SPACE
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SEISMIC HAZARD & VULNERABILITY

A Seismic Analysis Framework

Building Types

Structural Types

Concrete Moment Fram with Unreinforced Masonry Walls

Concrete Slab-Column Frame

Lightly Reinforced Concrete Frame (Non-Engineered RC)

Unreinforced Masonry with Concrete Roof & Floor (BC)

Unreinforced Masonry with Flexible Roof (BF,BL)

Vertical Irregularities in Structures

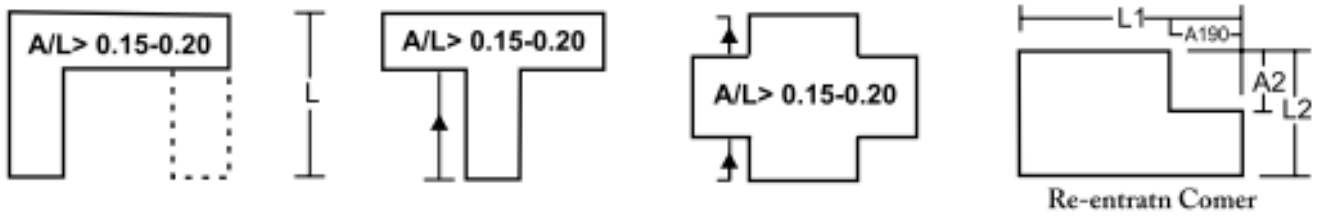
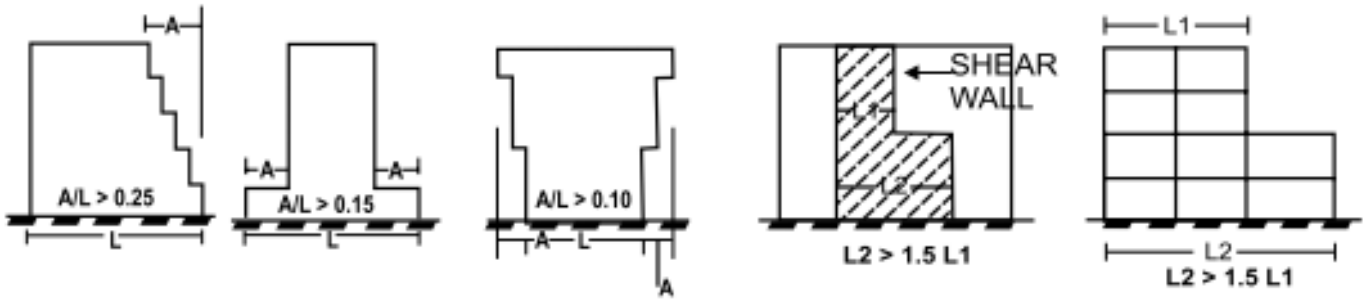
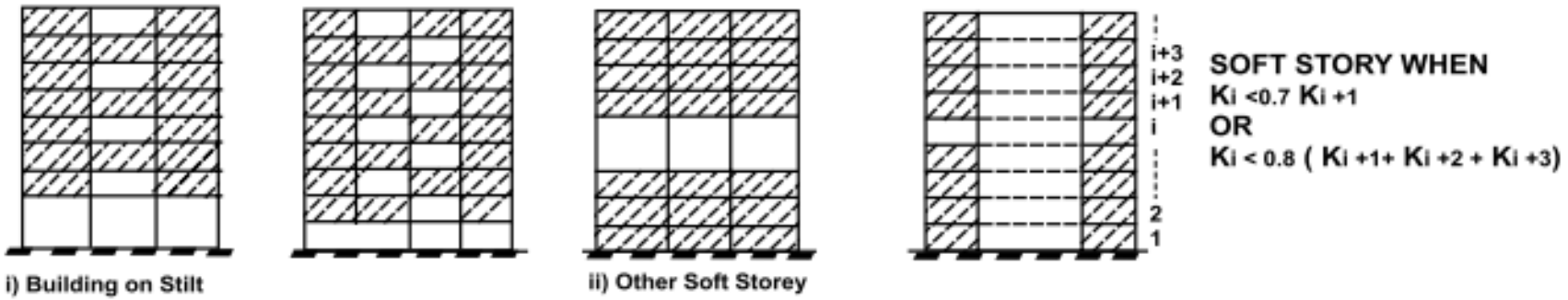


Fig. 6.3 : Plan Irregularities



a) Geometrical Irregularities



b) Storey Stiffness Irregularities

Common Structural Defects

Historically, damages due to earthquakes occurs in connection areas such as

- beam column connection,
- roof trusses-beam connection
- column-foundation connection

Common weaknesses found in masonry buildings are in

- Inadequate structural layout (unsymmetrical)
- Insufficient load-bearing capacity of the walls
- Inadequate connection between the walls.
- Poor quality materials or work methods in the construction.

