



# Retrofitting of Structures

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# Contents

- ★ Earthquake Forces
- ★ Structural damages due to earthquakes
- ★ Basic concept of Retrofitting
- ★ Case Studies

# Earthquake Forces

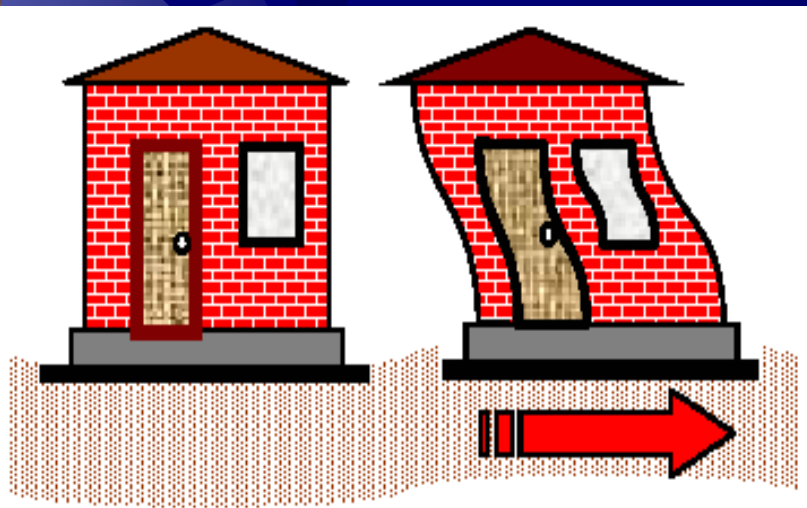


Figure 1: Effect of Inertia in a building when shaken at its base

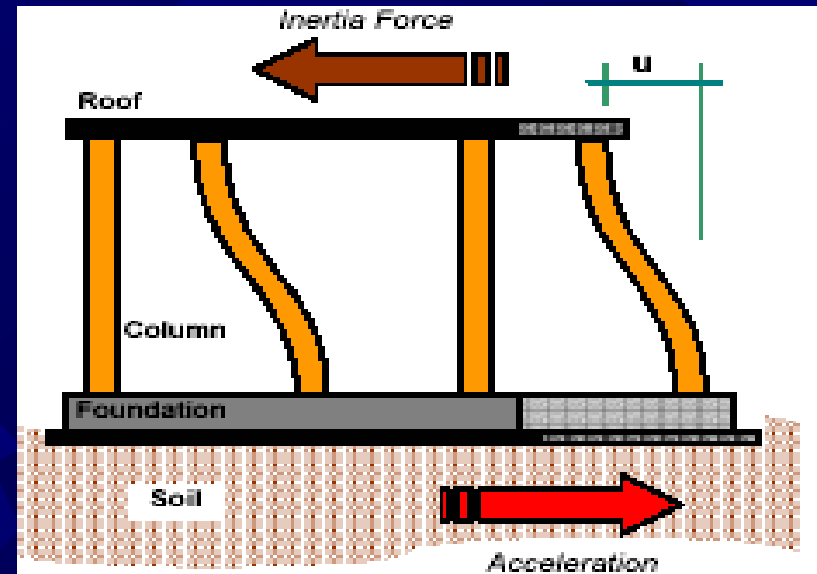
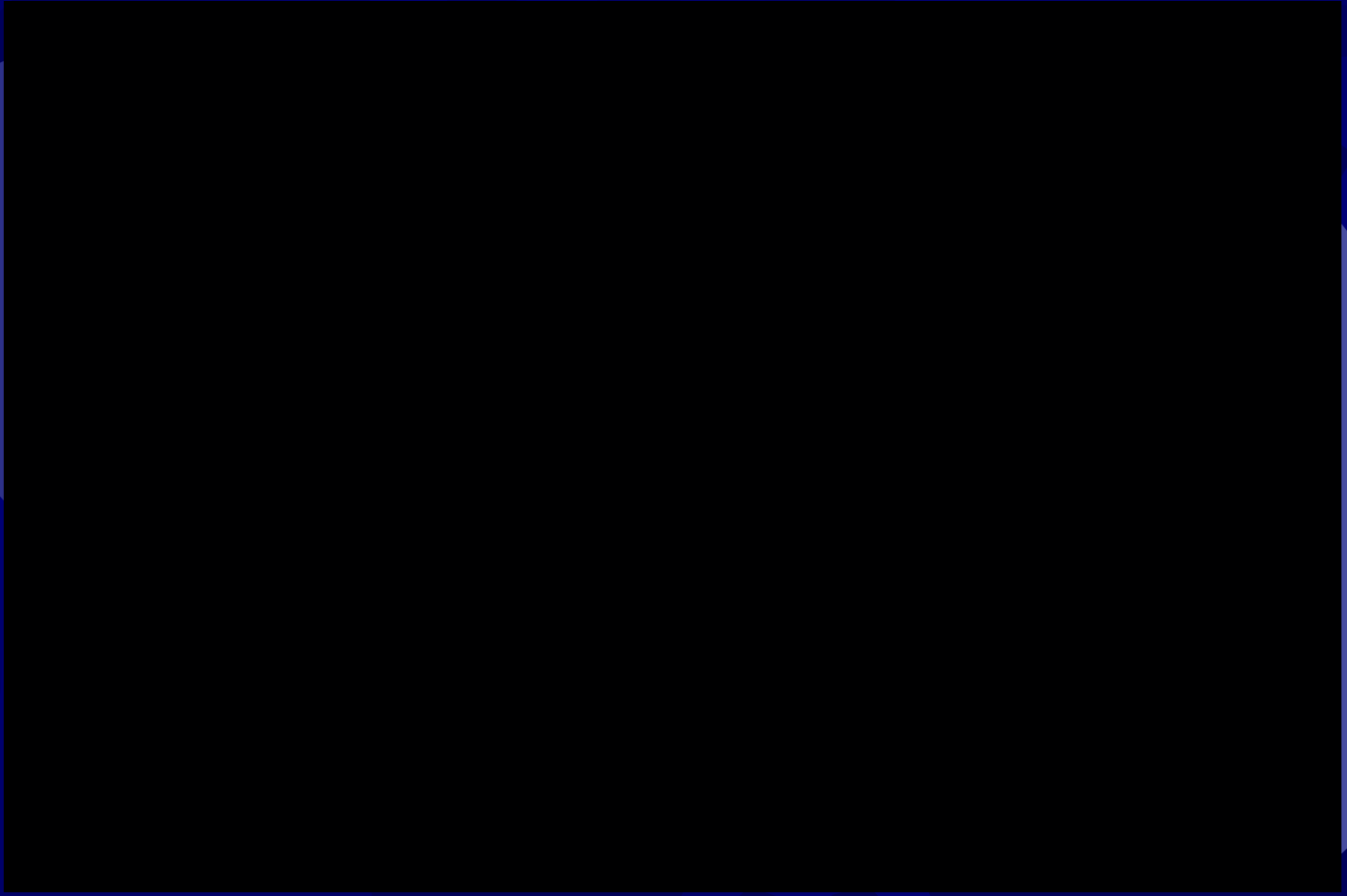


