STRUCTURAL MITIGATION MEASURES

NATURAL DISASTERS

- CYCLONE
- EARTHQUAKE
- TSUNAMI
- FLOOD
- LANDSLIDE

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Principal Consultant
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PHASES OF DISASTER MANAGEMENT CYCLE

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The 6.9 quake at 6.11pm was followed by a 4.8 quake at 6.41pm and a 4.6 quake at 7.24pm.
- WHAT HAPPENS IN EQ
- WHY EQ HAPPENS
- MAGNITUDE AND INTENSITY OF EQ
- HOW BUILDINGS BEHAVE IN EQ
- GUIDELINE FOR EQ RESISTANCE

- HOW BUILDINGS ARE DEFICIENT
- CHANCES OF EQ IN KOLKATA
- WHAT IF EQ OCCURS IN KOLKATA
- MEASURES TO BE TAKEN TO REDUCE THE EQ HAZARD

STRUCTURAL MITIGATION MEASURES OF BUILDINGS FOR EARTHQUAKE
GLOBAL SEISMIC HAZARD MAP

Produced by the Global Seismic Hazard Assessment Program (GFHAP), a demonstration project of the UN International Decade of Natural Disaster Reduction, conducted by the International Lithosphere Program.


STRUCTURAL MITIGATION MEASURES OF BUILDINGS FOR EARTHQUAKE
What happens in earthquake?

- Earthquake shakes the ground
- In nature, it forms mountains, shifts river courses, dries old rivers, forms new rivers
- In man-made society, it shakes the man-made objects

- If the structure is strong enough, it will crack but will stand
- If it is not strong enough, it will be severely damaged
- If it is weak, it will collapse
• THE MAN MADE STRUCTURES ARE DESIGNED TO CATER SOME PREDETERMINED VERTICAL FORCES NAMELY DL, LL

• DETERMINING EARTHQUAKE FORCES ARE COMPARATIVELY NEW SCIENCE

• BUILDINGS CONSTRUCTED DO NOT FOLLOW THE GUIDELINE OF DESIGNING FOR EARTHQUAKE LOADING

• INADEQUATE COVERAGE IN MUNICIPA BYLAWS

• ADEQUATE COVERAGE IN THE MUNICIPAL BY-LAWS BUT CLANDESTINE BYPASSING OF THE LAWS

WHY STRUCTURES GET DAMAGED?
• Earthquake occurs in the earthquake prone zone.

• In the near past there is no record of strong earthquake in the region where we stay.

• So we are safe.

• But due to some strong earthquake at a distant earthquake prone zone it may cause harm in the structures in less earthquake prone zone.

• Or if the structures do not have adequate provisions for withstanding earthquake it can cause devastation.
WHY DEVASTATION OCCURRED IN LATUR WHICH IS IN ZONE I
• VERY LITTLE INFORMATION ABOUT THE EQ HISTORY AVAILABLE IN THESE ZONES

• EQ OCCURRENCE IN 30TH SEPTEMBER, 1993 WAS OF MODERATE MAGNITUDE OF 6.3 AT A FOCAL DEPTH LESS THAN 10KM

• SUCH SHAKING IS NOT VERY UN-COMMON

• MAJOR VILLAGE HUTS MADE OF STONE AND THE BUILDINGS WHICH ARE OF POOR CONSTRUCTION COLLAPSED

• IT OCCURRED AT MIDDLE OF THE NIGHT AT 3.53AM WHEN ALL PEOPLE WERE FAST ASLEEP IN THE HOUSES

• STRUCTURES WHICH WERE STRONGER STOOD THE EQ.

