Gorkha Earthquake

•Date & Time of Occurrence: 25th April, 2015, at 11:56 local time

•Magnitude: 7.6 magnitude (ML)

•Epicenter: Barpak, Gorkha District (north-west) of Kathmandu and south of the China border. Epicenter of main shock is approximately 34 km (21 mi) east-southeast of Lamjung, Nepal

•Hypocenter: at the depth of approximately 15 km (9.3 mi).

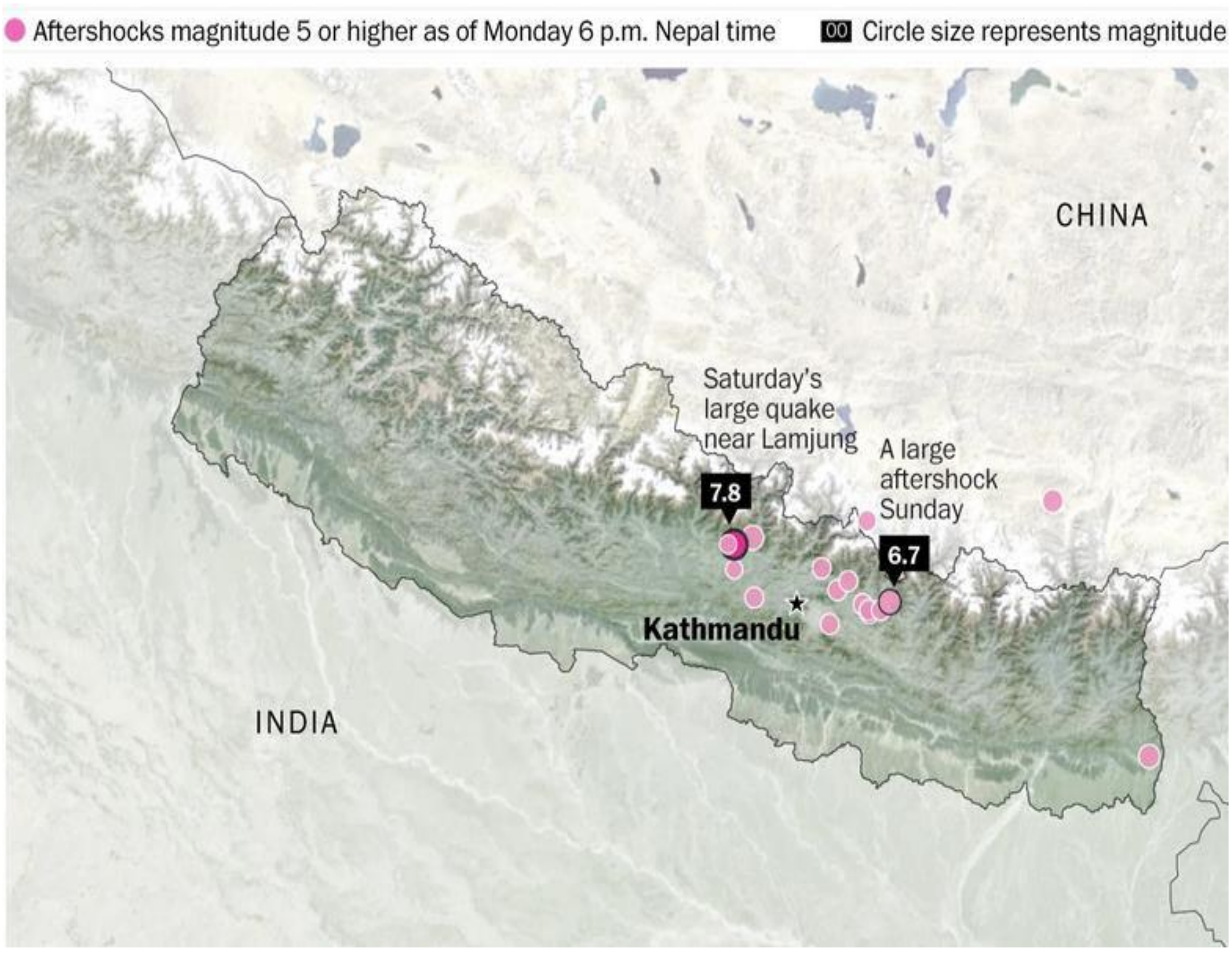
•Aftershocks: Dozens of aftershocks followed, including a 6.9 magnitude(ML) earthquake on 26th April 2015 at 12:54 local time with epicenter at Dolakha/Sindhupalchowk. Aftershocks 6.8 ML on 12 May at 12:51 with epicenter at Dolakha/Sindhupalchowk.

