International Journal of Combined Research & Development (IJCRD)
eISSN:2321-225X;pISSN:2321-2241 Volume: 12; Issue: 9; September -2023

BRIDGE UNDER DOUBLE STRESS: INVESTIGATING SEISMIC AND TRAFFIC LOADING

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Abstract— **In today's modern world, the growing demand for improved transit and connectivity has elevated the significance of transportation infrastructure, especially bridges. Bridges play a pivotal role in facilitating the safe and efficient movement of both vehicles and pedestrians over various obstacles, whether natural or man-made. However, the functionality and safety of bridges are constantly under threat from a range of stressors, including seismic activity and the heavy loads imposed by traffic. Notably, seismic sensitivity can lead to substantial damage to bridges and their supporting structures, resulting in loss of life, property destruction, and economic upheaval. Hence, it becomes imperative to delve into the impact of traffic loads on the seismic reliability assessment of highway bridge structures. Such an investigation holds the potential to enhance our understanding of how bridges behave dynamically under real-world loading conditions, ultimately enabling us to formulate more precise seismic reliability assessments that encompass the effects of traffic loading. This report seeks to explore how seismic events and vehicular traffic loads influence bridges by measuring various response parameters. Moreover, it aims to scrutinize the influence of truck loads on the seismic vulnerability of bridges, pinpointing critical truck positions that render a bridge most susceptible to earthquakes. These analyses will be conducted using specialized software, such as SAP2000. Anticipated outcomes of this report include valuable insights into how bridges respond to diverse stressors and the identification of pivotal factors that impact their structural integrity. These findings, in turn, can be harnessed to formulate more effective strategies for designing and maintaining bridges, ensuring the continued safety and efficiency of transportation infrastructure**

Keywords — *Seismic reliability assessment, Ground motions, Dynamic response, Seismic fragility*

1. Introduction

In an era marked by rapid urbanization and a surging global population, the demand for robust transportation infrastructure, including bridges, is undeniable. Bridges are essential for safe and efficient passage, even when challenging terrains require skewed bridge designs. They overcome obstacles like rivers, valleys, and highways, serving as vital components of transportation infrastructure. However, bridges are constantly under threat from various stressors, including seismic activity and the relentless loads imposed by traffic. Seismic events, in particular, pose a significant danger, capable of inflicting substantial damage to bridges and their supporting structures, resulting in loss of life, property destruction, and severe economic disruption. Recent years have witnessed a growing interest in studying the seismic behavior of bridges, particularly their dynamic response under the combined influence of seismic ground motions and the dynamic forces from vehicular traffic.

Historically, research has predominantly focused on the impact of live loads on bridges arising from road surface conditions and vehicle speeds. However, limited attention has been given to understanding the dynamic effects of sprung live loads on a bridge's seismic behavior, leaving critical knowledge gaps unaddressed. Traditional bridge design codes have incorporated minimal requirements for factoring live loads into seismic bridge design, assuming the simultaneous occurrence of the full design live load and a seismic event is remote. With increasing urban traffic congestion, the likelihood of a significant earthquake coinciding with a substantial live load has significantly increased; introducing additional gravitational and dynamic force effects that influence a bridge's seismic response.

This study builds upon prior research by introducing live traffic loads onto a conventional bridge for comprehensive evaluation, addressing a crucial knowledge gap in the field. While previous experiments and dynamic testing have explored various aspects of bridge behavior, none have specifically investigated the impact of live traffic loads due to their limited scale. Highway bridges, as elevated structures facilitating the smooth flow of traffic, play essential roles in surmounting natural and artificial obstacles. Roadway bridges, in particular, are of paramount importance due to the ubiquity of road transportation.

The Finite Element Method (F.E.M.), a powerful tool for addressing complex engineering problems, has gained increasing adoption, with the Canadian Highway Bridge Design code endorsing its use for analyzing and designing bridges of all types. To ensure the structural safety of highway bridges against seismic events, seismic reliability assessments are imperative. These assessments systematically quantify the probability of structural failure under seismic loads, factoring in uncertainties related to material properties, loading, and seismic hazard. Yet, traditional seismic reliability assessments have often overlooked the influence of traffic loading on bridge structures. Traffic loading introduces dynamic effects that can potentially impact the seismic performance of bridge structures, with heavy trucks, for example, inducing vibrations and dynamic loading that lead to gradual structural damage accumulation.

