Basics of Earthquake Engineering

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Global loss due to natural disasters

Loss of life from natural disasters
(Source: Herath and Katayama, 1994)

Loss of built environment from natural disasters
(Source: Andrew and Robin, 2002)
# BIGGEST EARTHQUAKES RECORDED

<table>
<thead>
<tr>
<th>SNo</th>
<th>Magnitude</th>
<th>Date</th>
<th>Place</th>
<th>Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.5</td>
<td>22/05/1960</td>
<td>Chile</td>
<td>5000 deaths, 20 Lakh homeless</td>
</tr>
<tr>
<td>2</td>
<td>9.2</td>
<td>28/03/1964</td>
<td>Alaska</td>
<td>125 deaths, Tsunami</td>
</tr>
<tr>
<td>3</td>
<td>9.1</td>
<td>26/12/2004</td>
<td>Indonesia</td>
<td>2.26 Lakh killed, Tsunami</td>
</tr>
<tr>
<td>4</td>
<td>9.0</td>
<td>04/11/1952</td>
<td>Russia</td>
<td>0 death, Tsunami</td>
</tr>
<tr>
<td>5</td>
<td>9.0</td>
<td>11/03/2011</td>
<td>Japan</td>
<td>15000 deaths, Tsunami</td>
</tr>
<tr>
<td>6</td>
<td>8.8</td>
<td>27/02/2010</td>
<td>Chile</td>
<td>500 deaths, Tsunami</td>
</tr>
<tr>
<td>7</td>
<td>8.8</td>
<td>31/01/1906</td>
<td>Ecuador</td>
<td>1000 deaths</td>
</tr>
<tr>
<td>8</td>
<td>8.6 – 8.9</td>
<td>11/04/2012</td>
<td>Indonesia</td>
<td>0 death</td>
</tr>
<tr>
<td>9</td>
<td>8.7</td>
<td>04/02/1965</td>
<td>Alaska</td>
<td>0 death, Tsunami</td>
</tr>
<tr>
<td>10</td>
<td>8.6</td>
<td>28/03/2005</td>
<td>Indonesia</td>
<td>1300 deaths</td>
</tr>
</tbody>
</table>

5 of the biggest in last 11 years
6 of the biggest resulted in Tsunami
More deaths in under prepared countries
Earthquake may be caused by volcanic eruption or by strain building process inside the earth mass. UNPREDICTABLE
Focus and Epicenter of Earthquake
Earthquake Shaking

Earthquakes are UNPREDICTABLE!!!
Typical Seismogram

- PGA
- Predominant Frequency
- Duration of Strong Motion

- Random
- Time Dependent
- Cyclic
No two earthquake motions are similar

![Seismograms of different earthquakes](image)
Magnitude

A number – RICHTER Scale $M = \log_{10} A$
Each increase in $M >$ the energy by 32 times
• Strength / Power of earthquake (Atom bomb – 5.0)
• Measure of strain energy released at hypocenter.
• Determined by seismographs
• It is independent of place

Moment Magnitude $M_w$ is more popular presently.
$M_w = \mu A_0 D$ is better to represent bigger earthquakes.

It is based on the seismic moment of the earthquake, which is equal to the rigidity of the Earth multiplied by the size of the area that slipped and average amount of slip on the fault
Richter scale suffers from saturation for bigger earthquakes
INTENSITY

• Is not Quantitative
• Modified Mercalli’s Intensity scale
• Measure of damaging effect of earthquake at a site

Depends on
• Local soil conditions
• Type of structures
• Focal Depth
• Knowledge on Earthquake Engg.
• Amount of shaking
• Frequency Content
• Epicentral distance etc.
How does the amplitude of a magnitude-8 earthquake compare to the amplitude of smaller events?

If we likened earthquakes to hills and mountain peaks, each peak is 10 times the height of the previous one.

- Mag. 6
- Mag. 7 = 10× larger than Mag. 6
- Mag. 8 = 10× larger than Mag. 7 = 100× larger than Mag. 6
How does the amplitude of a magnitude-8 earthquake compare to the amplitude of a magnitude-6 event?

