Tectonic Evolution and Seismic Hazards in Bangladesh: Insights from Geophysical and Geotechnical Studies

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Abstract: Bangladesh is located at the convergence of the Indian, Eurasian, and Burmese plates, a tectonic setting that makes the country one of the most seismically vulnerable regions in South Asia. The regional framework is characterized by active subduction along the Indo-Burmese Arc, strike-slip faulting, and crustal shortening across thrust systems. Among these structures, the Dauki Fault at the southern margin of the Shillong Plateau plays a central role in accommodating crustal strain and controlling regional seismicity. Additional features, including the Naga-Disang thrusts and several concealed intra-basin faults, further contribute to the high hazard potential. This study integrates geophysical and geotechnical approaches to improve seismic hazard understanding in the Bengal Basin. Geophysical datasets, including seismic reflection, gravity, and magnetotelluric surveys, delineate crustal deformation, fault propagation, and basin dynamics. Complementary geotechnical assessments, based on soil stratigraphy, shear-wave velocity (Vs30) profiles, and liquefaction analyses, reveal that unconsolidated alluvial and deltaic deposits significantly amplify ground motion. Probabilistic Seismic Hazard Analysis (PSHA) indicates that northeastern and southeastern Bangladesh, being proximal to active tectonic structures, face the greatest hazard, with peak ground accelerations exceeding 0.3g under worst-case scenarios.

Keywords: ***Bangladesh, Tectonics, Seismic hazard, Dauki Fault, Liquefaction, Probabilistic hazard analysis, Urban risk reduction.***

Introduction

Bangladesh occupies a tectonically complex region at the junction of three major plates, the Indian, Eurasian, and Burmese. This geodynamic setting renders the country highly vulnerable to seismic hazards. The Indo-Burmese subduction zone to the east, the Himalayan thrust system to the north, and intraplate faults within the Bengal Basin collectively control the region's seismicity (Figure 1). Among these, the Dauki Fault, which demarcates the Shillong Plateau from the Bengal Basin, is considered one of the most seismically active and structurally significant features. The Naga-Disang thrusts, Tripura fold belt, and several concealed basement faults add further complexity to the regional tectonic mosaic.

Bangladesh's seismic vulnerability is compounded by its demographic and socio-economic context. With more than 170 million people and some of the world's highest population densities, even moderate earthquakes pose the risk of widespread devastation.

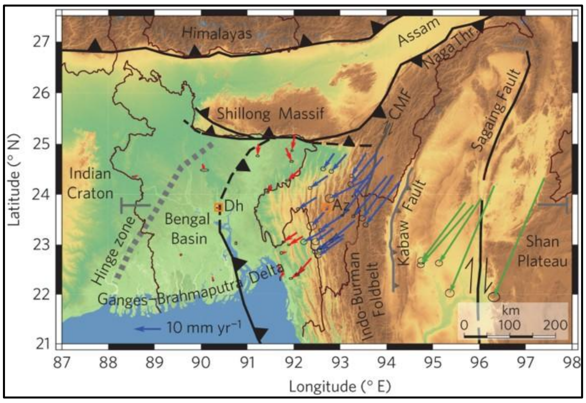

Figure 1, Tectonic setting and active faults of Bangladesh and adjoining areas (Steckler et al., 2016)

Major urban centers, Dhaka, Chattogram, and Sylhet, are situated in regions of high seismic potential while being underlain by thick alluvial deposits that are prone to amplification and liquefaction. Historical records, including the 1762 Arakan earthquake (M 8.5–8.8) and the 1897 Shillong earthquake (M 8.1), highlight the recurrence of large events capable of generating strong ground shaking, surface deformation, and even tsunamis.

Methodology

A multidisciplinary framework was adopted to evaluate seismic hazards in Bangladesh:

Geophysical Investigations

Seismic reflection profiling was used to map crustal stratigraphy and identify active faults within the Bengal Basin. Gravity anomaly analyses revealed density contrasts and subsurface lineaments, highlighting crustal deformation zones. Magnetotelluric (MT) surveys helped characterize lithological variations and detect fault zones masked by sedimentary cover.

