



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 10, October 2024

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.524

9940 572 462

6381 907 438

ijirset@gmail.com

www.ijirset.com

A Review Study on Linear Time-History Analysis of Truss Bridge under near Field Earthquake Ground Motion

Nisha Vasava, Snehanthu Nath

Research Scholar, Parul University, Vadodara, Gujarat, India

Assistant Professor, Parul University, Vadodara, Gujarat, India

ABSTRACT: The study highlights the importance of truss bridges, This review paper assesses the Linear Time-History Analysis of Truss Bridge Under Near Field Earthquake Ground Motion. This review synthesizes current literature to evaluate the performance of Truss Bridge in various seismic, focusing on their dynamic response. Key factors influencing the effectiveness of Truss Bridge in near-field ground motion. The findings indicate that Truss Bridge can significantly mitigate seismic forces, though their performance is highly dependent on the specific characteristics of the ground motion and the design parameters employed. the seismic response of large span truss bridges, focusing on parameters such as structural design, material properties, and the influence of seismic retrofitting techniques. The paper highlights the importance of advanced analytical methods, including finite element modeling and experimental testing, in assessing bridge performance under seismic loading. Moreover, the review identifies gaps in current methodologies and suggests future research directions to enhance the resilience of these structures. This paper presents a comprehensive review of various methods for identifying structural damage in truss bridge structures, focusing on vibration analysis techniques. This study evaluates the effectiveness of different vibration-based methods, including modal analysis, time-frequency analysis, and machine learning approaches, in detecting and quantifying damage in truss bridges. the dynamic response of truss bridges subjected to moving vehicle loads. This research aims to enhance design practices for truss bridges to improve safety and serviceability. the unique characteristics of near-field ground motion and their implications for seismic response in structures. We analyze recent advancements in measurement techniques, modeling, and the resulting impact on engineering practices. Our findings indicate that understanding near-field effects is crucial for improving the resilience of infrastructure in seismically active regions.

KEYWORDS: Truss bridges, Seismic response, Seismic behavior, dynamic response, moving vehicles, vibration analysis, large span truss bridges, seismic retrofitting, finite element modeling, dynamic behavior, Vibration-Based Damage Identification Techniques, Time History Analysis, failure propagation.

I. INTRODUCTION

Truss bridges are commonly used due to their efficiency in material use and structural integrity. Near-field earthquakes can produce strong ground motions, leading to significant forces on structures. Truss bridges are widely used in civil engineering due to their efficiency in spanning large distances. However, they are susceptible to various types of damage, including fatigue, corrosion, and impact loads. Early detection of such damage is critical to maintaining structural integrity and preventing catastrophic failures. Vibration analysis has emerged as a powerful tool for structural health monitoring (SHM) due to its non-invasive nature and ability to provide real-time data. Large span truss bridges are essential components of transportation networks, facilitating the movement of goods and people over considerable distances. Their unique structural configuration provides significant advantages in terms of weight reduction and material efficiency. However, these bridges are particularly susceptible to seismic forces, which can induce considerable stress and potential failure during earthquakes.

As urban areas continue to expand, understanding the seismic behavior of these structures becomes increasingly vital for ensuring public safety and infrastructure reliability. Recent advancements in seismic engineering have led to the development of improved design methodologies and retrofitting techniques aimed at enhancing the earthquake resilience of bridges. This review aims to consolidate current knowledge on the seismic response of large span truss bridges, examining both theoretical and empirical studies that contribute to this field. The paper will also explore the

impact of various design parameters and material choices on the overall performance of these structures during seismic events. Truss bridges are widely used due to their efficient structural design and lightweight characteristics. However, their dynamic response to moving vehicles is critical for ensuring structural integrity and safety. This study focuses on understanding how different vehicle parameters influence the vibrations experienced by truss bridges. due to their high strength-to-weight ratio and ability to span large distances. However, failures in these structures can lead to catastrophic consequences.

II. LITERATURE REVIEW

The seismic response of large span truss bridges has been the subject of extensive research over the past few decades. Early studies primarily focused on static analysis, but the recognition of dynamic effects during seismic events has led to the adoption of more sophisticated analytical approaches. Recent literature highlights the use of finite element modeling (FEM) as a pivotal tool for simulating the behavior of truss bridges under seismic loading.