Consequently, there is a pressing need to investigate how traffic loading influences the seismic reliability assessment of highway bridge structures. The primary objective of this study is to analyze the impact of traffic loading on the seismic reliability assessment of highway bridge structures, thereby enhancing our understanding of the dynamic behavior of bridges under realistic loading conditions. The aim is to develop more accurate seismic reliability assessments that fully account for the effects of traffic loading, ultimately contributing to safer and more resilient infrastructure in our rapidly urbanizing world.

2. Research Objectives and scope

The Scope and objectives of the Effect of Seismic Analysis of bridge with Traffic load are:

- To study the impact of seismic & vehicular traffic loads on bridges by measuring the responses with the following variations:
    - Number of Spans
    - Varying Pier Height
    - Varying Truck Loads
- To analyze the impact of truck load on bridge seismic fragility.

3. Methodology

Analyzing a bridge follows a well-defined sequence of steps, beginning with data collection. This phase involves gathering vital information like design plans, material specifications, and location-specific seismic data. Additionally, data related to expected traffic, including vehicle quantities and weights, is compiled. Once this foundational data is amassed, the next step involves creating a precise structural model of the bridge. This is typically accomplished using specialized software such as SAP2000, STAAD.Pro, or ANSYS. The model should faithfully represent the physical components of the bridge, encompassing elements like the deck, piers, abutments, and other pertinent parts. With the structural model established, materials and properties are assigned to each bridge component. This information can be derived from design plans or laboratory testing and is crucial for ensuring the accuracy of the analysis. Defining boundary conditions is the subsequent task, which dictates how the bridge interacts with its supports and the surrounding environment. This involves specifying whether connections are fixed or pinned and outlining support conditions at different points along the bridge. Following this, seismic loading is defined based on the collected seismic data, taking into account the region's seismic history and geological characteristics. The aim is to evaluate the bridge's response to potential seismic events. Next, traffic loading is defined, considering the weight and movement of vehicles on the bridge. This step relies on data related to traffic flow, taking into account factors like vehicle types, load distributions, and anticipated traffic patterns. To gain a comprehensive understanding of the bridge's structural integrity under various conditions, a hybrid linear analysis is performed. This advanced analysis assesses the bridge's response to both seismic and traffic loads. After the analysis is completed, the results undergo thorough scrutiny. Stress analysis is carried out, and parameters are assessed using Fragility curves. This process provides valuable insights into how the bridge behaves under different scenarios. Finally, a concise summary is generated to present the analyzed results for each parameter. This summary is a valuable resource for engineers, decision-makers, and stakeholders, helping them make informed choices regarding the bridge's design, maintenance, and safety improvements. In essence, this entire process is a meticulous, data-driven approach aimed at ensuring the structural soundness and resilience of the bridge under anticipated loads and potential hazards.

4. Modeling and analysis

Finite element analysis is indispensable for tackling complex structural problems. It proves especially valuable when dealing with intricate geometries, diverse material properties, complex boundary conditions, and various load scenarios. The finite element method has evolved into a potent computational tool, enabling the routine analysis of complex structures. Notably, there are several software packages available for finite element analysis, including SAP 2000, STAAD PRO, ATENA, ABAQUS, ANSYS, E-TABS, and others. For this study, SAP2000 is the chosen software. SAP2000 offers a user-friendly feature known as the Bridge Modeler Wizard tool, which guides users through the step-by-step development of SAP models with remarkable precision. Structural modeling is a critical process that involves establishing three fundamental mathematical models: (1) a structural model, comprising structural elements, joints (nodes or connecting points), and boundary conditions (supports and foundations); (2) a material model; and (3) a load model. This chapter delves into the specifics of the materials used, loading configurations, and support conditions.