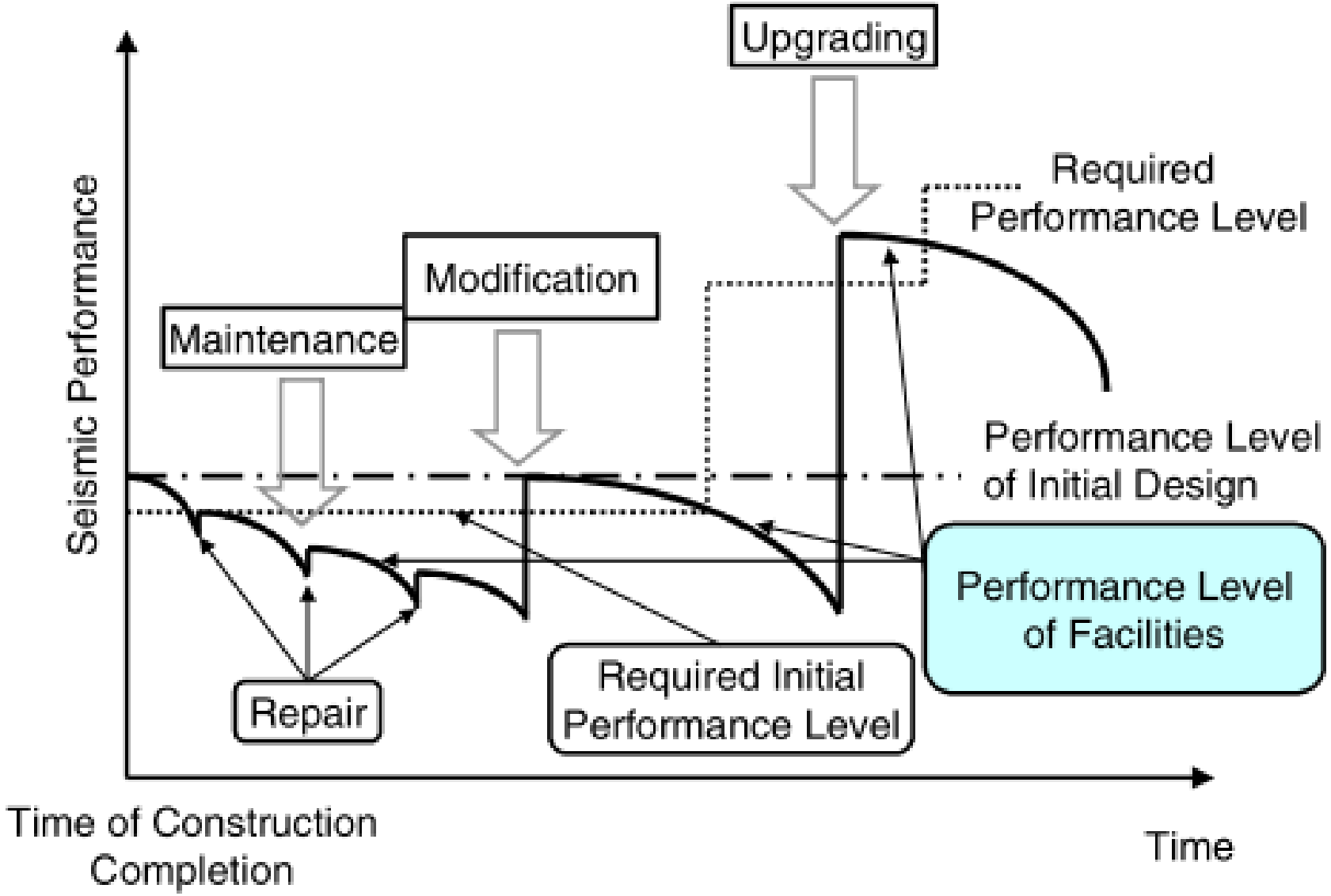


Figure 1: Relationship between deterioration and seismic performance

Seismic Hazard

- An indicator of Ground Shaking
- Function of
  - Magnitude
  - Distance
  - Duration of strong ground motion
  - Strength and number of aftershocks
  - Geological conditions on the wave path
  - Subsoil conditions at the site
  - Frequency or period of ground motion

Seismic Vulnerability

- An indicator of Vibration Characteristics
- Function of
  - Construction year
  - Foundation
  - Construction type
  - Construction height
  - Shape of building
  - Occupancy type
  - Relation to adjacent structures