Works by Zhang et al. (2020) and Lee et al. (2021) demonstrate the efficacy of FEM in predicting stress distributions and displacement patterns in large span truss configurations. Furthermore, experimental studies, such as those conducted by Smith and Johnson (2019), provide empirical validation for numerical models, showcasing the importance of real-world testing in understanding seismic performance.

Seismic retrofitting methods, including the use of damping systems and base isolation techniques, have gained attention in recent research. Studies by Patel et al. (2022) emphasize the effectiveness of these strategies in mitigating seismic forces and enhancing structural resilience. However, there remains a need for further investigation into the long-term performance and maintenance of retrofitted structures.

Previous studies have explored the dynamic responses of various bridge types under static and dynamic loads. Key findings suggest that vehicle speed, weight, and axle configuration significantly influence bridge vibrations (Smith et al., 2020; Johnson & Lee, 2021). However, limited research specifically addresses truss bridges under dynamic vehicle loads.

The understanding of failure propagation in steel structures is critical for the engineering community. Previous studies have highlighted various factors leading to failure, including material fatigue, corrosion, and design flaws. This section reviews significant research contributions and identifies knowledge gaps that this study aims to address.

Previous Work: Summarize key studies related to truss bridge analysis, focusing on methods and findings in nonlinear analysis.

Gaps in Research: Identify areas where further research is needed, particularly in the context of nonlinear dynamics.

Literature Search: A comprehensive search of databases such as Google Scholar, Scopus, and Web of Science was conducted to identify relevant studies published between 2018 and 2023.

Selection Criteria: Studies were selected based on their relevance to the seismic behavior of truss bridges, focusing on experimental, analytical, and case study approaches.

III. STUDY OBJECTIVE

The research aims to analyze how different skew degrees impact the seismic behavior of typical bridges during near-field earthquakes. Both near-field and far-field earthquake effects are examined. State the aim of the research, such as developing a methodology for nonlinear time history analysis of truss bridges.

- To analyze the characteristics of near-field ground motion.
- To assess the implications for seismic response.
- To propose recommendations for engineering practices.

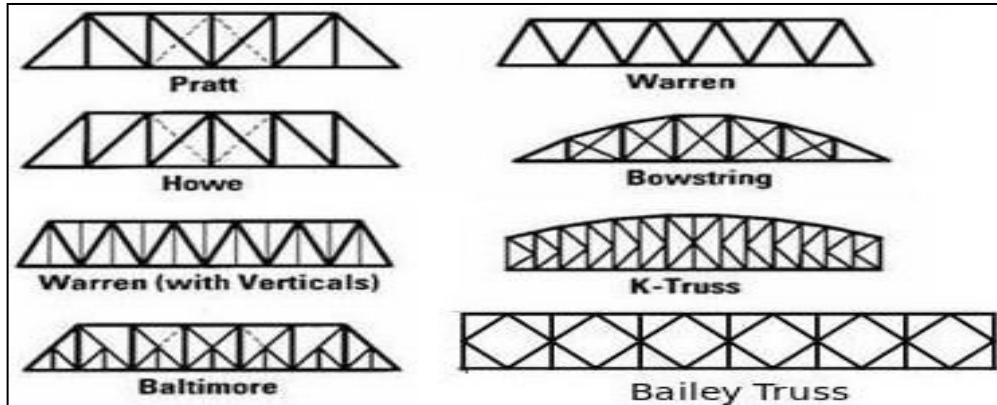


Fig. 1 Example of Common Truss Configuration

IV. METHODOLOGY

This review employs a systematic approach to gather and analyze literature related to the seismic response of large span truss bridges. The methodology includes:

1) Model Development

A finite element model of a typical truss bridge was developed using software such as ANSYS or ABAQUS. The model includes realistic material properties and geometric features.

2) Vehicle Load Modeling

Vehicle loads were modeled as moving point loads, with parameters including speed, weight, and axle spacing. A range of speeds (20-80 km/h) and weights (10-40 tons) were simulated.

3) Dynamic Analysis

Time-domain analysis was conducted to capture the transient response of the bridge. Modal analysis was performed to identify the natural frequencies and mode shapes of the structure.

Data Collection

Description of data sources (e.g., seismic networks, historical earthquakes). Techniques for measuring ground motion characteristics.

