Performance-Level Seismic Assessment of a Bridge in Bangladesh Utilizing Recent Earthquake Records

Bangladesh Univ. of Engineering and Technology, Bangladesh O Md Kamal Hossain Shikdar
Chittagong Univ. of Engineering and Technology, Bangladesh Member M Abdur R Bhuiyan
Bangladesh Univ. of Engineering and Technology, Bangladesh A.F.M. Saiful Amin

Abstract

Analyzing bridge responses using earthquake records from sites near the structure provides more realistic results than using distant events. Ground motions traveling through unknown soil layers can distort seismic response, and the absence of local intensity data makes distant records less reliable. To address this, the Bangladesh Meteorological Department (BMD) has recorded earthquakes across the country, mostly from nearby sources like Northeast India and Myanmar. This study used ground motion data from 47 such events, with moment magnitudes of 3.9–6.2 and depths of 10–150 km, reflecting regional seismic risk along the Indo-Eurasian boundary. Response spectra from these events were applied to a bridge near the recording site. Structural responses—displacements, moments, and stresses—were compared with those from code-based spectra for a 100-year return period. The aim was to evaluate whether typical Bangladeshi bridges can sustain service-level performance under realistic seismic input. The findings highlight the advantage of using real records which provide more accurate assessments than code spectra alone.

1. Introduction

Bangladesh is situated near the Indo-Eurasian tectonic boundary, where the Indian, Eurasian, and Burmese plates interact, placing the country at moderate to high seismic risk. While no major recent earthquakes have originated within its borders, nearby sources such as the Indo-Burma subduction zone and Shillong Plateau pose credible threats. Historically, the lack of local ground motion records led to reliance on foreign datasets that often misrepresent regional conditions. The BMD now provides local earthquake recordings that can enhance seismic hazard assessments. Although recent events have not occurred along fault lines within major cities like Dhaka, their proximity underscores the importance of reassessing infrastructure resilience. The 2020 edition of the BNBC adopts probabilistic seismic hazard analysis and MCE-based zoning but offers limited guidance for service-level performance, such as for 100-year return period events. This study helps bridge that gap by using BMD-recorded ground motions to develop response spectra, which are then applied to a bridge model to evaluate service-level performance. Using real, unscaled motions supports performance-based design and contributes to refining national design spectra. It also highlights the need to better understand soil amplification and damping effects in the Ganges, Brahmaputra basin, especially for distant seismic sources. Table 1 lists earthquakes (EQ) with Mw > 4.5, with bold entries shown in Figure 1 which uses dual Y-axes: the right for the service level EQ, and the left for EQ7, EQ9, EQ16, EQ40, and EQ46.

Table 1: Earthquake waveforms recorded by BMD from 2020 to 2023 (Date format: YY-MM-DD)

EQ ID	Date	UTC Time	Mw	EQ ID	Date	UTC Time	Mw	EQ ID	Date	UTC Time	Mw
EQ1	20-07-05	11:56:35	4.8	EQ14	22-08-24	21:48:11	5.0	EQ35	23-05-11	20:44:57	4.5
EQ2	20-12-08	5:14:35	5.1	**EQ16**	**22-09-29**	**22:22:37**	**5.6**	EQ36	23-05-29	02:33:31	4.9
EQ3	21-02-17	12:24:47	4.6	EQ17	22-10-19	9:22:40	4.9	EQ37	23-06-16	04:46:11	5
EQ4	21-02-25	2:34:27	4.9	EQ19	22-11-10	5:01:06	5.5	**EQ40**	**23-08-14**	**14:49:49**	**5.3**
EQ5	21-04-05	15:19:58	**5.2**	EQ20	22-12-05	3:02:58	4.9	EQ41	23-08-19	15:20:35	4.8
EQ7	**21-11-25**	**23:45:42**	**6.2**	EQ22	23-01-23	13:42:03	5.1	EQ42	23-08-20	07:42:43	4.7
EQ8	22-01-18	2:22:16	4.5	EQ23	23-01-31	4:49:06	4.6	EQ43	23-09-09	10:18:30	4.8
EQ9	**22-01-21**	**10:12:32**	**5.4**	EQ29	23-03-12	11:43:44	4.8	EQ44	23-09-11	17:32:01	5
EQ10	22-05-21	3:14:07	4.5	EQ31	23-04-10	00:46:37	4.6	**EQ46**	**23-10-02**	**12:45:16**	**5.4**
EQ13	22-07-31	2:28:10	5.1	EQ33	23-04-30	06:56:57	4.6	EQ47	23-10-22	01:54:21	5.2

2. Earthquake records and comparison with 100-Year Code Spectrum

The service-level response spectrum corresponding to a 100-year return period (PGA ≈ 0.09g for Dhaka) was developed. Structural response outputs displacements, internal forces, and stresses were extracted from the bridge model under each input spectrum and benchmarked against the 100-year spectrum response. A two-span section of the Dhaka Ashulia Elevated Expressway was modeled in finite element method to assess its structural response under real earthquake ground motions. The model used a linear-elastic approach suitable for service-level analysis and incorporated dynamic properties representative of local soil profiles. EQ16 was used in the FEM analysis as it exhibited the highest ground motion intensity at the site, as shown in Figure 1.

