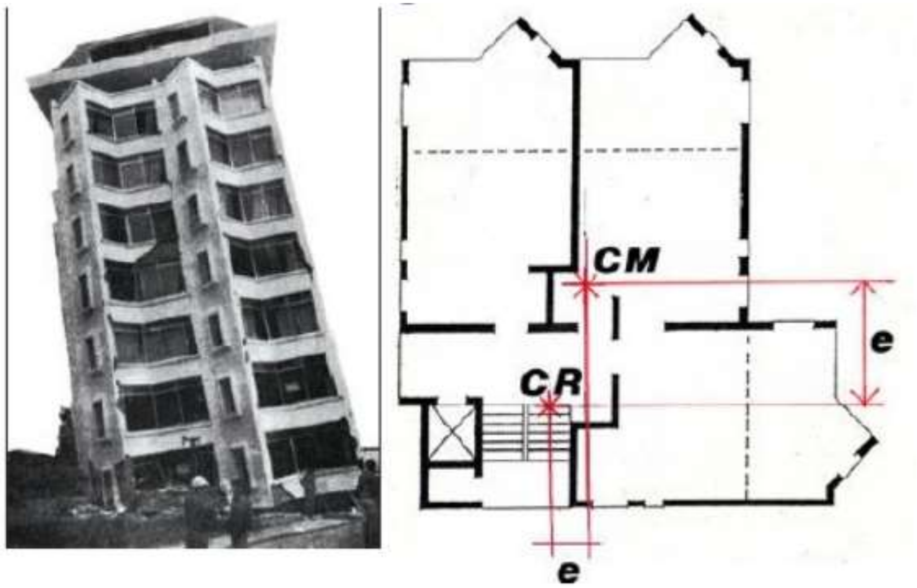
- If the decision is made to use shear walls, then their presence must be recognized from the beginning of schematic design, and their size and location made the subject of careful architectural and engineering coordination early

VARIATIONS IN PERIMETER STRENGTH AND STIFFNESS

- This problem may occur in buildings whose configuration is geometrically regular and symmetrical, but nonetheless irregular for seismic design purposes.

- A building's seismic behavior is strongly influenced by the nature of the perimeter design. If there is wide variation in strength and stiffness around the perimeter, the center of mass will not coincide with the center of resistance, and torsional forces will tend to cause the building to rotate around the center of resistance.

VARIATIONS IN PERIMETER STRENGTH AND STIFFNESS



Left, the building after the earthquake. Right, typical floor plan showing the Center of Mass (CM), Center of Resistance (CR), and Eccentricity (e) along the two axes

The figure shows an apartment house in Viña del Mar, Chile, following the earthquake of 1985. The apartment, designed with open frontage, had only three apartments per floor, with the service areas and elevator concentrated to the rear and surrounded by reinforced concrete walls that provided the seismic resistance. The lack of balance in resistance was such that the building rotated around its center of resistance, tilted sharply, and nearly

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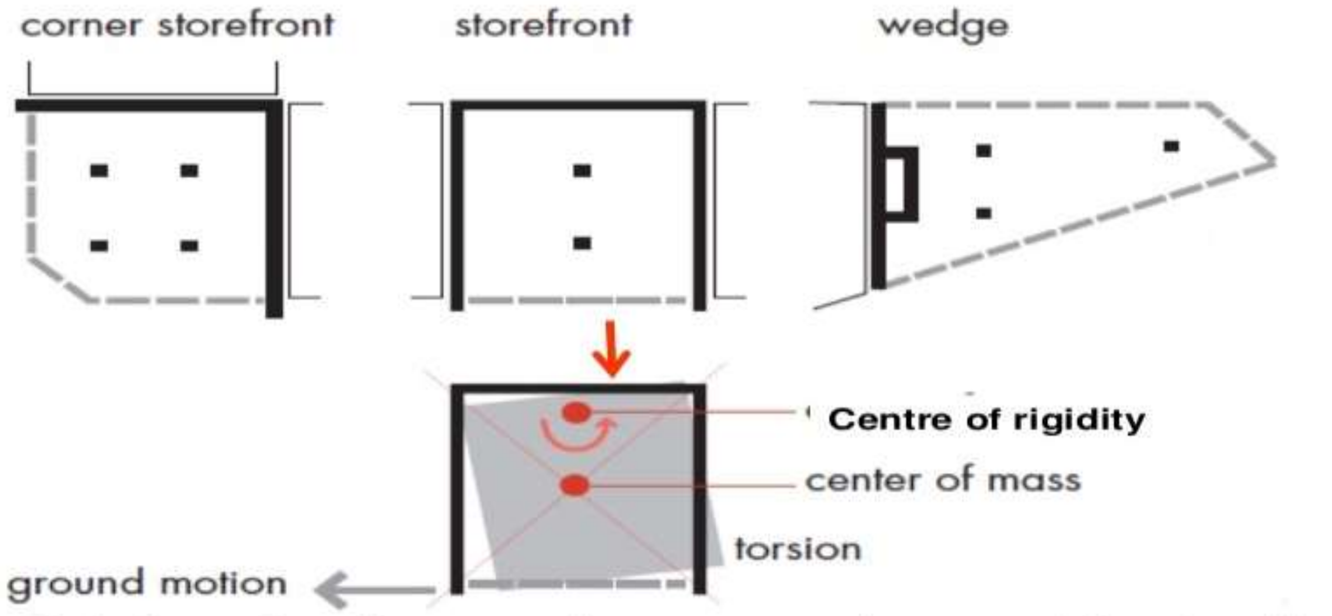
VARIATIONS IN PERIMETER STRENGTH AND STIFFNESS