• ZONING OF THE EARTHQUAKE MAP OF INDIA UNDERGONE CHANGES DUE TO THE OCCURRENCE OF DEVASTATION IN LATUR

WHY DEVASTATION OCCURRED IN LATUR WHICH IS IN ZONE I
SEISMIC HAZARD MAP OF INDIA AS PER SEISMIC CODE IS -1893
<table>
<thead>
<tr>
<th>STAGE</th>
<th>TIME</th>
<th>EVENT</th>
<th>REACTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>POSITIVE</td>
<td>NEGATIVE</td>
</tr>
<tr>
<td>1</td>
<td>0-1 MINUTE</td>
<td>MAJOR EARTHQUAKE</td>
<td>PANIC</td>
</tr>
<tr>
<td>2</td>
<td>1 MINUTE TO 1 WEEK</td>
<td>AFTERSHOCKS</td>
<td>RESCUE AND SURVIVAL</td>
</tr>
<tr>
<td>3</td>
<td>1 WEEK TO 1 MONTH</td>
<td>DIMINISHING AFTERSHOCKS</td>
<td>SHORT TERM REPAIRS</td>
</tr>
<tr>
<td>4</td>
<td>1 MONTH TO 1 YEAR</td>
<td></td>
<td>LONG TERM REPAIRS, ACTION FOR HIGHER STANDARDS</td>
</tr>
<tr>
<td>5</td>
<td>1 YEAR TO 10 YEARS</td>
<td></td>
<td>DIMINISHING INTEREST</td>
</tr>
<tr>
<td>6</td>
<td>10 YEARS TO NEXT TIME</td>
<td></td>
<td>RELUCTANCE TO MEET COSTS OF SEISMIC PROVISIONS, INCREASING NON-COMPLIANCE WITH REGULATIONS</td>
</tr>
<tr>
<td>7</td>
<td>THE NEXT TIME</td>
<td>MAJOR EARTHQUAKE</td>
<td>REPEAT STAGES 1 - 7</td>
</tr>
</tbody>
</table>

LONG TERM HUMAN RESPONSE TO EARTHQUAKE (FROM KEY, 1988)
WHY EARTHQUAKE HAPPENS?
• CRUST THICKNESS 30KM
• CRUST IS COMPRISED OF SEVERAL PIECES CALLED PLATES
• OCEANIC PLATES
• CONTINENTAL PLATES
• WHEN TWO PLATES RUN INTO EACH OTHER OR SLIDING PAST EACH OTHER – EQ OCCURS

STRUCTURE OF EARTH – INNER CORE
NORTH BOUND MOVEMENT OF INDIAN TECTONIC PLATE
FAULTS OR CRACKS IN A PLATE

• WHEN UNDERGROUND ROCK SUDDENLY BREAKS ALONG A CRACK – EQ OCCURS

FAULTS OR CRACKS IN A PLATE
EXPERIMENT WITH FOAM
FOCUS AND EPICENTRE

Diagram showing the relationship between the focus, epicenter, and fault scarp.
### Magnitude:

- Scientists are interested in measuring seismic energy in order to categorize earthquakes and to better understand tectonic processes.
- Magnitude measures the energy released at the source of the earthquake.
- Magnitude is determined from measurements on seismographs.
- Measured in Richter scale (invented in 1934).

### Intensity:

- Society is interested in the strength of past and future earthquakes in order to assess and predict damage and loss of life.
- Intensity measures the strength of shaking produced by the earthquake at a certain location.
- Intensity is determined from effects on people, human structures, and the natural environment.
- Measured in Mercalli intensity scale (invented in 1902).
SEISMOGRAPH
I. Not felt except by a very few under especially favorable conditions.
II. Felt only by a few persons at rest, especially on upper floors of buildings.
III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; some chimneys broken.
VIII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb.
X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Abbreviated Modified Mercalli Intensity Scale
The following table gives intensities that are typically observed at locations near the epicenter of earthquakes of different magnitudes.

<table>
<thead>
<tr>
<th>Magnitude In Richter Scale</th>
<th>Typical Maximum Modified Mercalli Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 - 3.0</td>
<td>I</td>
</tr>
<tr>
<td>3.0 - 3.9</td>
<td>II - III</td>
</tr>
<tr>
<td>4.0 - 4.9</td>
<td>IV - V</td>
</tr>
<tr>
<td>5.0 - 5.9</td>
<td>VI - VII</td>
</tr>
<tr>
<td>6.0 - 6.9</td>
<td>VII - IX</td>
</tr>
<tr>
<td>7.0 and higher</td>
<td>VIII or higher</td>
</tr>
<tr>
<td>Magnitude</td>
<td>Earthquake Effects</td>
</tr>
<tr>
<td>-----------------</td>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td>2.5 or less</td>
<td>Usually not felt, but can be recorded by seismograph.</td>
</tr>
<tr>
<td>2.5 to 5.4</td>
<td>Often felt, but only causes minor damage.</td>
</tr>
<tr>
<td>5.5 to 6.0</td>
<td>Slight damage to buildings and other structures.</td>
</tr>
<tr>
<td>6.1 to 6.9</td>
<td>May cause a lot of damage in very populated areas.</td>
</tr>
<tr>
<td>7.0 to 7.9</td>
<td>Major earthquake. Serious damage.</td>
</tr>
<tr>
<td>8.0 or greater</td>
<td>Great earthquake. Can totally destroy communities near the epicenter.</td>
</tr>
</tbody>
</table>

