New ongoing projects on Seismic Hazard, Vulnerability, Risk Assessment and Microzonation

A.

"Seismic Hazard Assessment, Microzonation, and Evaluation of Vulnerability, Risk & Socio-Economic Impacts for the City of Kolkata" : Ministry of Earth Sciences, Seismicity Programme (grant of about Rs.5 Crores)

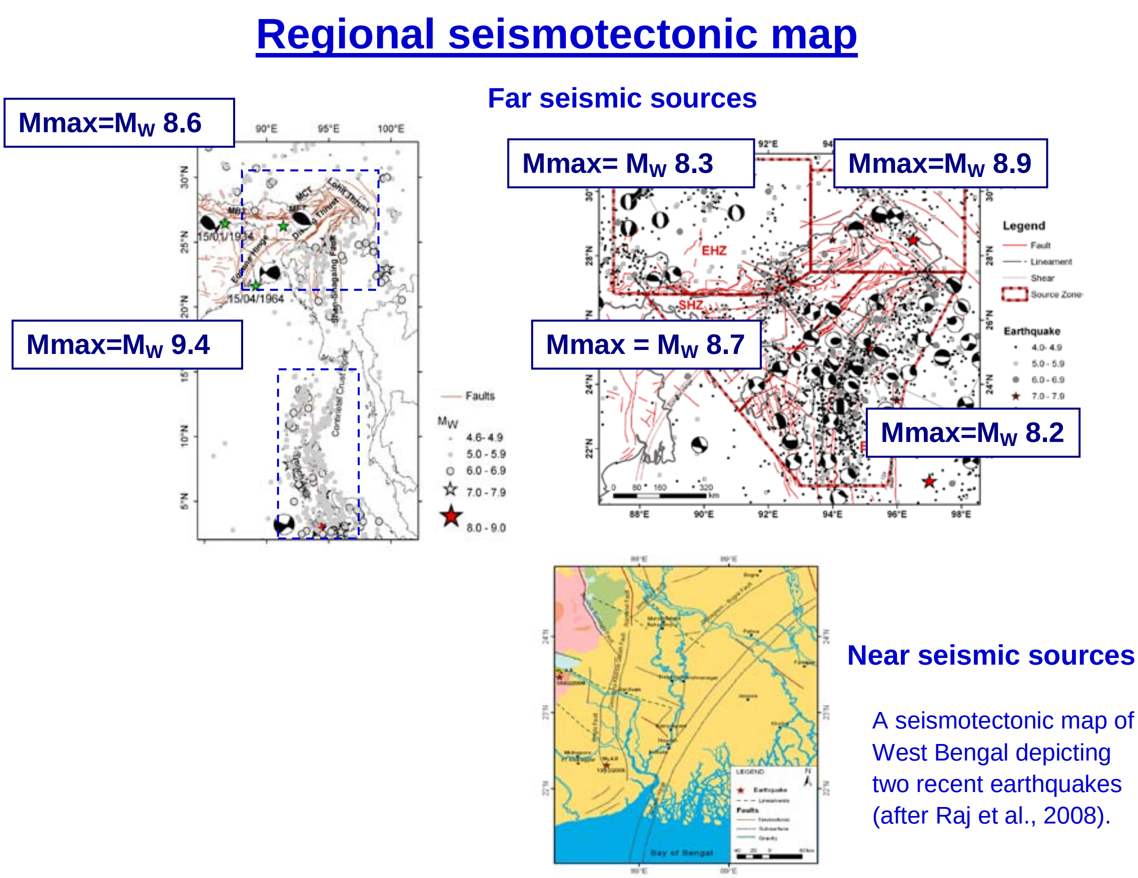
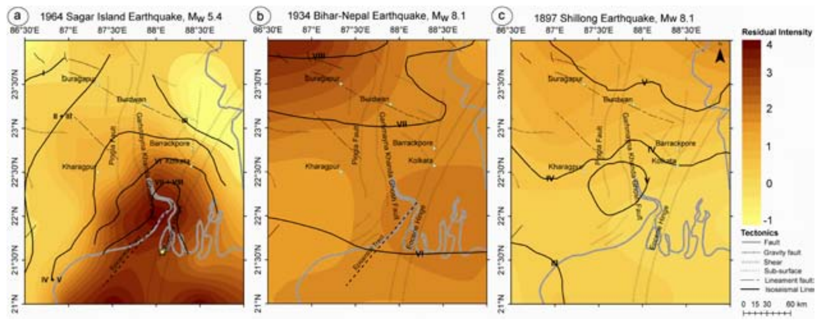
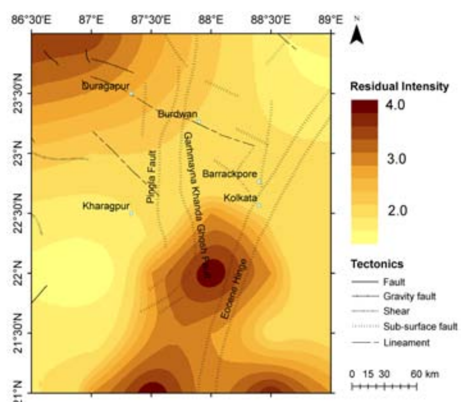