- A common instance of an unbalanced perimeter is that of open-front design in buildings, such as fire stations and motor maintenance shops in which it is necessary to provide large doors for the passage of vehicles.



Unbalanced perimeter resistance: storefronts and "wedges."

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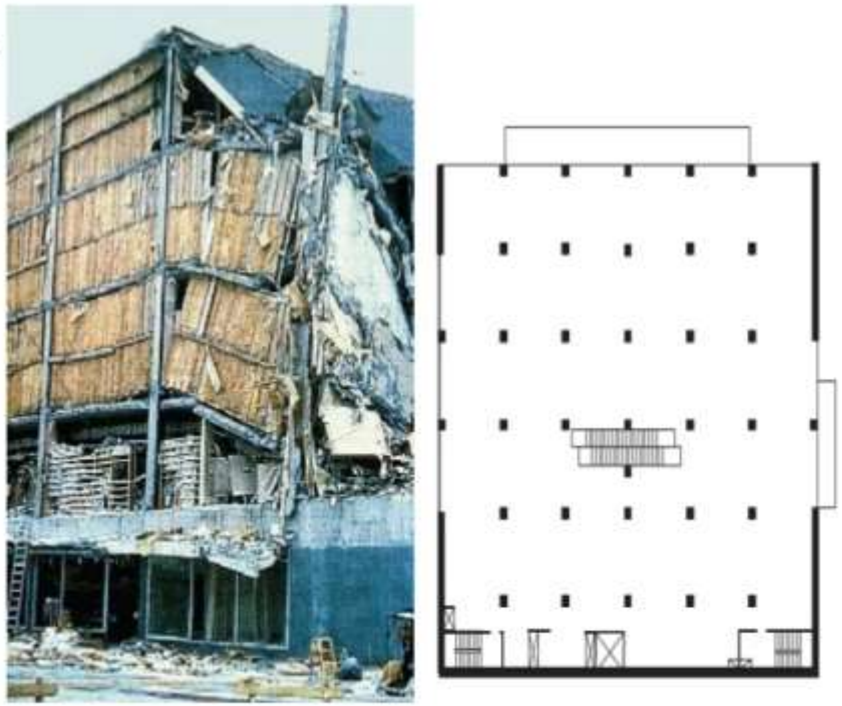
VARIATIONS IN PERIMETER STRENGTH AND STIFFNESS

- Stores, individually or as a group in a shopping mall, are often designed as boxes with three solid sides and an open glazed front
- The large imbalance in perimeter strength and stiffness results in large torsional forces. Large buildings, such as department stores, that have unbalanced resistance on a number of floors to provide large window areas for display are also common.



Penney’s store, Anchorage, Alaska, earthquake, 1964. Left: Damage to the store: Right: Second-floor plan, showing unbalanced perimeter resistance