Earthquake Magnitude Scale
<table>
<thead>
<tr>
<th>Class</th>
<th>Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great</td>
<td>8 or more</td>
</tr>
<tr>
<td>Major</td>
<td>7 - 7.9</td>
</tr>
<tr>
<td>Strong</td>
<td>6 - 6.9</td>
</tr>
<tr>
<td>Moderate</td>
<td>5 - 5.9</td>
</tr>
<tr>
<td>Light</td>
<td>4 - 4.9</td>
</tr>
<tr>
<td>Minor</td>
<td>3 - 3.9</td>
</tr>
</tbody>
</table>

Earthquake Magnitude Classes
## HISTORICAL OCCURRENCES OF EARTHQUAKE IN INDIA

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Year</th>
<th>Region</th>
<th>Magnitude</th>
<th>Toll</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1897</td>
<td>Assam</td>
<td>8.7</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1905</td>
<td>Kangra, HP</td>
<td>8.0</td>
<td>19,600</td>
</tr>
<tr>
<td>3</td>
<td>1934</td>
<td>Bihar, Nepal</td>
<td>8.3</td>
<td>18,700</td>
</tr>
<tr>
<td>4</td>
<td>1950</td>
<td>Arunachal</td>
<td>8.5</td>
<td>1526</td>
</tr>
<tr>
<td>5</td>
<td>1956</td>
<td>Gujarat</td>
<td>7.0</td>
<td>113</td>
</tr>
<tr>
<td>6</td>
<td>1967</td>
<td>Koyna, Maharashtra</td>
<td>6.5</td>
<td>177</td>
</tr>
<tr>
<td>7</td>
<td>1988</td>
<td>Bihar &amp; Nepal</td>
<td>6.4</td>
<td>900</td>
</tr>
<tr>
<td>8</td>
<td>1991</td>
<td>Uttarkashi</td>
<td>6.6</td>
<td>2000</td>
</tr>
<tr>
<td>9</td>
<td>1993</td>
<td>Latur, Maharashtra</td>
<td>6.3</td>
<td>9748</td>
</tr>
<tr>
<td>10</td>
<td>1999</td>
<td>Chamoli, Uttarkashi</td>
<td>6.8</td>
<td>100</td>
</tr>
<tr>
<td>11</td>
<td>2001</td>
<td>Bhuj, Gujarat</td>
<td>6.9</td>
<td>20,000</td>
</tr>
<tr>
<td>12</td>
<td>2005</td>
<td>Pakistan</td>
<td>7.6</td>
<td>80,000</td>
</tr>
</tbody>
</table>

- There are 16 major occurrences of major earthquake in India in the last 100 years
- There are 9 major earthquake in the last 50 years
DEFLECTION OF THE STRUCTURE DEPENDS ON DL OR LL ON THE STRUCTURE

SEISMIC LOAD ON THE STRUCTURE DEPENDS ON DEFLECTION OF THE STRUCTURE

F = ma = kΔ

SEISMIC LOADING ON BUILDING
• Seismic force on building depends on its flexibility.
• Uniform flexible building behaves better.
• Sudden change in flexibility causes soft storey effect.

Seismic behaviour of building.
- Designing building with maximum possible EQ is uneconomic
- Designing building with less EQ is unsafe
- Proper detailing should be undertaken to make the building safe against EQ

The design approach adopted in the code is to ensure that the structure

- Should withstand minor earthquake (less than design basis earthquake, DBE)
- Should resist moderate earthquake (DBE) without significant structural damage
- Should withstand a major earthquake (maximum considered earthquake, MCE) without collapse

What seismic code is -1893: 2002 proposes
FOR WELL PERFORMANCE IN EQ BUILDING SHOULD BE:

- OF SIMPLE AND REGULAR CONFIGURATION
- HAVE ADEQUATE LATERAL STRENGTH
- HAVE ADEQUATE STIFFNESS
- HAVE ADEQUATE DUCTILITY
TORSIONAL IRREGULARITY WHEN $D_2 > 1.5D_1$