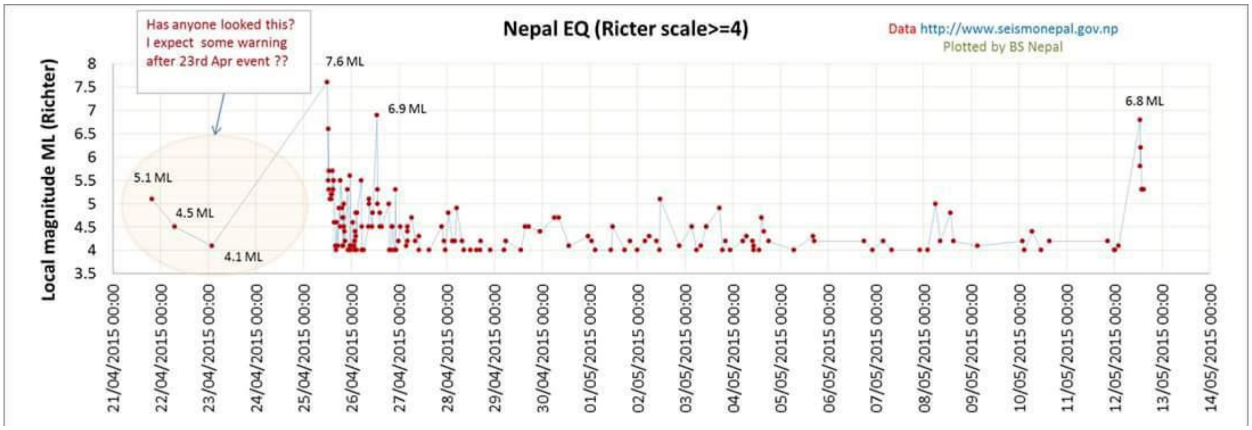
•No. of aftershocks: 265 (As of 25 May 2015)

•Intensity Generated: The earthquake has been found with a maximum Mercalli Intensity of IX (Violent).

•Casualties: 8,659 dead (official data as of 2072-02-11 9:00 pm)

21,952 injured (official data as of 2072-02-11 9:00 pm)





Cause of the Earthquake

•The temblor was caused by a sudden thrust, or release of built-up stress, along the major fault line where the Indian Plate, carrying India, is slowly diving underneath the Eurasian Plate, carrying much of Europe and Asia.

•Kathmandu, situated on a block of crust approximately 120 km (74 miles) wide and 60 km (37 miles) long, reportedly shifted 3 m (10 ft) to the south in just 30 seconds.

Effect of the Earthquake in the Vicinity

•According to "Did You Feel It?" (DYFI?) responses on the USGS website, the intensity in Kathmandu was VIII (*Severe*).

•Tremors were felt in the neighboring Indian states of Bihar, Uttar Pradesh, Assam, West Bengal, Sikkim, Uttarakhand, Odisha, Andhra Pradesh,Gujrat, in the Indian capital region around New Delhi[and as far south as Karnataka.

•Many buildings were brought down in Bihar. Minor cracks in the walls of houses were reported in Odisha. Minor quakes were registered as far as Kochi in the southern state of Kerala. The intensity in Patna was V (*Moderate*).

•The intensity was IV (*Light*) in Dhaka, Bangladesh.

•The earthquake was also experienced across southwestern China, ranging from the Tibet Autonomous Region to Chengdu, which is 1,900 km (1,200 mi) away from the epicenter.