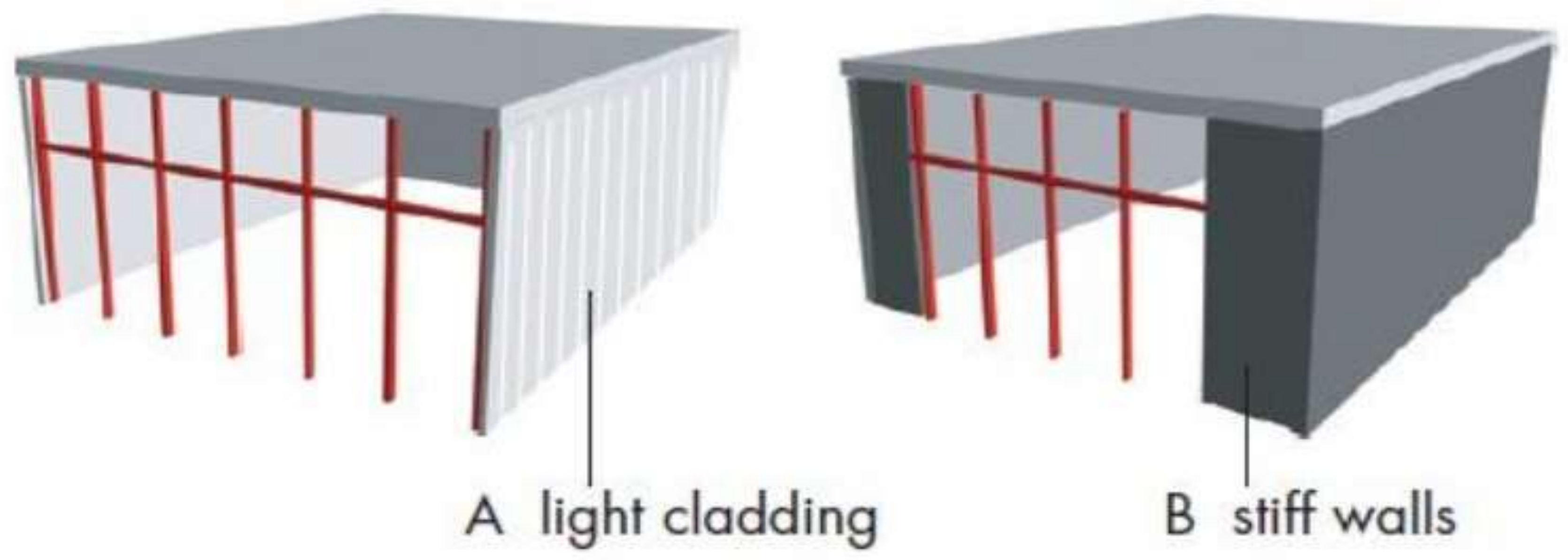
SOLUTIONS

- The solution to this problem is to reduce the possibility of torsion by endeavoring to balance the resistance around the perimeter.

- The first strategy is to design a frame structure of approximately equal strength and stiffness for the entire perimeter.

- The opaque portion of the perimeter can be constructed of nonstructural cladding, designed so that it does not affect the seismic performance of the frame. This can be done either by using lightweight cladding or by ensuring that heavy materials, such as concrete or masonry, are isolated from the frame (Figure A)