BUILDING IRREGULARITIES VULNERABLE FOR EQ
PLAN IRREGULARITY WHEN A/L > 0.15 - 0.2 OR THE RE-ENTRANT CORNER LENGTH > 0.25 OF LENGTH OF THE BUILDING IN THE SAME DIRECTION

BUILDING IRREGULARITIES VULNERABLE FOR EQ
FLEXIBLE DIAPHRAGM

RIGID DIAPHRAGM

VERTICAL COMPONENT OF SEISMIC RESISTING SYSTEM

DIAPHRAGM DISCONTINUITY – COMBINATION OF RIGID AND FLEXIBLE DIAPHRAGM

OR

OPENING IS MORE THAN 50% OF THE OVERALL DIAPHRAGM OR

STIFFNESS OF DIAPHRAGM BETWEEN FLOORS VARY MORE THAN 50%

BUILDING IRREGULARITIES VULNERABLE FOR EQ
OUT OF PLANE DISCONTINUITY

SHEAR WALLS

OUT OFF PLANE OFFSET OF LATERAL LOAD CARRYING MEMBERS

BUILDING IRREGULARITIES VULNERABLE FOR EQ
NON-PARALLEL SYSTEM OF HORIZONTAL LOAD CARRYING MEMBERS

BUILDING IRREGULARITIES VULNERABLE FOR EQ
STOREY STIFFNESS FOR THE BUILDING

- \( K_n \)
- \( K_{n-1} \)
- \( K_{n-2} \)

SOFT STOREY WHEN

- \( K_i < 0.7 \ K_{i+1} \) OR
- \( K_i < 0.8( \ K_i+1+K_{i+2}+K_{i+3} )/3 \)

STIFFNESS IRREGULARITY – SOFT STOREY OR EXTREME SOFT STOREY

BUILDING IRREGULARITIES VULNERABLE FOR EQ
SOFT STOREY EFFECT IN BUILDING
HEAVY MASS

MASS IRREGULARITY WHEN

\[ W_i < 2 W_{i+1} \text{ OR } W_i > 2 W_{i-1} \]

BUILDING IRREGULARITIES VULNERABLE FOR EQ
VERTICAL GEOMETRIC IRREGULARITY WHEN $L_2 > 1.5L_1$

BUILDING IRREGULARITIES VULNERABLE FOR EQ
IN-PLANE DISCONTINUITY IN VERTICAL ELEMENTS RESISTING LATERAL FORCES WHEN \( b > a \)

BUILDING IRREGULARITIES VULNERABLE FOR EQ
STOREY STRENGTH (LATERAL)

F_n
F_{n-1}
F_{n-2}
F_4
F_3
F_2
F_1

WEAK STOREY WHEN

F_i < 0.8 F_{i+1}

DISCONTINUITY IN CAPACITY – WEAK STOREY

BUILDING IRREGULARITIES VULNERABLE FOR EQ
WHAT IS DUCTILITY?
• IMPORTANT SERVICES – 1.5
• COMMUNITY BUILDINGS – 1.5
• ALL OTHER BUILDINGS – 1.0

IMPORTANCE FACTOR IS 1.5 BECAUSE OF:

• ASSEMBLY BUILDING LIKE SCHOOL, CINEMA HALL WHERE COLLAPSE WILL CAUSE MORE LOSS OF LIFE
• BRIDGES, ROAD EMBANKMENT WHERE COLLAPSE WILL CAUSE THE HELP SERVICES TO REACH THE SPOT
• TRANSMISSION LINE TOWER, TELEPHONE TOWERS WHERE COLLAPSE WILL HINDER THE DISASTER MANAGEMENT ACTION
TYPICAL BUILDING DETAIL
MAP OF INDIA SHOWING EARTHQUAKE ZONES

SEISMIC HAZARD MAP OF INDIA AS PER SEISMIC CODE IS -1893: 2002
In the standard building being constructed in Kolkata, the design of the members have tremendous shortfall compared with actual requirement.
• EQ OF SUFFICIENT MAGNITUDE OCCURS
• IT OCCURS CLOSE ENOUGH TO A POPULATED CENTRE
• POPULATION CENTRE HAVING BUILDINGS WHICH ARE NOT EQ RESISTANT
• TIME OF OCCURRENCE – IF OCCURS IN DAY TIME LOSS OF LIFE IS LESS AS MANY REMAINS AT OUTSIDE, IF OCCURS IN NIGHT TIME LOSS OF LIFE IS MORE

IS IT POSSIBLE THAT SUCH CONDITION OCCURS IN KOLKATA ...

