# Implications of seismic construction or lack of it on building safety and cost


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# Presentation order

- Introduction
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# Introduction

- Human development has evolved over time as needs change with awareness and acquisition of knowledge
- Habitat has changed – nomadic to settlement
- Forms of building differ dependent on knowledge and exposure
- Economic development has grown at different pace across the globe

# Purpose of building

- Security from differing conditions
  - Environment: rain, cold, heat, wild animals,
- Aesthetics
- Space limitations
- Business interests

# Forces on buildings

- Gravity
  - Vertical
    - Imposed
    - Dead
    - Earth
- Weather
  - Wind
  - Snow
  - Thermal
  - Water
- Earth movement
  - Seismic
  - Subsidence
- Manmade
  - Machinery operations
  - Vehicular

# Structural response

- Forces on buildings generate
  - Direct stresses: compression and tension
  - Bending stresses
  - Shear stresses
  - Torsional forces
- Structural members are designed to accommodate or counteract forces that are anticipated to be mobilized

# Conventional building

- Forces generally considered are:
  - gravity forces
  - Earth pressure
  - Water pressure
  - Wind
- Structural members and connections are designed to overcome impact of these types of forces
- Seismic forces introduce a different type of response – need to define value on Richter scale (6.5) or peak ground acceleration (0.5g)