Figure 2: Inertia force and relative motion within a building

# Structural Damages



# Structural Damages



# Structural Damages

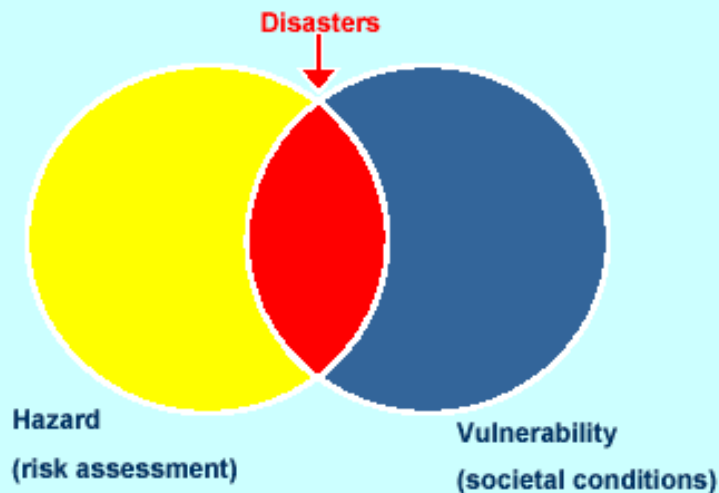


# Structural Damages

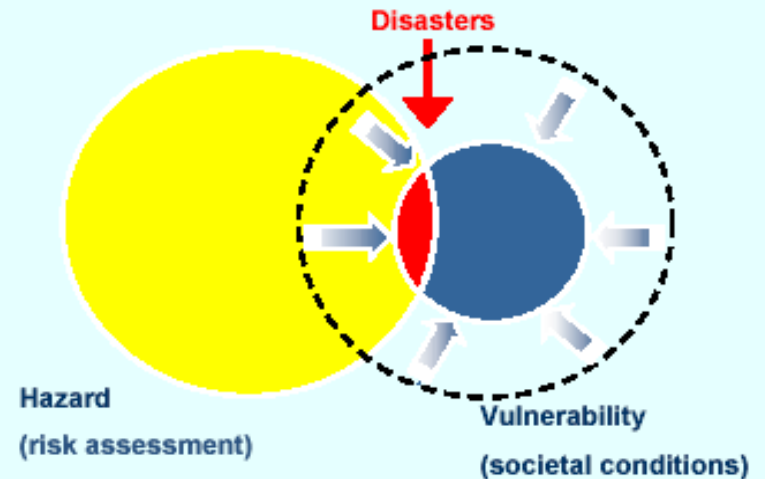


# Basic Concepts

## Hazards Confronting Vulnerable Communities Cause Disasters



## Less Disasters



$$\text{Disaster risk} = \text{Hazard} \times \text{Vulnerability}$$



# Basic Concepts

- ☀ Simple Repair:

Bringing a structure into its pre-damage condition

- ☀ Retrofitting Repair:

Improving capacity of structure

# Basic Concepts

## ☀️ Retrofitting Techniques

- ☀️ Use of fiber-reinforced polymer (FRP) in shape of strips, fabrics and rods
- ☀️ Reinforced shotcrete overlay
- ☀️ Reinforced plaster coating
- ☀️ Structural re-pointing
- ☀️ Vertical core technique (reinforced/post-tensioned)

# Basic Concepts

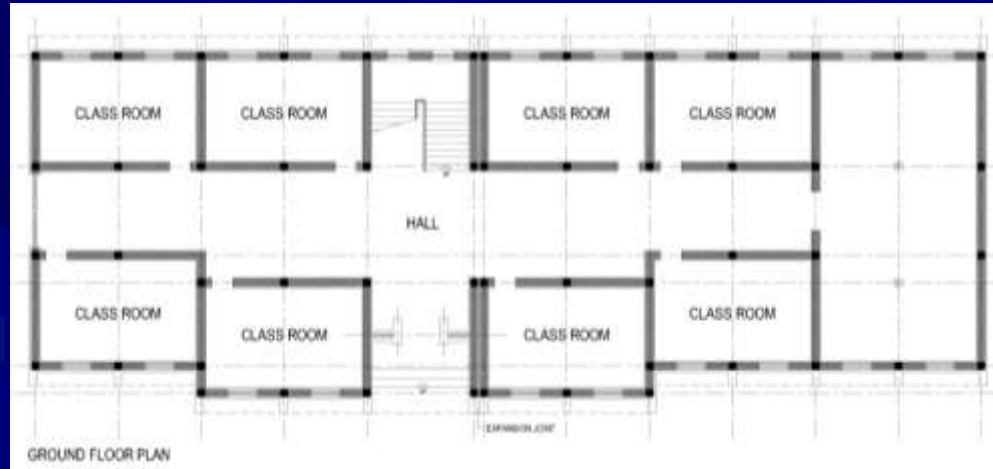
## ☀ Retrofitting Techniques

- ☀ Use of steel strips
- ☀ Grout and epoxy injection
- ☀ Addition of structural elements
- ☀ Anchoring and stiffening of floor
- ☀ Base-isolation
- ☀ Reinforced Concrete Jacketing

# Case Studies

- ✦ Schools in Iran, funded by Japan
  - ✦ Tohid School Bam, Kerman School, Kerman, Jiroft School, Tehran
- ✦ DHQ Hospital Swabi
- ✦ Guest House Batagram, funded by SDC

# Tohid School Bam, Iran



RC column, RC bond beam and flat arch



RC column, RC bond beam, flat arch and expansion joint

# Tohid School Bam, Iran



Poor quality masonry with too thick mortar joints



poor quality RC column with steel bars exposed



Poor quality masonry and columns bars exposed at floor level



Diagonal cracks in masonry pier between two openings

# Tohid School Bam, Iran



Steel I beam as lintel above window opening



Steel I-beams with flat arch and bracing steel bars



Anchor bolts for steel I-beams



Steel I section column projecting from roof and connecting I-beams

# Tohid School Bam, Iran





# Batagram Guest House and GHS



# Batagram Guest House and GHS



# Batagram Guest House and GHS



# Steps in a Standard Retrofitting exercise

## ★ Structural Damage Assessment

- Preliminary assessment by filling standard Performance
- Detail assessment
  - DT , NDT, soil test for onward use in Numerical model
  - Numerical models---linear/non linear

## ★ Design of Retrofitting Scheme

## ★ Execution of work

# DHQ Hospital Swabi