Loading

The Indian Roads Congress (I.R.C.) prescribes the use of IRC: 6-2014 as the recommended standard for the design of road bridges. This code is a comprehensive resource that covers various load definitions critical to bridge design. Within the framework of IRC: 6-2014, three primary load categories are delineated. Firstly, there is the Dead Load, which encompasses the intrinsic weight of the bridge structure itself, as well as additional components such as kerbs, parapets, and footings. Calculating reactions and moments stemming from dead load is relatively straightforward in comparison to other types of load stresses. Moreover, it is an aspect that can be reliably estimated and controlled during the construction phase of the bridge. Secondly, the code outlines Live Load considerations, specifically under IRC Class AA Loading. This involves the specification of two distinct Class AA vehicles: Class AA Tracked (700kN) and Class AA Wheeled (400kN). The code provides precise guidelines regarding axle length, wheel dimensions, and minimum setbacks for these vehicles. These specifications are of paramount importance in bridge design as they directly impact the structural integrity and safety of bridges under live load conditions. Lastly, IRC: 6-2014 addresses Seismic Load. This type of load accounts for the influence of seismic activity, such as earthquakes, on a structure. It encompasses forces originating from various sources, including ground contact, neighboring structures, and gravity waves generated by events like tsunamis. The consideration of seismic load is fundamental in the field of earthquake engineering and is vital for assessing a bridge's ability to withstand seismic events. In summary, IRC: 6-2014 provides clear and comprehensive guidelines for incorporating these key load types—Dead Load, Live Load (including specific vehicle specifications), and Seismic Load—when assessing the stresses on road bridges. This code is an invaluable resource that offers essential guidance for ensuring the design and safety of bridges in the context of transportation infrastructure.

Parametric Study and Time History analysis

A simply supported, single span, two lanes RCT-Beam bridge decks are considered in the study. The span parameter is varied as 15, 28 and 42m, Pier Height is varied to 10m and 15m interval is considered and speed is 75 kmph. The models of the bridge with varied span have been shown in Figure 1 to Figure 3.

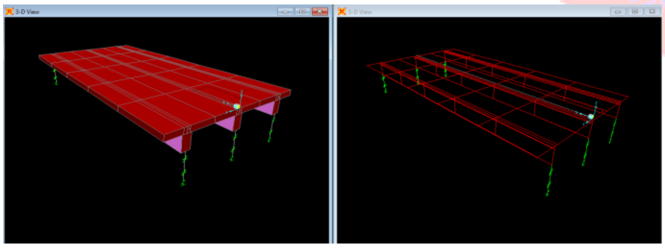

Figure1: Single Span bridge model

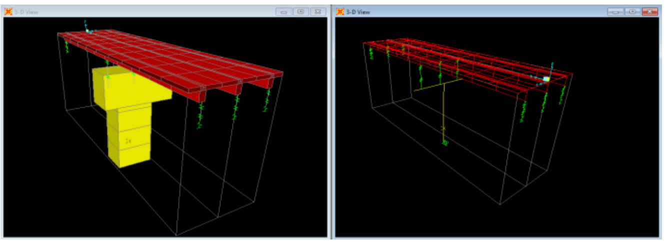

Figure2:2 Span bridge model

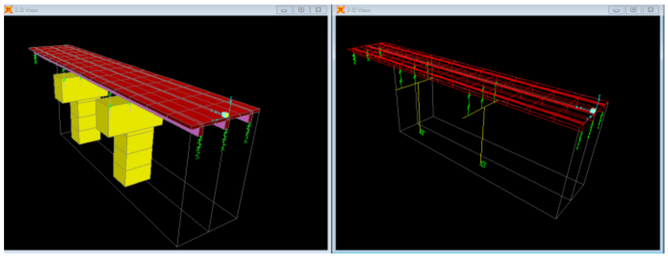

Figure3:3 Span bridge model

Time history analysis in SAP2000 is a dynamic analysis method used in structural engineering to simulate and assess the behavior of a structure subjected to dynamic loads over a specified period of time. This analysis is particularly important when studying structures that are exposed to seismic, wind, or other types of dynamic loads. time history analysis in SAP2000 is a powerful tool that allows engineers to assess the dynamic behavior of structures under various loading conditions, making it an essential part of the structural design and analysis process for earthquake-resistant and other dynamic-sensitive structures

Time history ground motion refers to the recorded and visual representation of the real-time movements of the Earth's surface during an earthquake. Seismometers are typically employed to capture this data accurately. Time history analysis, on the other hand, is a crucial component of structural analysis aimed at calculating how a structure responds to a specific earthquake event. In time history analysis, the ground motion data used is often sourced from actual earthquake occurrences, such as data recorded at the El Centro Site. This data is then utilized to simulate and assess how a structure behaves in response to the seismic forces generated during the earthquake.