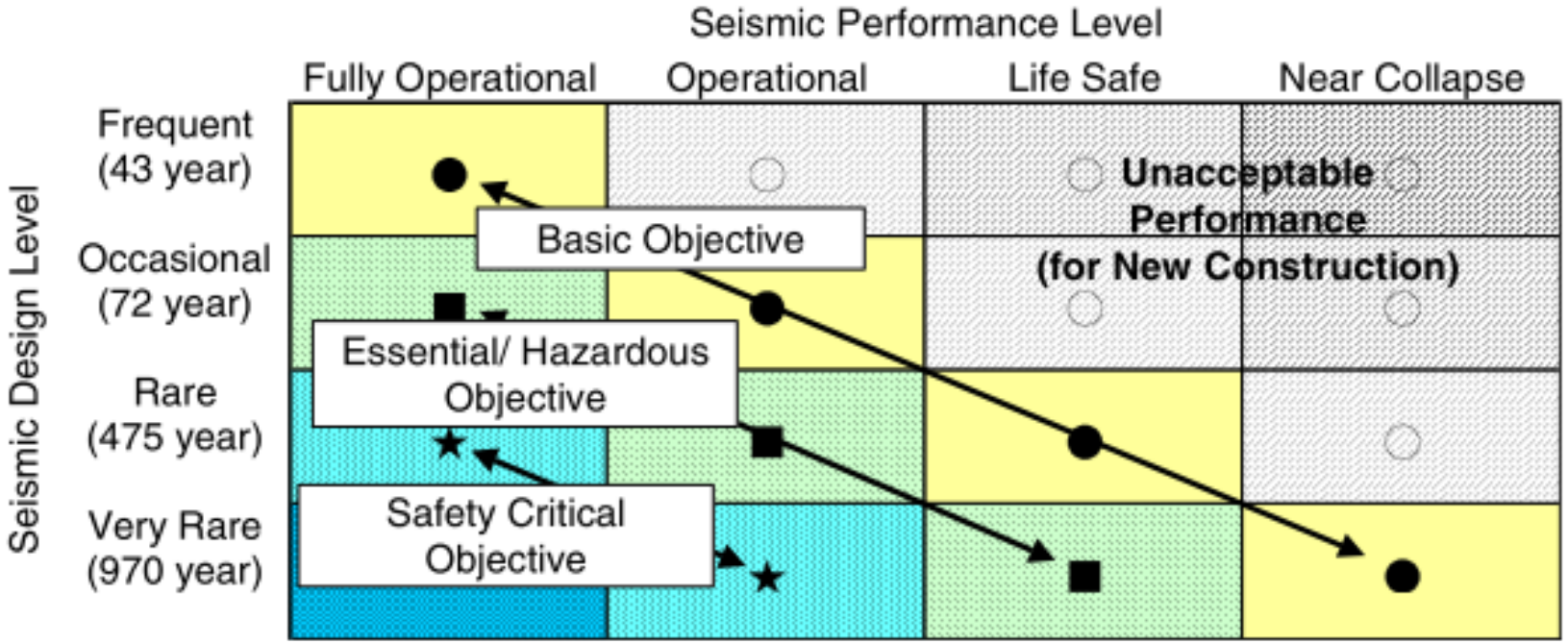


Figure 2: Recommended seismic performance objectives for buildings (risk assessment matrix)

Structural Investigation

The structural investigation can be divided into

- Upper structure investigation
  - Non-destructive test (NDT)
  - Semi-destructive /destructive test (DT)
- Sub-structure investigation
- Detailed Structural Analysis

Upper structure investigation

- Non-destructive test (NDT)
  - To assess the upper structure condition wrt material properties
  - **Schmidt Hammer Test** to calculate compressive strength using ASTM C 805
  - **Ultrasonic Pulse Velocity Test** (UPV) to check crack depths by measuring the concrete density using ASTM C 597

- Semi-destructive /destructive test (DT)
  - **Core Drill Test** to get the concrete's strength by drilling the existing concrete on site and testing it at the laboratory.

Sub-structure investigation

- To investigation for soil properties and foundation
- **Hand boring test** and **Soil penetration test** for assessing soil properties
- **Foundation digging** to check the existence of the foundation, including the dimensions and the bearing area.

Detailed Structural Analysis

- Detailed structural analysis is conducted to estimate the structural behavior when subjected to applicable loads.
- Results from structural investigations should be used for the detailed structural analysis.
- The results of structural analysis will be used for designing of retrofitting approaches/strategy.