Figure 32: Near and far source locations in the perspective of West Bengal Seismicity.

The numerical modeling of strong ground motion to estimate the seismic intensity at the bedrock level through the established correlation between peak ground acceleration & seismic intensity. The residual intensity estimated as the difference





(after *Nath et al., 2009, Pers. Comm.*)

The site amplifications, in terms of twice the residual intensity (**Hough and Bilham, 2008**), could be as high as 8 times in the Eocene hinge zone and to the southeast. Lower site amplifications in range of 3-4 times observed in SW-NE extent. These observations ascribe potential high seismic

Figure 33: Macroseismic-driven Site-Amplification Factor Distribution in the West Bengal.

Objectives

The proposed research aims at achieving and the assimilation of several following aspects in the evaluation of seismic hazard and building up levels of seismic microzonation of Kolkata city.

i) Establish the geological and geomorphologic units of Kolkata and its surrounding areas, including the lithological characteristics and bedrock configuration at different locations.

ii) Identify and characterize major/minor faults, lineaments, and seismotectonic units that are seismically active.

iii) Characterize the seismic activities based on historical seismicity and recorded ground motion data. The attributes pertinent include location of potential sources, magnitude, intensity, focal mechanism and epicentral distances, etc. Selection of suitable attenuation laws.

iv) Evaluate spatial variation of shear wave velocity (i.e. average V_S profiles) through geophysical survey, geotechnical borehole logging, and HVSR modeling to develop a database of shallow subsurface stratigraphy information.

v) Evaluate the spatial distribution of predominant frequency of the soil through Nakamura's technique.

vi) Establish seismic (ground) response through theoretical and numerical modeling of wave propagation to identify amplification effects associated with near surface ground motions from thick alluvium deposits during an earthquake, during which critical facilities and infrastructure are expected to remain operational.

vii) Determine the ground motion parameters such as peak ground acceleration/velocity distribution at different locations. Determine the ground response spectrum, duration and the time history of earthquake inputs.

viii) Assess seismic stability and estimation of permanent ground deformation within typical river-front structures.

ix) Site classification on the basis of the shear wave velocity model, and the geotechnical assessments.

x) Assess the liquefaction potential from the detailed borehole geotechnical data and shear wave velocity profiles using suitable model studies. Identification of threshold value, maximum epicentral distance and depth based on field and laboratory studies.

xi) Local specific deterministic and probabilistic seismic hazard analysis.

xii) Generate thematic hazard maps in terms of site classification, site response, predominant frequency, spectral accelerations, and peak ground accelerations on GIS platform.

xiii) Prepare inventory for the demographic, buildings typology, and landuse patterns.

xiv) Identify building hazards from resonance phenomenon on the basis of predominant frequency of the basin to demarcate zones of varying risk.

xv) Risk assessment of the city through scenario generations to identify damage levels and achieve a probabilistic account.