•Tremors were felt in Pakistan and Bhutan

Casualties

1. Nepal

•The earthquake killed more than 8000 in Nepal and injured more than twice as many. The rural death toll may have been lower than it would have been as the villagers were outdoors, working when the quake hit. As of 15 May, 6,271 people, including 1,700 from the 12 May aftershock, were still receiving treatment for their injuries.

•*The Himalayan Times* reported that as many as 20,000 foreign nationals may have been visiting Nepal at the time of the earthquake, although reports of foreign deaths were relatively low. Hundreds of people are still considered missing and more than 450,000 are displaced.

2.India:

•A total of 78 deaths were reported in India - 58 in Bihar, 16 in Uttar Pradesh, 3 in West Bengal and 1 in Rajasthan.

3.China:

•25 dead and 4 missing, all from Tibet.

4. Bangladesh:

•4 dead

Emergency Declaration

•At 14.00 pm on 25 April, 2015 , CNDRC meeting headed by Rt'Hon Acting PM and Home Minister took place which recommend declaring of emergency and request the international support.

•Government of Nepal, cabinet declared emergency area at 16.00 hrs local time to 14 highly affected districts and appealed to International Communities for assistance. Cabinet also declared the Custom exemption to relief goods and visa fee exemption to the SAR Team members and humanitarian actors, for custom exemption, the UN model agreement has taken as a base.

Affected Districts

•The government has designated 14 most affected districts, namely Gorkha, Kavrepalanchok, Dhading, Nuwakot, Rasuwa, Sindupalchok, Dolakha, Ramechhap, Okhaldunga, Makwanpur, Sindhuli, Kathmandu, Bhaktapur and Lalitpur.

•On 10 May, an additional nine affected districts were added by the government; Tanahu, Kaski, Nawalparasi, Chitwan, Syangja, Parsa, Lamjung, Palpa and Parbat.

Affected and not-affected districts

•Districts not affected:

1.Mugu

2.Humla

3.Accham

4.Bajhang

5.Dailekh

6.Baitadi

•Districts affected: other 69 districts

Data as of 19 May, 2015 Data Source: MoHA

Formation of Himalayas

•About 225 million years ago, India was a large island still situated off the Australian coast, and a vast ocean (called Tethys Sea) separated India from the Asian continent. When Pangaea broke apart about 200 million years ago, India began to forge northward.

•About 80 million years ago, India was located roughly 6,400 km south of the Asian continent, moving northward at a rate of about 9 m a century.

•When India rammed into Asia about 40 to 50 million years ago, its northward advance slowed by about half. The collision and associated decrease in the rate of plate movement are interpreted to mark the beginning of the rapid uplift of the Himalayas

Magnitude of an Earthquake

•Several magnitude scales are widely used and each is based on measuring of a specific type of seismic wave, in a specified frequency range, with a certain instrument.

•The scales commonly used in western countries, in chronological order of development, are local (or Richter) magnitude (ML), surface-wave magnitude (Ms), body-wave magnitude (mb for short period, mB for long period), and moment magnitude (Mw or M)

Local (Richter) Magnitude (Ml)

•Richter magnitude was the first widely used instrumental magnitude scale to be applied in the USA (Richter, 1935). The scale is based on the amplitude (in mm) of the largest seismogram wave trace on a Wood–Anderson seismograph (free period 0.8 s), normalized to a standard epicentral distance of 100 km.

•Each successively larger magnitude was defined as a 10-fold increase in amplitude beyond the base level. Thus, a maximum seismogram amplitude (at a distance of 100 km) of 0.01 mm represents ML 1.0, 0.1 mm equals ML 2.0, 1 mm equals ML 3.0, and so on.

•Richter (1935) devised a nomograph to normalize the amplitudes for earthquakes closer or farther away than 100 km, based on the attenuation of seismic energy in California.

•The Richter magnitude scale accurately reflects the amount of seismic energy released by an earthquake up to about ML 6.5, but for increasingly larger earthquakes, the Richter scale progressively underestimates the actual energy release.