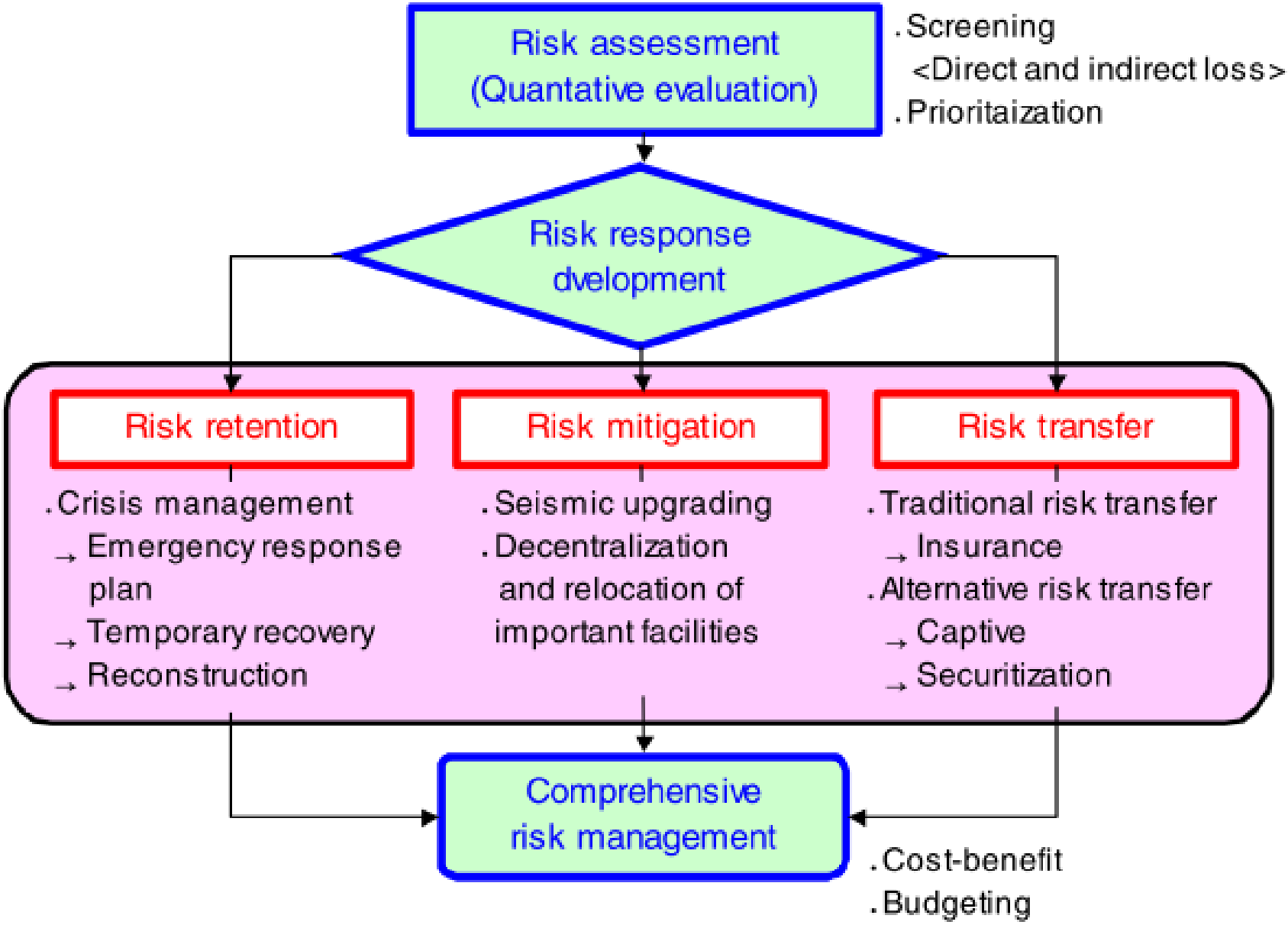


Figure 3: A framework for seismic risk management

