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Research Article

Seismic performance evaluation of arch segments on Rumbai Jaya bridge using incremental dynamic analysis method

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ABSTRACT: Steel arch bridges are critical transportation infrastructures whose seismic reliability must be rigorously evaluated, particularly in high-seismicity regions such as Indonesia. Despite the widespread application of performance-based seismic assessment, probabilistic evaluations of existing steel arch bridges using Incremental Dynamic Analysis (IDA) remain limited. This study investigates the seismic performance and reliability of the Rumbai Jaya Bridge using Incremental Dynamic Analysis (IDA) within the Performance-Based Earthquake Engineering (PBEE) approach. A three-dimensional finite element model was subjected to twelve spectrally matched ground-motion records representing multiple seismic source mechanisms, with excitation intensities progressively scaled from 0.1g to 1.0g. Structural performance was quantified through drift-based limit states and seismic fragility curves following the NCHRP Synthesis 440 criteria. The analytical model exhibited a fundamental period of 0.48 s dominated by transverse vibration, while demand-to-capacity ratios of 0.40, 0.61, and 0.39 for bending moment, shear, and axial force, respectively, confirmed adequate structural capacity prior to seismic excitation. The IDA results revealed considerable record-to-record variability, with the Tohoku ground motion producing the most critical response, reaching a maximum drift of 12.33%. Nevertheless, the mean structural response remained below the Near Collapse threshold, exhibiting an average drift of only 4.64% at the maximum intensity of 1.0g. Fragility analysis further demonstrated that, under the site-specific design peak ground acceleration of 0.151g, the probabilities of exceeding the Operational and Collapse limit states were only 11.67% and 0.21%, respectively, indicating a substantial seismic safety margin. These findings demonstrate the robustness of the Rumbai Jaya Bridge against design-level earthquakes and highlight the effectiveness of IDA-based fragility assessment as a reliable method for performance evaluation and risk-informed management of steel arch bridges in high-seismic regions.

Keywords: *Steel truss bridge, Incremental dynamic analysis (IDA), Fragility curve, Rumbai Jaya bridge, Seismic performance*

1. INTRODUCTION

Bridges constitute one of the most critical components of transportation infrastructure because their post-earthquake functionality directly influences emergency response, economic recovery, and regional connectivity. In seismically active countries such as Indonesia, ensuring the seismic resilience of bridge systems has become an increasingly important engineering challenge. Indonesia is located along the Pacific Ring of Fire, where seismic hazards are generated by subduction zones, active crustal faults, and intraslab earthquakes. [1, 2]. Historical events, including the 2008 Wenchuan earthquake and the 2023 Kahramanmaraş earthquake, demonstrated that bridge failures may interrupt transportation networks, delay emergency response, and generate substantial socioeconomic losses [3,4,5]. Consequently, improving bridge resilience has become one of the principal objectives of Performance-Based Earthquake Engineering (PBEE), which aims to evaluate structural performance under multiple earthquake intensity levels rather than

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merely satisfying strength requirements. Among various bridge systems, steel arch bridges possess distinctive structural characteristics because gravity loads are primarily transferred through compressive arch action instead of flexural resistance. This mechanism enables high structural efficiency and long-span capability while simultaneously introducing highly nonlinear dynamic behavior during seismic excitation. Recent investigations have demonstrated that the seismic response of steel arch bridges is strongly influenced by spatially varying ground motions, near-fault velocity pulses, soil–structure interaction, and multiple earthquake source mechanisms [6, 7, 8] Moreover, nonlinear geometric effects and force redistribution significantly affect the seismic vulnerability of arch springings and crown sections, making their performance assessment considerably more challenging than that of conventional girder bridges [9].