If we likened earthquakes to hills and mountain peaks...
Fire Crackers of different magnitudes of blasts
## Intensity of Earthquake – Modified Mercalli’s Scale

<table>
<thead>
<tr>
<th></th>
<th>Intensity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Insignificant</td>
<td>Only detected by instruments</td>
</tr>
<tr>
<td>II</td>
<td>Very Light</td>
<td>Felt by sensitive persons, Oscillation of hanging objects</td>
</tr>
<tr>
<td>III</td>
<td>Light</td>
<td>Small vibratory motion</td>
</tr>
<tr>
<td>IV</td>
<td>Moderate</td>
<td>Felt inside building, Noise produced by moving objects</td>
</tr>
<tr>
<td>V</td>
<td>Slightly Strong</td>
<td>Felt by most persons, some panic, minor damages</td>
</tr>
<tr>
<td>VI</td>
<td>Strong</td>
<td>Damage to non seismic resistant structures</td>
</tr>
<tr>
<td>VII</td>
<td>Very Strong</td>
<td>People panic, serious damage to poor construction</td>
</tr>
<tr>
<td>VIII</td>
<td>Destructive</td>
<td>Serious damage to structures in general</td>
</tr>
<tr>
<td>IX</td>
<td>Ruinous</td>
<td>Serious damage to well built structures, almost total destruction of non-seismic resistant structures</td>
</tr>
<tr>
<td>X</td>
<td>Disastrous</td>
<td>Only seismic resistant structures remain standing</td>
</tr>
<tr>
<td>XI</td>
<td>Disastrous in Extreme</td>
<td>General Panic, almost total destruction, ground cracks &amp; opens</td>
</tr>
<tr>
<td>XII</td>
<td>Catastrophic</td>
<td>Total destruction</td>
</tr>
</tbody>
</table>
Intensity VIII - Destruction of Buildings

(a) Fright and panic. Also, persons driving motorcars are disturbed. Here and there branches of trees break off. Even heavy furniture moves and partly overturns. Hanging lamps are damaged in part.

(b) Most buildings of Type C suffer damage of Grade 2, and few of Grade 3. Most buildings of Type B suffer damage of Grade 3, and most buildings of Type A suffer damage of Grade 4. Occasional breaking of pipe seams occurs. Memorials and monuments move and twist. Tombstones overturn. Stonewalls collapse.

(c) Small landslips occur in hollows and on banked roads on steep slopes; cracks develop in ground up to widths of several centimeters. Water in lakes becomes turbid. New reservoirs come into existence. Dry wells refill and existing wells become dry. In many cases, changes in flow and level of water are observed.

Note:
- Type A structures - rural constructions; Type B - ordinary masonry constructions; Type C - Well-built structures
- Single, Few - about 5%; Many - about 50%; Most - about 75%
- Grade 1 Damage - Slight damage; Grade 2 - Moderate damage; Grade 3 - Heavy damage; Grade 4 - Destruction; Grade 5 - Total damage
Magnitude & Intensity

Richter’s Scale

Magnitude

100 Watt Bulb

Bright (100 lumens)

Near

Normal (50 lumens)

Dull (20 lumens)

Far

Intensity

M M Scale
What are Earthquakes?

- The shaking or trembling caused by the sudden release of energy
- Usually associated with faulting or breaking of rocks
- Continuing adjustment of position results in aftershocks
What is the Elastic Rebound Theory?

- Explains how energy is stored in rocks
  - Rocks bend until the strength of the rock is exceeded
  - Rupture occurs and the rocks quickly rebound to an undeformed shape
  - Energy is released in waves that radiate outward from the fault
What is the Elastic Rebound Theory?

Original position

Deformation

Rupture and release of energy

Rocks rebound to original undeformed shape
Focus and Epicenter of an Earthquake

• The point within Earth where faulting begins is the focus, or hypocenter.
• The point directly above the focus on the surface is the epicenter.
Seismographs record earthquake events

At convergent boundaries, focal depth increases along a dipping seismic zone called a Benioff zone.
Where Do Earthquakes Occur and How Often?

~80% of all earthquakes occur in the circum-Pacific belt
  – most of these result from convergent margin activity
  – ~15% occur in the Mediterranean-Asiatic belt
  – remaining 5% occur in the interiors of plates and on spreading ridge centers
  – more than 150,000 quakes strong enough to be felt are recorded each year
Plate Tectonic Theory
Plate Tectonics – Epicenters of recent earthquakes of moderate magnitude

8 to 10 cm
Every year
Plate Movements
Faults

- Normal Fault
- Reverse Fault
- Strike Slip Fault
Normal Fault
Reverse Fault
Strike Slip Fault

Conservative plate margin
relative movement of adjacent continental plates

earthquake focus

Two plates slide laterally
The Economics and Societal Impacts of EQs

- Building collapse
- Fire
- Tsunami
- Ground failure

Damage in Oakland, CA, 1989
What are Seismic Waves?