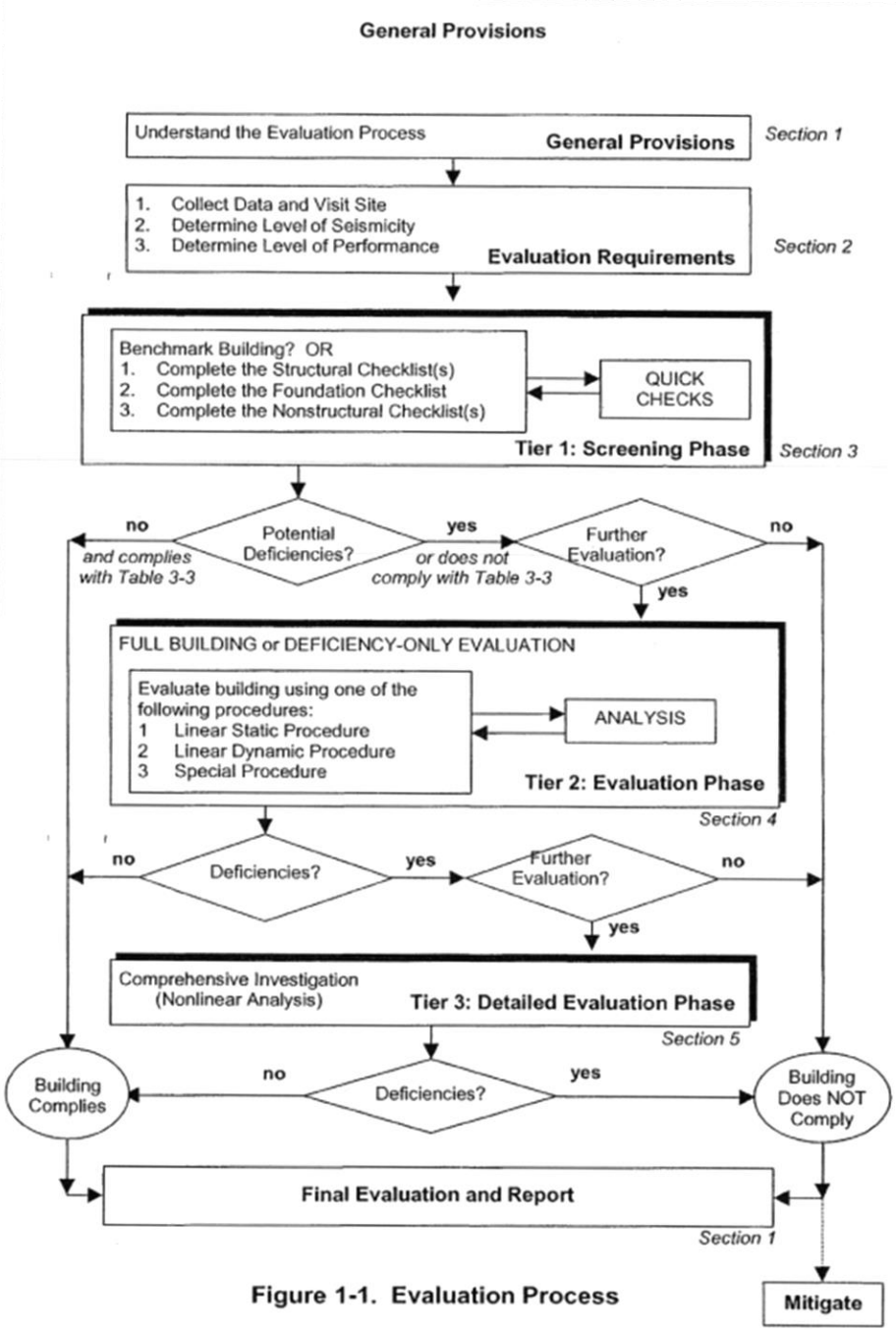


Figure 1-1. Evaluation Process

FIGURE 2- ASCE 31-03 Evaluation Procedure