# Typical structural arrangements

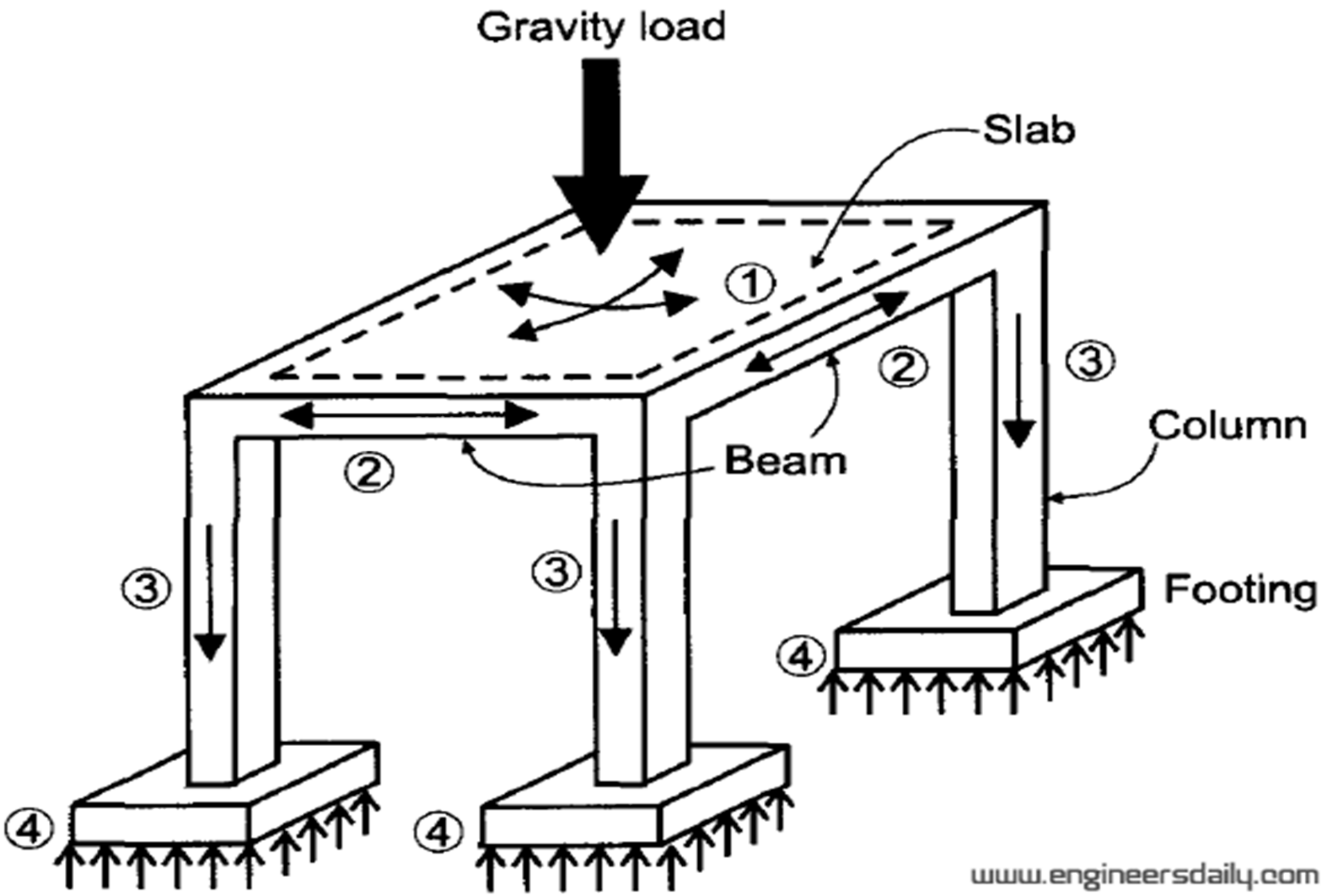


Figure 1: Gravity loads transfer mechanism

# Seismic force effect

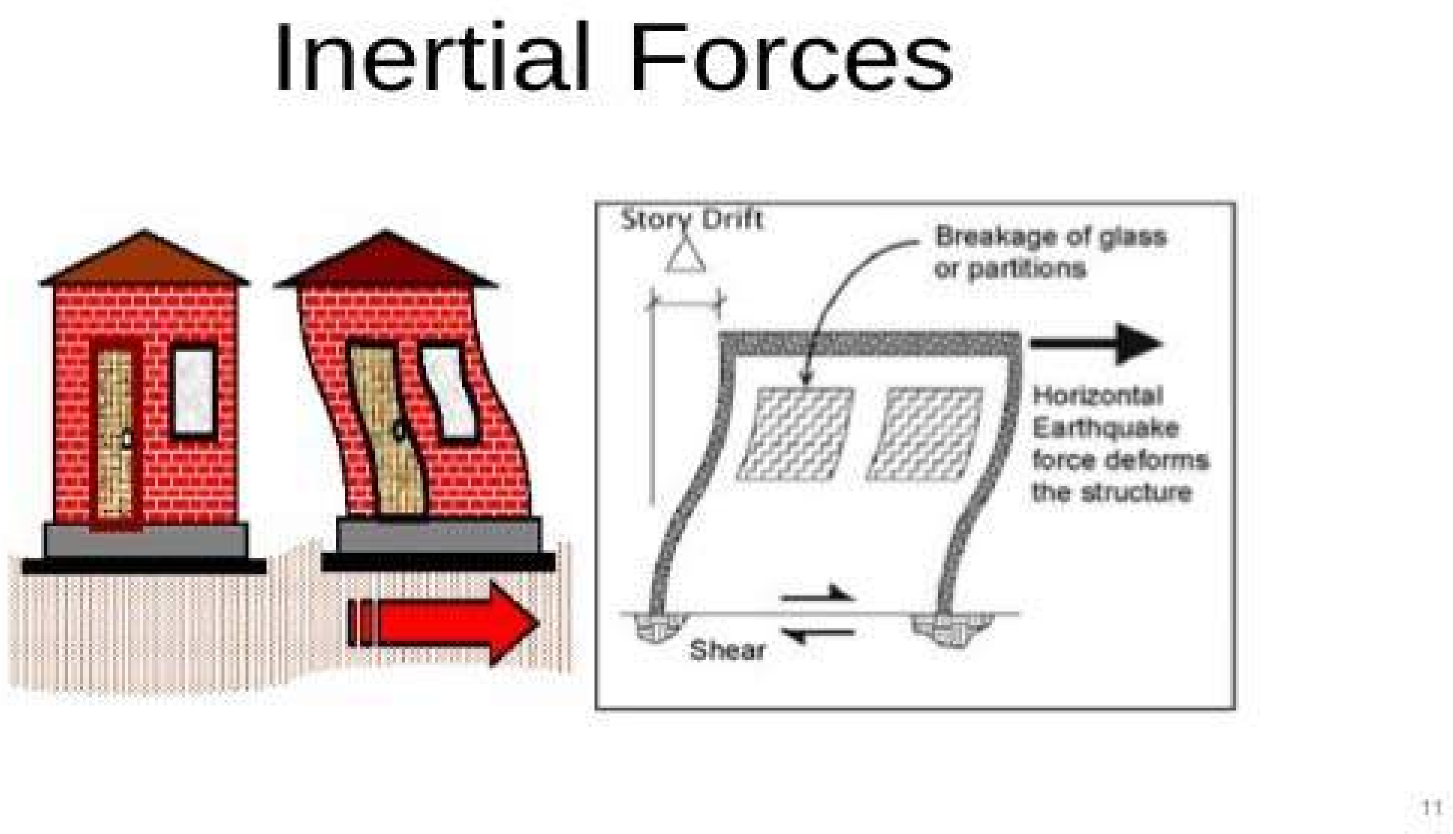


Figure 2: Seismic force effect on building

# Seismic loads are a function of:

- Seismic Zone and proximity to fault line
- Building mass
- Buildings period of vibration – generally a function of height and type of bracing element
- Properties of foundation materials (soil or rock)
- Structural type configuration, material, degree of ductility, damping)
- Building category (Risk and Importance factors)