•The scale has been said to "saturate" above ML 6.5, from a combination of instrument characteristics and reliance on measuring only a single, short-period peak height

Surface-Wave Magnitude (MS)

•The surface-wave magnitude scale was developed to solve the "saturation" problem of Richter magnitude above ML 6.5. The measurement procedure is similar to measuring the Richter magnitude, except that the peak wave amplitude is measured for surface waves that have periods of 20 s, from long-period seismographs at teleseismic distances (Gutenberg, 1945). The surface-wave magnitude calculation does not require a seismograph record within 100 km (or nearby) of the epicenter, so the teleseismic records of many large-to-moderate magnitude earthquakes worldwide have been assigned surface-wave magnitudes.

•Because of this large data set, Ms is the typical magnitude used in empirical comparisons of magnitude versus earthquake rupture length or displacement (e.g. Bonilla et al., 1984).

• However, the surface-wave magnitude scale also saturates, at about Ms > 8.

Body-Wave Magnitude (MbLg)

•The short-period body-wave magnitude (mbLg) is the principal magnitude used in the tectonically “stable” eastern part of North America and Canada.

•This magnitude is measured from peak motions recorded at distances up to 1000 km on instruments with a passband in the range 1–10 Hz. Peak motions usually correspond to the Lg wave. This magnitude scale is little used in paleoseismology because it saturates at magnitude levels below that of Ms.

Moment Magnitude (MW OR M)

•The moment magnitude scale is the most recent scale and is fundamentally different from the earlier scales. Rather than relying on measured seismogram peaks, the Mw scale is tied to the seismic moment (M0) of an earthquake.

• The seismic moment is defined as

$M0 = DA\mu$

•where D is the average displacement over the entire fault surface, A is the area of the fault surface, and m is the average shear rigidity of the faulted rocks. The value of D is estimated from observed surface displacements or from displacements on the fault plane reconstructed from instrumental or geodetic modeling. A is derived from the length multiplied by the estimated depth of the ruptured fault plane, as revealed by surface rupture, aftershock patterns, or geodetic data. The method thus assumes that the rupture area is rectangular. The shear rigidity of typical crustal rocks is assumed to be about 3.0–3.5 1011 dyne/cm2

•The seismic moment thus more directly represents the amount of energy released at the source, rather than relying on the effects of that energy on one or more seismographs at some distance from the source.

•Moment magnitude is calculated from seismic moment using the relation of Hanks and Kanamori (1979) for southern California

$Mw = 2/3 \log M0 - 10.7$

where Mw is the moment magnitude and M0 is the seismic moment

•The seismic moment scale was developed to circumvent the problem of saturation in other magnitude scales, and is typically used to describe great earthquakes (i.e., Ms > 8).

•Kanamori (1983) composed a graph relating Mw to ML, Ms, mb, and mB.

Basis of Categorization

•Material type

•Load resisting system

•Configuration

•Height of Building

•Quality of Construction

•Ground Slope

Category as per National Building Code

Four levels of design and construction

International state-of-art (Part I)

-Sophisticated design philosophies and analytical techniques in the world

Professionally engineered structures (Part II)

-Designed by professional engineers following code requirements

-Hospitals, meeting halls, factories, warehouses, multi-storied buildings, residential buildings . Masonry: unreinforced; RCC frames: with and without masonry infills

Buildings of restricted size designed using mandatory rules-of-thumb (Part III)

-Small buildings with limitation of height, number of stories and floor area can be designed by professional advisor reinf., eq. resisting elements etc.

-Limits on span and height, member sizes, min.