GREAT DISASTER OCCURS WHEN
- Epicentres are in Himalayan ranges or in Bay of Bengal.
- Several faults have been identified in the region and evidence of movement is also there.
- As per Prof. Murty, there is an earthquake fault line at 100km from Kolkata.
- Earthquake data base is incomplete – 200 years record available.

Chances of earthquake in Kolkata.
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<td>IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.</td>
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<td>XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.</td>
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LIST OF PAST EQ AROUND KOLKATA REFERENCE: 'Amateur Seismic Centre, http://www.asc-india.org/, Pune, India'
04 June 1764 - Kandi-Khargram area, West Bengal.
24.000 N, 88.000 E (1)
Maximum observed intensity VIII (1).

01 February 1811 - Kolkata area, West Bengal.
22.600 N, 88.400 E (1)
Maximum observed intensity VI (1).

03 April 1822 - Kolkata area, West Bengal.
22.600 N, 88.400 E (1)
Maximum observed intensity VII (1).

08 July 1828 - Kolkata area, West Bengal.
22.600 N, 88.400 E (1)
Maximum observed intensity VII (1).

08 July 1834 - Rangpur area, Bangladesh.
25.800 N, 89.400 E (1)
Maximum observed intensity VIII (1).

21 July 1834 - Rangpur area, Bangladesh.
25.800 N, 89.400 E (1)
Maximum observed intensity VIII (1).
11 November 1842 - Bihar-Bengal.
27.000 N, 88.300 E
Maximum observed intensity IX. Damage at Munger, Bihar. Felt at Kolkata, Darjeeling and Guwahati.
Seiches observed in the northern Bay of Bengal.

10 August 1843 - Darjeeling area, West Bengal.
27.000 N, 88.300 E
Maximum observed intensity VII.

06 August 1845 - Kolkata area, West Bengal.
22.700 N, 88.400 E
Maximum observed intensity VII.

27 February 1849 - Darjeeling area, West Bengal.
27.000 N, 88.300 E
Maximum observed intensity VIII.

09 February 1851 - Kolkata area, West Bengal.
22.600 N, 88.400 E
Maximum observed intensity VII.

May 1852 - Darjeeling area, West Bengal.
27.000 N, 88.300 E
Maximum observed intensity IX.
16 February 1861 - Kolkata area, West Bengal.
22.600 N, 88.400 E (1)
Maximum observed intensity VIII (1).

29 March 1863 - Darjeeling area, West Bengal.
27.000 N, 88.300 E (1)
Maximum observed intensity VII (1).

20 December 1865 - Rajshahi-Murshidabad area, India-Bangladesh border.
24.400 N, 88.700 E (1)
Maximum observed intensity VI (1).

25 December 1865 - Krishnanagar area, West Bengal.
23.400 N, 88.500 E (1)
Maximum observed intensity VI (1).

09 August 1869 - Darjeeling area, West Bengal.
27.000 N, 88.300 E (1)
Maximum observed intensity VII (1).

12 June 1897 - Assam-Meghalaya, Mw 8.1 (12).
26.000 N, 91.000 E
This is the most powerful intraplate earthquakes in the Indian sub-continent. Close to 1,500 people were killed in Assam, Meghalaya and adjoining parts of the Bengal. Damage (MM VII) in the Kolkata are and to a much greater extent in the duars of northern West Bengal.
29 September 1906 - Kolkata area, West Bengal.
22.600 N, 88.400 E (1)
Maximum observed intensity VI (1).

06 December 1906 - Kolkata area, West Bengal.
22.600 N, 88.400 E (1)
Maximum observed intensity VI (1).

02 July 1930 - Dhubri, Assam, Ms 7.1 (4).
25.800 N, 90.200 E, OT=21:03:34 UTC (4)
Most masonry buildings in Dhubri were destroyed. Felt in much of the Bengal and Assam.

15 January 1934 - Indo-Nepal Border region, Mw 8.0 (13)
26.500 N, 86.500 E, OT=08:43:25 UTC (4)
Close to 10,700 people killed in North Bihar and Nepal. Heavy damage in the towns of Muzaffarpur, Motihari, Dharbhanga, and Munger (Monghyr). Tremors were felt (11) all over the Indian subcontinent, and were felt strongly at many places in West Bengal including Kolkata.