- Response of material to the arrival of energy fronts released by rupture

- Two types:
  - Body waves
    - P and S
  - Surface waves
    - R and L
Primary Wave

Secondary Wave

1. Slinky at rest.
2. Push slinky
3. Wave compresses and expands coils of slinky
4. Wave travels down slinky

A.

1. Tie rope to post
2. Shake rope
3. Wave "shakes" rope at right angles to the direction wave is traveling
4. Wave travels down rope
Body Waves: P and S waves

- Body waves
  - P or primary waves
    - fastest waves
    - travel through solids, liquids, or gases
    - compressional wave, material movement is in the same direction as wave movement
  - S or secondary waves
    - slower than P waves
    - travel through solids only
    - shear waves - move material perpendicular to wave movement
Surface Waves: R and L waves

- **Surface Waves**
  - Travel just below or along the ground’s surface
  - Slower than body waves; rolling and side-to-side movement
  - Especially damaging to buildings
How is an Earthquake’s Epicenter Located?

Seismic wave behavior
- P waves arrive first, then S waves, then L and R
- Average speeds for all these waves is known
- After an earthquake, the difference in arrival times at a seismograph station can be used to calculate the distance from the seismograph to the epicenter.
How is an Earthquake’s Epicenter Located?

Time-distance graph showing the average travel times for P- and S-waves. The farther away a seismograph is from the focus of an earthquake, the longer the interval between the arrivals of the P- and S-waves.
How is an Earthquake’s Epicenter Located?

- Three seismograph stations are needed to locate the epicenter of an earthquake.
- A circle where the radius equals the distance to the epicenter is drawn.
- The intersection of the circles locates the epicenter.
How are the Size and Strength of an Earthquake Measured?

- **Intensity**
  - subjective measure of the kind of damage done and people’s reactions to it
  - isoseismal lines identify areas of equal intensity

- **Modified Mercalli Intensity Map**
  - 1994 Northridge, CA earthquake, magnitude 6.7
How are the Size and Strength of an Earthquake measured?

**Magnitude**

- Richter scale measures total amount of energy released by an earthquake; independent of intensity
- Amplitude of the largest wave produced by an event is corrected for distance and assigned a value on an open-ended logarithmic scale
What are the Destructive Effects of Earthquakes?

- **Ground Shaking**
  - amplitude, duration, and damage increases in poorly consolidated rocks
Can Earthquakes be Predicted?

Earthquake Precursors
– changes in elevation or tilting of land surface, fluctuations in groundwater levels, magnetic field, electrical resistance of the ground
– seismic dilatancy model
– seismic gaps
Can Earthquakes be Predicted?

Earthquake Prediction Programs
- include laboratory and field studies of rocks before, during, and after earthquakes
- monitor activity along major faults
- produce risk assessments
Is prediction of earthquake possible?????

Perhaps each one of you can get noble prize for providing scientific proof of different available methods.

Animals, fishes and birds are considered Better predictors.

Prediction is still an art. Present advances in technology can not predict, control or Stop earthquakes. We can only attempt To control the damaging effects.
26\textsuperscript{th} January 2001 Bhuj Earthquake of 7.2 Mw Killed > 20000 people

January 2001

January 2003
Causes for Earthquake

- Tectonic earthquake
- Volcanic earthquake
- Rock fall or collapse of cavity
- Microseism
- Explosion (Controlled blast)
- Reservoir induced earthquake
- Mining induced earthquake
- Cultural Noise (Industry, Traffic etc.)
Dead & Live loads

Wind force

Earthquake Force

Vertical & Static

Lateral & Dynamic

Earthquake
Flood
Hurricane/ Cyclone
Earthquake Force Vs Wind Force

Zero Mean :: Cyclic

Non-zero Mean :: Oscillatory
Statics
\[ \sum F_A = 0 \]

Dynamics
\[ \sum F_A - F_I = 0 \]
\[ F_I = m \cdot a \]

Inertia ???

Dynamics is dangerous & action packed. But interesting
Period of Vibration

- Building at Rest
- Ground Accelerates to Left
- Ground Accelerates to Right
- Ground & Building at Rest
Failure of Shear wall

Fig 3. Principal modes of failure for reinforced concrete shear walls

(a) sliding  (b) rocking  (c) bending

Sliding  Rocking  Bending
Inertia due to earthquake

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

Figure 2: Inertia force and relative motion within a building

Figure 3: Principal directions of a building

Figure 4: Flow of seismic inertia forces through all structural components.