Significant advances have recently been achieved in enhancing bridge seismic resilience through the development of Steel Fiber Reinforced Concrete (SFRC), rocking self-centering systems, seismic isolation devices, viscous dampers, and other energy-dissipation technologies [10, 11]. Nevertheless, these developments mainly focus on improving the seismic behavior of newly designed bridges. The evaluation of existing bridge infrastructure remains a major engineering concern because aging structures may exhibit different deterioration mechanisms and reserve capacities. Furthermore, most previous studies rely on deterministic seismic analyses, including equivalent static procedures and linear response spectrum methods, which cannot adequately capture progressive stiffness degradation, nonlinear deformation, collapse mechanisms, and record-to-record variability during strong earthquakes [12]. As a result, these approaches may underestimate or overestimate the actual seismic vulnerability of bridge structures.

Incremental Dynamic Analysis (IDA) has become one of the most comprehensive nonlinear procedures for evaluating structural performance from the elastic stage to global collapse by progressively scaling multiple earthquake records [13]. When integrated with seismic fragility analysis, IDA provides a probabilistic framework capable of quantifying structural reliability and estimating the likelihood of exceeding predefined performance limit states [14]. Within the PBEE, this methodology explicitly incorporates record-to-record variability through Probabilistic Seismic Demand Analysis (PSDA), thereby providing a more realistic representation of earthquake uncertainty than conventional deterministic approaches [12, 15]. Although IDA has been widely applied to buildings, cable-stayed bridges, and reinforced concrete bridge systems, relatively few studies have investigated existing steel arch bridges founded on soft-soil deposits under multiple tectonic earthquake scenarios representative of Indonesian seismicity [16]. Moreover, comprehensive seismic performance evaluations integrating IDA with the NCHRP Synthesis 440 performance criteria for Indonesian steel arch bridges remain scarce.

The Rumbai Jaya Bridge, located in Indragiri Hilir, Riau Province, is a strategically important steel arch bridge founded on soft soil, making it potentially susceptible to seismic wave amplification and complex nonlinear structural responses. Despite its importance within the regional transportation network, no previous study has comprehensively quantified its seismic reliability using a probabilistic performance-based approach. Existing investigations in Indonesia have primarily focused on prestressed concrete bridges or general bridge vulnerability assessments, leaving the seismic safety margin of steel arch bridges insufficiently understood [17]. This knowledge gap limits the development of evidence-based maintenance strategies and resilience-oriented bridge management under future earthquake hazards.

Therefore, this study presents a comprehensive probabilistic seismic performance assessment of the Rumbai Jaya Bridge using Incremental Dynamic Analysis integrated with the Performance-Based Earthquake Engineering method. Twelve spectrally matched ground-motion pairs representing crustal, megathrust, and intraslab earthquakes were employed to evaluate the structural response over a wide range of seismic intensities. Seismic fragility curves were subsequently developed according to the NCHRP Synthesis 440 performance criteria to quantify the probabilities of exceeding various performance limit states. The novelty of this research lies in the integration of multi-source Indonesian seismic scenarios, nonlinear IDA, and probabilistic fragility analysis for an existing steel arch bridge founded on soft soil. The findings provide a scientific basis for seismic risk assessment, resilience evaluation, and performance-based management of steel arch bridge infrastructure in earthquake-prone regions.

2. METHODOLOGY

This study adopted a Performance-Based Earthquake Engineering (PBEE) concept to evaluate the seismic reliability of the Rumbai Jaya Steel Arch Bridge. PBEE has become the preferred methodology for seismic performance assessment because it explicitly relates seismic hazard, structural demand, damage states, and decision variables, thereby providing a probabilistic basis for evaluating structural performance beyond conventional force-based design.

The analytical procedure consisted of six consecutive stages: (i) development of a three-dimensional finite-element model, (ii) verification of the structural model through modal analysis and section-capacity evaluation, (iii) selection and spectral matching of earthquake ground motions, (iv) nonlinear Incremental Dynamic Analysis (IDA), (v) seismic fragility assessment, and (vi) interpretation of bridge reliability under increasing seismic intensities. The adopted workflow enables both deterministic and probabilistic evaluation of bridge performance while explicitly considering structural nonlinearity and record-to-record variability.