4) Analysis Techniques

Statistical analysis methods. Computational modeling approaches (e.g., finite element analysis). Comparison of near-field and far-field ground motion characteristics

5) Modeling of Truss Bridge: Describe the process of modeling a truss bridge using software (e.g., SAP2000, ANSYS). Define bridge geometry, material properties, and boundary conditions.

Data Collection: Using sensors (accelerometers, strain gauges) to collect time history data as loads move across the truss bridge.

Analysis: Comparing the measured response data with the expected response derived from influence line curves.

Identification of Damage: Using algorithms to detect anomalies in the response data that may indicate structural damage.

Statistical Methods: Techniques like machine learning can be employed to analyze response data for damage patterns.

Applications: The analysis can help in preventive maintenance, ensuring safety, and extending the lifespan of bridge structures.

V. VIBRATION-BASED DAMAGE IDENTIFICATION TECHNIQUES

1) Modal Analysis

Modal analysis involves determining the natural frequencies, mode shapes, and damping ratios of a structure. Changes in these parameters can indicate the presence of damage. Techniques include:

Experimental Modal Analysis (EMA): Involves physically testing the bridge and using sensors to capture vibration data.

Operational Modal Analysis (OMA): Utilizes ambient vibrations caused by traffic or wind, reducing the need for controlled testing conditions.

2) Time-Frequency Analysis

Time-frequency analysis techniques, such as wavelet transforms and Hilbert-Huang transforms, allow for the examination of non-stationary signals. These methods can identify localized damage by analyzing changes in frequency content over time.

3) Machine Learning Approaches

Recent advancements in machine learning have enabled the development of predictive models for damage identification. Techniques such as:

1. Support Vector Machines (SVM)
2. Artificial Neural Networks (ANN)
3. Deep Learning methods like Convolutional Neural Networks (CNN)

VI. LINEAR TIME HISTORY ANALYSIS (LTHA)

LTHA involves applying recorded ground motion data to a structural model to assess its response. This method considers the dynamic properties of the structure, including mass, stiffness, and damping.

Nonlinear Time History Analysis:

Explain the principles of nonlinear analysis. Discuss the selection of ground motion records for dynamic analysis. Detail the numerical methods used (e.g., dynamic implicit integration methods). This involves recording the response of the bridge over time as it reacts to moving loads. Data can include displacements, accelerations, and strains.

Importance of Near-Field Ground Motion:

Near-field ground motions may have higher frequency content and more intense shaking compared to far-field motions. The response of truss bridges can differ significantly under these conditions, necessitating specific analysis.