Reduce Mass
Earthquake effects on Buildings

Direction of forces on Building:
- U-D (up-down)
- E-W (east-west)
- N-S (north-south)

Movement of building:

Earthquake force:

Inset image:
- Surface Waves
- Body Waves
- Fault Rupture
- Geologic Strata
Effects of Earthquake

Inertia Force $F = ma$
Levels of acceleration

1 "g" parachute team
4 "g" roller coaster
9 "g" air force display team
0.001 "g" human perception
Level of acceleration during earthquake

• 2007 Honda RA107 F1 race car Accelerates from 0 to 160 kmph in 4 s
• Indian cars 0 to 100 kmph in 18 s

• \( v = u + at \)
• 100 kmph = 27.77 m/s
• \( v = 27.77 \text{ m/s}, \ u = 0 \text{ and } t = 18 \text{ s} \)
• \( a = 1.54 \text{ m/s}^2 \)

• During earthquake 20 m/s\(^2\) acceleration can happen in 3 different directions
Wife asked husband to present something big for her birthday

Husband : What shall I get you?

Wife : I would like something that accelerates 0 to 100 in 10 seconds
She was expecting something like this
But, husband presented her with something very different
The husband is in a critical and stable condition in ICU
0 to 60 kmph in 1.6 sec
Fastest F1 Car

Formula 1 cars are some of the fastest and radically accelerating vehicles on Earth and are considered by many car enthusiasts to be the pinnacle of motorsports. Today’s F1 0-60 times are exponentially faster than predecessors of even a couple decades ago. Formula One race cars have been recorded to reach 0-60 as fast as 1.6 seconds, however the typical range for modern day F1 cars is between 2.1 to 2.7 seconds. The 2007 Honda RA107 f1 race car goes 0-100 mph in a blistering 4 seconds flat. The 2015 Infiniti Red Bull RB11 Formula One race car jets 0 to 60 in only 1.7 seconds, and perhaps even more impressive can reach 190 mph in under 10 seconds. Although top fuel dragsters hold the top spot for fastest accelerating race car class, the F1 race car boasts a range of superior performance stats. F1 0-60 times are extreme, however so are their ability to perform...
The 2015 Infiniti Red Bull RB11 Formula One race car jets 0 to 60 in only 1.7 seconds, and perhaps even more impressive can reach 190 mph in under 10 seconds. Although top fuel dragsters hold the top spot for fastest accelerating race car class, the F1 race car boasts a range of superior performance stats.

[Formula One F1 0-60 Times - Zero To 60 Times](http://www.zeroto60times.com/formula-one-f1-0-60-times/)
Best racing Car

May accelerate from 0 to 60 kmph in 1.6 s
U = 0
V = 16.67 m/s
T = 1.6 s
A = (V – U) / T = 10.4 m/s²

Maximum recorded earthquake motion = 2g = 20 m/s²

That too in three different directions
Newton’s Laws of Motion & Earthquake Engineering
Effect of Inertia

Newton’s First Law of Motion

Every object continues to remain in its initial status unless acted upon by external force.

Lesson: Wear your Seat Belts
Everyone unconsciously knows the second law that heavier objects require more force to move the same distance as lighter objects.

Lesson: Do not disturb Bad persons.
Newton’s Third Law of Motion

For every action there is an equal and opposite reaction

Rockets Action: Push down on ground with powerful engine.
Reaction: Ground pushes the rocket upwards with equal force.

Lesson: If you hit some body, expect the same reaction.
TYPES OF LOADING

- RAPID OR TRANSIENT LOADING
- STATIC LOADING
- SLOW LOADING
- CYCLIC OR REPETITIVE LOADING
Typical Seismogram

- PGA
- Predominant Frequency
- Duration of Strong Motion

Start of Primary Waves
Start of Secondary Waves
Start of Surface Waves

Trace Amplitude
Strong Motion

- Random
- Time Dependent
- Cyclic
No two earthquake motions are similar.
Static Vs Dynamic Loading

Static Loading

Dynamic Loading

\[ F = m \cdot a \]
DAMPING AND RESONANCE

Effect of Damping

Effect of Resonance
$$H = W \times A_h$$

$$A_h = \frac{ZI}{2R} \left( \frac{S_a}{g} \right)$$

**Zone Designation** | **Zone Factor** $Z$
---|---
Zone II | 0.10
Zone III | 0.16
Zone IV | 0.24
Zone V | 0.36
Earthquake Resistant Design Philosophy