2.1. Characterization mechanical characteristics and numerical modeling. Steel arch bridges possess unique mechanical characteristics that enable the transformation of vertical gravity loads into a predominantly horizontal thrust at their abutments. Consequently, this load-transfer mechanism substantially minimizes mid-span bending moments, making them vastly more structurally efficient compared to traditional straight girder systems. In practice, the performance of this structure relies heavily on the quality of its constituent materials.

Structural steel members were modeled using nonlinear frame elements based on Grade 50 steel and also material properties followed SNI 1729:2020, which specifies a standard modulus of elasticity of 200,000 MPa and a yield strength ranging from 210 to 250 MPa, as presented in Table 1. A three-dimensional numerical model was developed using the structural analysis software to accurately

Table 1. Properties of structural steel.

Parameter	General values
Modulus of Elasticity (E)	200.000 MPa
Shear Modulus (G)	80.000 MPa
Poisson's Ratio (μ)	0,30
Coefficient of Linear Expansion (α)	12 x 10-6/°C
Yield Stress	210 - 250 MPa
Ultimate Stress	360 - 700 MPa

represent the bridge geometry, boundary conditions, material properties, and loading configuration. The bridge loading provisions followed SNI 1725:2016. Static loading included self-weight, superimposed dead load, pedestrian load, lane loading (D Load), and truck loading (T Load), which were combined according to the Indonesian bridge design code before nonlinear seismic analysis was performed.

The structural modeling precisely represents the bridge's actual condition, encompassing the definition of structural steel (Grade 50) and concrete materials, transverse and longitudinal girder sections, piers, pier heads, pile caps, vehicle deck slabs, and the fixed support configurations at the base. Static gravity loading was applied, including the structural self-weight, superimposed dead loads, pedestrian loads, and traffic live loads consisting of 'D' lane loads and 'T' truck loads. These loading scenarios were linearly combined, and nonlinear plastic hinges were subsequently assigned to critical steel member locations to identify the material yielding process up to the structural collapse phase under incremental seismic loads.

In the seismic load preparation phase, this study adopts the Performance-Based Earthquake Engineering (PBEE) principles by selecting 12 pairs of ground motion records from the Pacific Earthquake Engineering Research Center (PEER) and NHR3 databases. These records are categorized into three dominant tectonic source scenarios: shallow crustal, megathrust subduction, and deep intraslab earthquakes. Data selection prioritized recording stations with low shear wave velocities (Vs30 < 175 m/s) to minimize spectral distortion and accurately represent the soft soil characteristics at the bridge site.

The raw seismic records were numerically processed for spectral matching, aligning the ground motion waveforms with the target design response spectrum curve required by SNI 1726:2019. The Peak Ground Acceleration (PGA) values derived from this matching process were then extracted to serve as the input acceleration scale factors.

The primary analytical stage involves Incremental Dynamic Analysis (IDA), characterized by nonlinear time-history simulations in which the bridge model is excited by a suite of seismic records at progressively increasing intensity levels. Compiling the resulting dynamic response and deformation data enables the construction of seismic fragility curves. These probabilistic functions are utilized to provide a quantitative assessment of the bridge's structural resilience and to forecast damage states under diverse seismic hazard levels, providing a robust technical basis for seismic risk mitigation.

