Meeting on Seismic Hazard in Asia

ICTP, Trieste, Dec.4-8, 2006

Seismicity and Seismic Hazard Assessment in Bangladesh: Reference to Code Provisions

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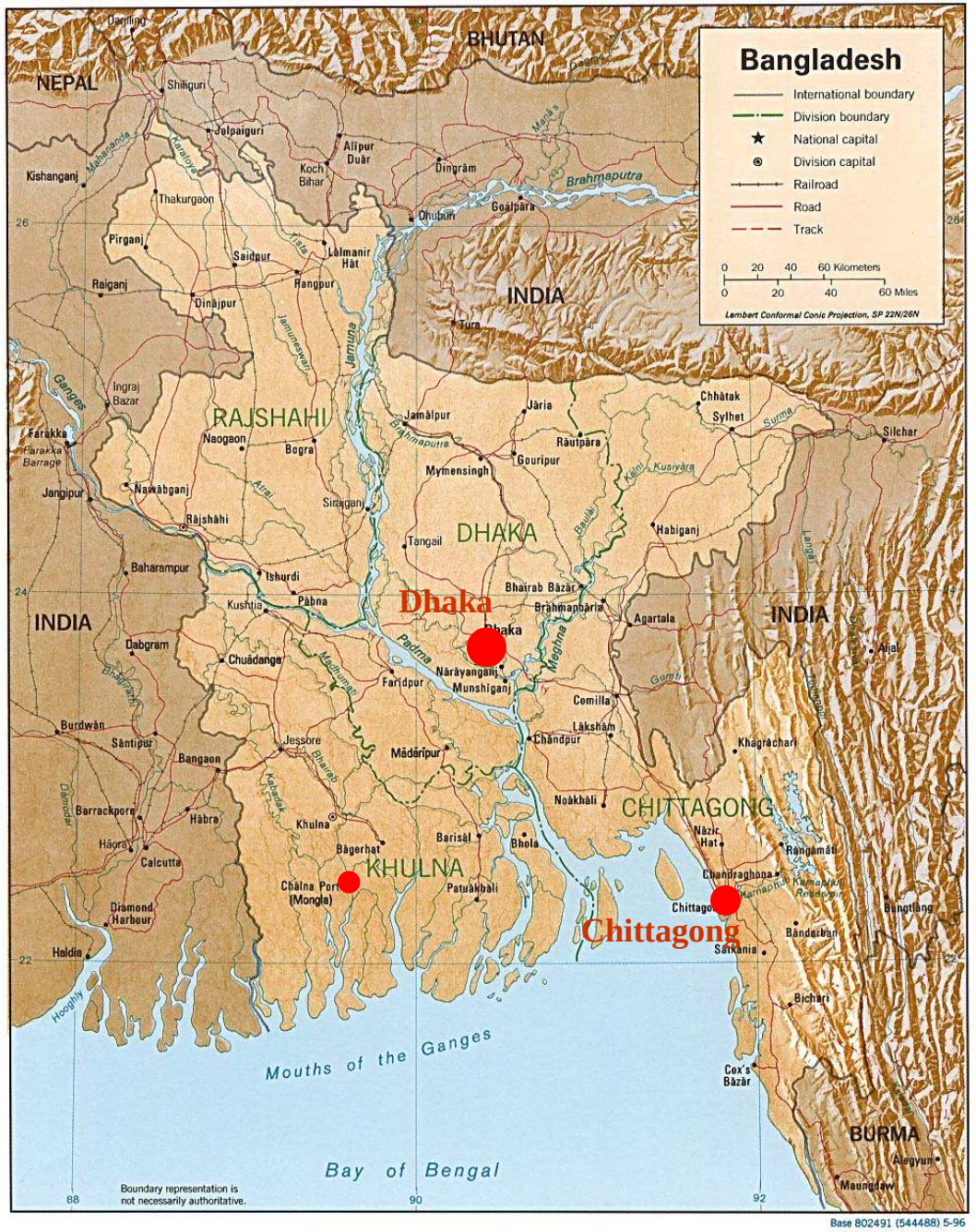
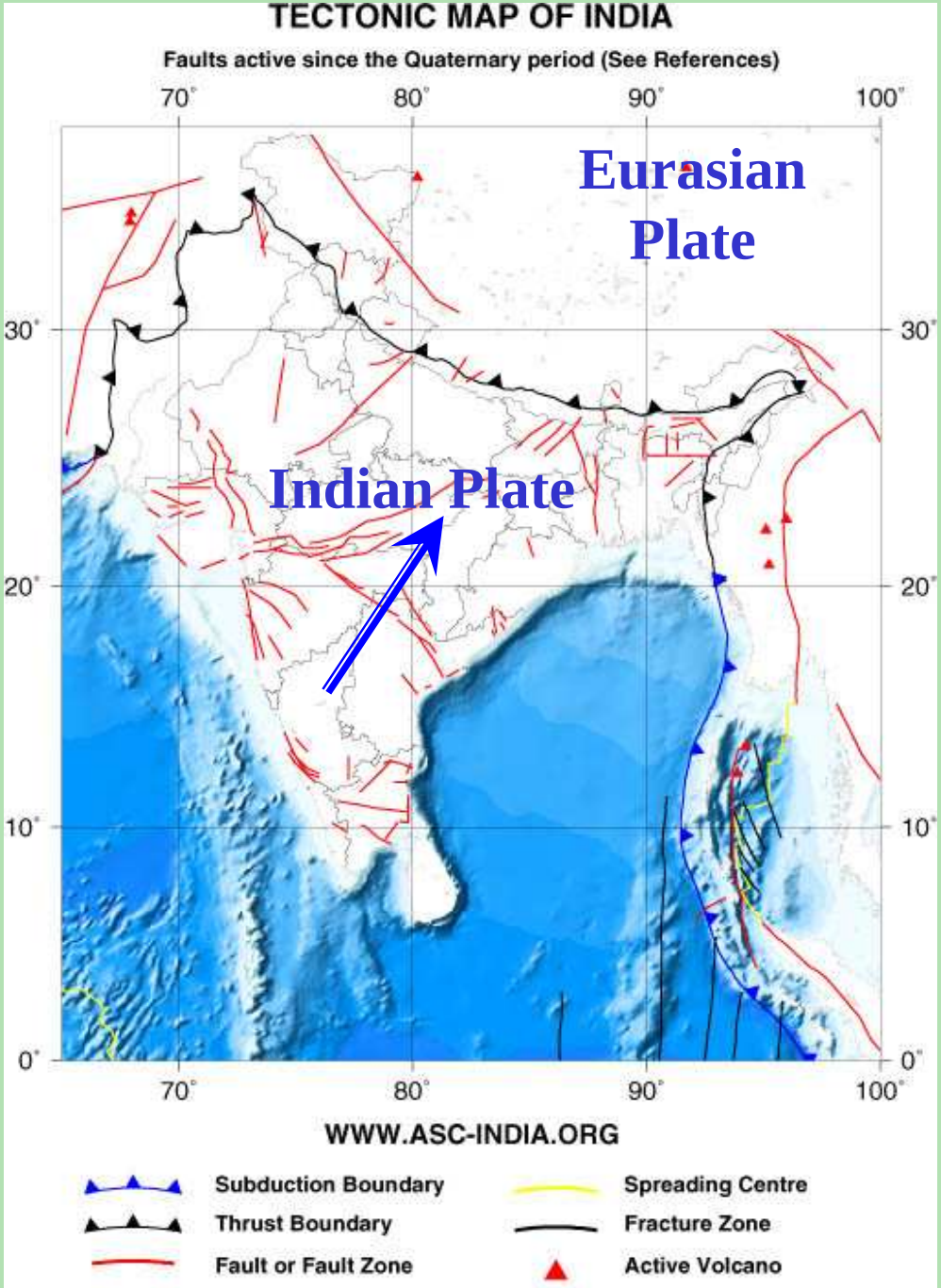
CONTENTS:

- Earthquake Occurrence in and around Bangladesh
- Seismic Hazard Assessment
- Earthquake Vulnerability of Urban Areas
- Local Soil Effects
- Seismic Instrumentation
- Remarks on Research Activity

Bangladesh Landform:

- Area: 147,570 sq.km
- Population 150 million
- **230 Rivers** 2,140 km
- **Deltaic plain** of Ganges, Brahmaputra & Meghna
- **Flat and low topography**
- **Hills in SE and NE**
- 700 km long coastline





Earthquake

- **Bangladesh is located in a tectonically active region close to the plate boundaries of the north moving Indian plate and the Eurasian plate to its north and east.**
- **Lack of earthquake awareness and preparedness may lead to massive disaster if major earthquake strikes.**
- **Recent tremors have frequently shaken the south-eastern region (Chittagong), some have caused damages.**

SEISMICITY IN AND AROUND BANGLADESH

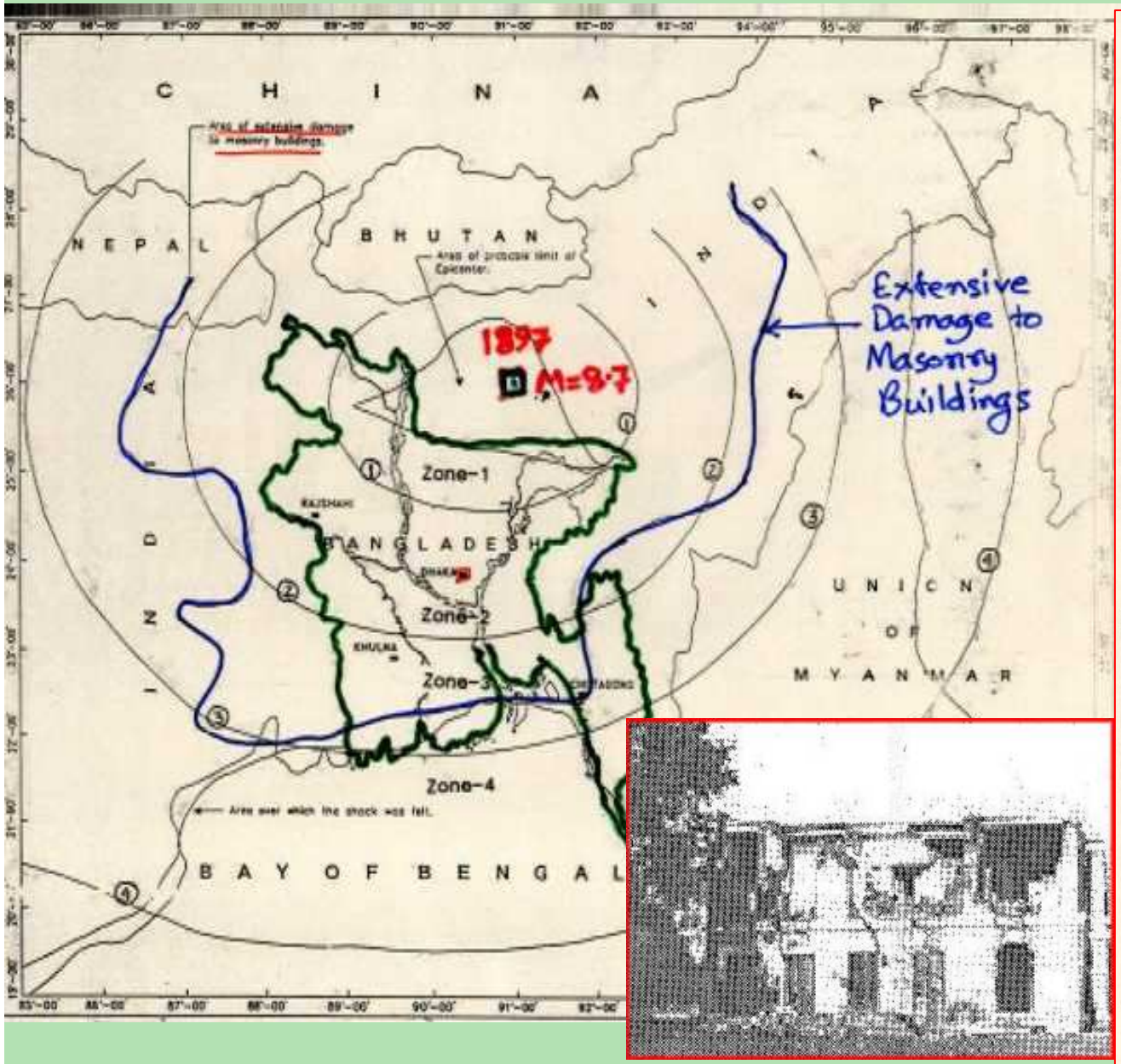
Strong Earthquakes affecting Bangladesh

Date	Earthquake	Magnitude	Distance (km) from Dhaka
10 Jan, 1869	Cachar Earthquake	7.5	250
14 July, 1885	Bengal Earthquake	7.0	170
12 June, 1897	Great Indian Earthquake	8.7	230
8 July, 1918	Srimongal Earthquake	7.6	150
3 July, 1930	Dhubri Earthquake	7.1	250

Five earthquakes (M≥7) during 1869-1930 (61 years)

No large earthquake in last 50+ years!

1897 Great Indian Earthquake (M=8.7)



GEOLOGICAL SURVEY OF INDIA.