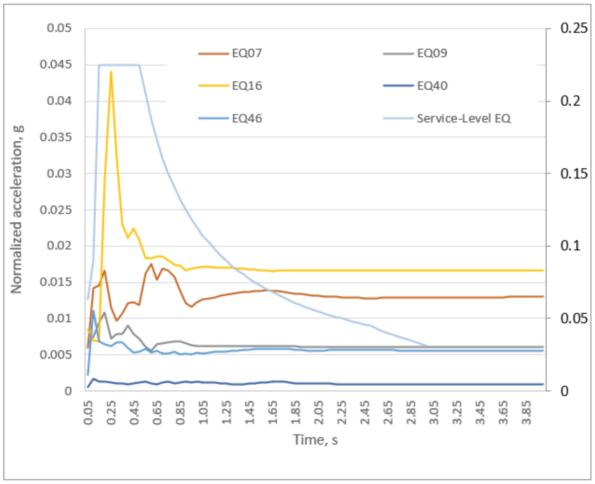
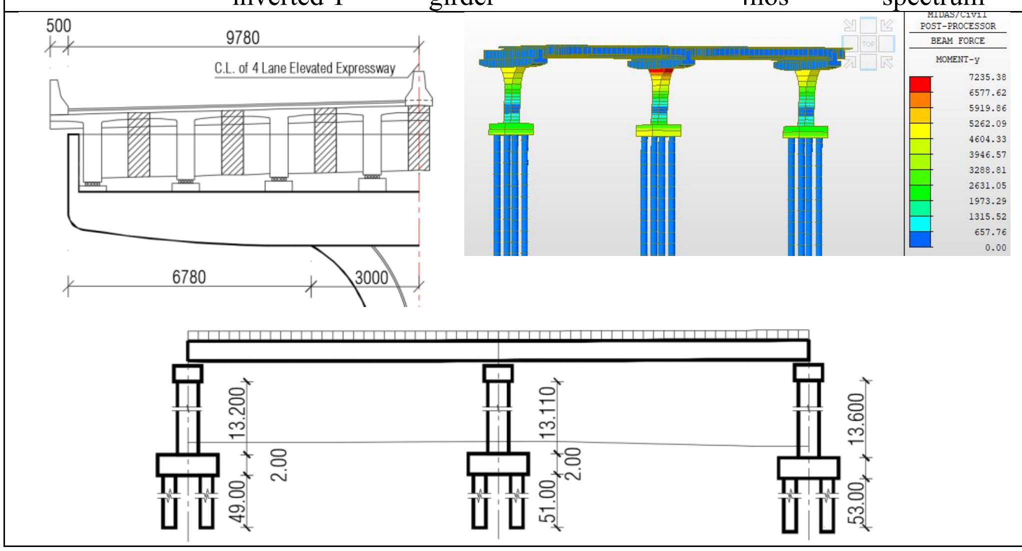


Fig 1: Response Spectrum of real and service-level earthquake (EQ).

3. Results and Discussion

Evaluation reveals that though real records generally induced lower demands, their responses were within a reasonable range for service-level assessments. The findings emphasize the importance of evaluating real records to capture frequency-dependent variability, offering more realistic insights than code spectra alone. Key outputs included deck displacements, internal forces, and reactions. Real ground motion caused a deck deflection of 11 mm and a moment of 1,481 kN-m at the pier cap, compared to 47 mm and 7,235 kN-m under the 100-year code spectrum. Pier stress reached 1,330 kN/m² from real data versus 5,283 kN/m² under the code. Similarly, support reactions were 270 kN and 1,074 kN for recorded and service-level earthquake, respectively. Though real records generally induced lower demands, their responses were within a reasonable range for service-level assessments.

Width (m)	Span (m)	Per cap	Number of sgirders	Site class	Pile	Input load
20.56	30	Prestressed inverted T	8nos T girder	C	1.2m dia 4nos	Response spectrum



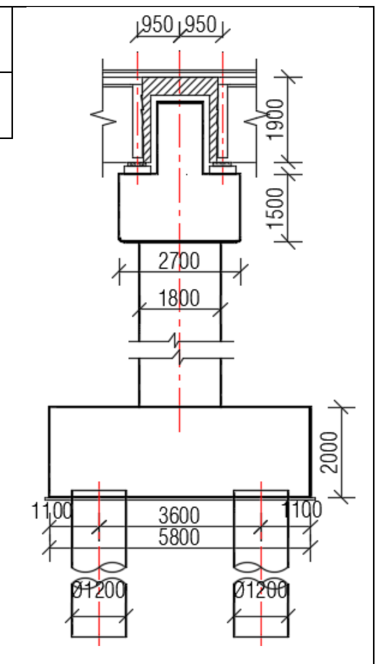


Fig 2: Bridge Geometry and FEM model (centre) shows the contour of moment after applying EQ

4. Conclusion

The BMD's recent earthquake recordings offer a valuable resource for advancing performance-based seismic evaluation in Bangladesh. This paper illustrates how real seismic data can be used to generate response spectra and assess service-level performance in structural models. Comparison with the 100-year return period spectrum shows that many recorded events induce demands slightly below design levels. Although the current analysis focuses on one bridge model and a single representative spectrum, future work will focus on developing probabilistic fragility curves to evaluate the likelihood of damage under varying seismic intensities. These curves will represent the likelihood of exceeding specific damage states as a function of ground motion intensity and will enable more rigorous performance-based evaluation.

References

American Association of State Highway and Transportation Officials (AASHTO). (2020). AASHTO LRFD Bridge Design Specifications (9th ed.). American Association of State Highway and Transportation Officials, Washington, D.C., USA.

Bangladesh National Building Code (BNBC). (2020). Bangladesh National Building Code 2020 (Vols. 1–4). Housing and Building Research Institute (HBRI) and Bangladesh Standards and Testing Institution (BSTI), Dhaka, Bangladesh.

MIDAS Information Technology Co., Ltd. (2022). MIDAS Civil – Integrated Solution System for Bridge and Civil Structures (Version 2022). MIDAS IT, Seongnam, South Korea.