2.2. Seismic load and site amplification. The seismic vulnerability assessment of bridge infrastructure necessitates an in-depth evaluation of soil conditions and structural height, as specified by the Indonesian Code in SNI 1726-2019 and SNI 2833-2016. Seismic waves originating from the bedrock undergo amplification as they propagate to the surface, which is quantified by the site coefficients F_a for short periods (0.2 seconds) and F_v for a 1-second period. The design response spectrum parameters at the ground surface are formulated through the mathematical functions in Equation (1) and (2):

$$S_{MS} = F_\alpha \cdot S_S \quad (1)$$

$$S_{M1} = F_v \cdot S_1 \quad (2)$$

where S_s and S_1 represent the regionally mapped bedrock acceleration parameters. Furthermore, the Peak Ground Surface Acceleration Coefficient (A_s) is calculated by multiplying the Peak Ground Acceleration (PGA) by the corresponding amplification factor, using Equation (3).

$$A_S = F_{PGA} \cdot PGA \quad (3)$$

2.3. Structural section capacity evaluation. The evaluation of the performance and reliability of structural bridge elements, particularly load-bearing components such as concrete piers, is determined by their cross-sectional capacity to withstand a combination of internal forces. Based on the provisions of SNI 2847:2019, the assessment of cross-sectional capacity encompasses three crucial parameters: flexure (moment), shear, and axial force.

First, the design moment capacity (φM_n) is calculated based on the principles of force equilibrium and strain compatibility, assuming an equivalent rectangular concrete stress block distribution. This nominal strength accounts for the contribution of the tensile steel reinforcement reaching its yield point, as well as a strength reduction through the φ factor to ensure cross-sectional safety against the factored moment (M_u). The flexural capacity requirement is mathematically expressed as shown in Equation (4).

$$\varphi M_n \geq M_u \quad (4)$$

where M_n is the nominal flexural strength of the cross-section, and M_u is the factored bending moment. Second, to prevent the occurrence of diagonal cracking that triggers sudden brittle failure, the evaluation of the nominal shear capacity (V_n) applies a more stringent strength reduction factor. The total shear strength is the accumulation of the shear-resisting capacity provided by the concrete material (V_c) and the contribution of the shear reinforcement or stirrups (V_s), with the fundamental equation for shear yield stress given in Equation (5).

$$V_n = V_c + V_s \quad (5)$$

Third, the design axial capacity (φP_n) is evaluated based on the combined compressive strength of the concrete and the longitudinal reinforcement, rigorously accounting for the effects of load ec-

centricity. The standard mandates an additional reduction factor to accommodate the uncertainty of the axial load position relative to the cross-sectional centroid. The nominal axial strength (P_n) is formulated in Equation (6).

$$P_n = 0{,}85fc' \cdot (A_g - A_{st}) + f_y \cdot A_{st} \quad (6)$$

where fc' denotes the specified compressive strength of concrete, f_y is the yield strength of the longitudinal reinforcement, A_g represents the gross cross-sectional area of the concrete, and A_{st} is the total cross-sectional area of the reinforcement.

2.4. Incremental dynamic analysis (IDA). The IDA methodology is implemented as an advanced nonlinear time-history analysis wherein the structural model is subjected to a suite of ground motion records, the intensities of which are incrementally scaled until the structure reaches dynamic instability or collapses [18, 19]. To satisfy the probabilistic validity requirements set forth in SNI 1726:2019, this analysis mandates the use of a minimum of 11 pairs of ground motion records representing multiple fault mechanisms, such as crustal, megathrust, and intraslab earthquakes.

The computational results derived from the IDA are subsequently converted into seismic fragility curves. The structural degradation benchmarks utilized in the development of these curves are based on international standards [20], which classifies the drift ratio into 5 Limit States, as presented in Table 2 and Table 3.

These five performance levels hierarchically represent the structural transition phases, ranging from Fully Operational (no damage), Operational (minor damage), and Life Safety (moderate damage/safety limit), to Near Collapse (pre-collapse state), and finally Collapse (total failure). This standard enables the quantification of bridge failure probabilities across various seismic hazard ranges with high accuracy.

Table 2. Classification of bridge damage levels based on NCHRP 440.