R. D. Oldham. Memoirs, Vol. XXIX, Pl. XXV.

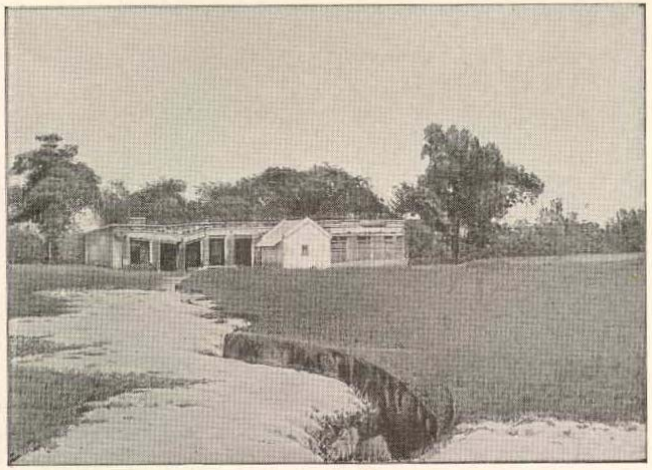


FIG. 1. FISSURE IN COMPOUND OF JUDGE'S HOUSE, RANGPUR.

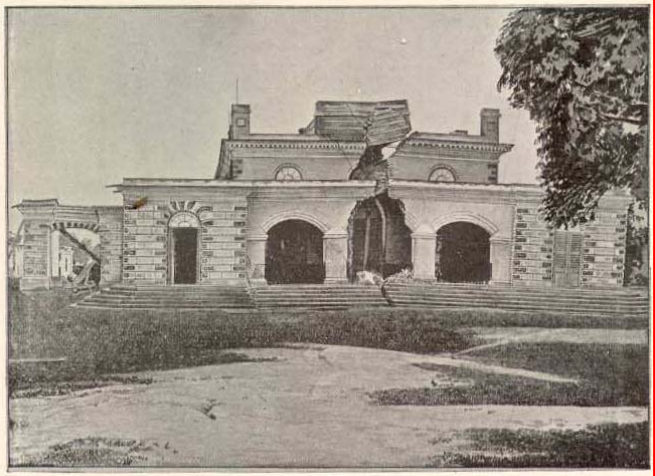


Photo-Block. Survey of India Offices, Calcutta, 1898

FIG. 2. COLLECTOR'S HOUSE, RANGPUR.

1918 Srimangal Earthquake (M=7.6)

GEOLOGICAL SURVEY OF INDIA.

Memoirs, Vol. XLVI, Pl. 1.

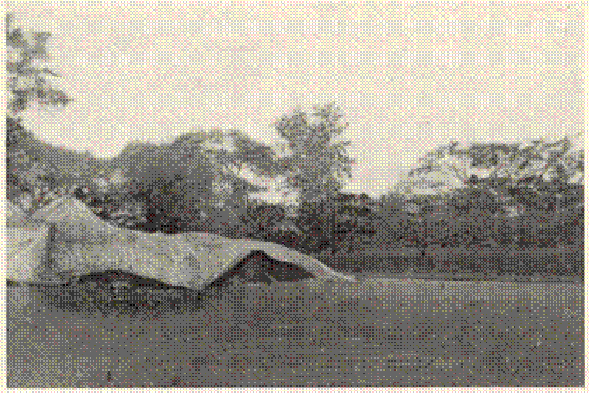
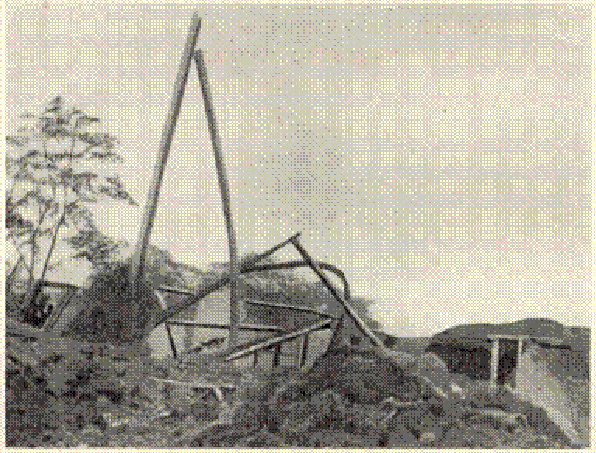


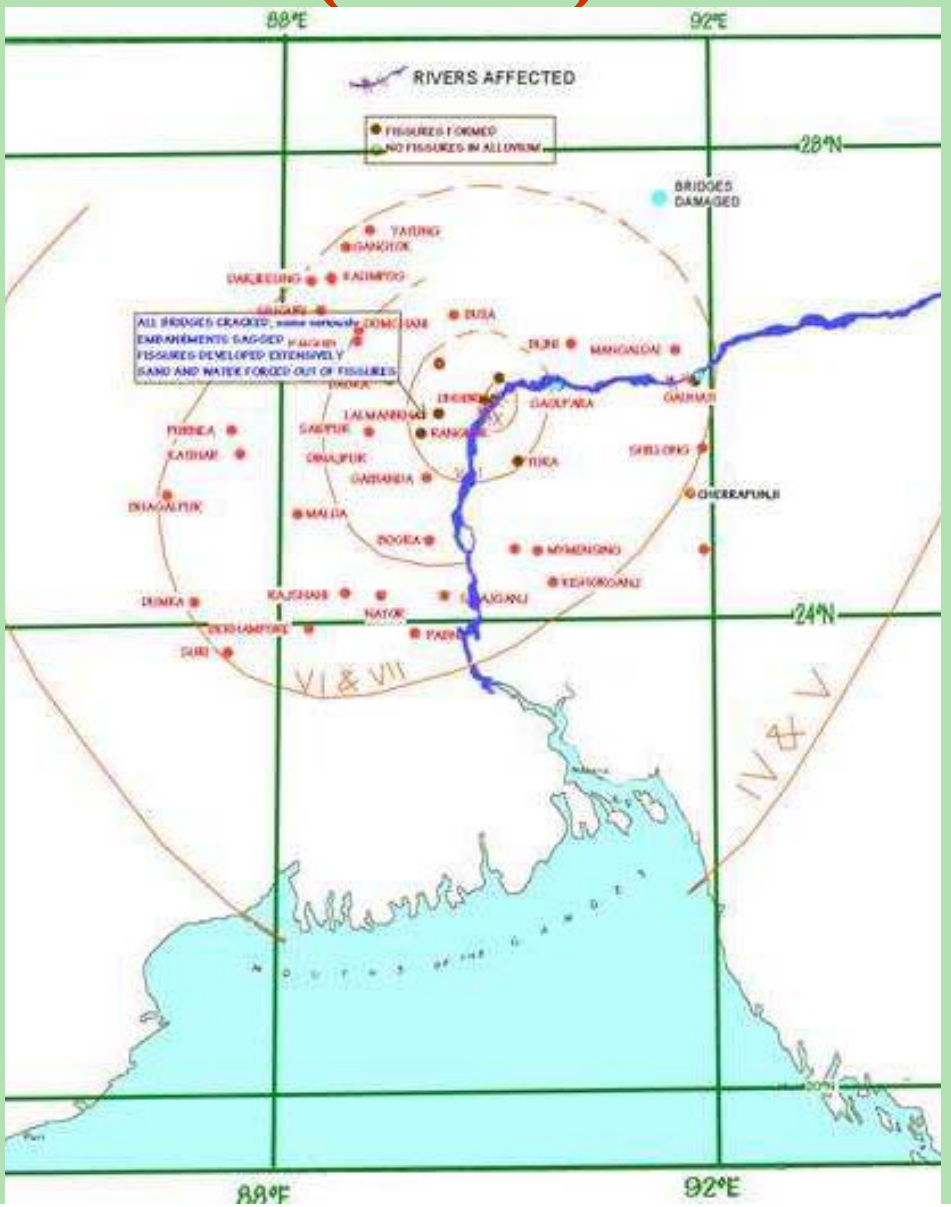
FIG. 1. THE CLUB AT KALIGHAT.



Photograph by Murray Stuart. *G. S. I. Calcutta*

FIG. 2. Dr. MUMFORD'S BUNGALOW AT KALIGHAT.

1930 Dhubri Earthquake (M=7.1)



Moderate Damaging Earthquakes in Bangladesh: Last 10 Years

- **May 1997 earthquake in Sylhet (M=5.6):** Wall Cracks.
- **Nov. 1997 earthquake at Myanmar Border (M=6.0):** Collapse of a building in Chittagong city (18 deaths).
- **July 1999 earthquake in Moheshkhali Island (M=5.1):** Serious damage and collapse of mud-walled houses, Serious damage to a cyclone shelter column
- ***Dec 2001 earthquake near Dhaka city (M=4.2-4.8): Panic & Injuries***
- **July 2003 earthquake in Rangamati (M=5.6):** Serious damage to brick masonry buildings and mud-walled houses. Major cracks in a building in Chittagong.

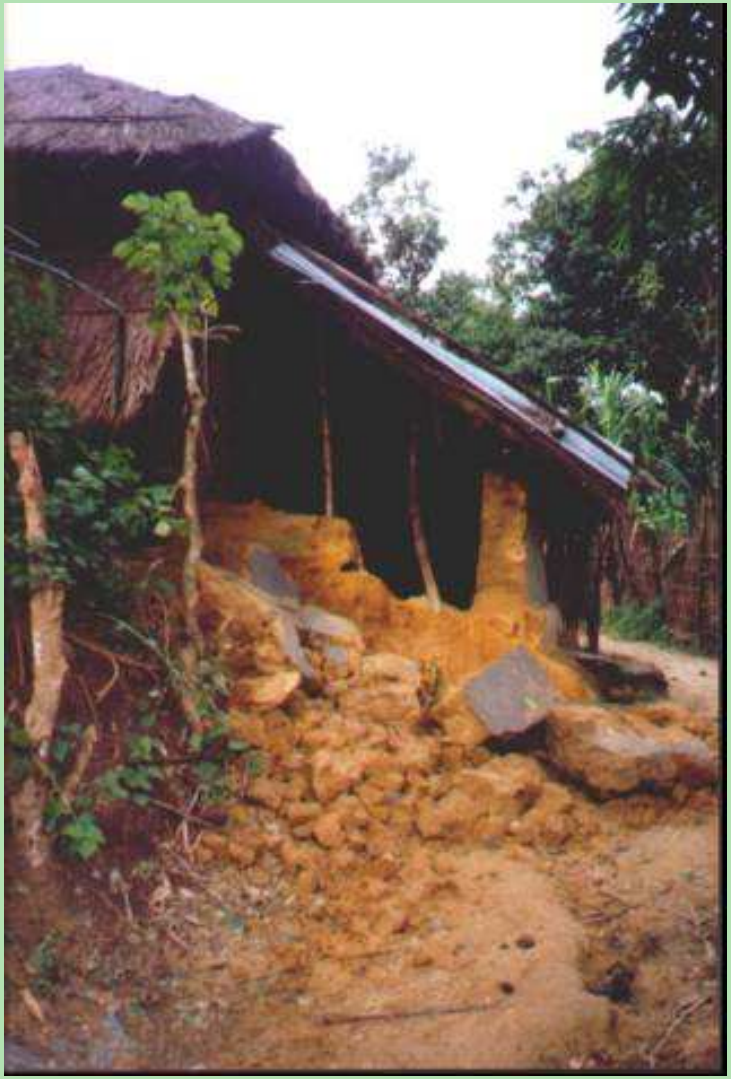
Concrete Frame Building is common in urban areas.

1997 collapse of this reinforced concrete frame building in Chittagong city was trigerred by M=6.0 earthquake more than 100 km away.

Cyclone Shelter

Column damage during 1999 Moheshkhali earthquake (M=5.1)

Mud-walled house in rural areas
(damaged/collapsed during recent earthquakes)



Unreinforced brick masonry buildings with concrete roof common in rural and urban areas

Damaged in an M=5.6 earthquake

Long soil crack along the river

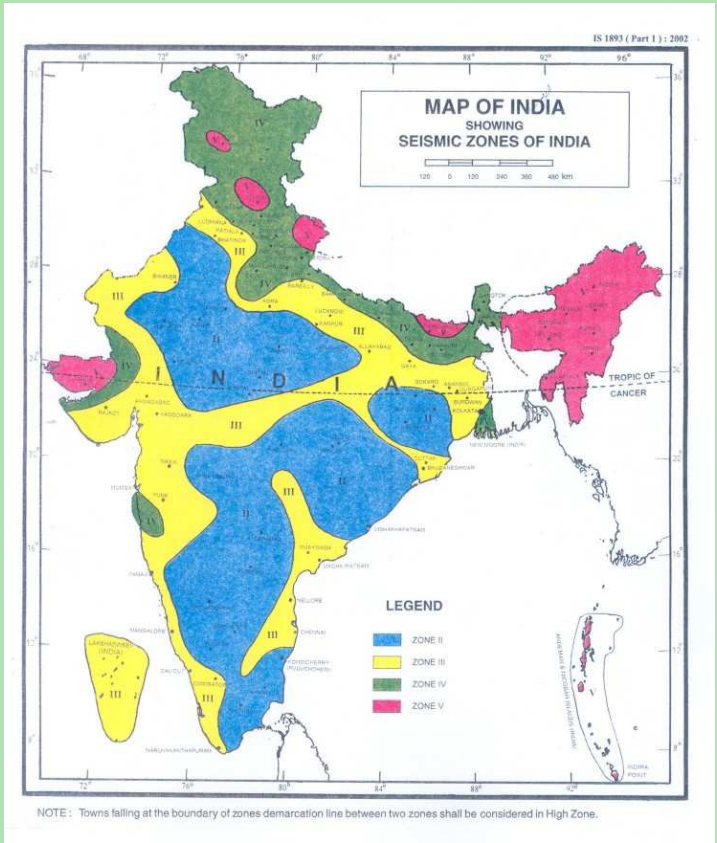
Slumping of soil at river bank

2003 M=5.6 Rangamati Earthquake

SEISMIC HAZARD ASSESSMENT FOR BANGLADESH:

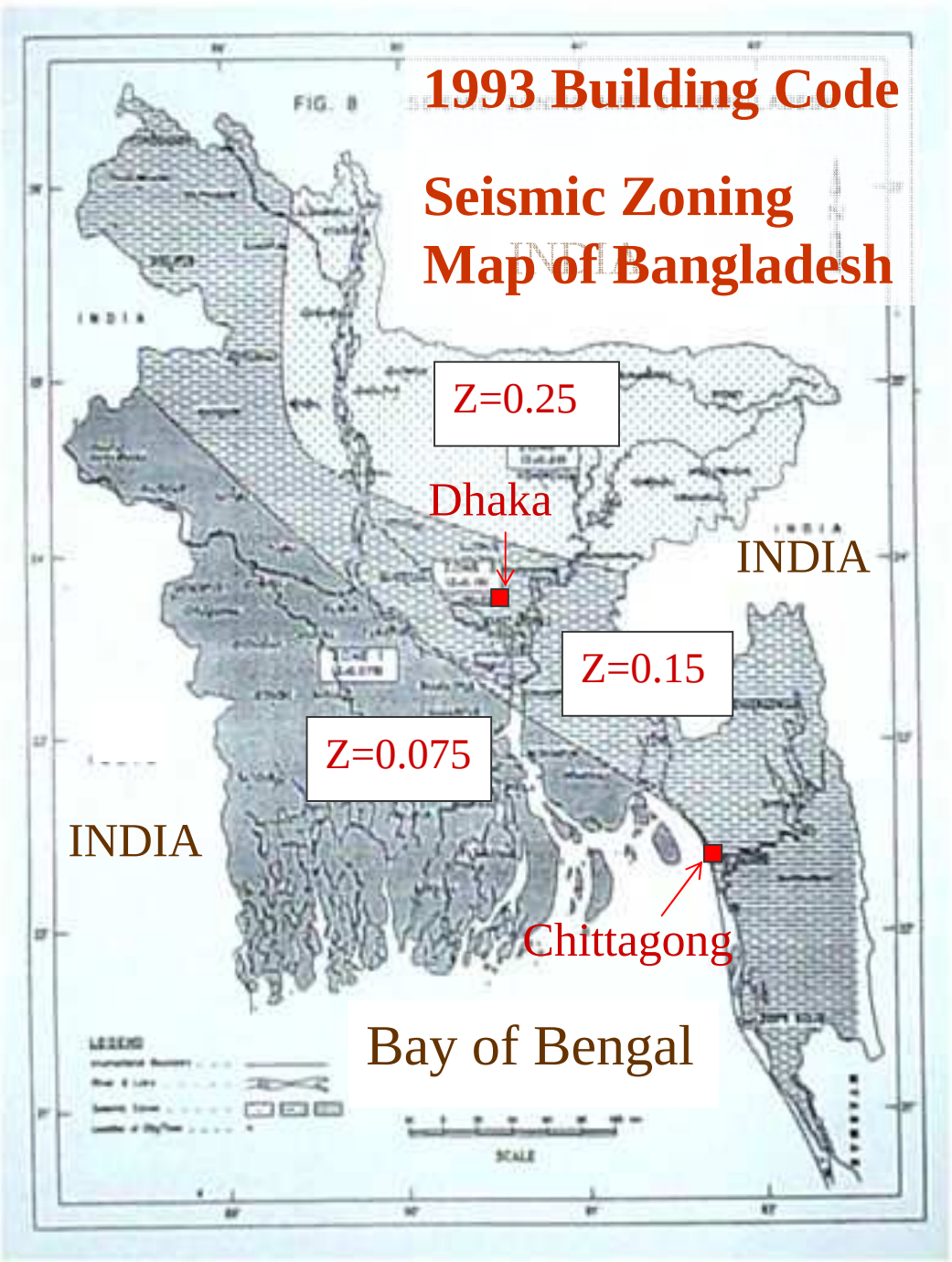
REFERENCE TO 1993 BUILDING CODE

Seismic Zoning Map of India (IS 1893, 2002)