Work Plan

A general framework of the work plan is outlined as follows:

[1] Collation and synthesizing of all available data on geology, geomorphology, sub-surface geology:

- ❖ Collection of data from published sources as well as from unpublished reports of GSI or other agencies (from existing bore hole logs carried out by GSI, CGWB, Metro Rail etc.).
- ❖ All available data on N-value data and litholog from SPT bore holes carried out by different organizations beyond 30/50 m depth (as available with KMC, KMDA, KEIP, etc.).
- ❖ All available data on the subject in different scales to be digitized and to be brought into a single platform.
- ❖ Preparation of detailed geological, geomorphological and land use map of Kolkata Megacity on 1:25,000 scale of the Survey of India toposheet base with the help of aerial photographs, satellite imagery, subsurface information, field mapping and field verification.

- ❖ Mapping of all the faults, both exposed and concealed, in and around Kolkata covering at least 300 km radius and classify them according to their authority and age of movements along them.
- ❖ Preparation of a seismotectonic map of an area of 300 km radius around Kolkata, listing and plotting of all past-earthquake events with magnitude and depth of each event.
- ❖ To map the ground water table – pre monsoon and post monsoon, for the first 20 m layer.

[2] Analysis of regional seismicity, and seismotectonics based on available earthquake catalogues, published literatures, and earthquake recordings.

[3] Review of available geotechnical data from various sites representing major geomorphologic units covering the Kolkata area

[4] The MASW and Microtremor survey will be carried out by IIT Kharagpur at around 1000 testing sites in the city (through outsourcing to professional vendors). The work plan consists of various steps as follows:

- – Transportation of equipment from IIT Kharagpur: The equipments have to be transported to Kolkata for carrying out the testing at the above proposed sites. The instrument is delicate and needs to be handled by trained skilled person.
- – Carrying out of MASW survey: Since the work requires dedicated trained personals it is proposed take assistance in the form of service in data acquisition, comprehensive maintenance contract with dedicated vendors/professionals engaged in similar activities in Govt. /Semi Govt. / private undertaking organizations. The work will include the data acquisition from the testing sites (around 1000 in numbers) within a year and half. Each test site will be examined by a 50-100 meter length receivers spread with appropriate receiver spacing and at some sites microtremor records for about an hour.

[5] Deep subsurface investigation to 300 m depth of 20-30 representative sites in Kolkata area involving drilling, Standard Penetration Testing, cross-hole seismic measurements and soil sampling and seismic and radio-isotope piezocone penetration testing (to 50 m depth)

[6] Shallow subsurface investigation to 50 m depth at 200/300 representative sites across Kolkata involving drilling, Standard Penetration Testing, cross-hole seismic measurements and soil sampling and seismic and radio-isotope piezocone penetration testing.

[7] Laboratory simple shear testing of selected undisturbed soil samples

[8] Strong motion ambient noise survey, estimation of receiver function and Nakamura Ratio, mapping of dominant frequency clusters

[9] Development of a one- and two- dimensional numerical model for estimating the response of very deep alluvium deposits based on state-of-the-art software packages

[10] Selection ground motions representative of the OBE.

[11] Estimation of peak ground acceleration for design earthquakes.

[12] Deterministic and Probabilistic Seismic Hazard Assessment

[13] GIS based thematic mappings.

[14] First-order identification of vulnerable areas.

[15] Risk Analysis

[16] Preparation of reports summarizing the data, analysis and findings.