Level	Damage classification	Explanation	Category
I	No	Hairline cracks starting to appear	Fully operational
II	Minor	The crack is starting to widen, early signs of damage are starting to appear.	Operational
III	Moderate	The structure is starting to deform the outer concrete layer is starting to peel off, slanted cracks are in several areas	Limited damaged
IV	Major	Very large cracks, concrete is starting to peel off extensively	Life safety
V	Local Failure /Collapse	The main reinforcement is bent or brokenhe upper reinforcement is broken, the interior of the concrete is severely destroyed	Collapse

Table 3. Seismic performance parameter limits (% Drift) NCHRP 440.

Level	Category	% Drift
I	Fully Operational	<1,0
II	Operational	1,0
III	Life Safety	3,0
IV	Near Collapse	5,0
V	Collapse	8,7

2.5. Seismic fragility assessment. The seismic performance of the bridge was quantified using fragility analysis based on NCHRP Synthesis 440. Structural response was classified into five performance levels: Fully Operational (FO), Operational (OP), Life Safety (LS), Near Collapse (NC), and Collapse (C) according to the corresponding drift limits.

Fragility functions were assumed to follow a lognormal cumulative probability distribution, which has been widely adopted in Performance-Based Earthquake Engineering due to its ability to represent uncertainties associated with structural capacity and seismic demand [21]. The probability of exceeding each damage state was calculated as Equation (7).

where IM denotes the earthquake intensity measure, θ is the median structural capacity, β is the logarithmic standard deviation, and Φ represents the cumulative standard normal distribution.

The generated fragility curves prvide a probabilistic description of bridge performance under increasing seismic intensity and enable quantitative estimation of structural reliability and collapse probability.

$$P(DS \mid IM) = \Phi\left(\frac{\ln(IM) - \ln(\theta)}{\beta}\right) \quad (7)$$

3. RESULTS AND DISCUSSION

3.1. Verification of dynamic characteristic and cross-section capacity. Before conducting dynamic seismic load simulations, the Rumbai Jaya Bridge finite element model underwent verification to guarantee a consistent representation of its physical response. Modal analysis using the Eigenvector approach was executed to determine the natural periods, frequencies, and mode shapes, key indicators of the structure's mass and stiffness distribution, as illustrated in Table 4 and Figure 1.

Based on Table 4, the bridge possesses a fundamental natural period (T1) of 0.48 seconds, with dominant translation in the transversal direction, which is a typical dynamic behavior for arch truss systems. The model complies with SNI 1726-2019 standards, as the cumulative modal mass participation ratio exceeds the 90% minimum threshold, reaching 92% in the X direction and 97% in the Y direction by the 15th mode. This confirms that the model accurately captures the entire structural inertial response. Subsequently, a cross-sectional capacity check was performed to ensure that the bridge elements can withstand extreme load combinations in accordance with SNI 1725:2016 prior to seismic loading. This analysis focuses on the most critical point, specifically the reinforced concrete pier elements with a circular cross section of 1.5 meters in diameter under the load combinations shown in Table 5.

Table 4. Natural period and frequency of the Rumbai Jaya bridge structure.

Step type	Step num	Period	Frequency	CircFreq
Mode	1	0,48	2,06	12,96
Mode	2	0,29	3,39	21,33
Mode	3	0,27	3,72	23,38
Mode	4	0,24	4,24	26,64
Mode	5	0,22	4,53	28,46
Mode	6	0,16	6,16	38,69
Mode	7	0,14	7,12	44,76
Mode	8	0,14	7,27	45,68
Mode	9	0,12	8,06	50,65
Mode	10	0,12	8,66	54,40
Mode	11	0,10	10,40	65,35
Mode	12	0,09	10,70	67,26
Mode	13	0,08	11,85	74,46
Mode	14	0,08	12,57	79,00