Geotechnical Studies

Soil stratigraphy and borehole records provided insights into local subsurface layering. Shear-wave velocity measurements allowed classification of site conditions for ground-motion modeling. Liquefaction potential was evaluated in major cities using standard penetration test (SPT) and cone penetration test (CPT) data.

Probabilistic Seismic Hazard Analysis (PSHA)

Integrated regional fault models, recurrence intervals, and ground-motion prediction equations (GMPEs). Generated seismic hazard maps estimating peak ground accelerations (PGAs) with 10% and 2% probability of exceedance in 50 years.

Results

The combined datasets reveal that the Bengal Basin is affected by crustal shortening and flexure related to the Indo-Burmese subduction zone. The Dauki Fault shows strong evidence of Quaternary activity, indicating a high seismic potential. Gravity and MT data suggest connectivity between basement-rooted faults and shallow sedimentary structures, providing potential rupture pathways. Dhaka and Chattogram are underlain by thick unconsolidated Holocene sediments, classified as NEHRP site class D–E, making them highly susceptible to shaking amplification. Sylhet, while geologically more stable, is located near the Dauki Fault, increasing its seismic risk. Borehole studies identify significant zones of liquefaction potential, especially in reclaimed or riverbank areas of Dhaka and Chattogram. PSHA results show northeastern and southeastern Bangladesh with PGAs exceeding 0.3–0.35 g for 2% probability in 50 years (Figure 2). These values are comparable to high-risk zones in Nepal and northern India.

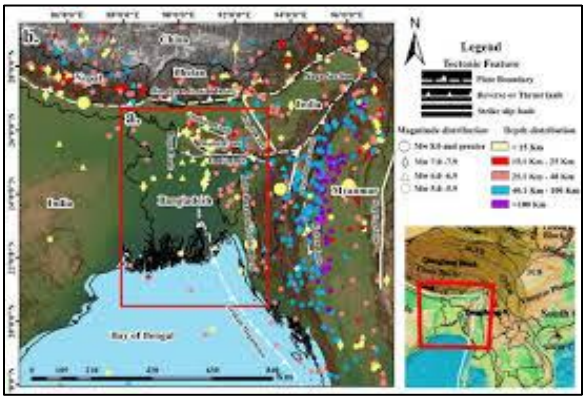

Figure 2, Probabilistic seismic hazard map of Bangladesh and its adjoining area (Pasari et al., 2023)

Discussion

The results highlight a dual challenge of natural tectonic hazard combined with human-induced vulnerability. Geophysical evidence confirms that Bangladesh is not only exposed to Himalayan and Indo-Burmese tectonics but also threatened by intraplate reactivation of basement faults. This means the country faces multi-source seismic risk. On the geotechnical side, the widespread presence of soft alluvium greatly amplifies seismic waves. Dhaka, a megacity with over 20 million residents, is especially at risk. Simulation models suggest that even a magnitude 6.5 earthquake beneath the Dauki Fault could trigger catastrophic losses due to structural fragility.

Moreover, the lack of widespread compliance with seismic design codes significantly increases disaster potential. Although Bangladesh National Building Code (BNBC) includes seismic provisions, enforcement remains inconsistent. Past studies show that a large portion of Dhaka's building stock does not meet modern seismic safety standards, making retrofitting essential. Internationally, Bangladesh's seismic scenario is comparable to other plate-boundary megacities such as Kathmandu, Manila, and Istanbul. Lessons from these regions, such as early warning systems, microzonation mapping, and mandatory retrofitting, can provide a pathway for risk reduction.

Conclusion

This study demonstrates that seismic hazards in Bangladesh are governed by the interaction of active tectonic processes, unfavorable geotechnical conditions, and human vulnerabilities. The integration of geophysical and geotechnical data provides a more robust basis for hazard modeling and urban risk planning. Key recommendations include:

- Expansion of geophysical monitoring networks (seismographs, GPS, InSAR).
- Nationwide site-specific geotechnical investigations and microzonation studies.
- Enforcement of seismic building codes and retrofitting of critical infrastructure.
- Development of community-based preparedness and public education initiatives.
- Exploration of regional cooperation for real-time earthquake early warning systems.

Given the inevitability of future large earthquakes, proactive action is essential. Bangladesh's resilience will depend not only on scientific research but also on effective translation of hazard knowledge into policy, planning, and public practice.

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