The deliverables of the proposed research can be listed as follows:

1. Collection and collation of existing Geologic and Seismic data
2. Engineering geology, Geomorphic and Hydro-geological Study
3. Additional geologic, geomorphic, ground water, geophysical data collection, Structural Models, Regional polygons, identification of seismogenic areas, focal mechanism study
4. Ground motion modelling, PGA, PGV Estimation
5. Shallow Stratigraphic Sections
6. Deep Stratigraphic Sections
7. Seismo Stratigraphic Model from MASW
8. Shear wave and Surface wave tomography and soil classification based on S-wave, Blow-counts, cone penetration test.
9. Soil Map, Liquefaction Potential Determination and geotechnical Soil Map
10. Synthetic MCE and Attenuation
11. Deterministic Seismic hazard Analysis (DSHA) and Probabilistic Seismic hazard Analysis (PSHA)
12. Strong Motion Seismometry and Site Spectral Analysis
13. Contour Map of Estimated Permanent Ground Deformation
14. Preliminary Assessment of Ground Improvement Measures
15. Assessment of potential damage for critical facilities
16. Deterministic and probabilistic hazard attributes generation and Integration on GIS
17. Vulnerability and risk assessment
18. Final Report Summarizing the Findings of the Study
19. Recommendations regarding possible mitigation measures
20. Publication of Microzonation Maps

B.

"Probabilistic Seismic Hazard and Risk Assessment of Darjeeling Sikkim Himalaya": Ministry of Earth Sciences, Seismicity Programme (grant of about Rs.50 Lakh)

The broad objectives of the concluding project study were as follows:

I.

1. Overall maintenance of the existing hardware of the entire network consisting of eleven ETNAs and one K2.
2. Repairing of semi-permanent observatories and relocation of dilapidated observatory housing and electric wiring.
3. Installation of solar panels with rechargeable batteries to overcome the nagging electricity problem by ensuring uninterrupted power supply.

II. In-depth seismicity analysis of the terrain that includes b-value, D_C, fractal dimension mapping, source zone classification and estimation of maximum earthquake.

III. Determination of spatial variation of ground motion from existing strong motion network installed as part of the previous project of this group.

1. Semi-empirical/ Stochastic ground motion synthesis estimation of the ground motion from the small magnitude earthquake data ($M \leq 5$). The strong motion characteristics for the earthquakes of larger magnitude ($M>7$) will be computed from the strong motion data of the smaller magnitude earthquakes. Simulation of Seismic Scenario for a characteristic earthquake/Scenario/ Maximum Earthquake through Deterministic Seismic Hazard Assessment approach using finite/extended finite source synthesis. It may be mentioned here that both MBT and MCT are capable of producing earthquakes of large magnitude.
2. Integration of ground failure susceptibility, soil, geology, geomorphology and slope etc. through Geographic Information System (GIS) for the generation of second order high-resolution microzonation hazard map in 1:25,000 scale.

- ***Nine*** station huts have been reconstructed / renovated after most of them suffered extensive decay after a survival of more than a decade. ***Three*** stations have been relocated to new sites after land sliding and slumping problems were encountered. Necessary spares and solar panels have been procured. ***Five*** stations have been repaired and reinstalled in Sept 2007. The remaining stations have been maintained for power board and electronic faults. The entire network has been fully operational powered with solar panels since Feb 2008. The delay is attributed to the continuous rain and rain-triggered landslides that cut off Sikkim from the main land for days. The network is under a 3 years' comprehensive AMC with M/s Pinnacle Geosystems, New Delhi.

- Two more new Accelarographs (ETA) are being procured, purchase order in favour of Kinematrics Inc. USA have been raised. Three stations are being relocateddue site-specific damage due to flash flood and ground sliding.