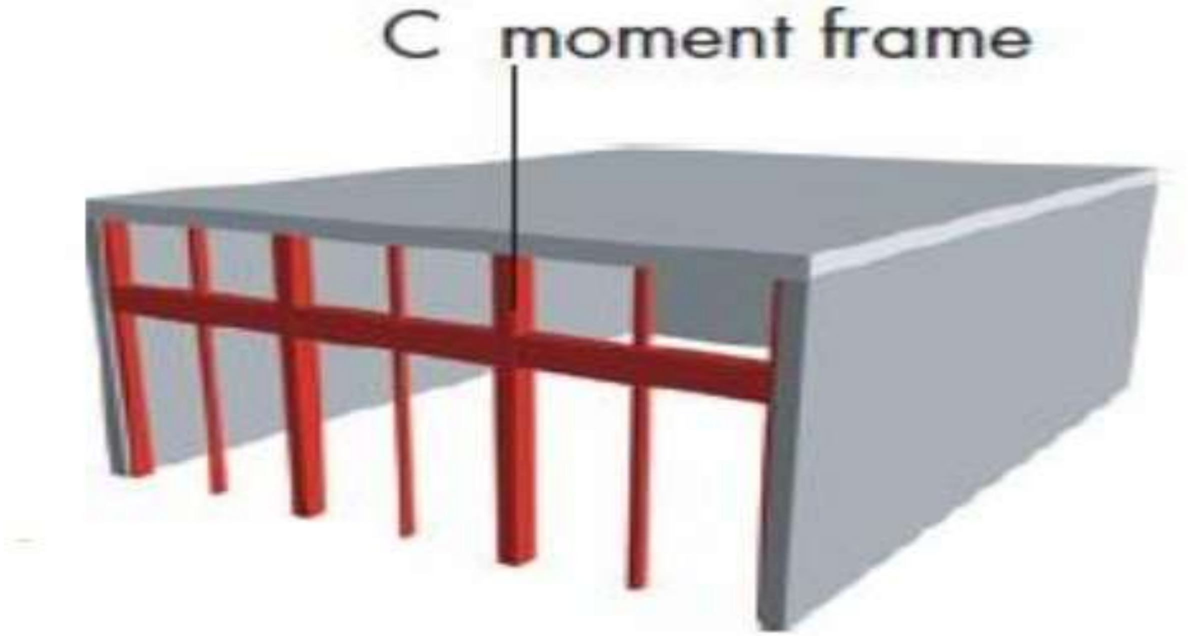
SOLUTIONS



- A second approach is to increase the stiffness of the open facades by adding sufficient shear walls, at or near the open face, designed to approach the resistance provided by the other walls (Figure B).
- A third solution is to use a strong moment resisting or braced frame at the open front, which approaches the solid wall in stiffness.

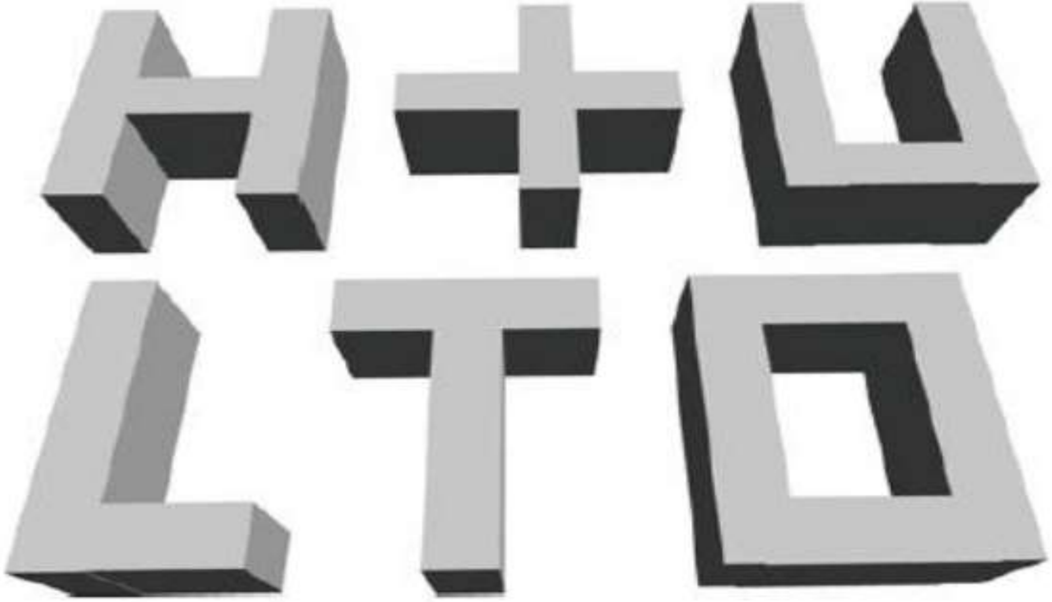
SOLUTIONS

The ability to do this will depend on the size of the facades; a long steel frame can never approach a long concrete wall in stiffness. This is, however, a good solution for wood frame structures, such as small apartment buildings, or motels with ground floor garage areas, or small store fronts, because even a comparatively long steel frame can be made as stiff as plywood shear walls (Figure C).



RE-ENTRANT CORNERS

The re-entrant corner is the common characteristic of building forms that, in plan, assume the shape of an L, T, H, etc., or a combination of these shapes Re-entrant corner plan forms.



Re-entrant corner plan forms.