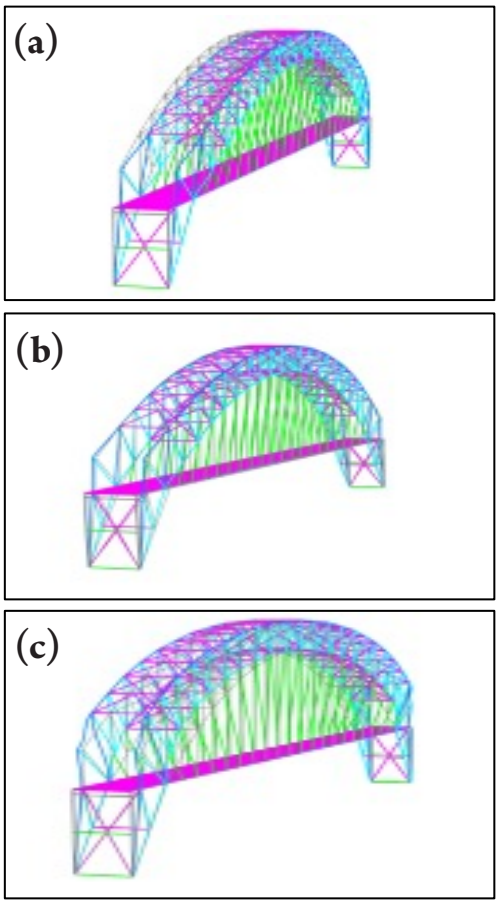

Figure 1. Mode Shape 1 (a) Mode Shape 2 (b) Mode Shape 3 (c) Mode shape of the bridge.

Table 5. Recapitulation of pillar capacity evaluation.

Internal force type	Ultimate force	Design capacity	Performance ratio (D/C)	Status
Bending Moment (M)	2,591.87 kNm	6,406.76 kNm	0.40	Safe
Shear F orce (V)	863.98 kN	1,419.29 kN	0.61	Safe
Axial Comp-ression (P)	8,612.13 kN	22,310.04 kN	0.39	Safe

Based on Table 5, it is observed that the performance ratios for all internal forces within the pier elements are well below the critical threshold of 1.0. The ultimate moment recorded a ratio of 0.40, while the shear force and axial compressive load showed ratios of 0.61 and 0.39, respectively. These figures conclusively demonstrate that the pier cross sections are protected against potential brittle failure and possess highly adequate initial strength reserves.

3.2. Incremental dynamic analysis (IDA) response. The IDA analysis was conducted by subjecting the model to 12 pairs of multi-scenario ground motion records (Crustal, Megathrust, and Intraslab), with intensities incrementally scaled from 0.1g to 1.0g, as illustrated in the curves in Figure 2. The simulation results in Figure 2 demonstrate that the increase in peak ground acceleration (PGA) is directly proportional to the structural performance degradation. A significant record-to-record variability is observed; the Tohoku record triggered a drift of up to 12.33% (Collapse level), whereas the Geiyo and Morgan records consistently maintained drift levels

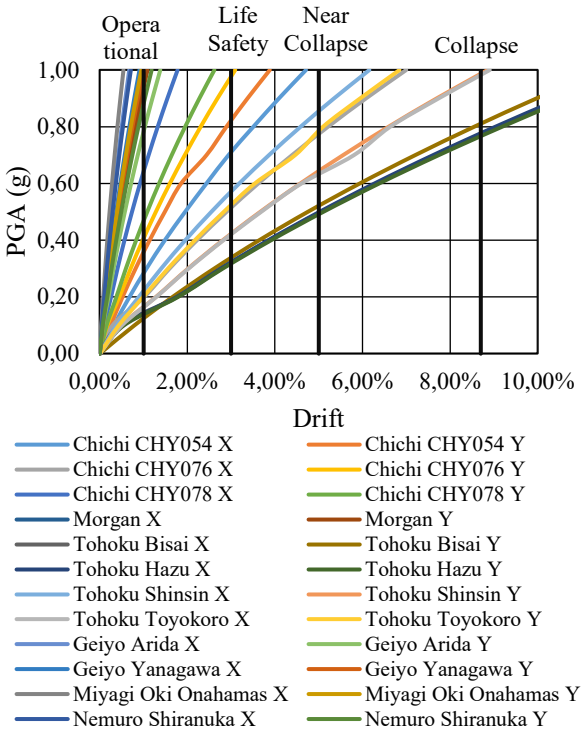

Figure 2. Incremental dynamic analysis (IDA) curve of Rumbai Jaya Bridge.