**Level 1 Design**

- **Design Basis Earthquake**
  - Common earthquake which the structure can experience in its life time
  - Probability of occurrence in 50 years is more

SYSTEM CAN UNDERGO SOME DISTRESS WITHOUT SERIOUS STRUCTURAL DAMAGE

**Level 2 Design**

- **Maximum Credible Earthquake**
  - Biggest earthquake that may not be experienced during the life of structure
  - Less probability of occurrence in 50 years

SYSTEM SHOULD FAIL, BUT WITH WARNING
## Earthquake Design Philosophy

<table>
<thead>
<tr>
<th>Minor shaking</th>
<th>No structural damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate shaking</td>
<td>Repairable structural damage</td>
</tr>
<tr>
<td>Major shaking</td>
<td>Even irreparable structural damage, but ductile failure!</td>
</tr>
</tbody>
</table>

![Diagram showing base shear and roof displacement for different levels of shaking]

- **Base Shear**
- **Roof Displacement**
  - **Minor**
  - **Moderate**
  - **Major**
WTC design was excellent. It experienced DUCTILE failure. There was enough warning before collapse (about 40 mnts).
Performance of Building

- High Strength, High Stiffness, Brittle
- Moderate Strength & Stiffness, Ductile
- Low Strength, Low Stiffness, Brittle

Base Shear vs. Roof Displacement
Earthquake Resistant Design Philosophy

**Figure 2:** Tension Test on Materials—ductile versus brittle materials.

**Figure 3:** Ductile chain design.
Structure designed to withstand Inertia at joints

IS13920
Ductile Detailing
What is a disaster?

An occurrence inflicting widespread destruction and distress: calamity, cataclysm, catastrophe and tragedy. Disaster may be natural or man made.

What is a disaster Management?

It is managing the disaster such that the loss of life and economic loss are minimum & common man does not feel the effect of disaster.
Disaster Management

Hazard + Risk = Disaster

Pre disaster Risk reduction process

Post disaster recovery
Hazard + Risk = Disaster

Risk is Manmade
Population Explosion
Unscientific construction
Irregular growth
Industrial Development
Lack of free space in city
Environmental Pollution
Lack of greenery
Water Pollution etc.
WorldRiskIndex

Natural hazard sphere

Exposure

Exposure to natural hazards

Vulnerability – Societal sphere

Susceptibility

Likelihood of suffering harm

Coping Capacity

Capacities to reduce negative consequences

Adaptive Capacity

Capacities for long-term strategies for societal change
Risk Index = Exposure X Vulnerability
Exposure
• Population exposed to natural disaster such as earthquake, flood, cyclone and drought

Vulnerability
• Susceptibility
• System Capacity
• Individual Capacity
Susceptibility
- Public infrastructure: Population without access to sanitation, and clean water, population in slum
- Nutrition: Population under below par nutrition
- Poverty
- Population below poverty line
- GDP

System Capacity
- Good governance / corruption
- No. of physicians / hospital beds
- Insurance coverage
- Water resource
- Agricultural management

Individual Capacity
- Literacy rate
- Gender parity
- % female representatives in parliament
- Life expectancy
<table>
<thead>
<tr>
<th>Ranking</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Qatar</td>
</tr>
<tr>
<td>3</td>
<td>Saudi Arabia</td>
</tr>
<tr>
<td>13</td>
<td>Singapore</td>
</tr>
<tr>
<td>20</td>
<td>France</td>
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<tr>
<td>45</td>
<td>USA</td>
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<tr>
<td>87</td>
<td>China</td>
</tr>
<tr>
<td>95</td>
<td>India</td>
</tr>
<tr>
<td>100</td>
<td>Pakistan</td>
</tr>
<tr>
<td>169</td>
<td>Philippines</td>
</tr>
</tbody>
</table>
Objectives of Earthquake Disaster Management

1. Saving Life
2. Restricting the amount of damage
3. Organizing efficient & effective rescue measure
4. Providing relief, rehabilitation & reconstruction
5. Forecasting warning
6. Education and Training
7. Earmarking necessary funds
8. Stockpiling of supply
Disaster Management

**Preparedness** - Creation of Awareness
Training on self help during crisis
Education at schools
Monitoring System
Warning Mechanism
Learning from past disasters
Mock Drill

**Response** - Rehabilitation Center
Food, Shelter, Medicine etc.
Trained Relief workers
Lifelines to be re-established
Bringing back normalcy
Repair, if need be
Disaster Management