21 March 1935 - Pabna, Bangladesh, Ms 6.2 (4).
24.250 N, 89.500 E, D=080.0 kms, OT=00:04:02 UTC (4)
Prolonged tremors were felt in much of the Bengal including at Kolkata. An aftershock occurred on 23 April 1935 and was also widely felt in the region.
10 December 1949 - Kishoreganj area, Bangladesh, M? 6.0 (8).
26.000 N, 89.000 E, OT=19:37:14 UTC (8)
This earthquake was located to the north-east of Saidpur and to the north-west of Rangpur in northern Bangladesh along the border with India.

15 August 1950 - Arunachal Pradesh, Mw 8.6 (GSI).
24.250 N, 89.500 E, D=080.0 kms, OT=00:04:02 UTC (GSI)
This is the most powerful earthquake in South Asia. The earthquake caused damage to buildings as far as Kolkata.

21 August 1960 - Samthar-Kalimpong area, West Bengal, Ms 5.5 (4).
27.000 N, 88.500 E, D=029.0 kms, OT=03:29:04 UTC (4)
This earthquake was located in the Darjeeling-Kalimpong area of northern West Bengal.

15 April 1964 - Sagar Island, West Bengal, Mb 5.2 (4).
21.600 N, 88.700 E, D=036.0 kms, OT=08:35:27 UTC (4)
Felt in southern West Bengal and eastern Orissa including at Kolkata and Hugli. Damage in areas near the epicentre such as at Contai and Diamond Harbour. The maximum intensity in Kolkata was V.

23 June 1976 - South of the Sunderbans, West Bengal, Mb 5.0 (4).
21.180 N, 88.620 E, D=050.0 kms, OT=15:38:42 UTC (4)
This earthquake was located in the Bay of Bengal off the Ganga Delta.
27.400 N, 88.800 E, D=047.0 kms, OT=19:00:45 UTC (4)
8 people injured and damage in Gangtok. Felt throughout eastern India, Bangladesh, Bhutan and Nepal (7).

26 March 1981 - Chingrakhali-Bhairabnagar area, West Bengal, Mb 4.9 (4).
21.180 N, 88.620 E, OT=02:47:10 UTC (4)
This earthquake was located along the India-Bangladesh border to the east of Canning, West Bengal.

12 June 1989 - Sunderbans, Bangladesh, Mw 5.7 (7).
21.861 N, 89.763 E, D=006.0 kms, OT=00:04:09 UTC (7)
1 person was killed and 100 injured in the Banaripara area of Bangladesh.
Felt in much of eastern Bangladesh including at Chittagong and Rangpur. It was also felt in Meghalaya, India.

20 June 2002 - Jayachari-Rajshahi, Bangladesh, Mw 5.1
25.868 N, 88.874 E, D=037.8 kms, OT=05:40:43 UTC
A moderate earthquake struck northern Bangladesh, on 25 June 2002 at 11:40 AM local time, causing several injuries in the Rajshahi division, Bangladesh. It had a magnitude of Mw=5.1 and was felt for close to 45-seconds.

28 November 2005 - Ganga Canyon, South of the Sunderbans, Mb 4.7
21.015 N, 89.158 E, D=010.0 kms, OT=16:57:13 UTC
A light earthquake occurred in the Ganga Canyon in the northern Bay of Bengal, off the Sunderbans on 28 November 2005 at 22:27 PM local time in India. The earthquake had a magnitude of Mb=4.7 and was felt in southern parts of West Bengal.
• THERE IS CHANCE OF GREAT EQ IN AND AROUND OUR CITY
• MAJOR STRUCTURES ARE NOT ADEQUATE ENOUGH FOR RESISTING EARTHQUAKE
• WHAT SHOULD BE OUR LINE OF ACTION AT THIS STAGE?

WHAT IF GREAT EARTHQUAKE OCCURS?
• EQ CAN NOT BE PREDICTED BY ANYONE, ANYWHERE IN ANY COUNTRY, THIS IS SCIENTIFIC TRUTH – SOME SAYS

• EQ SOMETIMES ARE PRECEDED BY SIGNALS LIKE CHANGE IN GWL, VARIATION OF SPRING DISCHARGE, UNUSUAL ANIMAL BEHAVIOUR ETC.