below 1.5% (ranging from Fully Operational to Operational) up to the maximum intensity. To evaluate the general performance trend, mean statistical response values from all ground motions were developed, as presented in Table 6 and Figure 3.

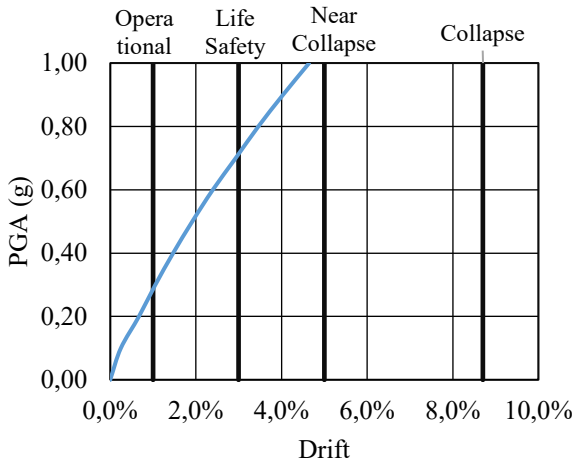

Figure 3. IDA curve average earthquake.

Table 6. Average statistical value of drift at each PGA level.

Intensity (g)	Drift (%)	Performance Level
0,0	0,00	Fully Operational
0,1	0,25	Fully Operational
0,2	0,67	Fully Operational
0,3	1,05	Operational
0,4	1,47	Operational
0,5	1,92	Operational
0,6	2,40	Operational
0,7	2,93	Operational
0,8	3,46	Life Safety
0,9	4,03	Life Safety
1,0	4,64	Life Safety

Based on the average data, the bridge structure begins to reach the Operational performance level at a ground acceleration intensity of 0.3g, with a mean drift value of 1.05%. The degradation toward the Life Safety damage state only occurs when the intensity exceeds 0.7g. Although the rate of drift increase (slope) continues to grow, indicating gradual inelastic softening, the mean structural response at the 1.0g extreme limit (4.64%) remains below the Near Collapse performance level (5.0%). This demonstrates the substantial reserve strength inherent in the steel arch system.

3.3. Seismic fragility curve and safety margin. The output from the IDA simulations is converted into fragility curves to quantify the probability of the structure exceeding specific damage states across various seismic hazard levels, as displayed in Figure 4. The fragility curves in Figure 4 demonstrate that the probability of exceeding the Operational damage level surges to 81.6% at the extreme

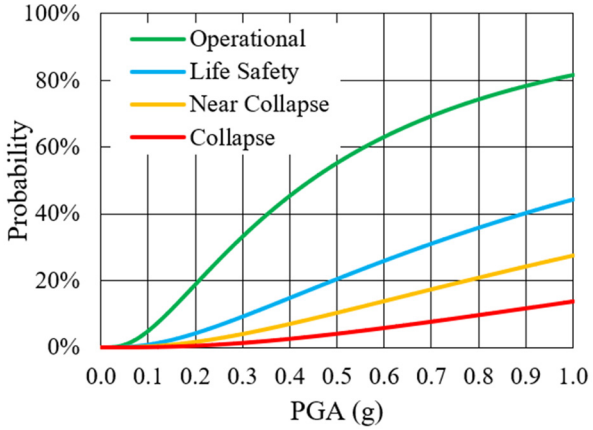

Figure 4. Seismic fragility curve.

Table 7. Probability of damage to the Rumbai Jaya Bridge.