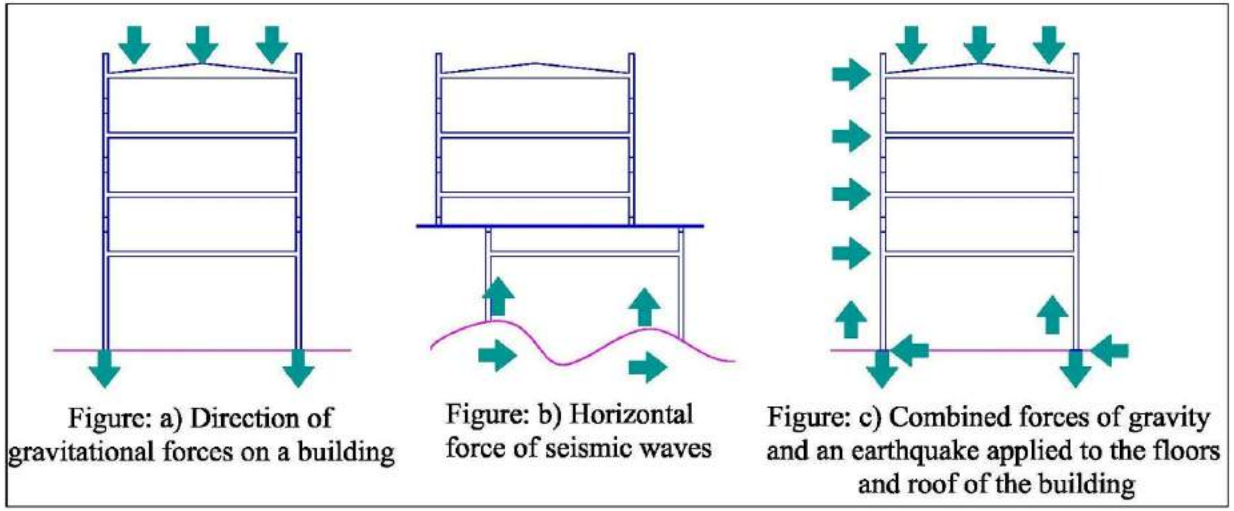


Figure 3: General interaction of gravity, wing and seismic forces

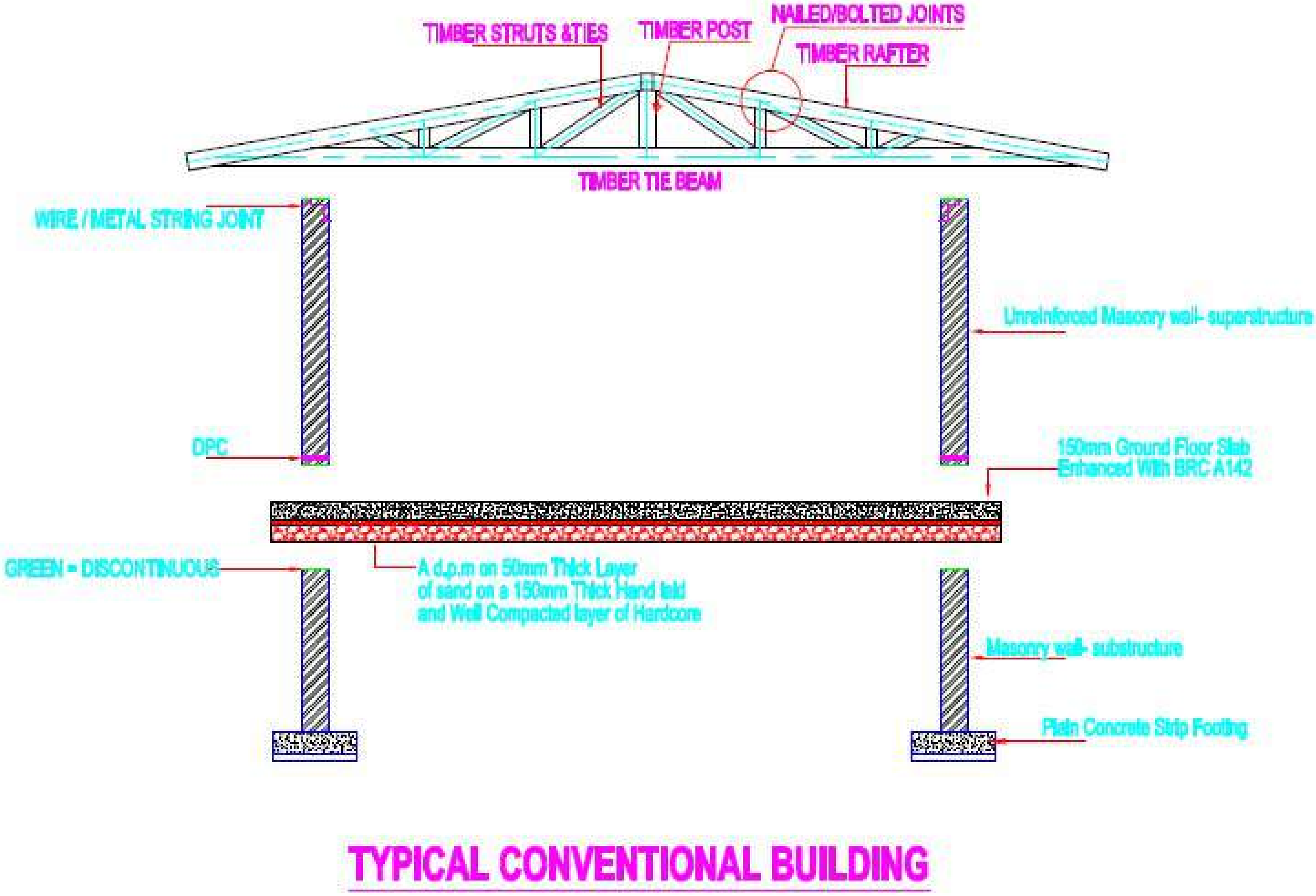


Figure 4: Single storey house structural members and connectivity

Figure 6: 2009 Karonga earthquake affected building (magnitude 6)