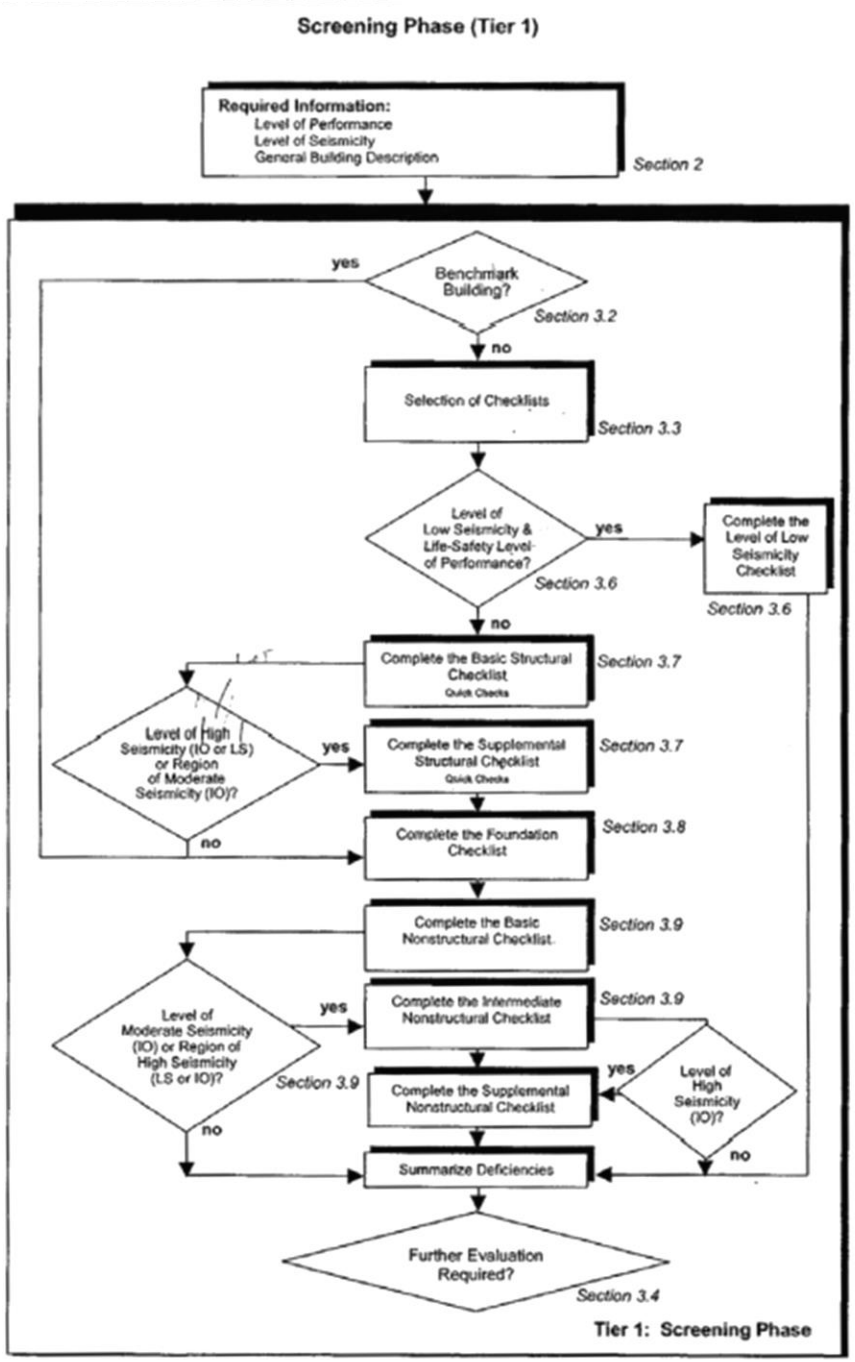
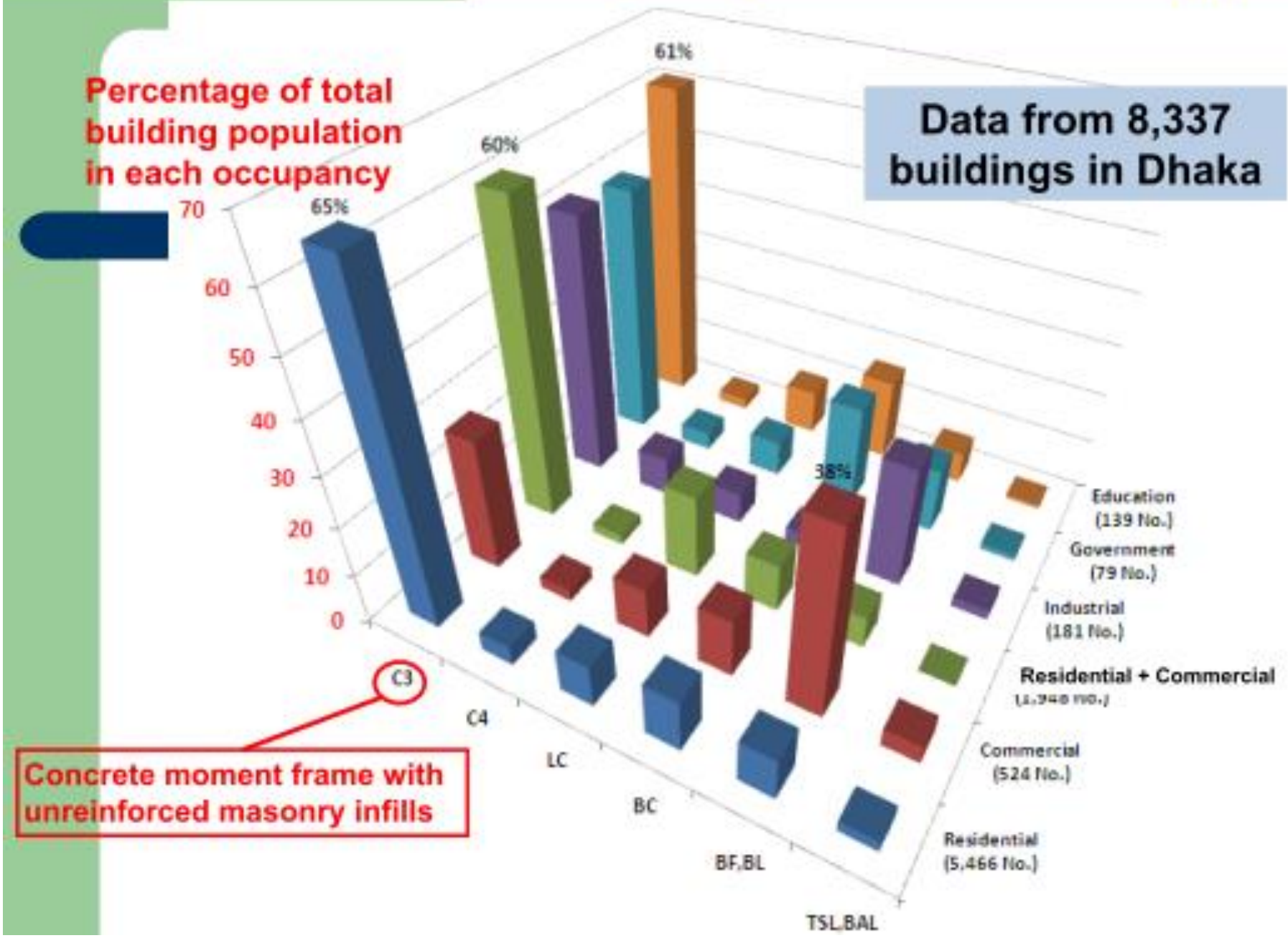