Damage State	Probability of damage occurring
Operational	11,67%
Life Safety	2,28%
Near Collapse	0,81%
Collapse	0,21%

intensity of 1.0g. However, regarding fatal structural damage at 1.0g, the Collapse curve exhibits the shallowest slope, with a probability of only 13.92%. Based on the design PGA of 0.1511g at the study location, the resulting damage probabilities for the Rumbai Jaya Bridge are summarized in Table 7. A comprehensive evaluation of the design seismic hazard at the Rumbai Jaya Bridge site (PGA 0.1511g) confirms a high level of safety. Based on Table 7, the probability of exceeding the Operational limit is only 11.67%, while the risk of total collapse is minimized to a marginal 0.21%. These figures definitively conclude that the Rumbai Jaya Bridge is predicted to operate with a high degree of safety, with no significant structural damage expected under future design earthquake excitations.

4. CONCLUSION

The present study demonstrated that the Incremental Dynamic Analysis (IDA) method provides a comprehensive approach for evaluating the seismic performance of the Rumbai Jaya Steel Arch Bridge under multiple earthquake scenarios. Modal analysis indicated that the bridge response is governed primarily by transverse vibration, with a fundamental period of 0.48 s, while the cross-sectional capacity assessment confirmed that the critical pier elements possess sufficient reserve strength to withstand the governing design load combinations. The low demand-to-capacity ratios for flexure, shear, and axial compression indicate that the bridge satisfies the required structural safety criteria prior to nonlinear seismic loading.

The nonlinear dynamic analyses revealed substantial record-to-record variability, highlighting the influence of earthquake characteristics on bridge response. Although the Tohoku ground motion generated the most critical response, resulting in

a collapse-level drift under extreme loading conditions, the average structural response remained below the Near Collapse performance limit even at the maximum investigated intensity of 1.0 g. Furthermore, the transition from the Operational to the Life Safety performance level occurred gradually with increasing seismic intensity, indicating stable inelastic behavior and considerable deformation capacity before significant structural deterioration.

Fragility analysis further confirmed the robustness of the bridge under the site-specific seismic hazard. At the design peak ground acceleration of 0.1511 g, the probabilities of exceeding the Operational and Collapse limit states were limited to 11.67% and 0.21%, respectively, demonstrating a substantial seismic safety margin. Even under the extreme loading scenario of 1.0 g, the predicted probability of global collapse remained relatively low, reflecting the inherent redundancy and resilience of the steel arch structural system.

Overall, the findings demonstrate that integrating nonlinear IDA with probabilistic fragility analysis provides a reliable method for evaluating the seismic reliability of existing steel arch bridges. Beyond verifying structural safety, the proposed methodology enables quantitative estimation of seismic risk and supports performance-based maintenance planning and resilience-oriented bridge management. These results contribute to the growing body of knowledge on probabilistic seismic assessment of long-span steel arch bridges, particularly those founded on soft-soil deposits in regions characterized by complex tectonic environments.

Future research should therefore integrate soil–structure interaction, deterioration-dependent material models, spatially variable ground motions, and climate-induced hazards into probabilistic seismic assessments. In addition, extending the proposed approach toward resilience-based evaluation by incorporating functionality recovery, economic loss, and post-earthquake serviceability would provide a more comprehensive basis for sustainable bridge management in earthquake-prone regions.

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CREDIT AUTHOR STATEMENT

Alex Kurniawandy: Supervision, Conceptualization, Methodology, Writing-Original draft preparation. **Anwar**: Investigation, Data curation, Formal analysis, Writing-original draft preparation. **Muhammad Ikhsan**: Visualization, Data curation, Formal analysis.

DECLARATIONS

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

AVAILABILITY OF DATA

All data supporting the findings of this study are included within the manuscript.

AI DISCLOSURE STATEMENT

The authors declare that no Generative AI tools were used in the preparation, writing, analysis, or editing of this manuscript.

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