Table 1: Bridge Analysis Parameters

1	Span	15m, 28m and 42m
2	Carriage way width	7.95m
3	Overall depth	1400mm
4	kerb	1m
5	Width of T-beam and cross beam	400mm
6	Depth of top slab	300mm
7	C/C distance between T-beams	2.5m
8	Live load	IRC Class AA Wheeled
9	Variation in pier height	10m and 15m
10	Speed considered	75 kmph
11	No. of bridge model analysed	120
12	Type of analysis	Direct integration Time-history method

5. Results and Discussion

This presentation showcases the outcomes of finite element analyses that have been conducted to examine the dynamic performance of T-beam bridges constructed with reinforced concrete (RC). The study delves into how factors like ground motion, speed, and aspect ratio influence the dynamic behavior of simply supported bridges.

The results of the finite element analysis are presented, focusing on critical structural response parameters. These parameters encompass essential aspects such as base shear, acceleration, and displacement of the bridge, which are influenced by various factors, including the applied dead load, ground motion, and the presence of moving vehicular loads.

Acceleration

Figure 5 (a to e) shows the variation in Acceleration absolute and relative due to change in Span and pier height of the bridge along with varying truck load with respect to seismic load.

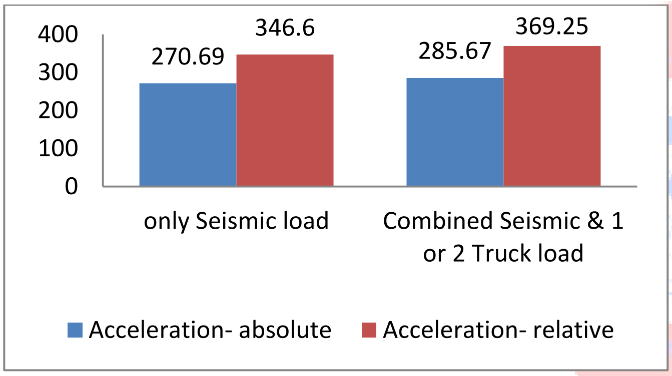

Figure 5 (a): Comparison of acceleration for single span bridge

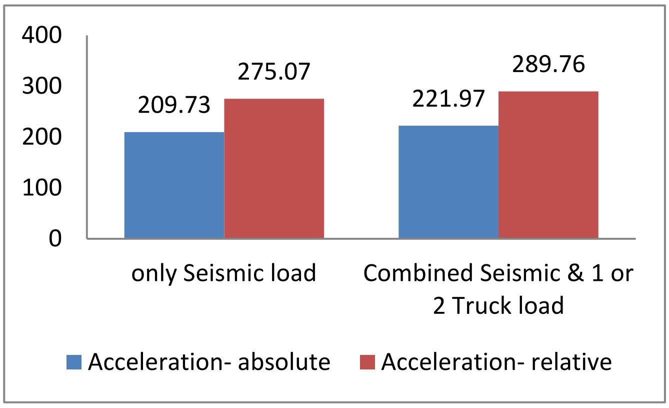

Figure 5 (a): Comparison of acceleration for 2 span, 10m peir height bridge

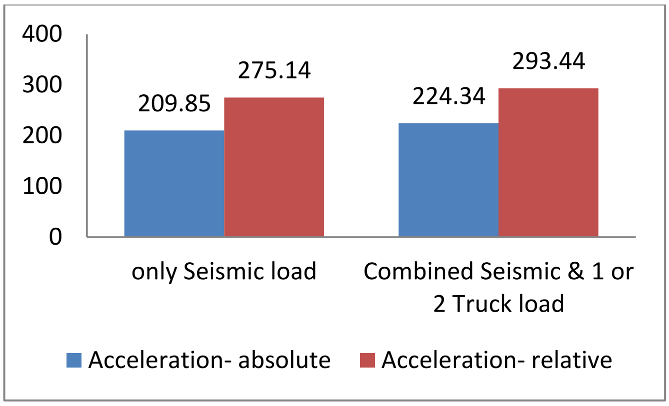

Figure 5 (a): Comparison of acceleration for 2 span, 10m peir height bridge

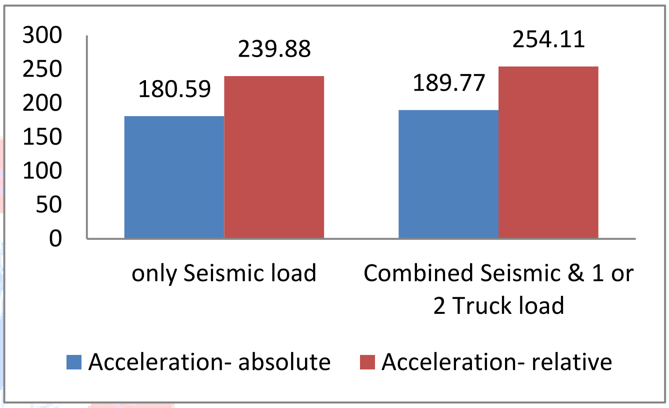

Figure 5 (d): Comparison of acceleration for 3 span, 10m peir height bridge

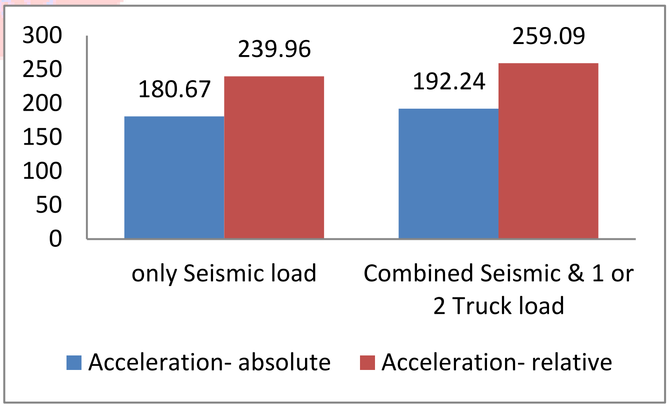

Figure 5 (e): Comparison of acceleration for 3 span, 15m peir height bridge

It is observed that the maximum acceleration for straight RC T beam bridges affected by Seismic events increases with the increase in heavy truck loads for all the aspect ratios. Acceleration increases significantly when both seismic and heavy truck loads are applied to a bridge, surpassing the acceleration under seismic load alone, due to the additional dynamic forces from the trucks.