1993 Building Code

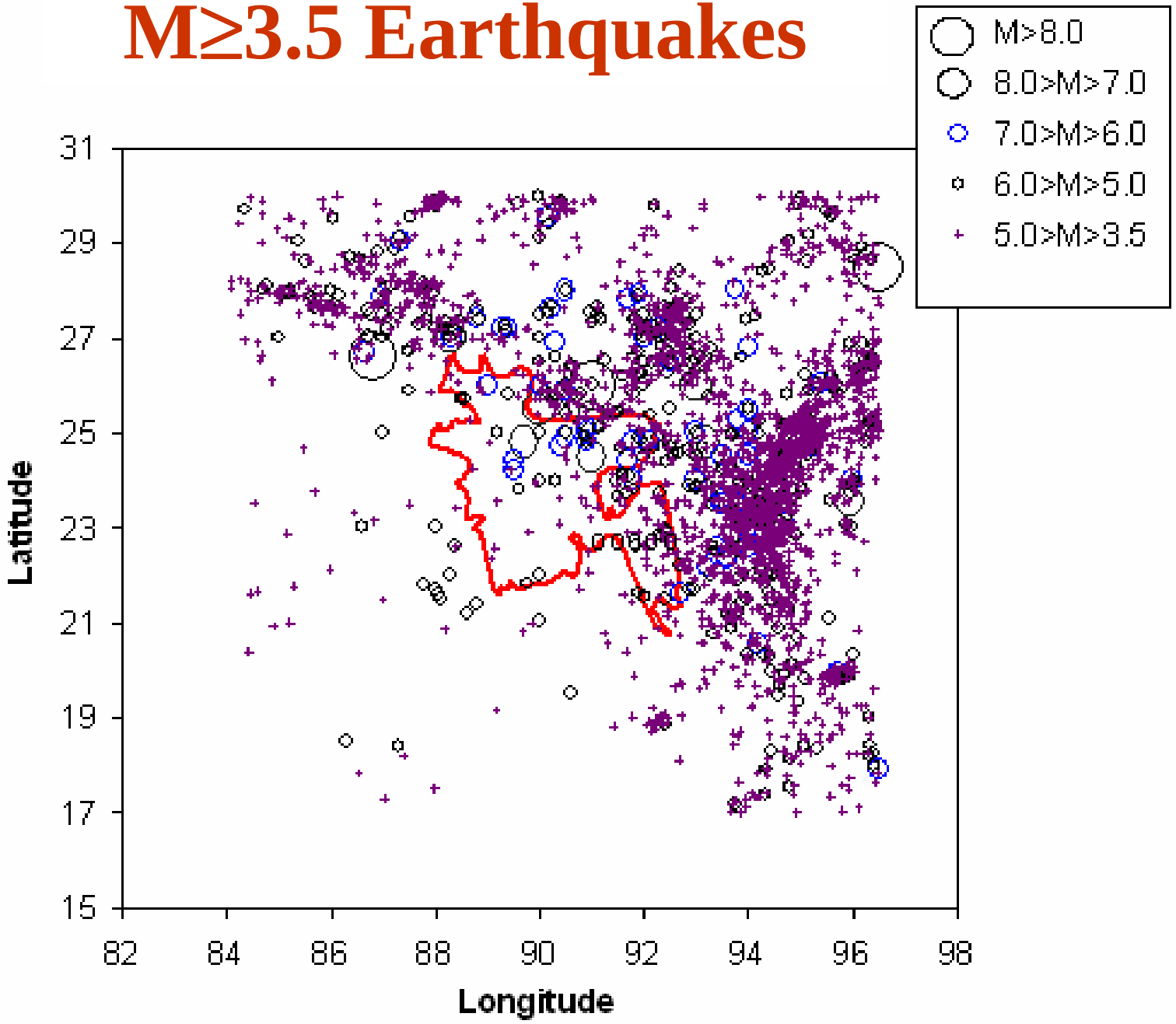
Seismic Zoning Map of Bangladesh

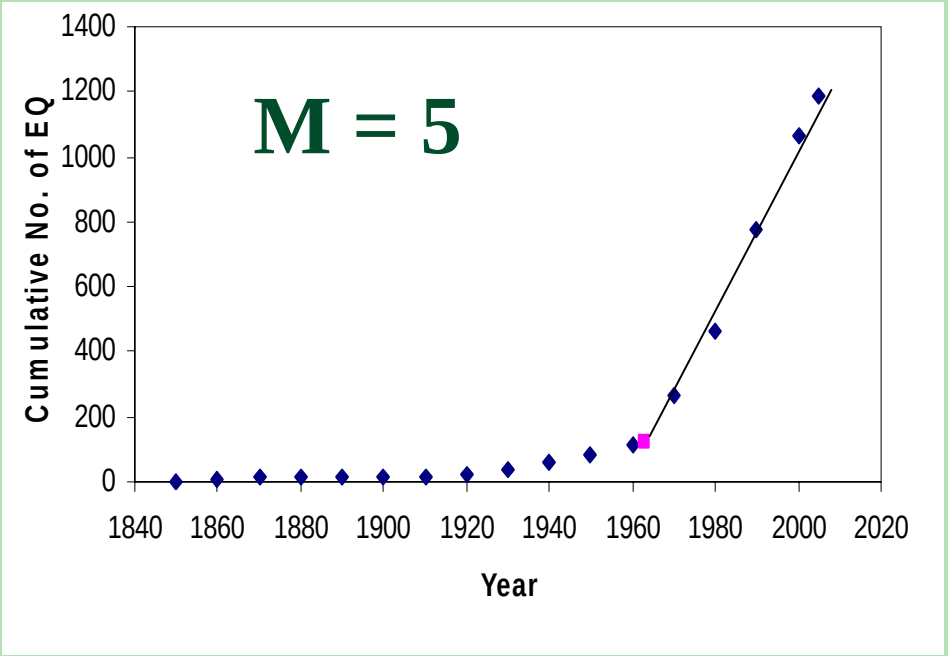


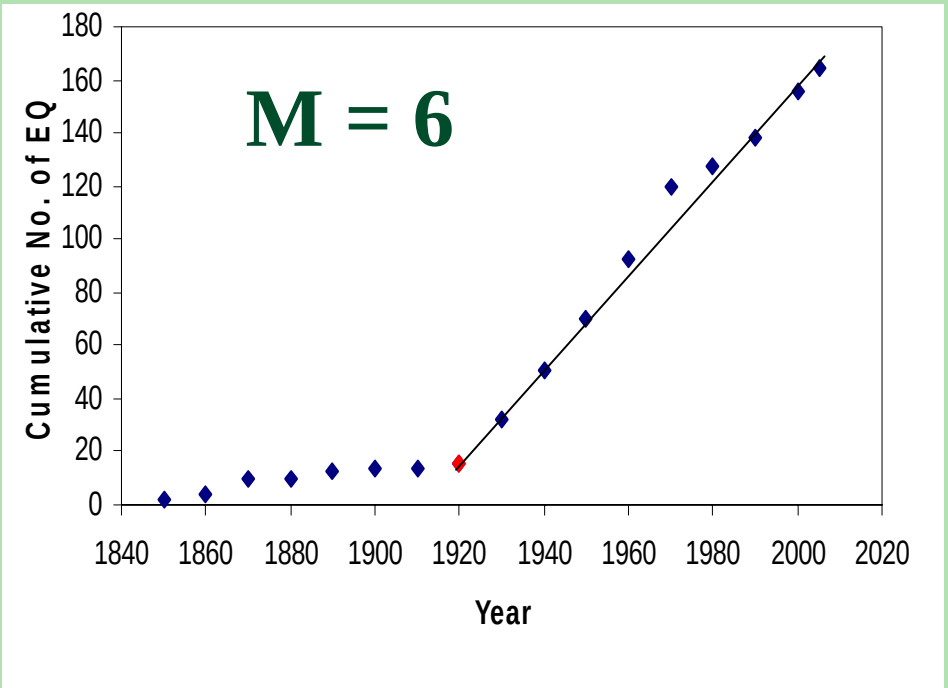
M≥3.5 Earthquakes

Earthquake Catalogue

1845-2005

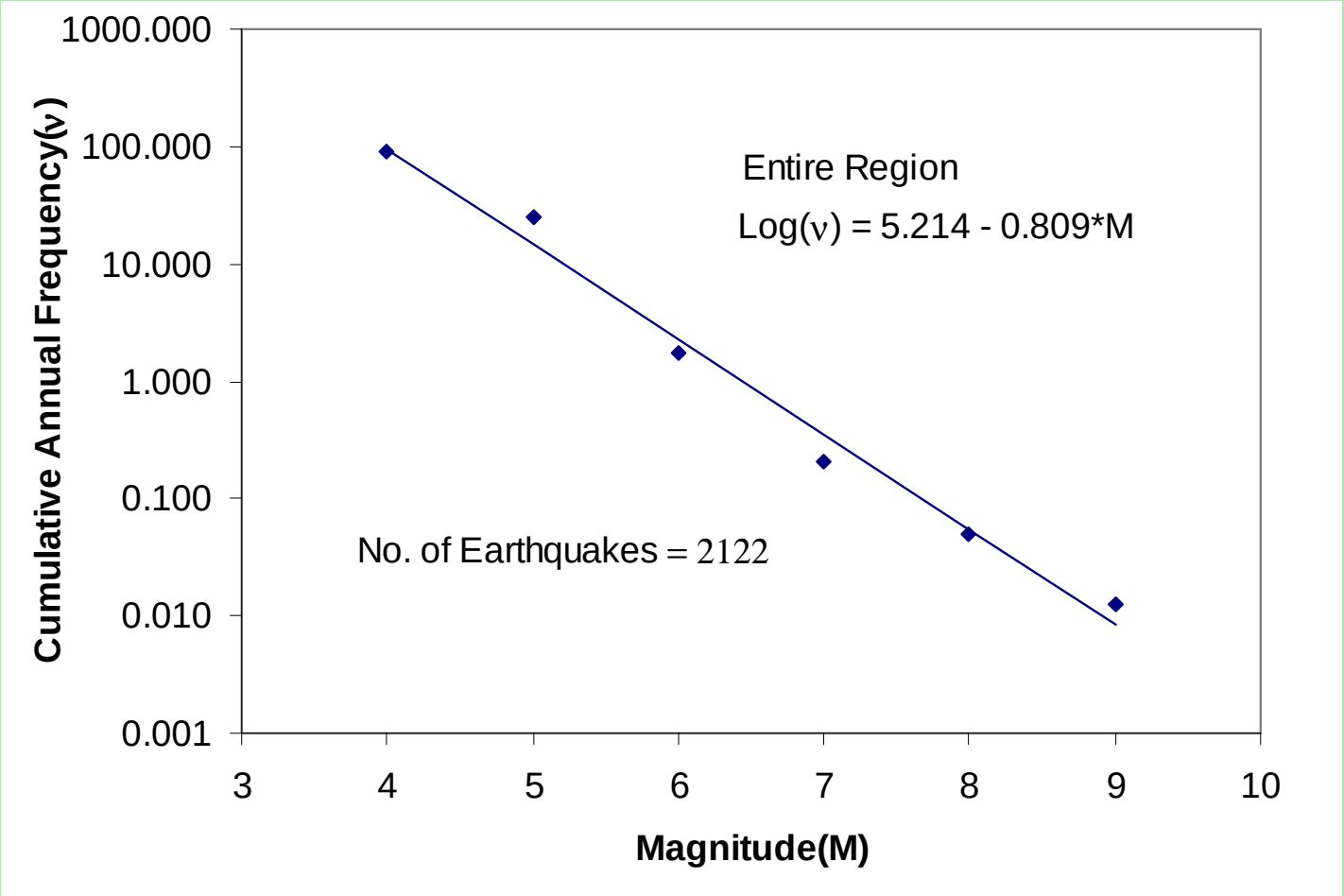






Checking Completeness of Earthquake Catalogue

Magnitude-Frequency relationship for Entire Region



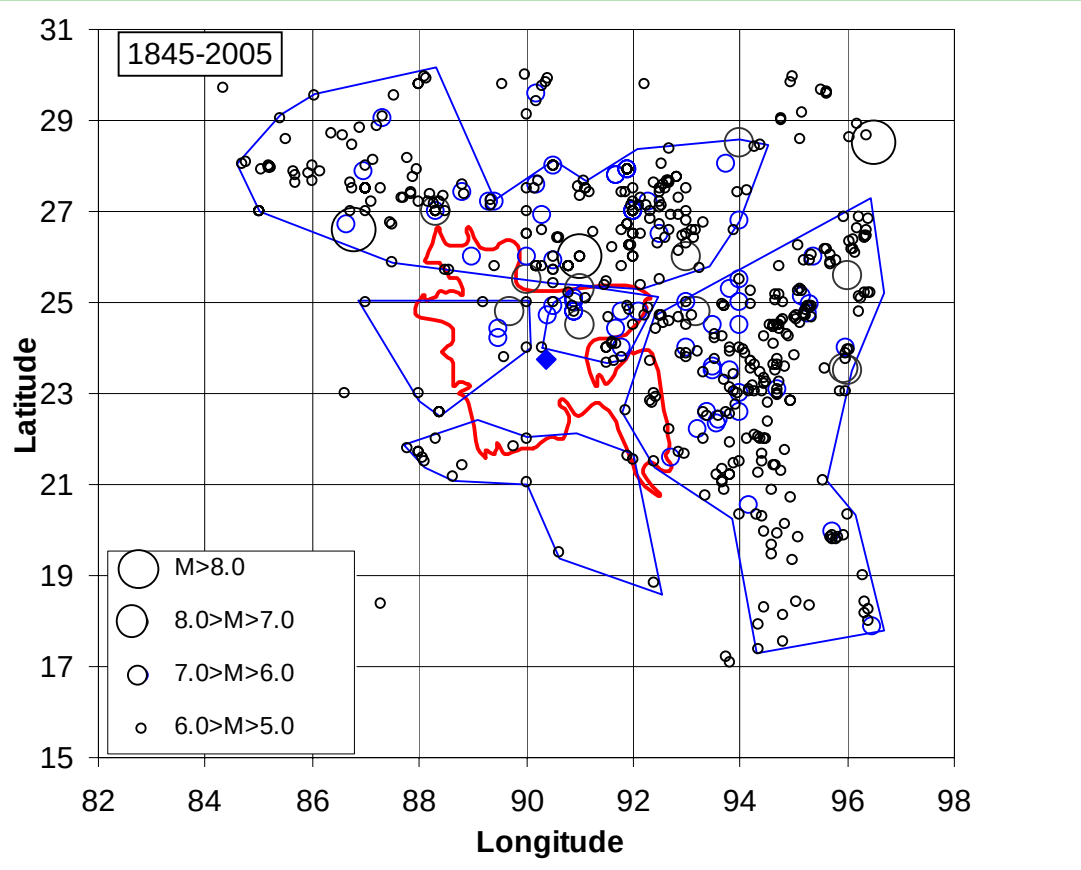
a = 5.21

b = 0.81

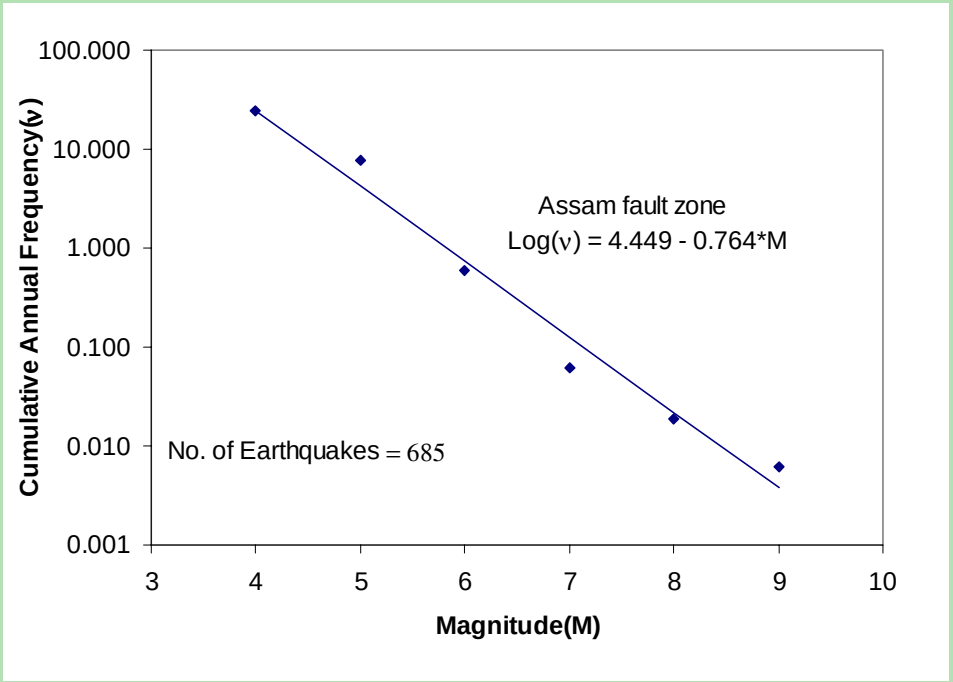
Table 2: Computed a, b values for five seismic source zones

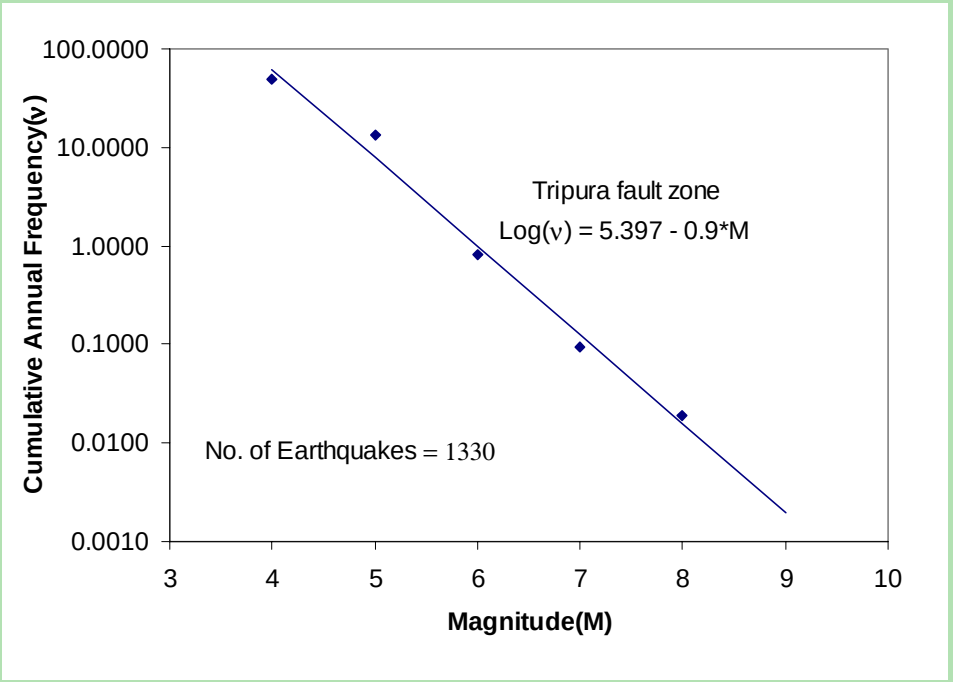
Zone	Location	Number of earthquakes	M_{max}	a	b
1	Assam fault zone	685	**8.7**	**4.449**	**0.764**
2	Tripura fault zone	1330	**7.7**	**5.396**	**0.9**
3	Sub-Dauki fault zone	59	**7.6**	**2.598**	**0.621**
4	Bogra fault zone	9	**7.0**	**3**	**0.809**
5	Coastal source zone	39	**5.7**	**3.389**	**0.793**