• CHINESE HAVE SOME SUCCESS IN FORECASTING EQ BY CLOSELY MONITORING AND ANALYSIS ANIMAL BEHAVIOUR

• EXTENSIVE RESEARCH IS GOING ON IN FAVOUR OF PREDICTION OF EQ BUT TILL DATE IT IS NOT SUCCESSFUL

FORECAST OF EARTHQUAKE
MEASURES TO BE TAKEN TO ESCAPE FROM EQ HAZARD
JINNAH ROAD BEFORE EARTHQUAKE IN QUETTA CITY, 1935

CURRENT STATUS OF BUILDINGS
CURRENT STATUS OF BUILDINGS

JINNAH ROAD AFTER EARTHQUAKE IN QUETTA CITY, 1935
• FIRST CODE OF PRACTICE FOR EQ RESISTANT DESIGN PUBLISHED AFTER 1935 QUETTA EQ
• BIS FIRST PUBLISHED SEISMIC CODE IS: 1893 IN 1962
• TILL DATE THERE IS NO LEGAL FRAMEWORK TO FORCE ALL CONSTRUCTION MUST IMPLEMENT SEISMIC CODE PROVISIONS
• RESULT – MOST BUILDINGS DO NOT MEET CODAL REQUIREMENT
• EVEN IF FROM NOW ON IT IS ENSURED THAT THE BUILDING WILL FOLLOW CODAL PROVISIONS STILL A LARGE NUMBER OF BUILDINGS WILL REMAIN DEFICIENT FOR EQ SAFETY
• NEED OF THE HOUR – A RATIONAL SEISMIC RETROFITTING POLICY
• PHASE WISE, FIRST THE GOVERNMENT OWNED BUILDING, THEN THE PRIVATELY OWNED BUILDING

CURRENT STATUS OF BUILDINGS
NEW LONGITUDINAL REINFORCEMENT

EXISTING SECTION
NEW ADDED SECTION
NEW LONGITUDINAL REINFORCEMENT

EXISTING SECTION
NEW ADDED SECTION
NEW LONGITUDINAL REINFORCEMENT

CASING A CONCRETE COLUMN

STRENGTHENING OF RCC MEMBERS

INCREMENTING THE SECTION & REINFORCEMENT OF EXISTING BEAM

RETROFITTING OF STRUCTURES DEFICIENT IN EQ RESISTANCE – IS 13935:1993 EDITION 1.1 (2002-04)
IN THE BY-LAWS PUBLISHED BEFORE 2007 NO GUIDELINE ON SPECIFIC REFERENCE TO EARTHQUAKE RESISTANT CODES

IN 2007 PUBLICATION SPECIFIC MENTION HAS BEEN INCLUDED THAT FOLLOWING CODES NEED TO BE CONSIDERED FOR DESIGNING OF BUILDING:

- IS 1893: 2002: CRITERIA FOR EQ RESISTANT DESIGN OF STRUCTURES
- IS 13920;1993: DUCTILE DETAILING
- IS 4326:1993: EQ RESISTANT DESIGN AND CONSTRUCTION OF BUILDINGS
- IS 13828:1993: IMPROVING EQ RESISTANCE IN LOW STRENGTH MASONRY BUILDING
- IS 13827:1993: IMPROVING EQ RESISTANCE IN EARTHEN BUILDING
- IS 13935:1993: REPAIR AND SEISMIC STRENGTHENING OF BUILDINGS
• WHETHER ONE SHOULD BE CONCERNED ABOUT EQ WHICH HAS LOW PROBABILITY OF OCCURRENCE THAN THE MORE DEMANDING PROBLEMS IN OUR CITY LIKE ENVIRONMENT, NOISE, TRAFFIC OR POWER SHORTAGE

• EQ ISSUE FIRST BE RECOGNIZED AND QUANTIFIED

• TO DISCUSS THE PROBLEM IN RATIONAL BASIS WITHOUT CAUSING PANIC

• AFTER THE PROBLEM IS IDENTIFIED AND ACTION PLAN IS FORMULATED POLITICAL AND ADMINISTRATIVE WILL TO BE MOTIVATED FOR IMPLEMENTATION

• IT IS TO BE UNDERSTOOD THAT THE PROBLEM NEEDS HUGE EFFORTS AND BEYOND THE CAPACITY OF FEW INDIVIDUALS OR FEW ORGANISATIONS