-RCC buildings with and without masonry infill; Load bearing masonry

Remote rural buildings where control is impractical (Part IV)

-Guidelines: Rural buildings- low strength masonry and earthen buildings

Building Categorization

•Non-engineered (non- strengthened)

Low strength

•Adobe building (up to 2-3 storeys incl. buingal)

•Stone in mud, timber floor (up to 3 storeys incl. buingal)

•Stone in mud, RC floor slab (up to 2-3 storeys)

•Brick in mud, timber floor (up to2-3 storeys incl. buingal)

•Brick in mud, RC floor slab (up to 2-3 storeys)

Building Categorization

•Non-engineered (non- strengthened)

Stone in cement mortar (up to 3 storeys, <1000sft. plinth area)

Brick in cement mortar (up to 3 storeys, <1000sft. plinth area)

RCC frame with masonry infill (up to 3 storeys, <1000sft. plinth area)

RCC frame with masonry infill (> 3 storeys, <1000sft. plinth area)

80% of building : up to 3 storey and <1000 sft. in plinth area

•Engineered Masonry Buildings (strengthened)

•Engineered RCC buildings

Why Buildings fail in an earthquake?

Insufficient Ductility

Insufficient Strength

Inappropriate Configuration and Connection

Vertical Load Path

↓

Floor Load and Live Load

↓

Slab

↓

Wall

↓

Foundation

MODE OF FAILURES

➢In-plane Failure

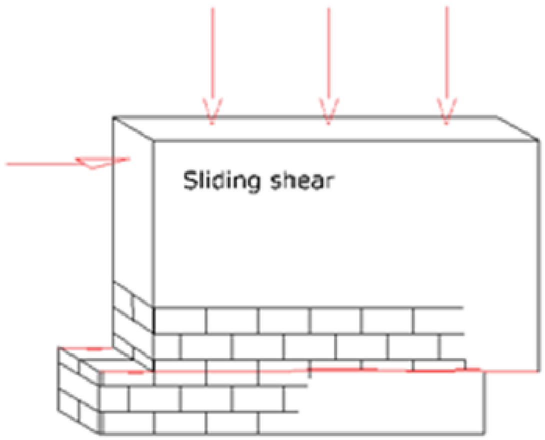
➢Out-of-plane Failure

➢Cracks at Corners and Junctions Between Walls

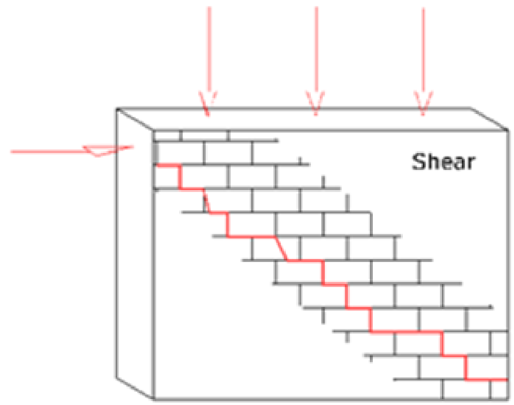
➢Diaphragm failure

➢Failure of Foundation

Failure of Walls: In Plane Failure



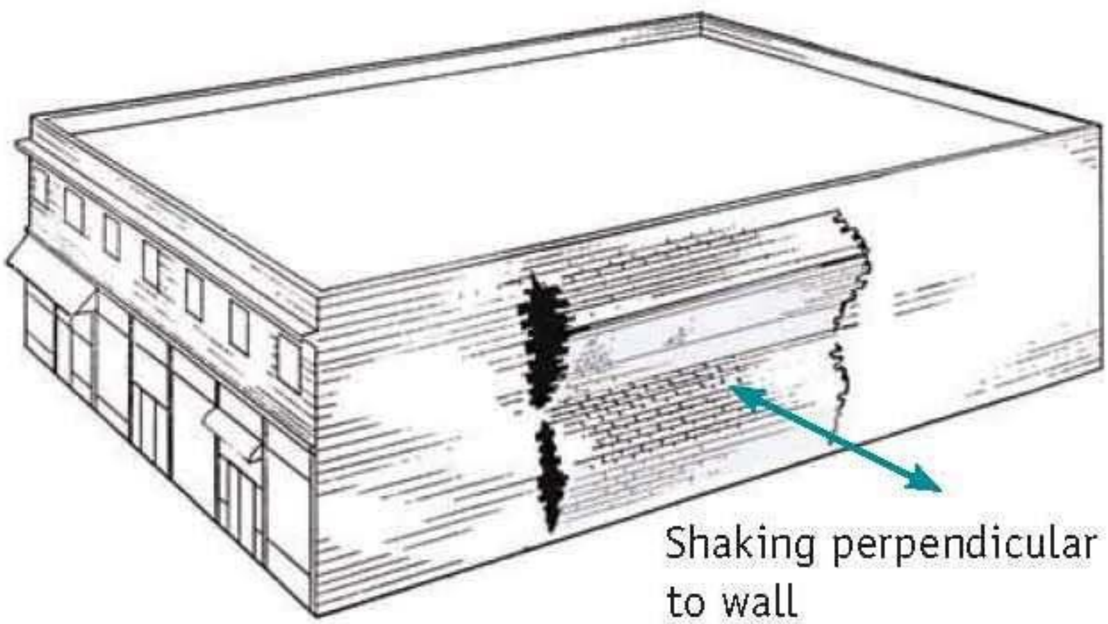
Sliding Shear



Shear

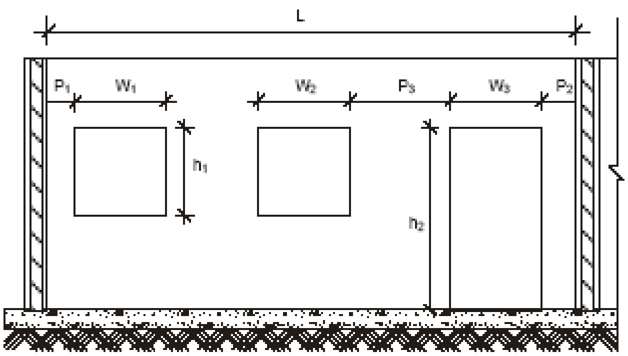
Failure of walls:

Out of plane failure



Criteria in Openings

W1+W2+W3 < 0.50L (for one story)
W1+W2+W3 < 0.42L (for two stories)
W1+W2+W3 < 0.33L (for three stories) P1 > 0.25h1 or 2’ P2 > 0.25h2 P3 > 0.50h1



What might be Earthquake Resistance Measures??