Five Seismic Source Zones



Magnitude-Frequency relationship





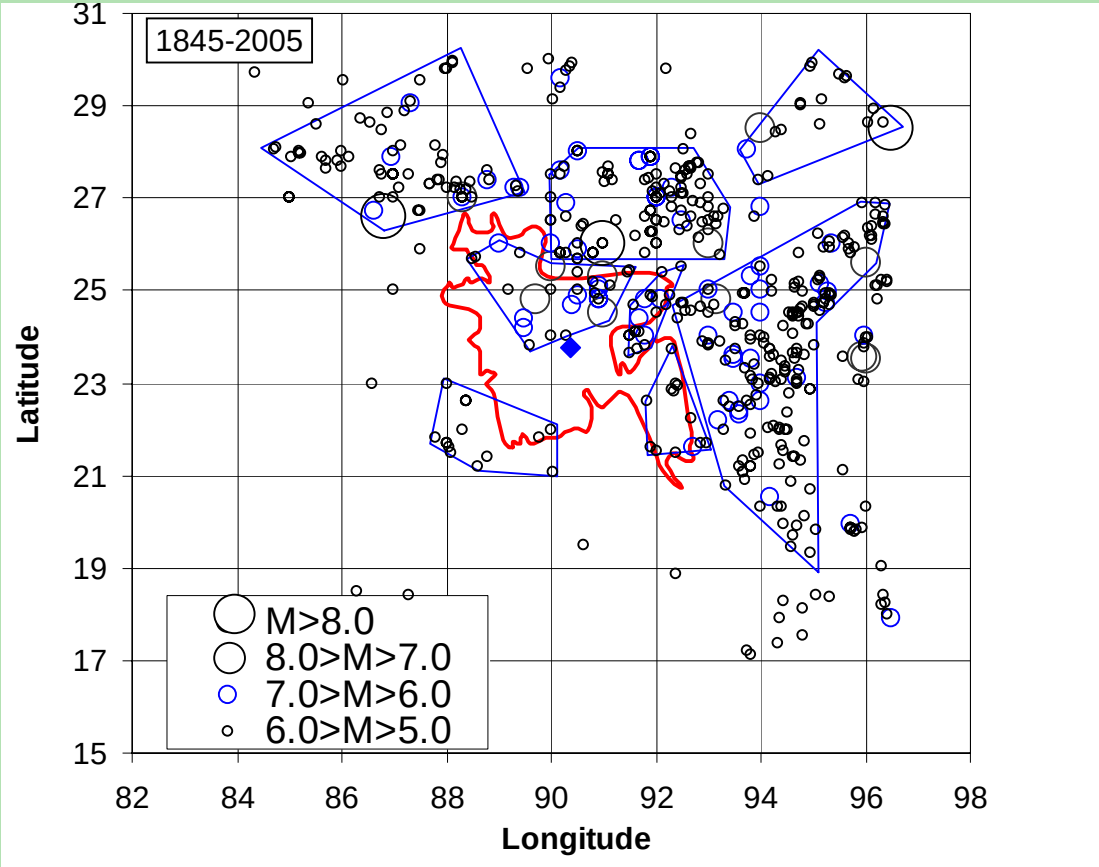
Assam Fault Zone

Tripura Fault Zone

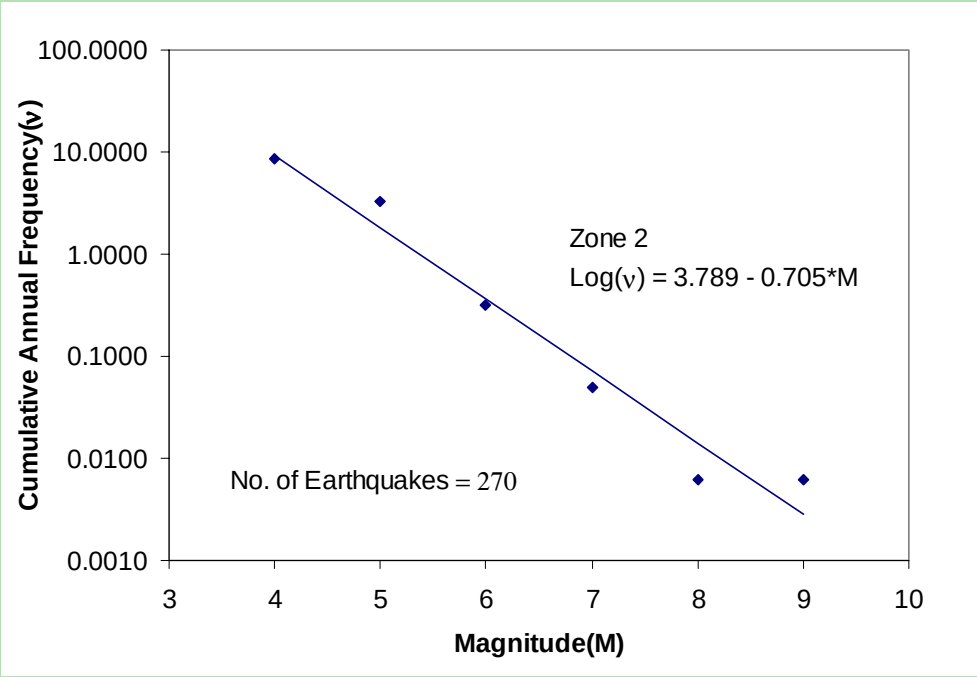
Table 3: Computed a, b values for eight seismic source zones

Zone	Location	Number of earthquakes	M_{max}	a	b
1	Nepal, Darjeeling	315	**8.3**	**4.872**	**0.929**
2	Meghalaya, Assam, Bhutan	270	**8.7**	**3.789**	**0.705**
3	NE Assam, Arunachal	86	**8.6**	**2.616**	**0.571**
4	Rangpur, Bogra, Dinajpur, Mymensingh, Dhaka, Sylhet	47	**7.6**	**2.556**	**0.592**
5	West Sylhet, Tripura	38	**6.5**	**3.116**	**0.73**
6	Southwestern Coastal Region	8	**5.7**	**2.9**	**0.809**
7	Chittagong	41	**6.5**	**3.59**	**0.828**
8	Mizoram, Manipur, NW Myanmar	1092	**7.6**	**5.467**	**0.933**

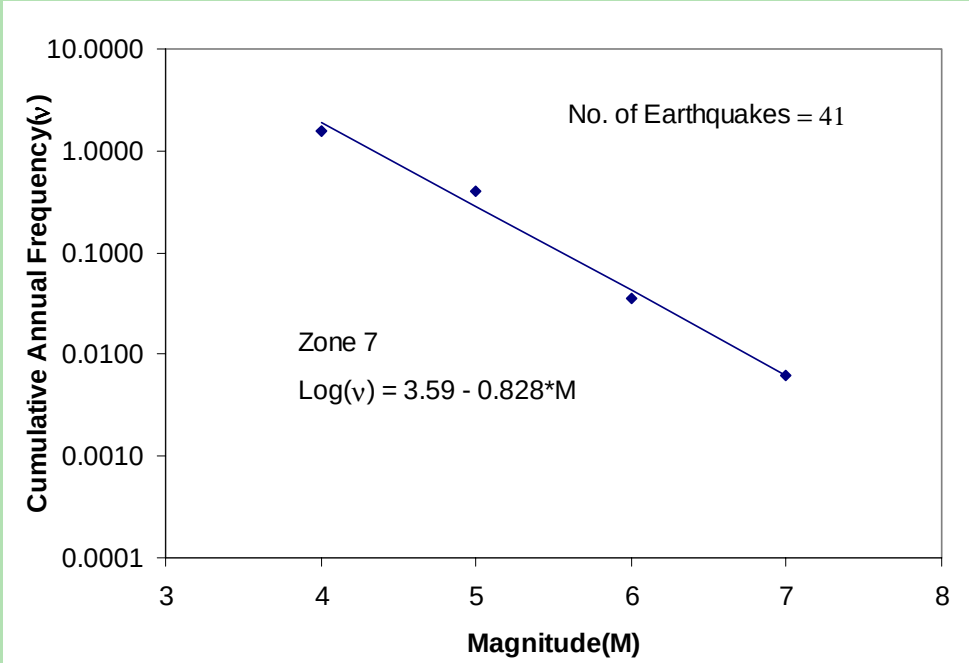
Eight Seismic Source Zones



Magnitude-Frequency relationship



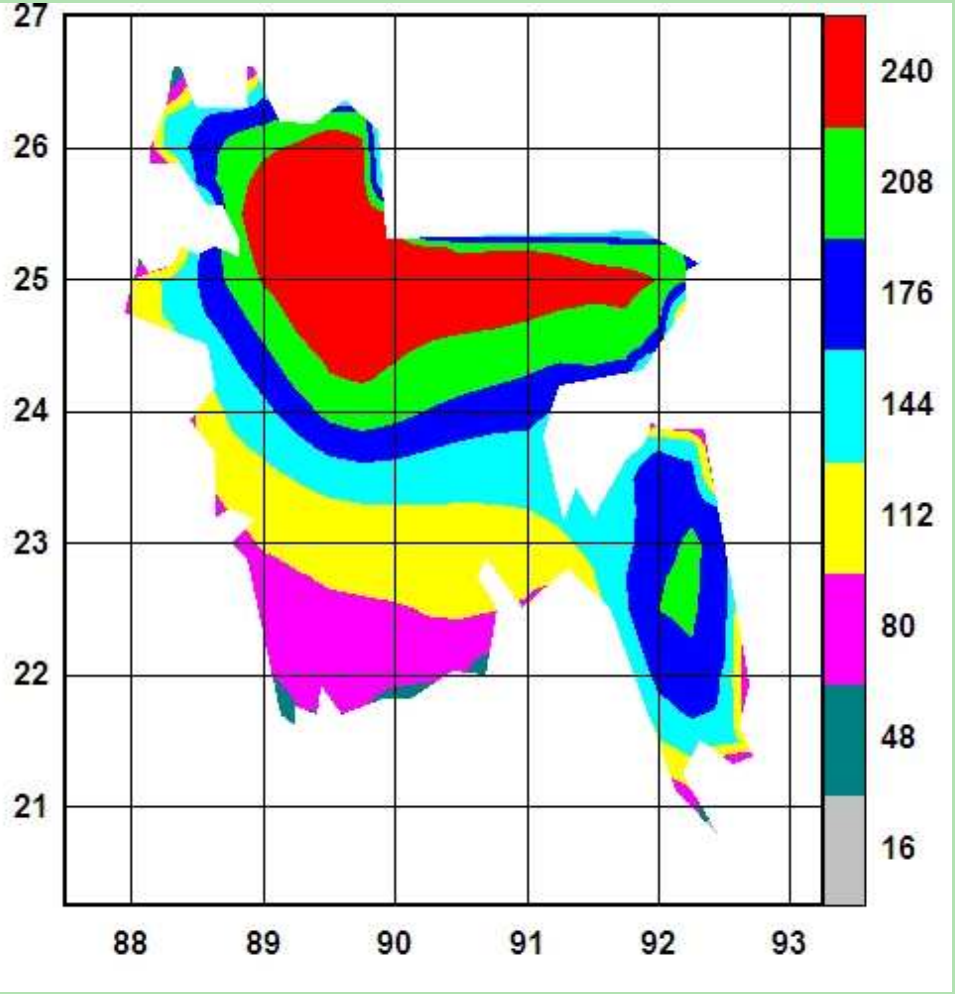
Zone 2 (Assam)



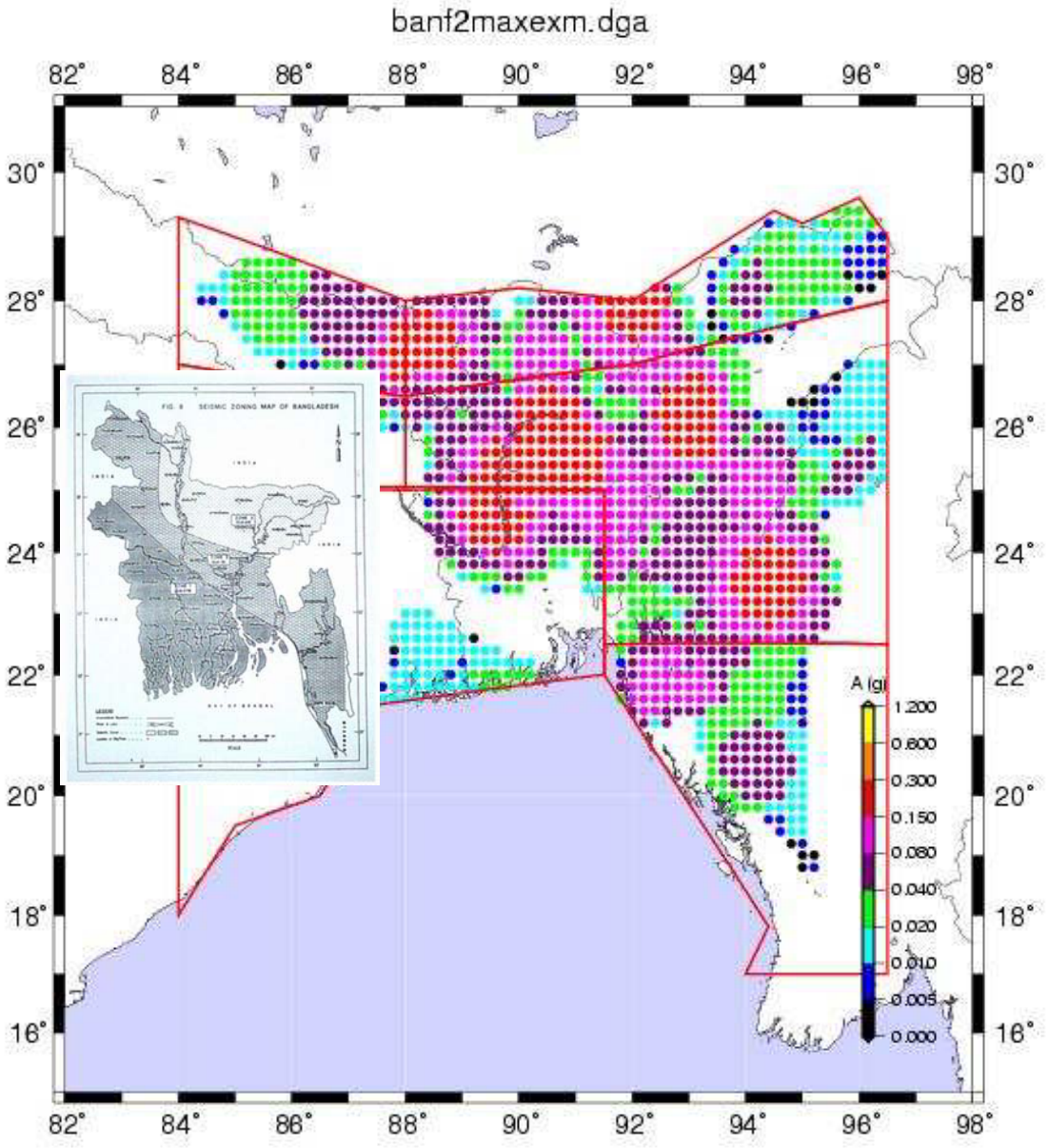
Zone 7 (Chittagong)

Estimation of Probabilistic seismic hazard (PGA in cm/sec^2) for Bangladesh

(8 seismic source zones, return period 500 years)



This is not the final hazard map!