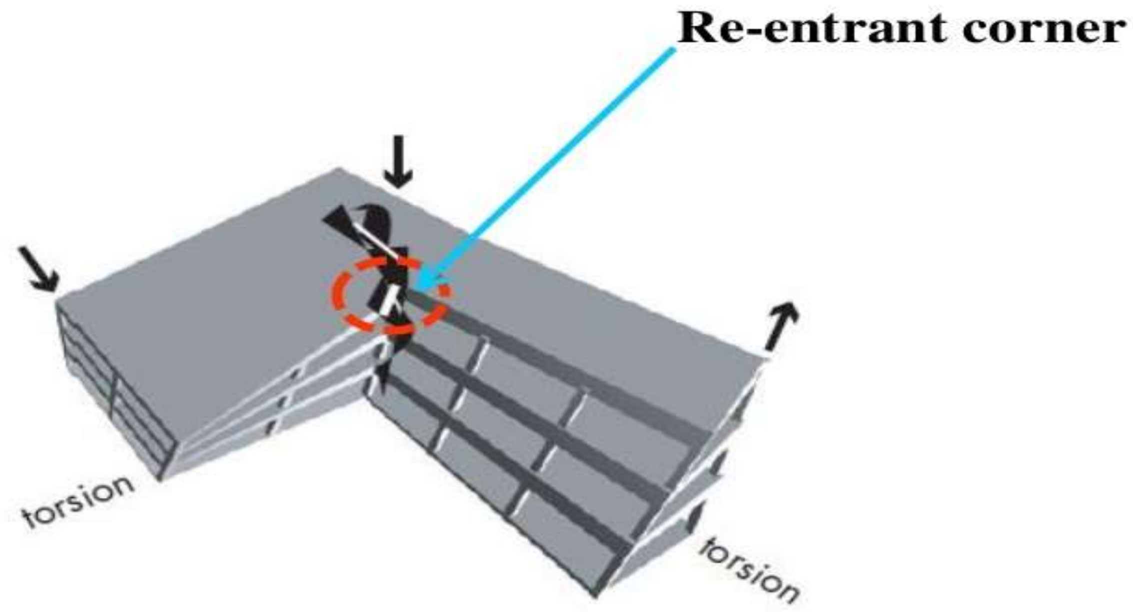
RE-ENTRANT CORNERS

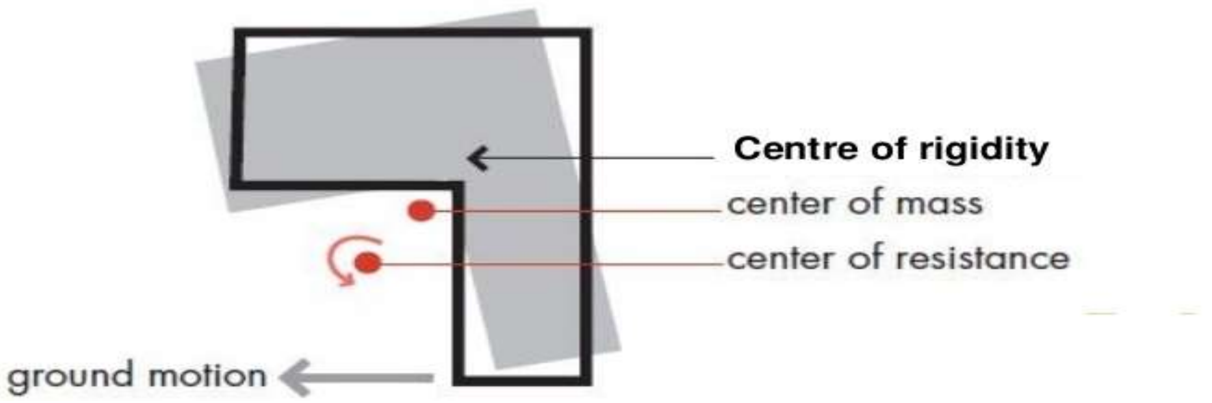
- There are two problems created by these shapes.

- The first is that they tend to produce differential motions between different wings of the building that, because of stiff elements that tend to be located in this region, result in local stress concentrations at the re-entrant corner.