Moment resisting frame

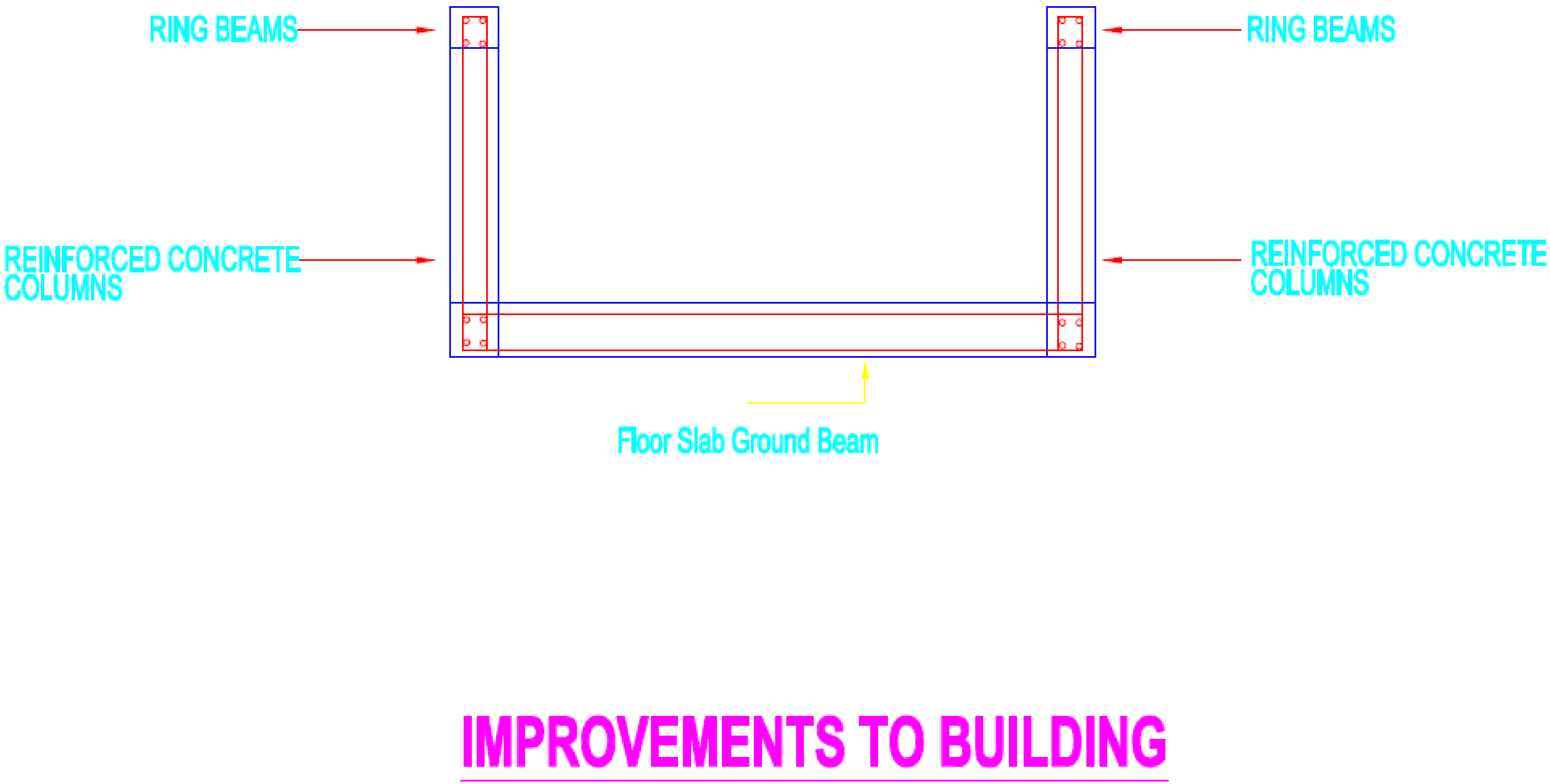


Figure 7: Reinforced Concrete Strengthening Mechanism for single storey building

# SAFETY IN BUILDING

- Buildings are build to withstand the above described forces
- The codes of practice provide guidance on best practice dependent on where building is to be built
- Malawi has a load code which includes seismic values
- None compliance to set standards leads to collapse of buildings and can lead to loss of life
- Most buildings were built without incorporating seismic forces and require retrofitting to be safe

# COST ELEMENTS

- The cost of a building depends on the type of elements used and its connectivity.
- The ease of connection of individual elements affects the overall cost of the building
- A full understanding of the seismic magnitude is crucial in optimizing the cost reduction
- Characteristics of element constituents can lead reduction in element size and hence reduce cost

Table 1: Typical additional cost s after incorporating seismic forces

| | | Current Local Seismic Code[2] | | Current National Seismic Code[3] | |
|---|---|---|---|---|---|
| **Building** | **Wind[1]** | **Cost Ratio[4]** | **Cost Premium** | **Cost Ratio[4]** | **Cost Premium** |
| Apartment | 1.0 | 1.003 | 0.3% | 1.012 | 1.2% |
| Office | 1.0 | 1.021 | 0.21% | 1.028 | 2.8% |
| Retail | 1.0 | 1.003 | 0.3% | 1.005 | 0.5% |
| Warehouse | 1.0 | 1.004 | 0.4% | 1.014 | 1.4% |
| Hospital | 1.0 | 1.025 | 2.5% | 1.025 | 2.5% |
| School | 1.0 | 1.010 | 1.0% | 1.014 | 1.4% |

Source: Hortacsu, A, and Harris, J.R., (2014) Tenth U.S. National Conference on Earthquake Engineering Frontiers of Earthquake Engineering

Table 2: Typical retrofit costs for unreinforced masonry buildings (URM)

| Portland URM Class | Estimated Retrofit Costs Per Square Foot | Typical Building Benefit-Cost Ratio |
|---|---|---|
| **Class 1** | $111.45 | N/A |
| **Class 2** | $82.62 | 1.474 |
| **Class 3** | $68.77 | 1.661 |
| **Class 4-A** | $68.77 | 1.661 |
| **Class 4-B** | $51.00 | 1.967 |
| **Class 5** | $20.00 | 1.940 |

Source: Goettel, K.A. 2016, Benefit-Cost Analysis of the Proposed Seismic retrofit Ordinance, City of Portland, USA

# STRATEGIC INTERVENTION

- Study the seismic level in the country (earth science) – What should be the design ground acceleration or Richter scale value adopted (PREPARE)
- Study typical construction including materials used and joint-system (engineering) (PREPARE)
- Study economic status of building owners (social science and economics)
- Study extent of housing for different categories including occupancy (NSO)
- Benefit/cost ratio determination can sway minds to allocate resources for retrofit

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