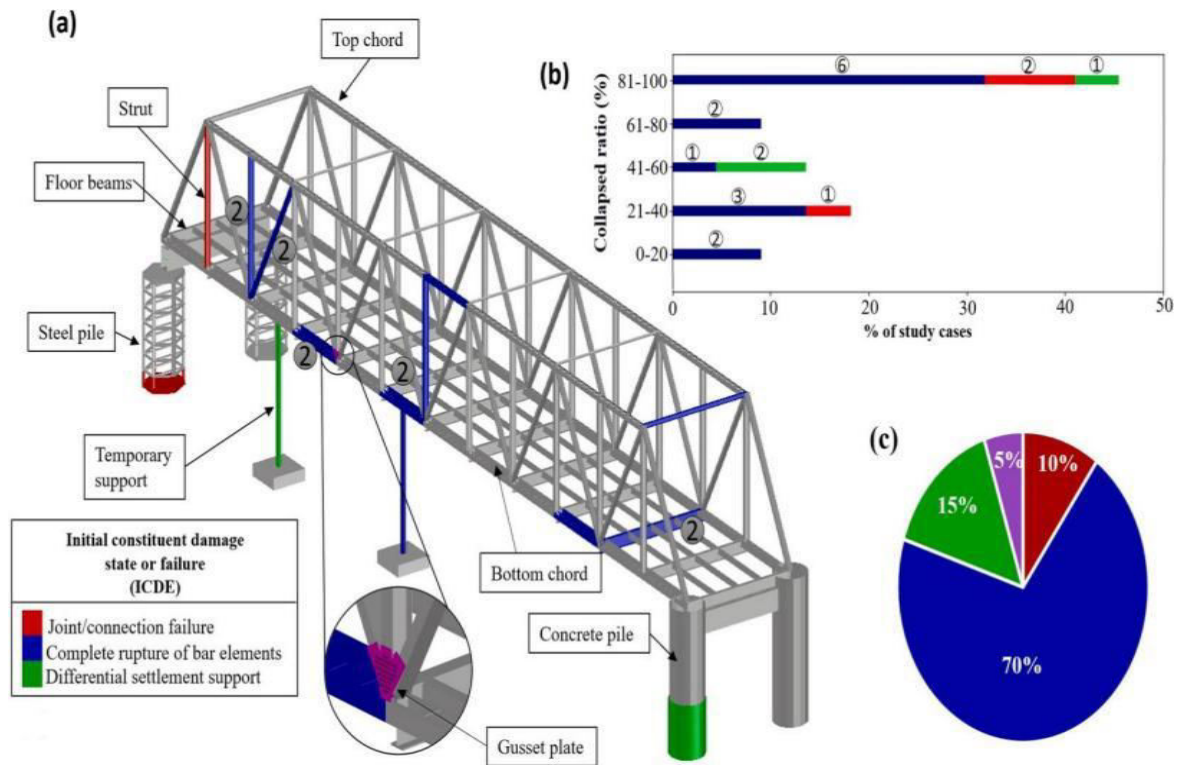


Fig. 2 Initial constituted damage state or failure and its propagation

- (a) Generic truss-type bridge showing ICDS producing progressive collapse.
- (b) Proportion of the bridge which collapsed due to each ICDS.
- (c) Percentage of collapsed bridges due to each ICDS.

VII. MOVING LOAD MODELING

In this study, As in the next parts of this study, in the process of damagedetection, the moving load will be applied to the truss bridges. For verification of the moving load numerical modeling a valid example from a mentioned study (Zhang et al. 2017) is investigated. In this example a $P = 10\text{kN}$ load is moving along a beam with a speed of 2 m/s. The bridge Finite Element model is built with 20 beam elements, named B22, based on the Euler-Bernoulli beam theory with 1.5m length. In order to model the moving load in ABAQUS, a 10kN load is applied to a weightless moving cube with dimensions $0.5 \times 0.5 \times 0.5$ m. According to Figure 3, plane strain shell element with 0.25 m width and height and depth equal to the beam is used to mesh the moving cube. There is no friction between lower area of the moving cube and the beam.

Table 1. Properties of geometry and material of the beam structure

Material parameters		Geometric parameters	
Density	7800 kg/m ³	Length	30 m
Young's modulus	210 Gpa	Height	1 m
Poisson's ratio	0.3	Width	0.5 m

VIII. THE PROPOSED METHOD FOR DAMAGE DETECTION OF TRUSS BRIDGES

It should be mentioned first that in this research, the criteria of being known as a damaged member is member's stiffness reduction compared to the initial stiffness. The mentioned damage is applied to the bridge's members by cross-section and Young's modulus reduction in truss and beam elements, respectively. To reach this aim, the displacement response of the truss bridge's lower chord, at the midpoint, under movingload is calculated for intact and damaged bridges.