MRT- Storey Limitation

- The Mandatory Rules of Thumb has limited the number of storeys as follows:
- Brick Masonry in Cement Mortar: 3 Storey
- Stone Masonry in Cement Mortar: 2 Storey
- Brick Masonry in Mud Mortar: 2 Storey

These Limitations are only for the use of MRT

Thickness of wall

Thickness of wall:

TABLE 1.1 : BUILDING SIZE LIMITATIONS

	Floor	Min. Wall Thickness (mm)	Max. Height (m)	Max. Short Span of Floor (m)	Canti-lever (m)
Load-Bearing Brick Masonry in Cement Mortar	2nd	230	2.8	3.5	1.0
	1st	230	3.0	3.5	1.0
	Ground	350	3.2	3.5	No
Load-Bearing Stone Masonry in Cement Mortar, or	1st	350	3.0	3.2	No
Load-Bearing Brick Masonry in Mud Mortar	Ground	400	3.2	3.2	No
Load Bearing Brick Masonry in Mud Mortar	1st	350	3.0	3.2	No
	Ground	350	3.2	3.2	No

Unsupported Wall Length

- The Maximum length of unsupported wall shall not exceed 12 times the thickness of the Wall.
- If it exceeds 12 times, buttresses has to be provided at an interval of 12 times the thickness or less.

Thickness to Height Ratio

MASONRY TYPE	RATIO
Stone	1:8
Brick	1:12
Stone/Cement Solid Block	1:12
Stabilized Soil Block	1:12

Horizontal Bands and Beams

The bands mostly used in a masonry building are:

1. Plinth Beam
2. Sill Band
3. Lintel Band
4. Floor Beams
5. Gable Band

Why are Bands Necessary?

- To Prevent In-Plane Failure
- Confines the Masonry
- Localizes any failures
- Helps the Masonry resist in-plane moments
- To Prevent Out-Of-Plane Failure
- Reduces the Unsupported length of masonry
- Ties the Walls together
- Better support for junctions
- To Prevent Cracks at Openings
- To Prevent Failure at Junctions

Stitches

- Stitches are provided at the T-Junctions and Corners of the buildings.
- Stitches prevent the Junctions failure.
- Stitches reduce the unsupported wall height near the junctions confining the masonry.