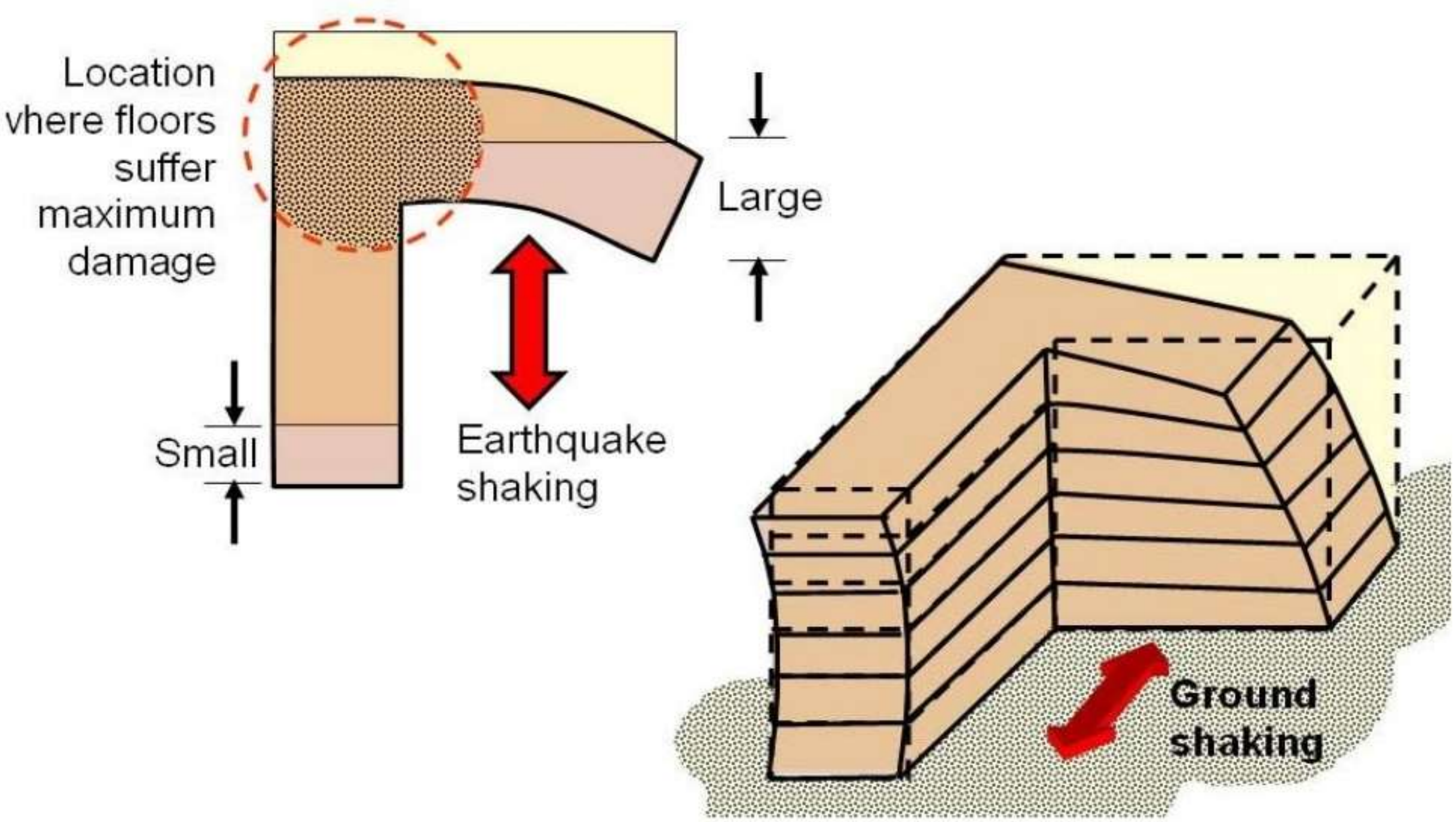
- The second problem of this form is torsion. Which is caused because the center of mass and the center of rigidity in this form cannot geometrically coincide for all possible earthquake directions. The result is rotation. The resulting forces are very difficult to analyze and predict.