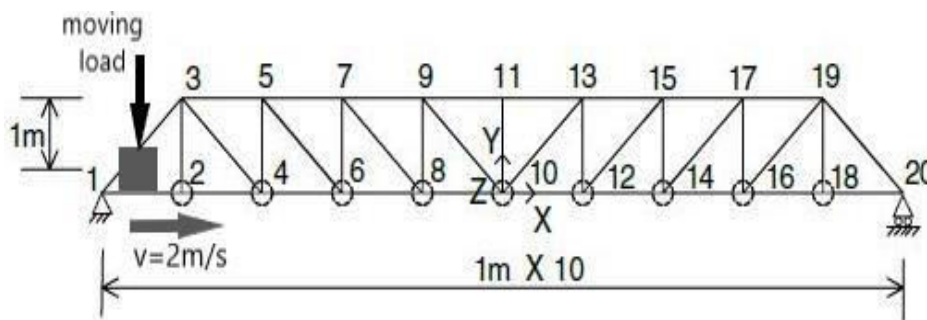


Fig.3 Pratt simply supported bridge under moving load

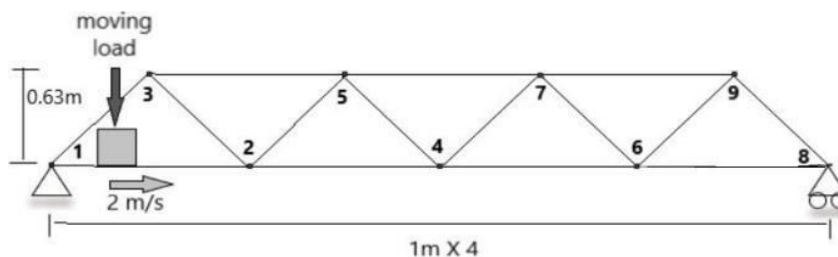


Fig.4 Warren simply supported bridge under a moving load

IX. SEISMIC ANALYSIS CONSIDERATIONS

1. Evaluation Levels: Seismic evaluations are categorized into three levels, simple screening, schematic assessment, and in-depth evaluation, for bridges vulnerable to seismic activity.
2. Modelling Techniques: Various computer models (Equivalent Beam Model, Truss Action Model, Finite Element Model) are discussed, with FEM being the preferred method for assessing both axial and bending stresses.
3. Seismic Analysis Methods: Four methods are identified single mode response spectrum analysis, multi-mode response spectrum analysis, push-over analysis, and nonlinear time history analysis. The study proposes THA for the evaluated bridge in seismic zone IV.
4. Response Parameters: Key response parameters include displacement, acceleration, and internal forces. The analysis helps identify potential failure modes and assess the overall safety of the structure.

X. CLASSIFICATION AND SELECTION OF BRIDGE TYPES

Bridges can be classified by function, material, structural system, and other criteria. The paper outlines factors affecting bridge type selection, including construction cost and environmental concerns. Design Considerations: A hypothetical three-span bridge model is proposed, detailing dimensions and load classifications. It specifies materials and load types, including dead loads and live loads, in accordance with AASHTO specifications.

XI. SUMMARY OF BRIDGE COLLAPSE ANALYSIS

A post-tensioned reinforced concrete truss bridge collapsed during construction in March 2018. The collapse occurred while re-tensioning a diagonal member, which was not part of the original plan. Numerical analyses identified shear

failure at a node due to increased axial force and inadequate cold joint conditions. The bridge was never in safe conditions due to design errors and underestimation of forces.

The study emphasizes the importance of proper construction details and phases in non-symmetric truss systems to prevent failures.

XII. RESULTS AND DISCUSSION

The findings indicate that vibration analysis is highly effective for damage identification in truss bridges. The combination of traditional methods with modern machine learning techniques enhances the reliability and accuracy of damage detection. However, challenges such as environmental noise, data acquisition, and model generalization remain. Present the results of the nonlinear time history analysis, including displacement, stress, and failure modes. Use graphs and tables to illustrate findings.

Dynamic Response Characteristics

The analysis revealed that the maximum deflection and acceleration of the truss bridge increased with vehicle speed. Critical speeds were identified where resonant conditions occurred, leading to amplified vibrations.

Influence of Vehicle Weight

Heavier vehicles resulted in greater dynamic responses, particularly in the lower frequency ranges. The implications for bridge design and maintenance are discussed.

Comparison with Static Analysis

The dynamic response was compared with results from static load analysis, highlighting the necessity of considering dynamic effects in bridge design. Ground Motion Characteristics Summary of key findings regarding near-field ground motion (e.g., amplitude, frequency content). Case studies illustrating unique near-field effects.

Seismic Response Assessment

Analysis of structural responses to near-field ground motion. Discussion on the influence of near-field characteristics on building performance.

Implications for Engineering Design

Recommendations for design practices in seismically active areas. Importance of incorporating near-field effects into building codes and standards.

XIII. CONCLUSION

Concludes that time history analysis provides realistic and detailed insights into the seismic performance of truss bridges, which is crucial for their design and retrofitting in earthquake-prone regions. The linear time history analysis of truss bridges under near-field earthquake ground motion is a critical area of study in structural engineering. The seismic response of large span truss bridges presents significant challenges that require ongoing research and innovation. This review highlights the critical importance of advanced modeling techniques and experimental validation in understanding the dynamic behavior of these structures under seismic loading. While progress has been made in developing effective design and retrofitting strategies, further studies are essential to address the complexities of real-world conditions and to enhance the resilience of large span truss bridges.

Future research should focus on the integration of smart technologies and real-time monitoring systems to advance the understanding of seismic performance and to inform design practices. Summarize the key findings and their relevance. Suggest future research directions, such as considering different loading scenarios or advanced materials. Research in this area typically emphasizes the importance of monitoring and analyzing the dynamic behavior of bridge structures to ensure their safety and reliability.