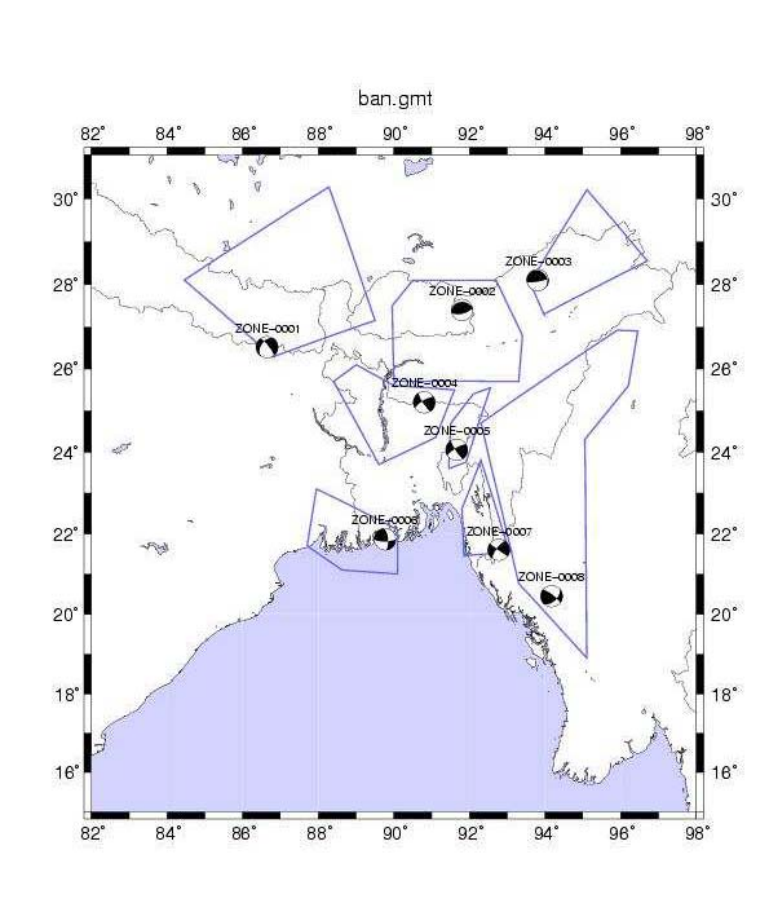


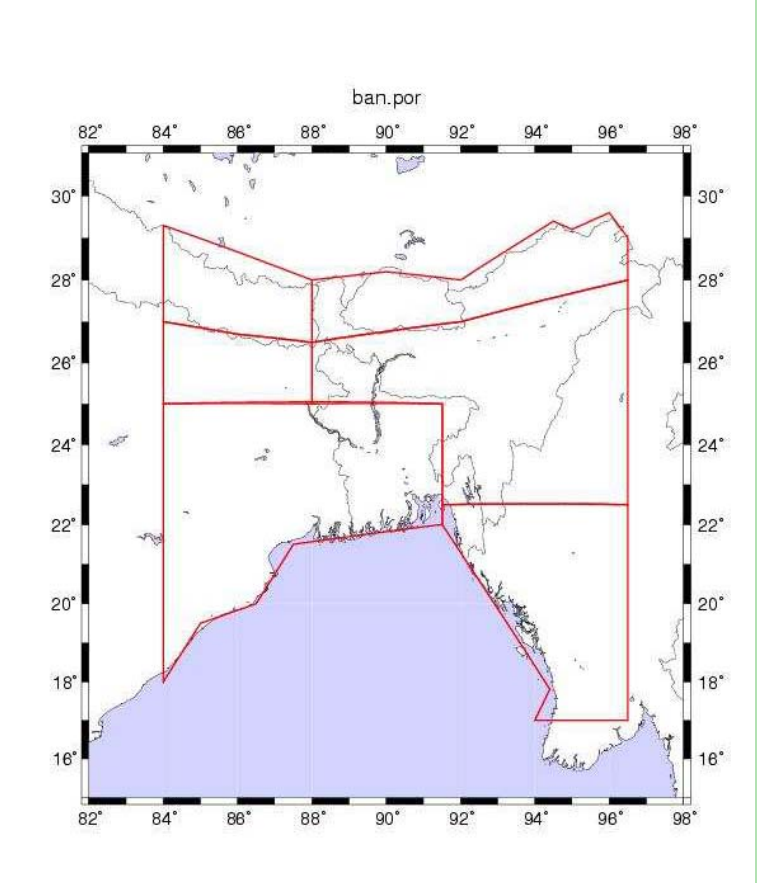
BUET-ICTP Research Collaboration
May-June 2006

DETERMINISTIC SEISMIC HAZARD ASSESSMENT FOR BANGLADESH

Peak Ground Acceleration (PGA) in g

Large Earthquakes greater than 7.4 have not been considered here, which will be considered later.

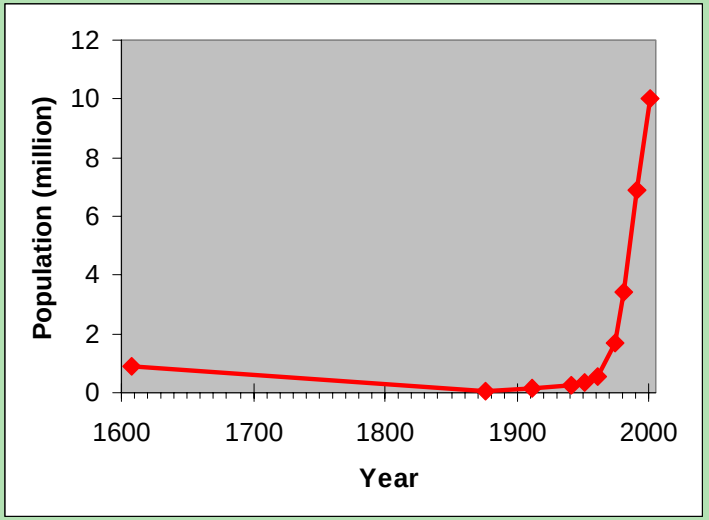

ban.gmt
ZONE-0001
ZONE-0002
ZONE-0003
ZONE-0004
ZONE-0005
ZONE-0006
ZONE-0007
ZONE-0008


ban.por

EARTHQUAKE VULNERABILITY OF URBAN AREAS

DHAKA CITY

A congested city



Population growth

Old Brick Buildings and Roof framing

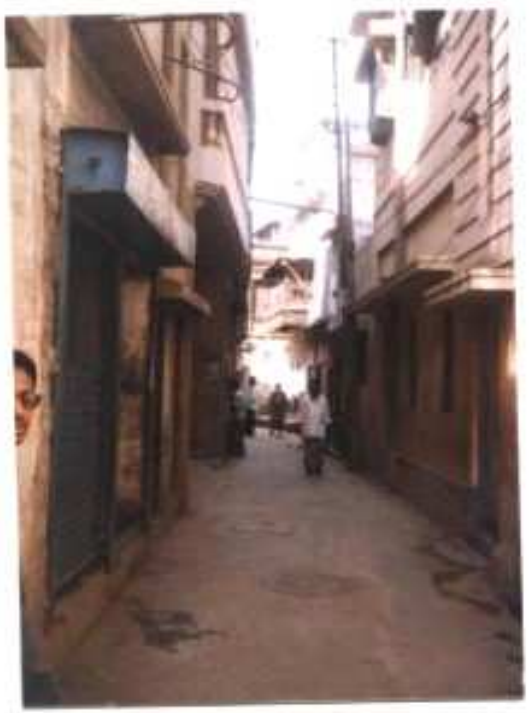
INDUCED FIRE RISK

Gas Oven

Risky Electrical Wiring

Narrow Lane

Narrow Roadways



High-Rise Building

Residential Area

Irregular Building

Open Ground Story (Car parking) 6-Storied Apartment Building

Possibility of pounding

Predicted Damage due to Intensity VIII earthquake in selected parts of Dhaka city

Thana	Sutrapur	Lalbagh	West Dhanmondi
URM:RCF buildings	65 : 35	49 : 51	32 : 68
Complete/Partial Collapse of URM/RCF buildings	5.8 %	5.5 %	5.3 %
Number of people at high risk of death and serious injury	18,600	27,300	18,800
Serious damage of buildings	16.7 %	13.5 %	10.1 %

LOCAL SOIL EFFECTS IN DHAKA CITY (MODERATE SEISMIC RISK):

REFERENCE TO 1993 BUILDING CODE

Bangladesh National Building Code (1993)

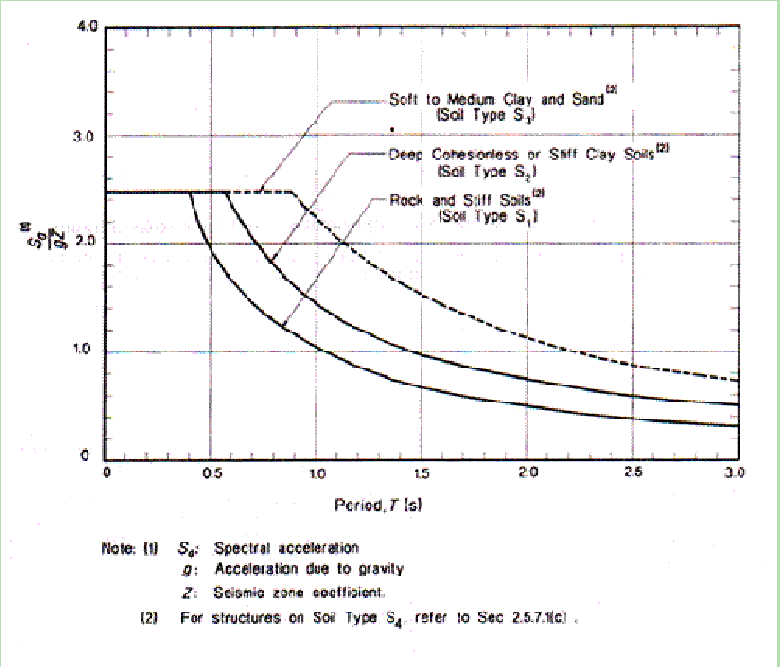
- Soils classified as S1, S2, S3, S4
- Three methods for seismic analysis

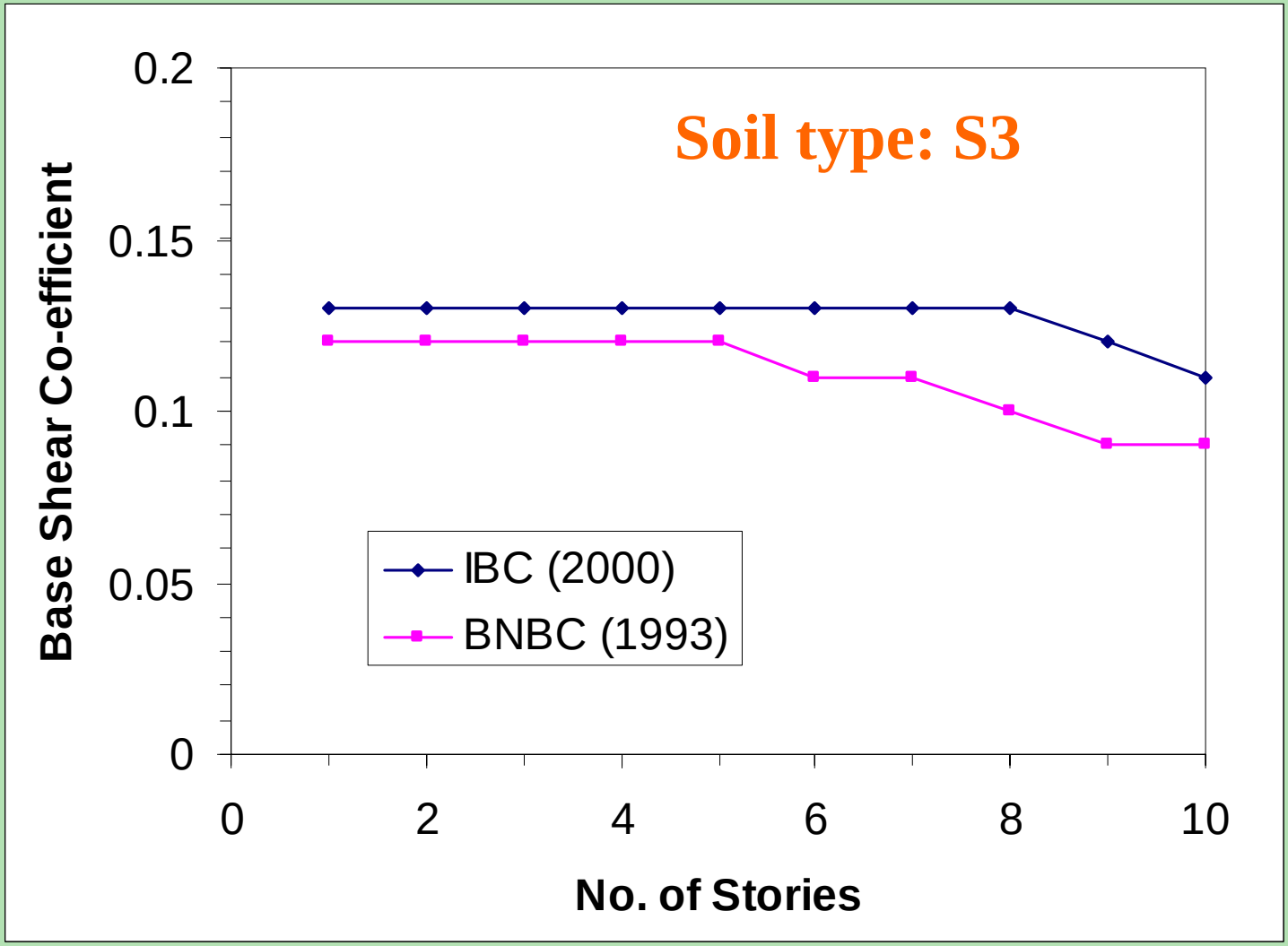
(a) Equivalent Static Force …….*Soil factor S=1, 1.2, 1.5, 2.0*

(b) Response Spectrum……*Response Spectrum Curves for S1, S2, S3*

(c) Time History Analysis

Soil classification	Site soil characteristics	Soil factor
S1	Rock-like material characterized by a shear wave velocity > 762 m/sec, or Stiff or dense soil conditions where soil depth<61 m	1.0
S2	Soil profile with dense or stiff soil conditions, where soil depth > 61 m.	1.2
S3	Soil profile 21 m. or more in depth and containing more than 6 m. of soft to medium stiff clay but not more than 12 m. of soft clay.	1.5
S4	Soil profile containing more than 12 m. of soft clay characterized by shear wave velocity < 152 m/sec	2.0