RE-ENTRANT CORNERS





RE-ENTRANT CORNERS



Differential deformation at the junction of two wings

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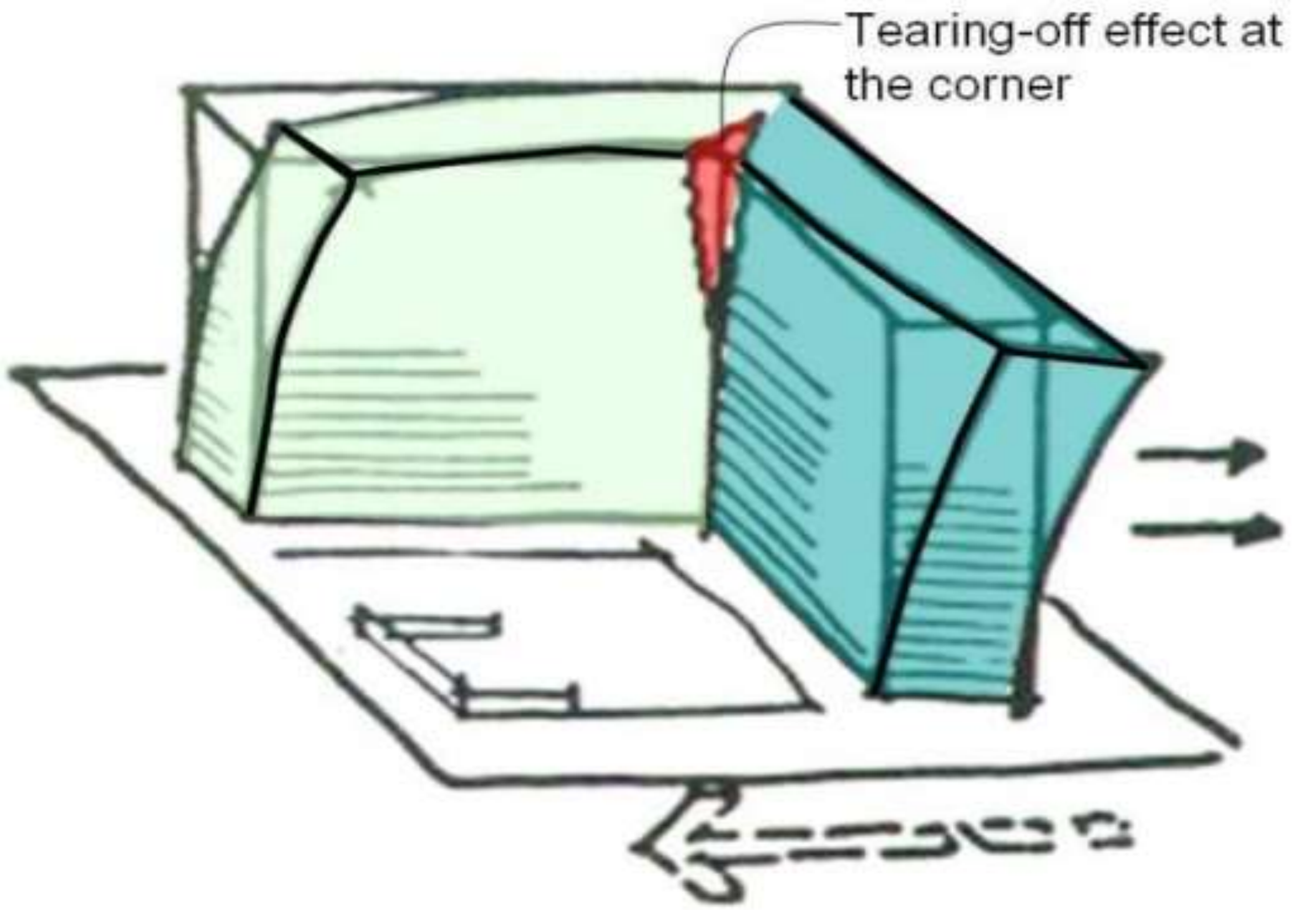
RE-ENTRANT CORNERS



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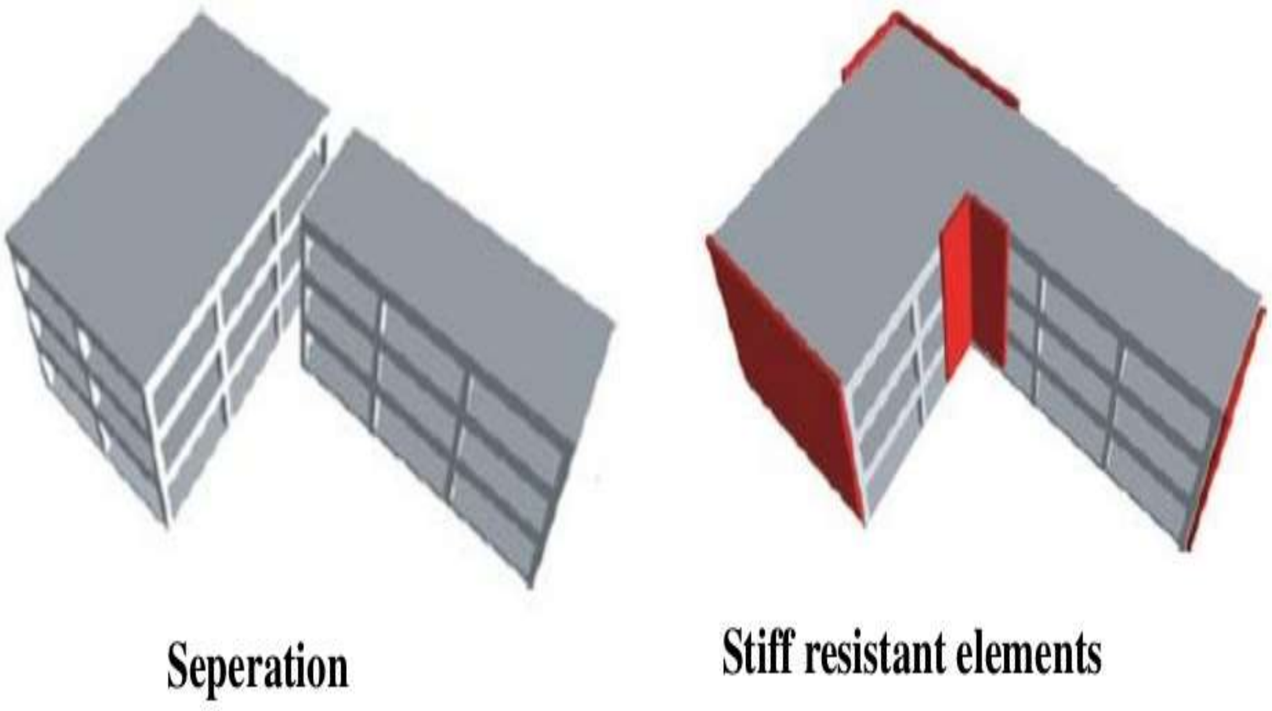
SOLUTIONS