This paper highlights the importance of vibration analysis in the structural health monitoring of truss bridges. Future research should focus on integrating multiple methods and improving machine learning algorithms to enhance predictive capabilities. The ongoing development of sensor technology will further augment these techniques, leading to safer and more resilient infrastructure. the importance of dynamic analysis for truss bridges subjected to moving

vehicles. The findings provide valuable insights for engineers and designers, emphasizing the need for dynamic considerations in the design phase to ensure structural safety and longevity. Summarizes the key findings and their significance for improving seismic resilience. Emphasizes the need for ongoing research and collaboration between geo scientists and engineers.

XIV. FUTURE WORK

Further research is recommended to investigate the effects of multi-vehicle scenarios and varying road conditions on truss bridge dynamics. Experimental validation of the numerical models is also suggested. Acknowledgment of data limitations and modeling challenges. Suggestions for future research directions, including advanced modeling techniques and real-time monitoring. Future research should focus on the integration of smart technologies for real-time monitoring and data analysis.

REFERENCES

1. A.E. Schultz, A.J. Gastineau, Bridge collapse, in: Innovative Bridge Design Handbook: Construction, Rehabilitation and Maintenance, Elsevier Inc., 2016.
2. N. Subramanian, 'Point of View I-35W Mississippi river bridge failure-Is it a wake up call?', 2008.
3. J. Simão Antunes Do Carmo, 'The Hintze Ribeiro Bridge Collapse and the Lessons Learned', in River Basin Management - Sustainability Issues and Planning Strategies, IntechOpen, 2021. doi: 10.5772/intechopen.96711.
4. J. Rocha, L. Lemos, and V. Dias Da Silva, 'Bridges built on alluvial beds: The failure of the Hintze Ribeiro', 2008. [Online]. Available: <https://www.researchgate.net/publication/259648896>.
5. R. Cao, A. Agrawal, S. El-Tawil, A computational case study of the Skagit River bridge collapse, Eng Struct (2021), <https://doi.org/10.1016/j.engstruct.2021.112215>.
6. M. Aldrich, 'Engineering Success and Disaster: American Railroad Bridges, 1840-1900', 199AD. doi: <https://www.jstor.org/stable/43522104>.
7. S.M. Pennington, M. Associate, The Bussey Railroad Bridge Collapse, Forensic Engineering Congress 2009 (2009) 105–125, [https://doi.org/10.1061/41082\(362\)11](https://doi.org/10.1061/41082(362)11).
8. A.G. Lichtenstein, H. Member, The Silver Bridge Collapse Recounted, Journal of Performance Constructed Facilities 7(4)(1993)249–261, [https://doi.org/10.1061/\(ASCE\)0887-3828\(1993\)7:4](https://doi.org/10.1061/(ASCE)0887-3828(1993)7:4)
9. K.M. Mahmoud, Risk-based Bridge Engineering vol. 1 (2019), <https://doi.org/10.4324/9780367815646>.
10. H.S. Birajdar, P.R. Maiti, P.K. Singh, Strengthening of Garudhatti bridge after failure of Chauras bridge, Eng Fail Anal 62 (Apr. 2016) 49–57, <https://doi.org/10.1016/j.engfailanal.2015.12.002>.
11. H.S. Birajdar, P.R. Maiti, P.K. Singh, Failure of Chauras bridge, Eng Fail Anal 45 (2014) 339–346, <https://doi.org/10.1016/j.engfailanal.2014.06.015>.
12. G. Zerayohannes, E. Gebreyohannes, A. Zekaria-Abdullahi, Investigation of the cause of failure of the Omo River Bridge, Structural Engineering International: Journal of the International Association for Bridge and Structural Engineering (IABSE) 27 (3) (Aug. 2017) 418–421, <https://doi.org/10.2749/1686617X14881937384729>.
13. Structural Concrete, Wiley-Blackwell (Sep. 2015) 323–332, <https://doi.org/10.1002/suco.201500022>.
14. G. Brunell, Y.J. Kim, Effect of local damage on the behavior of a laboratory-scale steel truss bridge, Eng Struct 48 (Mar. 2013) 281–291, <https://doi.org/10.1016/j.engstruct.2012.09.017>.
15. U. Starossek, 'Progressive collapse of structures', 2006. doi: doi.org/10.1680/pcos.61682.fm.
16. S.A. Derseh, T.A. Mohammed, Bridge structures under progressive collapse: A comprehensive state-of-the-art review, Results in Engineering 18 (Jun. 2023), 101090, <https://doi.org/10.1016/j.rineng.2023.101090>.
17. F. Kiakojouri, M.R. Sheidaii, V. De Biagi, B. Chiaia, Progressive collapse of structures: A discussion on annotated nomenclature, Structures 29 (Feb. 2021) 1417–1423, <https://doi.org/10.1016/j.istruc.2020.12.006>.
18. T.D. Stark, et al., I-5 Skagit River Bridge Collapse Review, J. Perform. Constr. Facil (2016), [https://doi.org/10.1061/\(ASCE\)CF.1943](https://doi.org/10.1061/(ASCE)CF.1943).
19. C. Pearson and N. Delatte, 'Collapse of the Quebec Bridge, 1907', Journal of performance of Constructed Facilities, vol. 20, no. (1), pp. 84–91, 2006, [Online]. Available: https://engagedscholarship.csuohio.edu/encee_facpub.
20. M. Buitrago, E. Bertolesi, P.A. Caldero'n, J.M. Adam, Robustness of steel truss bridges: Laboratory testing of a full-scale 21-metre bridge span, Structures 29 (Feb. 2021) 691–700, <https://doi.org/10.1016/j.istruc.2020.12.005>.
21. G. Caredda, M.C. Porcu, M. Buitrago, E. Bertolesi, J.M. Adam, Analysing local failure scenarios to assess the robustness of steel truss-type bridges, Eng Struct 262 (Jul. 2022), <https://doi.org/10.1016/j.engstruct.2022.114341>.