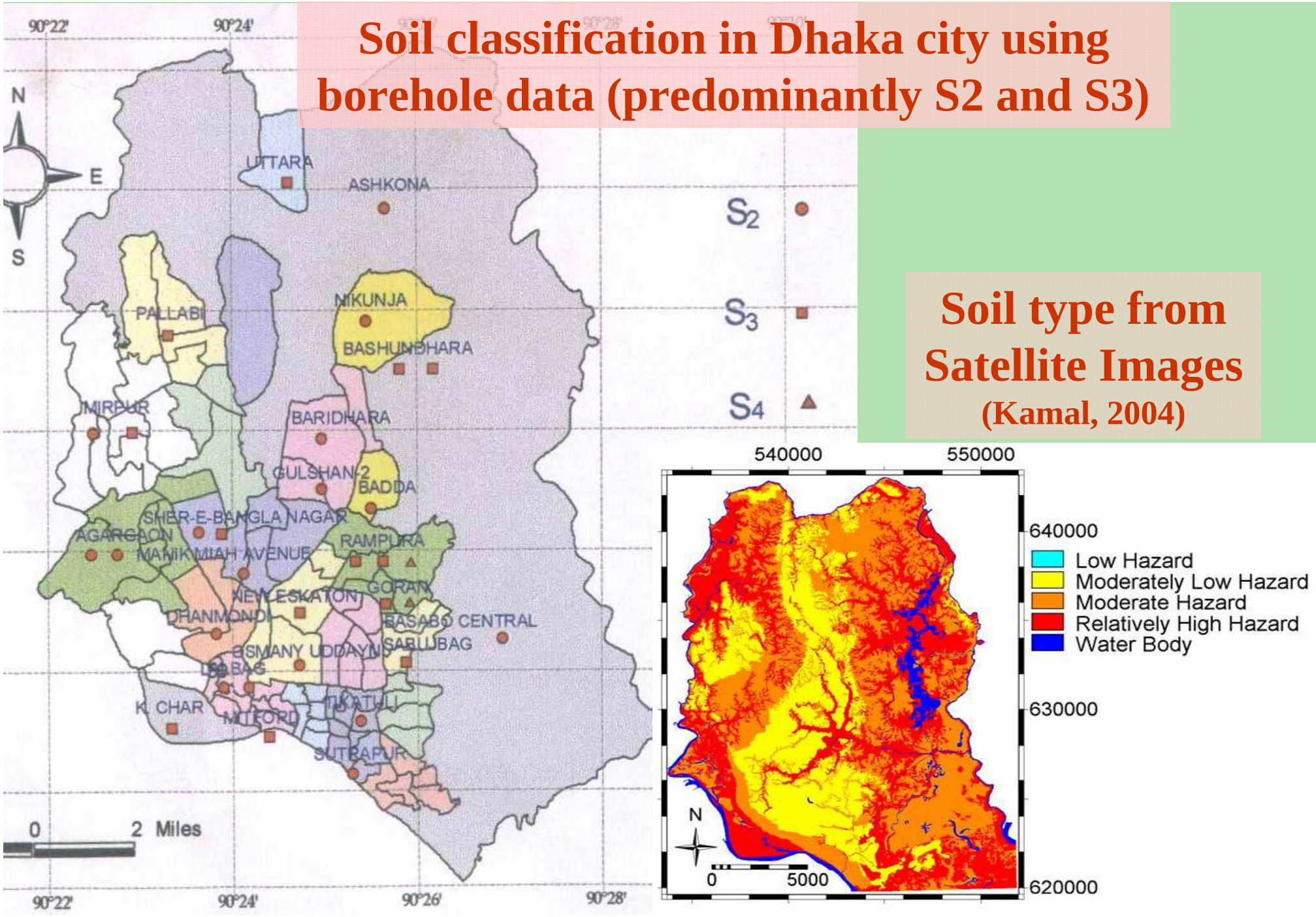
BNBC (1993)

vs.

IBC (2000)

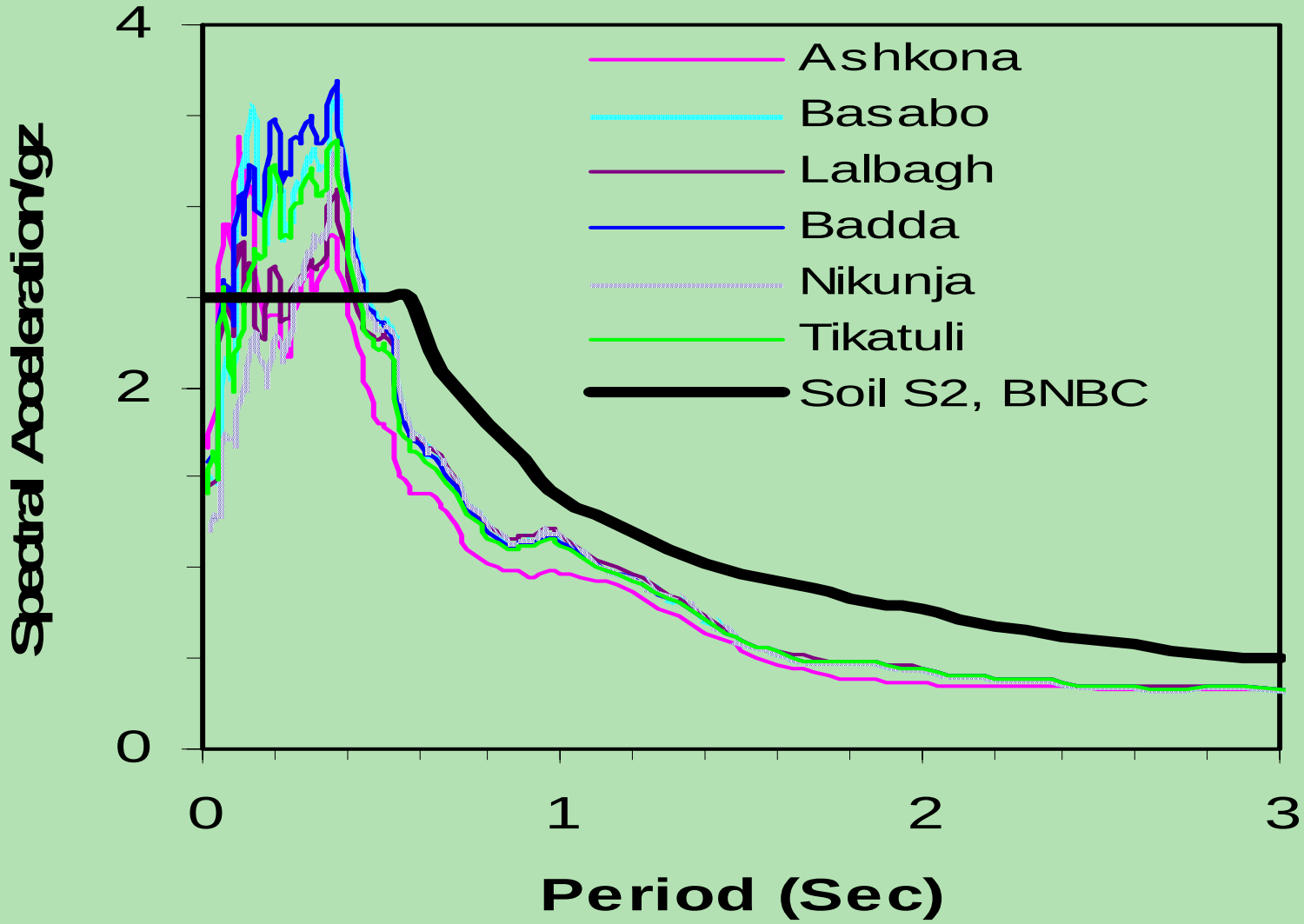
Taller buildings (6 stories or more) are subjected to larger base shear than what BNBC suggests

Soil classification in Dhaka city using borehole data (predominantly S2 and S3)

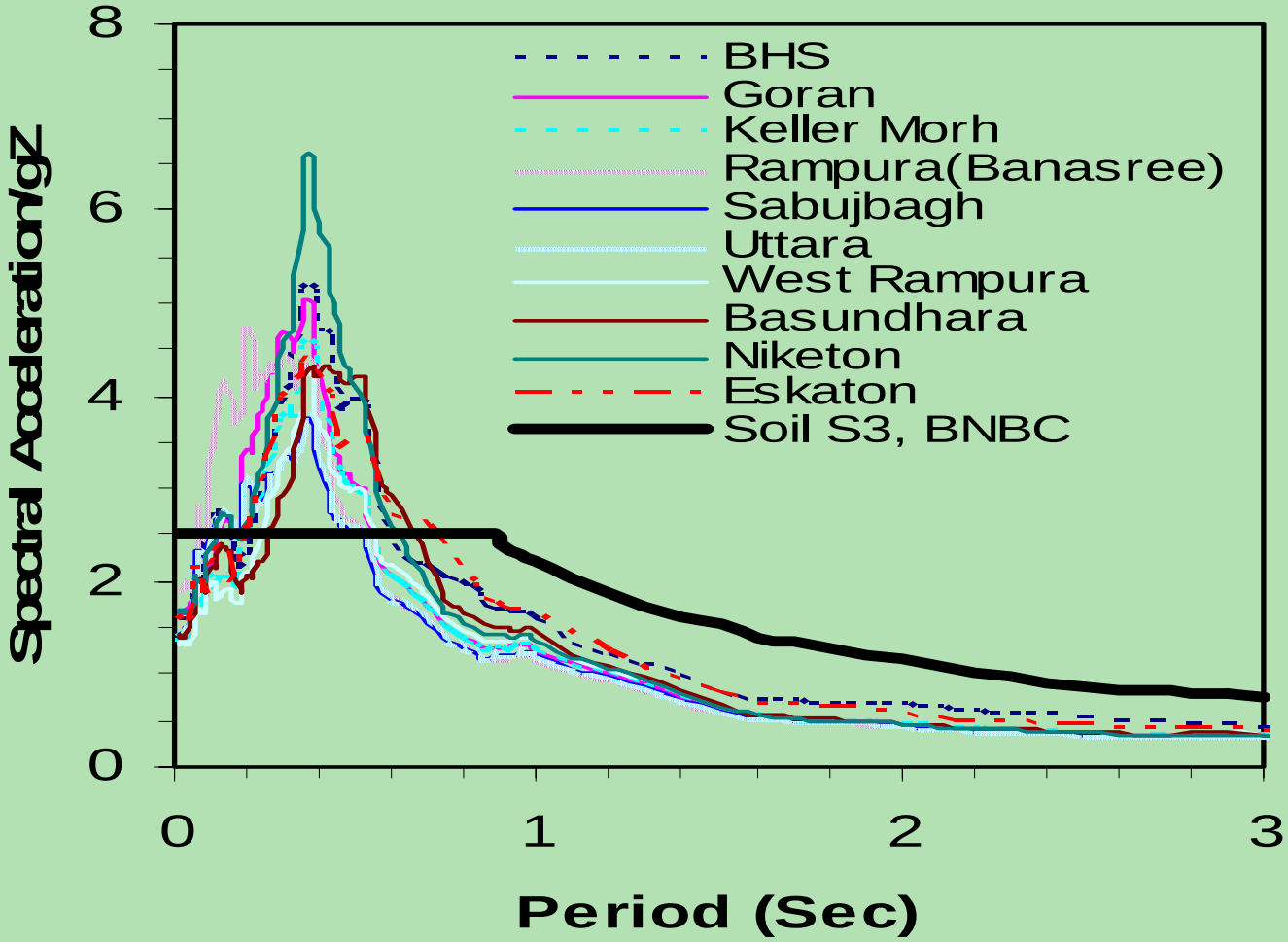


Soil type from Satellite Images (Kamal, 2004)

Response Spectrum (wave propagation analysis) obtained for Various S2 Sites in Dhaka City



Response Spectrum (wave propagation analysis) obtained for Various S3 Sites in Dhaka City



Remarks on Local Soil Effects:

- **Equivalent static load method:**

  BNBC appears to be unsafe for buildings 6 stories and taller when compared with recent IBC code.