The average **absolute acceleration** has increased by 5.944% adding one or two truckloads to the seismic load. The **relative acceleration** increases by 6.496% adding one or two truckloads to the seismic load.

6. Conclusion

- Increasing the number of spans in a bridge can influence its response to seismic and vehicular traffic loads. The study shows that the combined effect of seismic and truck loads leads to higher acceleration compared to seismic load alone, indicating that bridges with more spans may be more vulnerable to these combined loads.
- Variations in pier height have a significant impact on bridge performance. The results suggest that changes in pier height can affect the bridge's response to seismic and vehicular traffic loads. Further analysis may be needed to understand the specific relationships between pier height and response parameters.
- The variation in truck loads has a notable influence on bridge behaviour. The study demonstrates that the addition of truck loads amplifies the acceleration of the bridge under seismic conditions. This highlights the importance of considering realistic truck load scenarios in bridge design and evaluation.
- The study indirectly assesses the impact of truck loads on bridge seismic fragility by showing that combined seismic and truck loads result in increased displacement, acceleration. This suggests that the presence of heavy vehicular traffic can potentially reduce a bridge's seismic resilience, emphasizing the need for comprehensive fragility analyses.
- The findings underscore the vulnerability of bridges to combined seismic and vehicular traffic loads, indicating that engineering practices should incorporate these factors into the design and retrofitting of bridges. This includes considering the number of spans, pier height variations, and realistic truck load scenarios.

In summary, this study highlights the complex interplay between seismic and vehicular traffic loads on bridge performance, with a focus on the number of spans, pier height, and truck loads. The results emphasize the need for holistic design and mitigation approaches to enhance the resilience of bridges to these combined loads, ultimately contributing to safer and more durable infrastructure.