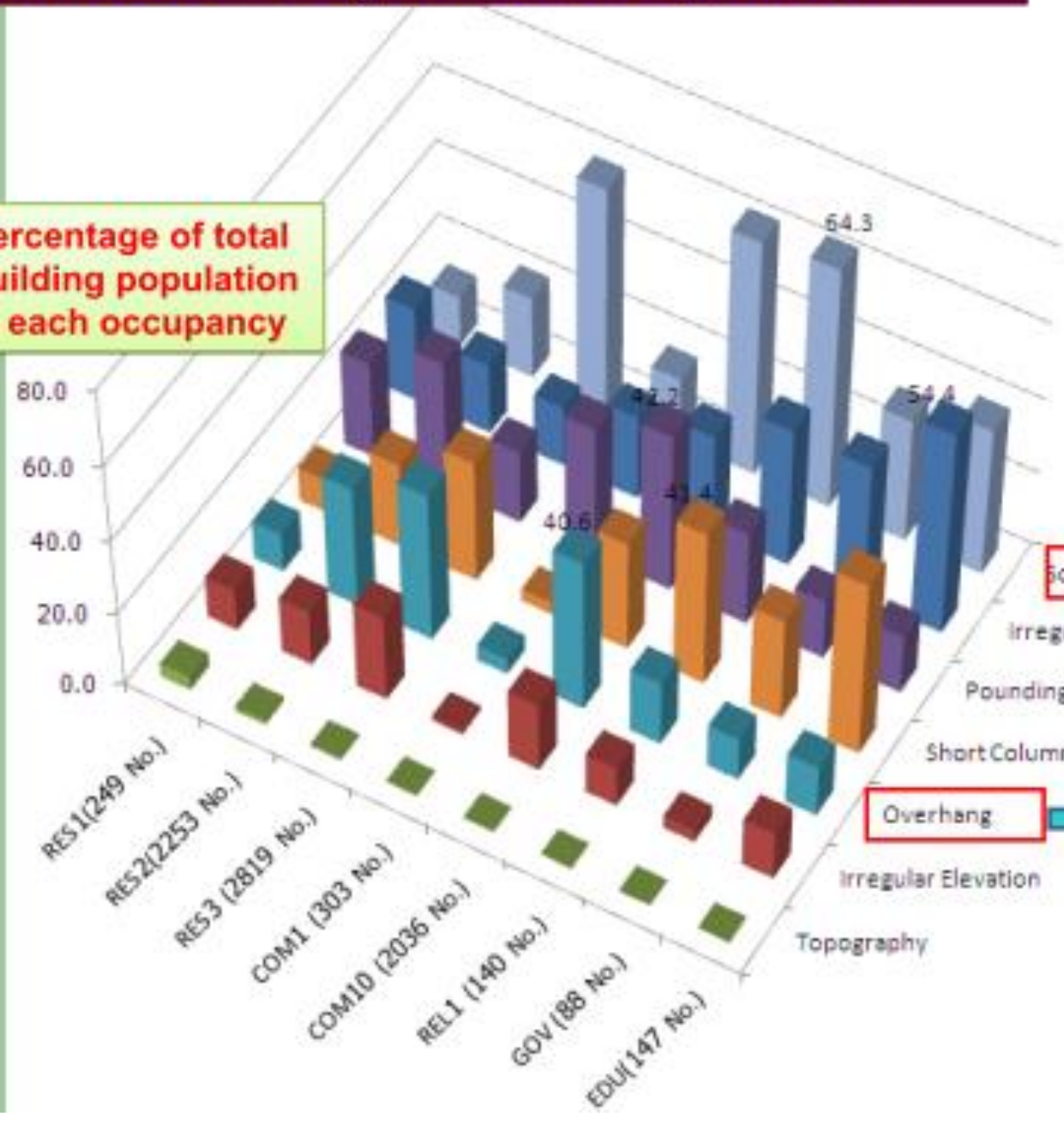
Figure 3-1. Tier 1 Evaluation Process

Correlation between occupancy class & structural type



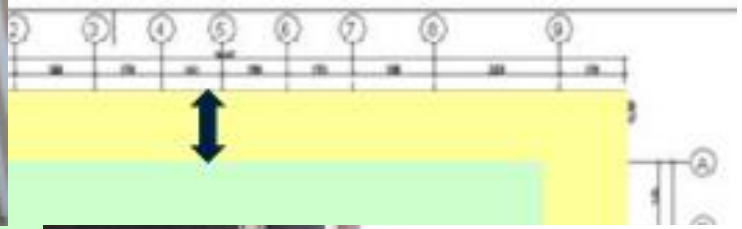
Seismic Building Vulnerability Factors

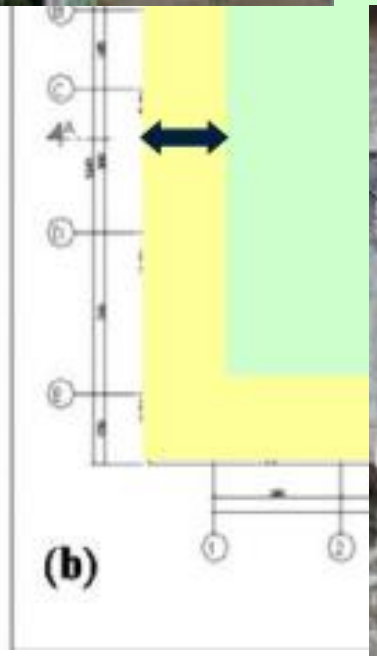
Percentage of total building population in each occupancy