• SCIENTIFIC AND ENGINEERING ACTIVITIES NEED TO BE INITIATED TO QUANTIFY THE SIZE OF THE PROBLEM

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PLAN OF ACTION
• MANPOWER DEVELOPMENT AT ALL LEVELS
• SEISMIC RISK AND HAZARD EVALUATION OF DIFFERENT PART OF THE CITY
• VULNERABILITY ASSESSMENT OF DIFFERENT TYPE OF CONSTRUCTION
• MANUALS TO BE DEVELOPED FOR GUIDELINE FOR NEW CONSTRUCTION AND RETROFITTING OF OLD ONES
• STRONG LEGAL AND ENFORCEMENT FRAMEWORK WITH APPROPRIATE INCENTIVES AND PUNITIVE MEASURES IS REQUIRED TOGETHER WITH AWARENESS PROGRAMME FOR GENERAL PUBLIC

PLAN OF ACTION
<table>
<thead>
<tr>
<th>Guideline for Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Design should include seismic provisions</td>
</tr>
<tr>
<td>- Qualified structural engineer/architect should be involved in the design</td>
</tr>
<tr>
<td>- Construction supervision is must</td>
</tr>
<tr>
<td>- In case of building designed by government department periodic filed supervision by the designer should be made imperative</td>
</tr>
<tr>
<td>- Municipal by-laws should be strict enough</td>
</tr>
<tr>
<td>- Grade of concrete should be high</td>
</tr>
<tr>
<td>- Detailing should be adequate enough</td>
</tr>
<tr>
<td>- Ductile detailing is must</td>
</tr>
<tr>
<td>- Fire extinguisher and fire alarm should be installed in building</td>
</tr>
<tr>
<td>- Emergency exit should be provided</td>
</tr>
</tbody>
</table>
FLOOD
- Severe winds over water
- Unusual high tide
- Tsunami
- Improper urban planning

- Hutmments or the structures made in the flood plane of the rivers – disaster cannot be averted
- Flood in the other part of land can be avoided by proper control of dam gates/ river defence/ coastal defence

Causes of flood - mitigation
EFFECT OF FLOOD DURING CONSTRUCTION
VALLEY TO BE BRIDGED
Caijiagou Railway Viaduct
Liduzhen, Chongqing, China
495 feet high / 151 meters high
(394) foot span / (120) meter span
2012
Chenab River Railway Bridge
Katra, Jammu-Kashmir, India
1,053 feet high / 321 meters high
1,509 foot span / 460 meter span
2015
Dukouhe Railway Bridge
Tunbaoxiang, Enshi, China
459 feet high / 140 meters high
420 foot span / 128 meter span
2010
Huatupo Bridge
Zhaotong, Yunnan, China
(394) feet high / (120) meters high
341 foot span / 104 meter span
2001
Labajin Bridge
Yingjing, Sichuan, China
722 feet high / 220 meters high
656 foot span / 200 meter span
2012
Nanpanjiang Badu Railway Bridge
Baduzhen, Guanxi, China
341 feet high / 104 meters high
(394) foot span / (120) meter span
2001
Shintabisoko Bridge
Yaotsu, Gifu, Japan
656 feet high / 200 meters high
722 foot span / 220 meter span
2010
VALLEY BEING BRIDGED
HAZARD VULNERABILITY OF INDIA:

• INDIAN SUBCONTINENT AMONG THE MOST DISASTER PRONE AREA
• 59% OF LAND VULNERABLE FOR EARTHQUAKE
• 8.5% OF LAND VULNERABLE FOR CYCLONE
• 5% OF LAND VULNERABLE FOR FLOOD

EARTHQUAKE HAZARD:

• 10.0% OF LAND IS LIABLE TO SEVERE EQ (INTENSITY IX OR MORE)
• 17.3% OF LAND IS LIABLE TO EQ OF INTENSITY VIII (SIMILAR TO LATUR EQ)
• 30.4% OF LAND LIABLE TO EQ OF INTENSITY VII (SIMILAR TO JABALPUR EQ)
<table>
<thead>
<tr>
<th>Measures to be taken for reducing the hazards in case of eq</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Political and administrative will should be motivated for implementation of the necessary measures</td>
</tr>
</tbody>
</table>

**Conclusion**
THANK YOU