- **Response spectrum method:**

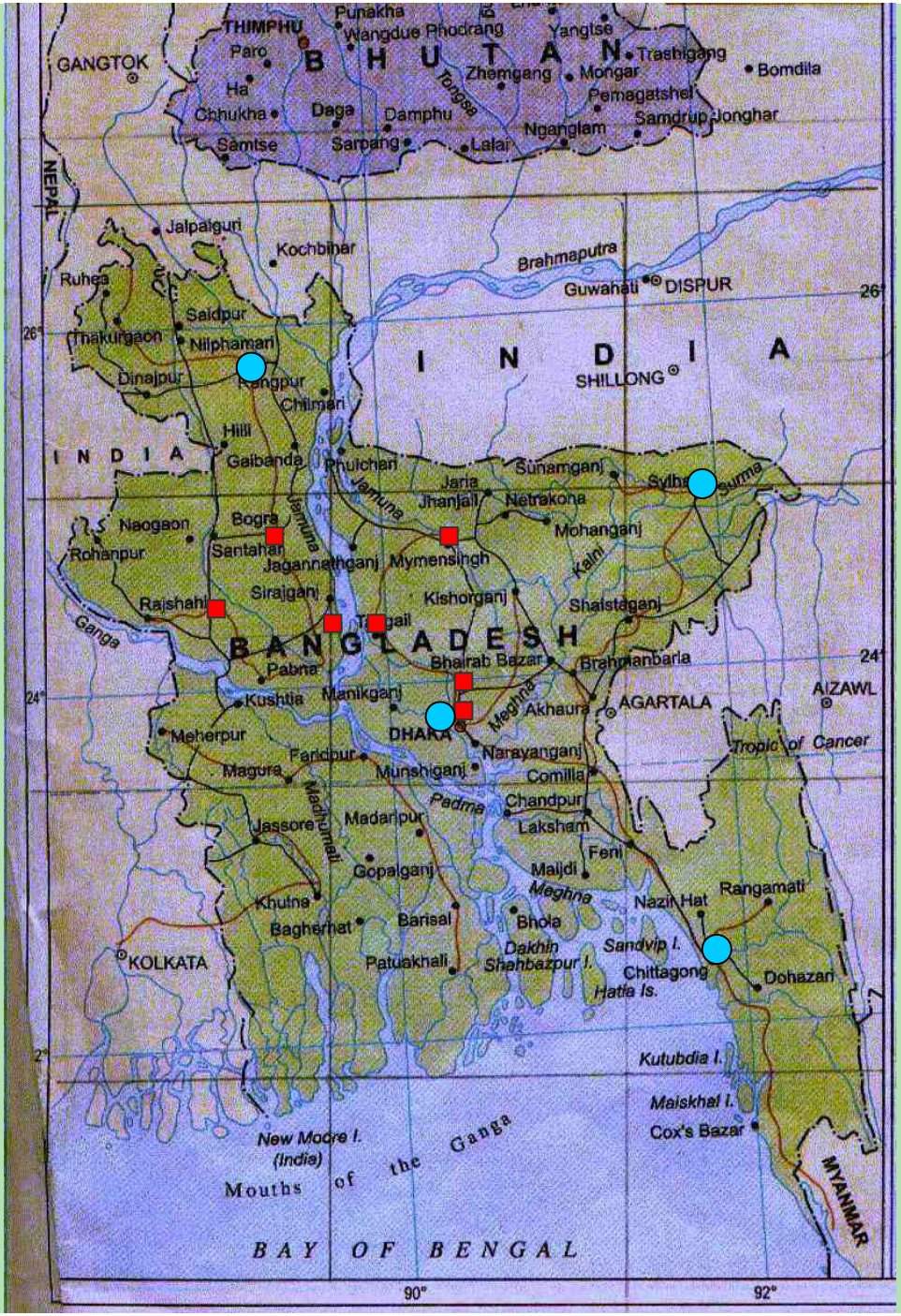
  BNBC design response spectra appear to underestimate peak spectral acceleration as shown by wave propagation analysis results.

- **Geotechnical earthquake design provisions in BNBC needs major revision.**

DIGITAL SEISMIC INSTRUMENTATION

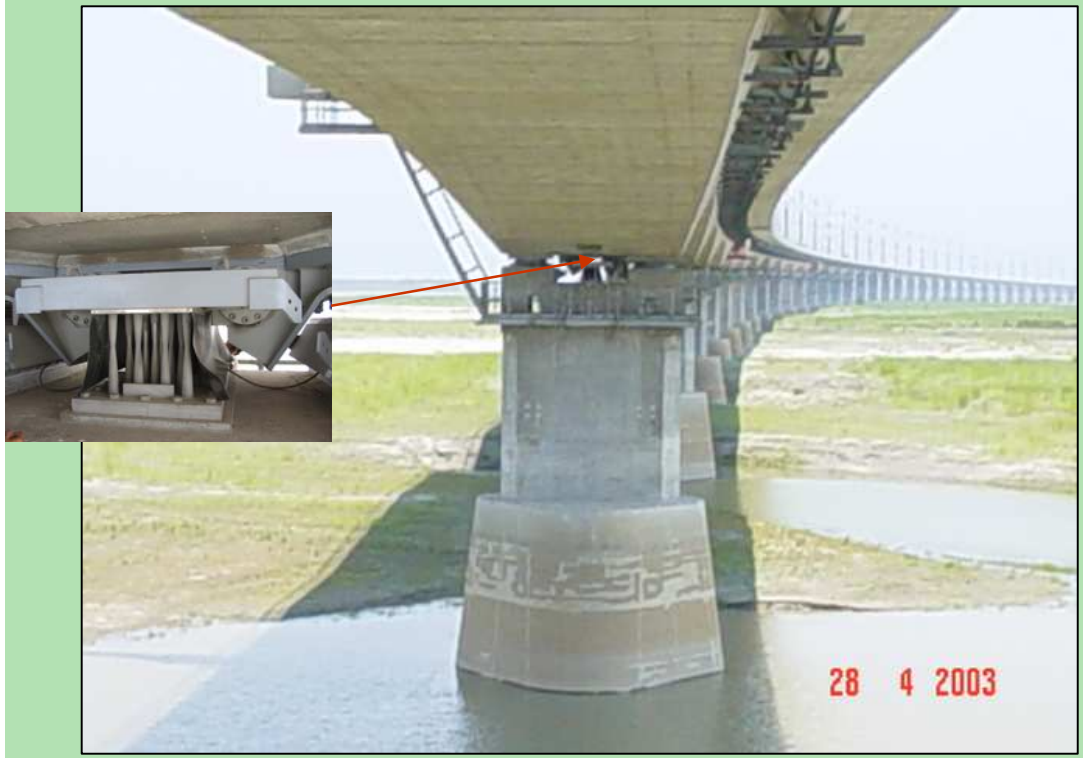
Digital Seismic Stations

- **7 Accelerometer** ■
  (JMBA-BUET) since 2003
- **4 Broad Band Seismometer + Accelerometer** ●
  (BMD) to be installed shortly
- **6 Short Period Seismometer**
  (BMD) planned for other locations.



Jamuna Bridge Seismic Instrumentation Project

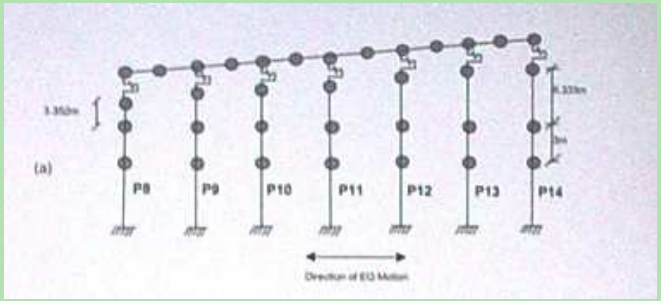
- 4.8 km long **base-isolated bridge** designed for M=7.0 magnitude earthquake in Bogra fault zone at a distance of 25 to 50 km
- Seismic Instrumentation (accelerometers) installed in 2003 on bridge and free-field stations
- Rare recordings of events



Numerical Study: Isolated vs. Non-isolated Bridge

(Ahmad, Al-Hussaini, Choudhury, 1999)

Numerical Model of Bridge Module



Isolator Force-Displacement loop

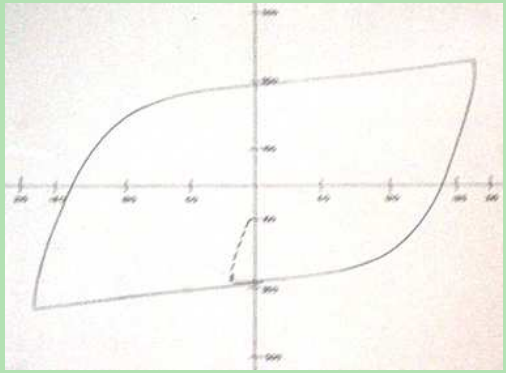


Table 3 Comparison of Isolated and Non-Isolated Pier in Longitudinal Direction

Pier	Isolated			Non-isolated		
	Design Earthquake Strength	Normalized Pier Force	Peak Pier Top Deck Displ. (m)	Design Earthquake Strength	Normalized Pier Force	Peak Pier Top Deck Displ. (m)
2-pile pier P8	100	0.079	0.397	41%	0.080	0.276
3-pile pier P12	100	0.171	0.631	35%	0.166	0.410

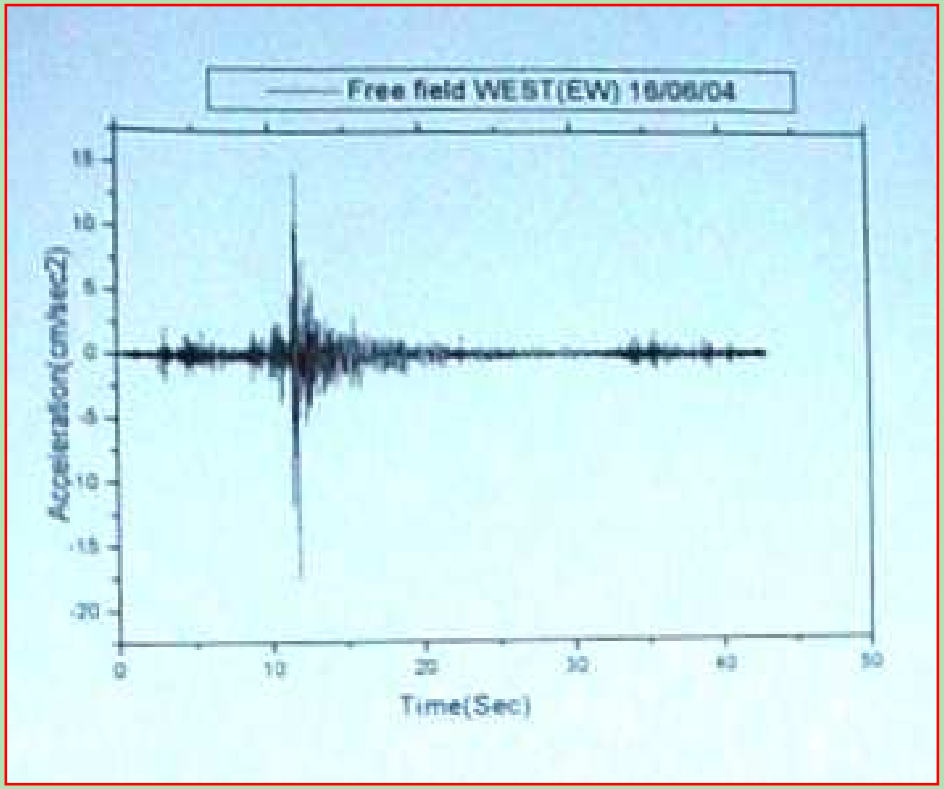
Table 2 Comparison of Isolated and Non-Isolated Pier in Transverse Direction

Pier	Isolated			Non-isolated		
	Design Earthquake Strength	Normalized Pier Force	Peak Pier Top Deck Displ. (m)	Design Earthquake Strength	Normalized Pier Force	Peak Pier Top Deck Displ. (m)
2-pile pier P8	100	0.181	0.708	32%	0.179	0.530
3-pile pier P12	100	0.155	0.611	35%	0.156	0.472

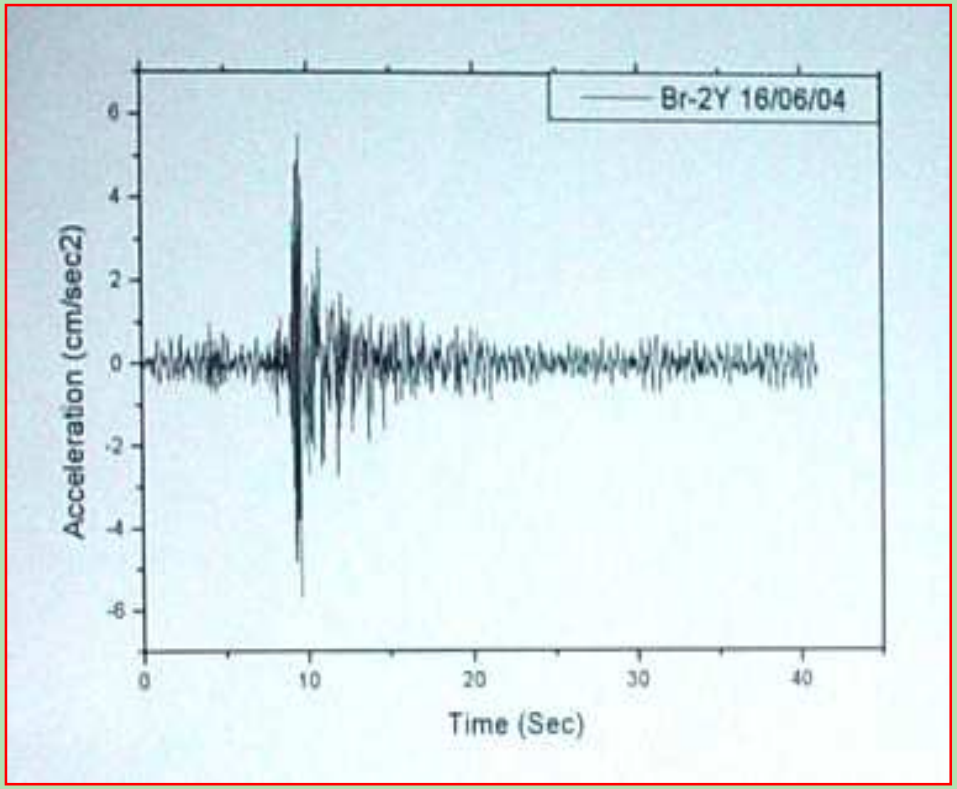
Seismic Data

(recorded July 16, 2004)

Free Field (West End)



Bridge: Pile Cap



Final Comments on Research Activity

Ongoing Research:

- **Probabilistic Seismic Hazard Assessment**
- **Analysis of Free-Field Record / Bridge Response**
- **Vulnerability Assessment of Structures**
- **Local Soil Effect**
- **Deterministic Seismic Hazard Assessment (in collaboration with ICTP)**

Proposed Activity in Collaboration with ICTP & Network Partners:

- **Formation of Suitable Earthquake Catalogue**
- **Deterministic Seismic Hazard Assessment**
- **Seismic Source / Geologic Structure Modelling**
- **Local Site Effect**

Thank you !