All the research objectives were achieved as follows:

- **Analysis of Earthquake Database of Northeast India** (Thingbaijam and Nath, 2008; Thingbaijam, et al.,2008)

Recent study by Scordilis (2006) exhibited that on a global scale, earthquake magnitudes estimated by National Earthquake Information Center (NEIC) (http://neic.usgs.gov/neis/epic/) and International Seismological Center (ISC) catalogues are practically equivalent. The ISC catalogue has been accredited with higher annual earthquake volume compared to any other global catalogues (Willemann and Storchak, 2001). Therefore, the preliminary data catalogue intended for the present analysis is derived from the ISC catalogue accessible at http://www.isc.ac.uk/bull (last accessed February 2007; ISC, 2007) covering a period 1906-2006, and the entire study region and the vicinity bounded within the latitude-longitude: 19ºN 85ºE and 32ºN 101ºE.

- Seismicity Analysis in Northeast India using b and fractal correlation Dimension estimation and mapping (Thingbaijam and Nath, 2008; Thingbaijam, et al.,2008)

A quantitative approach to seismicity analysis has been carried out with the assessment of seismicity parameters: a- and b-value, and correlation fractal dimension, D_C. The two parameters, b-value and D_C have been employed together in several studies. The correlations are seen to be dependent on the modes of failure within the active fault complex. Wyss et al. (2004) purposed that heterogeneity of seismogenic volumes leads to variations in D_C and b-values, and indicated a positive correlation between the two parameters dominant in regions of creeping and locked patches as well. Nonetheless, conclusively D_C and b-value together form a composite indicator of the underlying dynamics of the region. The spatial correlations can be interpreted from individual inferences of the variations of D_C and b-value. Low values indicate clustering of mainly large earthquakes identifying regions of high stress concentrations. High values suggest random occurrence of mainly smaller earthquakes indicating low stress buildup. Low D_C and high b-value indicates clustering of mainly smaller earthquakes that may be implicated with creeping parts of the fault zones. High D_C and low b-value indicates random occurrence of mostly larger earthquakes suggesting formation of asperities across the underlying faults (Oncel and Wyss, 2000). The spatial variations of both parameters in conjunction can be related to the tectonic dynamics across a region.

- **Source Zone Classification**

- Earthquake hazard zonation employing the following methodologies:

(i) Geomorphological characterization

(a) Geology (GE),
(b) Soil (SO),
(c) Slope (SL),
(d) Rock Outcrop (RO) and
(e) Landslides (LS).

(ii) *Seismological characterization*

(a) Prognosis of Maximum Earthquake

(b) Site-specific ground motion studies, namely estimation of Site Effects (SR), Predominant Frequency (PF), Peak Ground Acceleration (PGA), Peak Ground Velocity (PGV) and Response Spectra.

- **Deterministic Seismic Scenario in the Sikkim Himalaya Using Strong Ground Motion Synthesis**
- **Estimation of PGA (Peak Horizontal Acceleration) using Random Vibration Theory (RVT**)
- **Integrated Simulation of Earthquake Hazard.**

The hazard zonation map is required for the urbanization to sustain the state economy that is based primarily on tourism. Even Central Water Commission is interested to have a hazard zonation map of the area in view of the construction of several dams for Hydel projects.