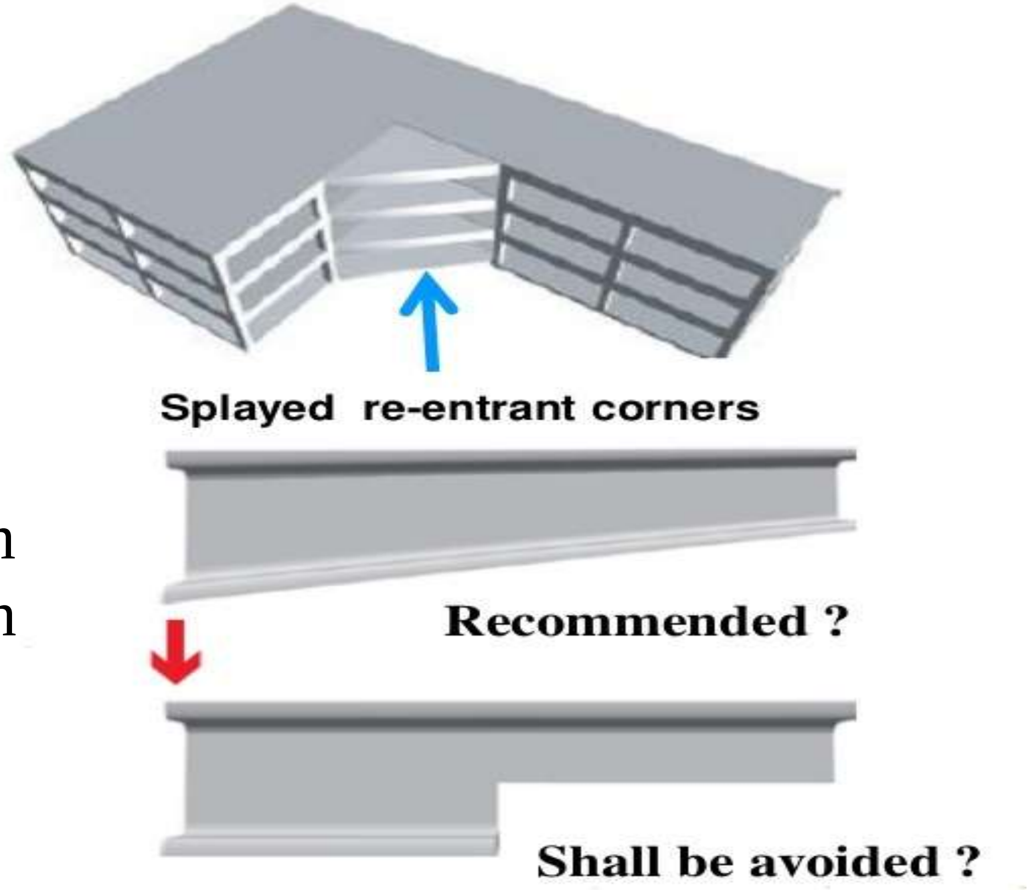
There are two basic alternative approaches to the problem of re- entrant-corner forms: structurally to separate the building into simpler shapes or to tie the building together more strongly with elements positioned to provide a more balanced resistance (see figure). The latter solution applies only to smaller buildings Separation Stiff resistant elements.

In case of separation building must be sufficiently away to ensure they do not pound together and damage each other in an earthquake.



SOLUTIONS

The use of splayed rather than right angle re-entrant corners lessens the stress concentration



This is analogous to the way a tapered beam is structurally more desirable than an abruptly notched one.

Thank You