Recovery - Rehabilitation & Reconstruction
Building new
Ensuring safety against new event
Learning from past disasters

Mitigation - Methods to control damage
Improvement
Auditing for seismic safety
Disaster Management

1. Prevention is better than cure.
2. Technical awareness among engineers.
3. Improving codal provisions and design aid.
4. Microzonation of the region.
5. Certification from authorized engineers for license.
6. Disaster Insurance.
Relief efforts are hampered when

1. Disaster occurs at night
2. Electricity fails
3. The visibility is poor
4. There is fall of debris on roads
5. Bridges & harbor facilities suffer damage
6. Climatic conditions are severe
7. Fire breaks
8. There is loss of communication
Local bodies comprise of

1. District Magistrate
2. Police & Civil Defense
3. Public Works
4. Public health & Medical Works
5. Fire Service
6. Utilities (Lifelines) such as gas, electricity, water & sewer mains, transport
7. National Red Cross
8. Personnel from Radio, TV, Telephone, Mobile & Internet services, P&T

+ You, Me & every one
Lifelines

- Lifelines are most important systems (basic needs) for habitation.
- Without lifelines life becomes hampered.
- One of the objectives of disaster management is to stop damage to lifeline or restore it at the earliest.
- Lifelines may be different for different regions depending on lifestyle and availability of resources.
- Drinking water, Electricity, Communication, telephone, road network etc. are lifelines.
Potable Water
Sewage disposal
Electricity
Telephone
Mobile Communication
Roads & Railways
Train service stopped after the earthquake (Unusual in Japan)
LIFE LINE will be STOPPED & brought to NORMALCY quickly
Disaster Management Training

- Mock Drill
- Awareness Camps
- Training in schools
- Display Boards
Disaster Preparedness

• Disaster Kits Containing
  – Food & Water for Three Days
  – First Aid Kit
  – Rescue & Repair Tools, Rope
  – Flashlights, Battery-Operated Radio, Spare Batteries

• Individuals
  – Walking Shoes
  – Individual Prescription Medications
    (Enough for Three Days)
LESSONS OF DISASTER SAFETY

- DON'T PANIC
- DROP
- COVER
- HOLD
- PROTECT YOUR HEAD
- TURN OFF GAS/ELECTRICITY
- EXTINGUISH FIRE
- FIND A WAY OUT
- GO AWAY FROM WATER/ELECTRIC/STONES
- GO ON HIGHER GROUND
- PAY ATTENTION TO ROOFS/FLAMES
- KEEP DISTANCE FROM SHADES/TREES/POWER LINES
- HELP NEIGHBOURS
- GO TO ASSEMBLY POINT
- HELP WITH FIRST AID
- STAY INFORMED
Requirements of Disaster Management
Seismograms & Strong Motion Accelerographs
Requirements of Disaster Management
Heights of Tsunami waves at different locations
Iso-seismal Map

A good warning & awareness system

Isoseismal map of Gujarat
After Bhuj Earthquake 2001

Typical NHK warning in Japan
Iso-seismal Map
A good warning & awareness system
Disaster Management – Policy makers should take action
Disaster Management – Role of leaders
Disaster Management – Role of leaders
During disaster people will be shocked, in grief, sensitive and needing help & advice
Neither the policy makers nor the general public should PANIC!!!
Rescue work in progress
Disaster Management – Provide food, shelter, medicine, clothings etc.
Taking shelter below sturdy tables
Awareness & Disaster Management
Taking shelter below sturdy tables
Awareness among children & Disaster Management
Protection next to column or strong wall
Protection next to column

Earthquake Resistant Construction
Strong Column Weak Beam Concept
Disaster Management – search for Rehabilitation Center
Earthquake Resistant Construction
Earthquake Resistant Construction - Bunga
Why Elevator survived, when rest collapsed?
(in Ahmedabad during the Bhuj earthquake of Jan 2001)

The collapsed Shrinath Apartments in Maninagar, Ahmedabad, in which many perished.
For you to Conclude

1. Is the knowledge of Earthquake engineering important?

2. Is Karnataka prone to earthquakes? Should all buildings in Karnataka be designed to resist earthquake and same force at all places?

3. Do earthquakes kill people or is it the engineers who kill people?

4. Is it important to strengthen Earthquake Disaster Management?
It is impossible to stop or predict earthquake. As engineers, let us all unite and move forward & work for reducing calamities due to natural and man made hazards.
Thank You