Conclusion

- Strength- Adequate section of Walls, Limiting storey nos.
- Ductility- Bands, Vertical rod,mortar type
- Connection- Bands, Stitch and proper bonding
- Configuration- Simple, Rectangular, Square, Circular

•Earthquake motion induces

- –Horizontal inertia force
- –Vertical inertia force

•Interacts with gravity
•Primary concern is lateral (horizontal) force.

•Earthquake force is induced where the mass is located, i.e., at the floors.

•This force is to be transferred safely to the ground.

•Need load transfer path and adequate strength.

•Floors must be able to pass this force to frames / walls

•Frames / walls should be able to pass it to the foundation

•Foundation should be able to transfer it to the soil

•The Strength Hierarchy…
–Based on consequence of their failure
•Example: Multi-storey RC Building

– Slab : Affects that room

– Beam : Affects that storey

– Column : Affects the building

– Foundation : More serious

– Soil : Even more serious

Geotechnical Issues

- •Ground displacement
- •Liquefaction/Lateral spreading
- •Subsidence
- •Landslides
- •Bearing capacity failure
- •Unequal Settlements
- •Slope Stability

Probable Solutions

Must seek advice from experienced geotechnical engineer

- Foundation reinstatement
- Change in load / load path
- Chemical grouting
- Reduce the number of storeys

Geophysical Exploration

- Seismic refraction method
- Electrical Resistivity method
- Micro tremor analysis
- Multi Channel Analysis of Surface Waves (MASW)

Soil Properties of the Ground Model

a) N value
b) Groundwater level
c) D50 (Mean particle size) and Fc (Fine content)
d) Vs (Shear wave velocity)
e) Density

Chemical Grouting

❖Rectifies the levelling by injecting structural resins into the foundation ground under the footing of the building.

❖The resins expand together chemically creating pressure at first directed so as to lift the building back to its correct level.

❖If there are weak layers in the ground, continuing injection at deeper levels compacts the ground, densifying and strengthening it to its bearing capacity.

❖The bearing capacity of weak strata can be increased by as much as 500%.

Simple Rules to Improve Seismic Resistance

• **Flexible** structures instead of rigid structures. Gabions perform better than stone / brick masonry for retaining walls and check dams.

• Concrete or masonry walls should have **joints** at regular intervals not exceeding 10m. If any movement occurs it is limited to a panel and stresses are not transferred to a longer stretch.

• Foundation on sand is good for bearing capacity for static loads, but for seismic conditions, sand may **liquefy**. Check FoS agains liquefaction.

•Foundation in clays is weak generally, but do not liquefy by seismic loads. Check for **cyclic strength reduction** for clayey soil.

• Foundation investigation is a must for all buildings. **SPT, CPT or Tor Vane** may help to get quick data.

• **Preloading** of foundations before construction may help to improve both bearing capacity and liquefaction resistance

Repair , restore , Restrengthening

REPAIR

➢Repair to a damaged building is done in order to enable it to resume all its previous functions and to bring back its **architectural shape**.

➢Repair **does not pretend to improve the structural strength** of the building and can be very deceptive for meeting the strength requirements of the next earthquake.

Action

- •**Patching up of superficial defects** such as cracks and fall of plaster.
- •**Repairing doors, windows**, replacement of glass panes.
- •**Checking and repairing** electric connections
- •**Checking and repairing** gas connections, plumbing ,heating, ventilation services.
- •**Re-building non-structural walls**, smoke chimneys, boundary walls, etc.
- •**Re-plastering of walls** as required.
- •**Rearranging disturbed roofing tiles**.
- •**Relaying cracked flooring** at ground level.
- •**Redecoration, whitewashing, painting**, etc.

RESTORATION

➢It is the **restoration of the lost strength of structural elements of** the building before the damage occurred.

➢Restoration is done whenever there is evidence that the structural damage can be attributed to exceptional phenomena that are not likely to happen again and that the original strength provides an adequate level of safety.