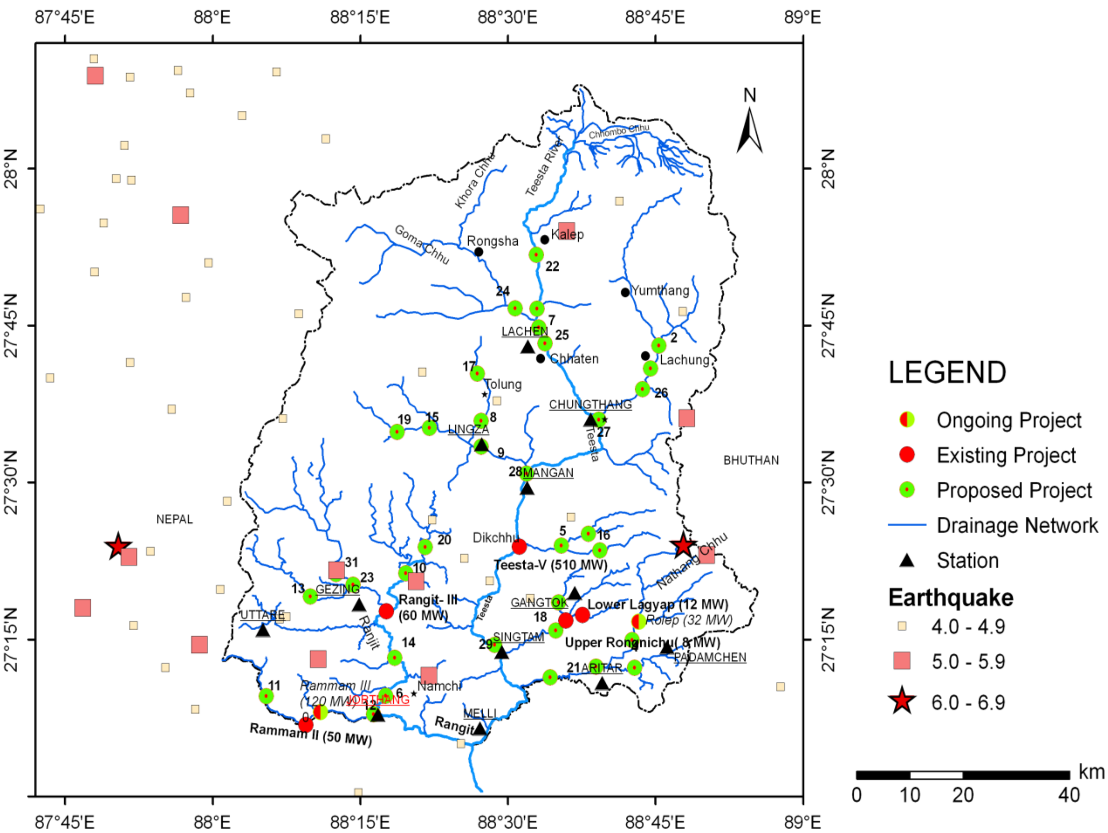


Figure 34: Location of hydropower stations and project sites in the Teesta river basin Sikkim.

Figure 35: Exiting Strong Motion Sations in the Sikkim Himalaya.

The ongoing new project aims at:

1. PSHA & Estimation of Site Specific Attenuation Relationships for Sikkim Region

The work planned in this study is intended for better understanding of the seismic hazards in the Sikkim region through a probabilistic approach. Assessment of the seismic hazard requires an appropriate strong-motion attenuation relationship, which depicts the propagation and modification of strong ground motion as a function of earthquake size (magnitude) and the distance between the source and the site of interest.This analysis provides pattern of the maximum intensity of shaking predictable at a site during a fixed time interval at a given probability level and the outcomes of a PSHA will be presented as seismic hazard maps.

The proposed project includes development of probabilistic seismic hazard maps for Sikkim through augmenting strong motion station network in the northern part of the Sikkim. This hazard map of the Sikkim region will provide information to Scientists and Engineers for planning purposes and Disaster Response Associations for emergency preparedness with more accurate understanding of the seismic hazards in the Northern Sikkim particularly for the Hydropower dam projects sites.

2. Integration of ground failure susceptibility, soil, geology, geomorphology and slope etc. through Geographic Information System (GIS) for the generation of third order high-resolution Probabilistic Seismic microzonation hazard map.
3. Risk assessment

Man Power Development: "*Man Power Development in Computational Seismology*" through a 24-month M.Tech. Programme at IIT Kharagpur. Coordinating the "*National Programme in Earthquake Engineering Education (NPEEE)*" in India sponsored by the Ministry of Human Resource Development and the "*National Programme for Capacity Building of Engineers in Earthquake Risk Management (NPCBEERM*" initiated and funded by the Ministry of Home Affairs.

Infrastructure Development at the Institute / Department:

- **Broadband Seismological Observatory.**
- **Advanced Computational Seismological Laboratory.**
- **Sikkim Strong Motion Array.**