22. B. Barros, B. Conde, M. Cabaleiro, B. Riveiro, Deterministic and probabilistic-based model updating of aging steel bridges, *Structures* 54 (Aug. 2023) 89–105, <https://doi.org/10.1016/j.istruc.2023.05.020>.
23. V. Sangiorgio, A. Nettis, G. Uva, F. Pellegrino, H. Varum, J.M. Adam, Analytical fault tree and diagnostic aids for the preservation of historical steel truss bridges, *Eng Fail Anal* 133 (Mar. 2022), <https://doi.org/10.1016/j.engfailanal.2021.105996>.
24. B. Barros, B. Conde, M. Cabaleiro, B. Riveiro, Design and testing of a decision tree algorithm for early failure detection in steel truss bridges, *Eng Struct* 289 (Aug.2023), <https://doi.org/10.1016/j.engstruct.2023.116243>.
25. O. Bouzas, B. Conde, M. Cabaleiro, B. Riveiro, A holistic methodology for the non-destructive experimental characterization and reliability-based structural assessment of historical steel bridges, *Eng Struct* 270(Nov.2022), <https://doi.org/10.1016/j.engstruct.2022.114867>.
26. F. Parisi, A.M. Mangini, M.P. Fanti, J.M. Adam, Automated location of steel truss bridge damage using machine learning and raw strain sensor data, *Autom Constr* 138(Jun.2022), <https://doi.org/10.1016/j.autcon.2022.104249>.
27. B. Imam, M. Chryssanthopoulos, A review of metallic bridge failure statistics, *IABMAS* (2010), <https://doi.org/10.1201/b10430-502>.
28. ISO 2394 General principles on reliability for structures', 2013. [Online]. Available: <http://standardsdevelopment.bsigroup.com>.
29. D.N. Farhey, 'Structural performances of bridge materials in the U.S. national bridge inventory 2013', in *Structural Engineering International, Int. Assoc. for Bridge and Structural Eng. Eth-Honggerberg, Feb. (2017)* 101–113, <https://doi.org/10.2749/101686617X14676303589039>.
30. S. Yan, X. Zhao, Y. Chen, Z. Xu, Y. Lu, A new type of truss joint for prevention of progressive collapse, *Eng Struct* 167 (Jul. 2018) 203–213, <https://doi.org/10.1016/j.engstruct.2018.04.031>.
31. K. Wardhana, F.C. Hadipriono, F. Asce, 'Analysis of recent bridge failures in the, United States' (2003). <https://doi.org/10.1061/ASCE0887-3828200317:3144>.



INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details