➢The main purpose is **to carry out structural repairs to load bearing elements.**

Some of the approaches

- •Removal of portions of **cracked masonry walls and piers** and rebuilding them in **richer mortar**. Use of **non shrinking mortar** will be preferable.
- •Addition of **reinforcing mesh on both -faces of the cracked wall**, holding it to the wall through **spikes or bolts** and then covering with **micro-concrete of 1:3 cement coarse sand plaster** it suitably. Several alternatives have been used.
- •**Injecting neat cement slurry or epoxy** like material, which is **strong in tension, into the cracks in walls, columns, beams,** etc.

RETROFITTING

➢**Upgrading the strength** of an existing structures with an aim to **increase it's capacity to withstand future earthquake**.

Need for Seismic Retrofitting

•Buildings not **designed to codes**.

•**Upgrading of code** based seismic design forces

•Upgrading of **Seismic Zones**

•**Deterioration of strength** on aging of the structure

•**Modification** of the existing structures affecting its strength adversely

•**Change in of use** of the buiding increasing the floor loads

•Can't demolish the structure due to it's **social, historical or cultural importance**

Basic Concept of Seismic Retrofitting

○The aim is at (**CEB 1997**):

➢Upgradation of **lateral strength** of the structure

➢Increase in the **ductility** of the structure

➢Increase in the **strength and ductility** of the structure

The choice of a retrofitting methodology depends on:

- Type of building
- Required level of performance
- Availability of technology
- Overall financial aspect, etc

- Jacketing – Section Enlargement.
- Provision of Shear wall
- Bracing
- **Dampers**
- **Base Isolation**
- Addition of frames
- Others – Reinforcing with walls with geo-mesh, Use of Fiber Reinforced Polymers (FRPs).

- Wall encasing by using Wire meshing.
- Use of Gabion wire.
- Use of PP (Polypropylene) band.
- Introduction of bands and stitches.
- Strengthening/stiffening of roofs/floors.
- Anchorage of roofs/floors with walls.
- Strengthening of foundation.

Grouting.

Repair and maintenance

Cement Slurry for Grouting in Masonry Wall

 Masonry in Cement Mortar or Lime Mortar : Non-shrink Cement + Sand (1:1)

 Masonry in Mud Mortar : Non-shrink Cement+Sandy Soil+Fine Sand (1:1:3) Sieved through 0.5mm sieve

Repair:

Steps of filling grouts in crack (Minor/Medium Cracks (0.5mm to 5mm))

➢Remove Plaster

➢Chisel V-shape crack

➢Fix the Aluminum or Plastic Nipples of 12mm dia. (30-40mm long) in V- groove @ 150-200 mm c/c

➢Clean the crack with compressed air through nipples

➢Seal the crack on both faces with 1:3CM or Polyester putty

➢Inject water from nipples from the higher end to saturate masonry and clean the dust . (Not done in Mud Mortar)

➢Inject grout from the lower end moving to the higher ones

➢Replaster/ Finsihing

REPAIR

Steps of filling grouts in crack (Major Cracks >5mm)

- Remove Plaster and Chisel **V-shape** crack
- Clean the crack with compressed air
- Fill the crack with CM (1:3) from both sides as deep as possible
- Provide wire mesh on both faces of the wall 6" on either side of the crack ,clamps and wire nails @ 300mm c/c
- Plaster with CM (1:3) covering the mesh by minimum of 12mm thk

REPAIR

Installing Ferro-cement plates at the corners

- Use galvanized weld-mesh 'g14' (2.0mm wires @25x25mm mesh) over a length of 500-600 mm on each side of the crack both inside and outside of the room in a depth of 300mm at widows sill on about 900 mm height above the floor
- Remove plaster and rake out mortar joints to 12-15mm depth
- Clean the surface and wet it with water
- Apply neat cement slurry and apply first coat of 12mm thk rough plaster
- Fix the mesh with 150mm long nails about 300mm apart while plaster is green
- Apply second coat of Plaster 16mm thk