Identifying Soft Storey

Identifying Heavy Overhang





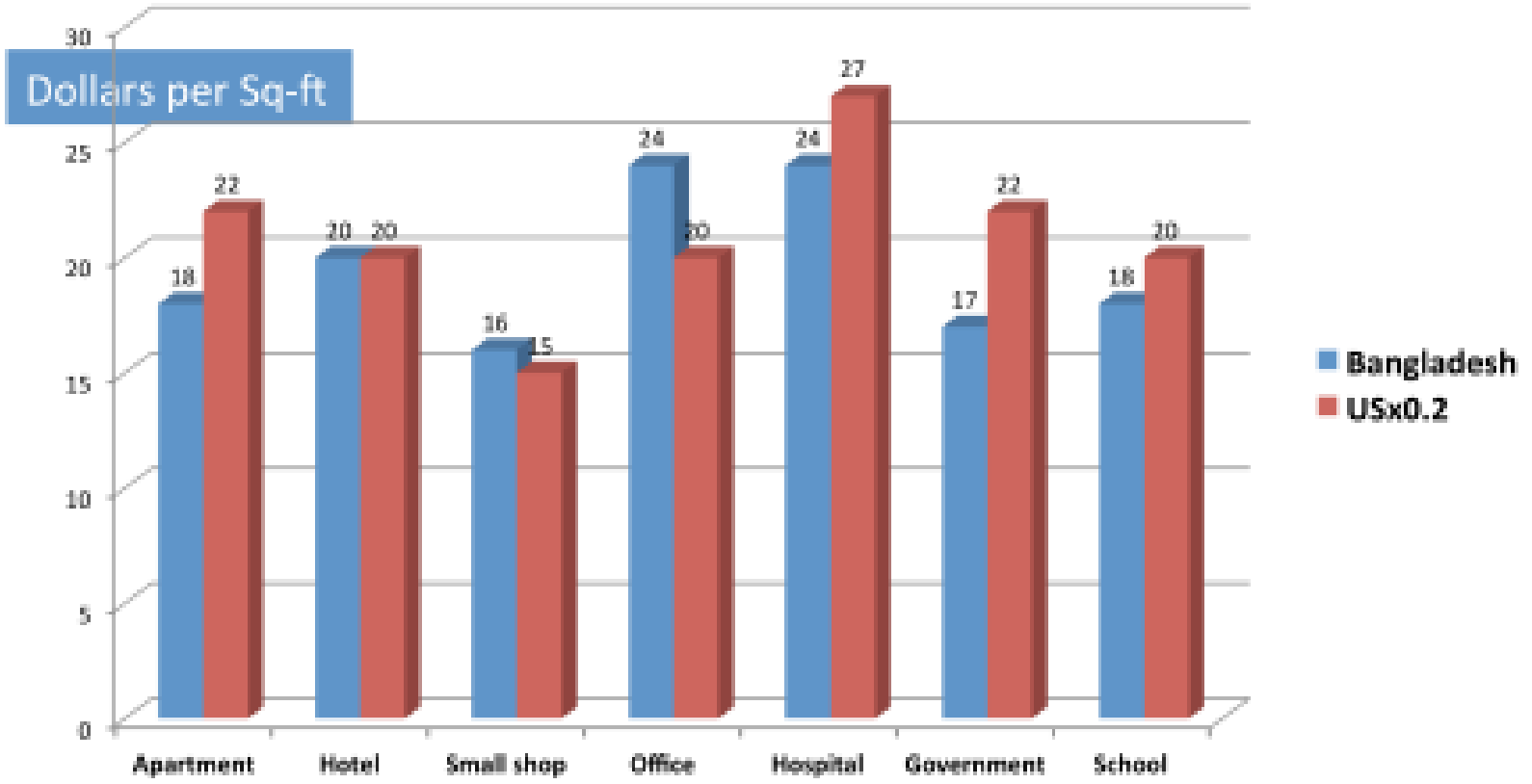
Identifying Short Column

Identifying Pounding Possibility

All new constructions have to have a seismic separation of 1.5% of the height between adjacent buildings to prevent pounding.

Full replacement cost

Replacement cost = Construction cost per floor area x floor area



Cost of contents

Cost of contents = **Replacement cost** x CV

CV : Content value from HAZUS Manual

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