7. Refereneces

[1] Kim, C. W., M. Kawatani, S. Konaka, and R. Kitaura. 2011. "Seismic responses of a highway viaduct considering vehicles of design live load as dynamic system during moderate earthquakes." Structure and Infra structure Eng. 7 (7–8): 523–534. https://doi.org/10.1080/15732479.2010

[2] Chen, S. R., and J. Wu. 2011. "Modeling stochastic live load for long-span bridge based on microscopic traffic flow simulation." Comput. Struct. 89 (9): 813–824. https://doi.org/10.1016/j.compstruc.2010.12.017.

[3] Ghosh, J., C. C. Caprani, and J. E. Padgett. 2014. "Influence of traffic loading on the seismic reliability assessment of highway bridge structures." J. Bridge Eng. 19 (3): 04013009. https://doi.org/10.1061/(ASCE)BE .1943-5592.0000535.
Qing Zeng, Elias G. Dimitrakopoulos, and Themelina S. Paraskeva. 2015. "Seismic response analysis of a coupled vehicle-bridge system." 5th ECCOMAS Thematic Conference on Computational Methods in Structural Dynamics and Earthquake Engineering. http://dx.doi.org/10.7712/120115.3498.743.

[4] Chen, L., and S. Chen. 2016. "Seismic fragility performance of skewed and curved bridges in low-to-moderate seismic region." Earthquakes Struct. 10 (4): 789–810. https://doi.org/10.12989/eas.2016.10.4.789.

[5] Chen, L., Zhou, Y. and Chen, S. (2019). "Hybrid nonlinear seismic analysis of bridges with moving traffic," J. of Aerospace Engineering, ASCE.
Giacomo Miluccio, Daniele Losanno, Fulvio Parisi and Edoardo Cosenza (2021). "Traffic-load fragility models for prestressed concrete girder decks of existing Italian highway bridges."Department of Structures for Engineering. https://doi.org/10.1016/j.engstruct.2021.113367

[6] Liu, L.; Yang, X.; Yan, B.; Miao, S. Dynamic Responses of RC Girder Bridge under Heavy Truck and Seismic Loads Combined. Sustainability 2022, 14, 9263. https://doi.org/10.3390/su14159263

[7] Peng Yuan, YouDong, RuiweiFeng and DanM.Frangopol (2022). "Towards probabilistic seismic performance of vehicle-bridge interaction systems: From stochastic dynamic model to fragility analysis." Earthquake Engineering & Structural Dynamics 52(5).

[8] Nitin Chavan; and Pranesh Murnal. 2015. "A Comparative study on seismic response of bridge with elastomeric bearing and elastomeric isolator." Journal of Civil Engineering and Environmental Technology.

[9] Kunnath, S. K., E. Erduran, Y. H. Chai, and M. Yashinsky. 2008. "Effect of near-fault vertical ground motions on seismic response of highway overcrossings." J. Bridge Eng. 13 (3): 282–290. https://doi.org/10 .1061/(ASCE)1084-0702(2008)13:3(282).

[10] Mackie, K., and Stojadinovic, B. (2001). "Probabilistic seismic demand model for California highway bridges." J. Bridge Eng., 10.1061/(ASCE)1084-0702(2001)6:6(468), 468–481.

[11] Nielson, B. 2005. “Analytical fragility curves for highway bridges in moderate seismic zones.” Ph.D. thesis, School of Civil and Environmental Engineering, Georgia Institute of Technology.

[12] Wibowo, H., D. M. Sanford, I. G. Buckle, and D. H. Sanders. 2012. “Effects of live load on seismic response of bridges: A preliminary study.” Civ. Eng. Dimension 14 (3): 1

[13] Chen, S. R., and J. Wu. 2010. “Dynamic performance simulation of long-span bridge under combined loads of stochastic traffic and wind.” J. Bridge Eng. 15 (3): 219–230. https://doi.org/10.1061/(ASCE)BE.1943-5592.0000078.

[14] Choi, E., R. DesRoches, and B. Nielson. 2004. “Seismic fragility of typical bridges in moderate seismic zones.” Eng. Struct. 26 (2): 187–199. https://doi.org/10.1016/j.engstruct.2003.09.006.