



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 5, May 2024

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

9940 572 462

6381 907 438

ijirset@gmail.com

www.ijirset.com

Traffic and Corrosion Effect on Bridge Deck-Dynamic Analysis and Fatigue Effect

Ashish G. Lokhande, Dr. N. S. Raman

P.G. Student, Department of Civil Engineering, Guru Nanak Institute of Engineering and Technology, Nagpur,
Maharashtra, India

Associate Professor, Department of Civil Engineering, Guru Nanak Institute of Engineering and Technology, Nagpur,
Maharashtra, India

ABSTRACT: Fatigue damage has become one of the most common degradation mechanisms of highway bridge decks, which is primarily caused by passing traffic. The increase of heavy traffic over recent years, especially those overweight trucks, further worsens the situation. In the meantime, highway bridges are subjected to various aggressive environmental conditions leading to serious corrosion problems. Corrosion problem, faced by millions of reinforced concrete structures worldwide, can cause deterioration of the reinforcing steel bars, cracks and spalling on the bridge deck surface. As the bridge deck surface deteriorates over time, the road surface roughness profile will vary accordingly. The varying surface roughness profiles over time will generate increased dynamic loads on the bridge decks through dynamic interaction between surface roughness, vehicles of stochastic traffic and bridge structures. The increased dynamic loads, coupled by the reinforcement deterioration of bridge deck due to corrosion, will further cause accelerated response and fatigue accumulations on the bridge deck. Such a nonlinear time-progressive process continues over time throughout the lifespan of the bridge deck, which has not been systematically characterized or studied. The present study aims to characterize the coupling effects between the time-varying dynamic loads from stochastic traffic, deterioration bridge decks due to corrosion, and bridge performance. To tackle such a problem, firstly, a hybrid FEM-based analytical strategy is developed for the bridge and stochastic traffic system considering the time-dependent corrosion process. Secondly, scenario-based numerical studies are conducted for the typical combinations of traffic, corrosion-induced reinforcement deterioration and associated surface profile variations. Finally, based on the numerical findings, the fatigue damage of the bridge deck over time is analyzed and the remaining life of the prototype bridge decks is assessed under the joint effect of corrosion and stochastic traffic.

KEYWORDS: Bridge Deck, FEM Analysis, cracks and spalling.

I. INTRODUCTION

The interconnectedness and complexity of infrastructure and transportation systems are vital for sustaining and fostering economic growth. They form the framework upon which societies operate, facilitating the movement of goods and people, enabling communication, and supporting essential services like energy distribution and waste management. Transportation infrastructure, for instance, not only includes roads, railways, airports, and ports but also the systems that manage traffic, logistics, and supply chains. A well-functioning transportation network is crucial for businesses to access markets, for commuters to reach their workplaces, and for emergency services to respond effectively.

Similarly, energy infrastructure ensures the reliable production, distribution, and consumption of energy resources, powering industries, homes, and transportation. Water resource management and waste management systems are essential for maintaining public health and environmental sustainability.

In essence, these systems collectively enable economic activities to flourish by providing the necessary foundations and support structures. Investments in infrastructure and transportation yield long-term benefits, enhancing productivity, competitiveness, and overall quality of life for citizens.

The statistics paint a clear picture of the critical role that infrastructure, particularly bridges, plays in the functioning of the United States. Bridges are vital links in transportation systems, facilitating movement across natural barriers and connecting roadways, which is essential for maintaining mobility and supporting economic activity.

However, the challenge lies in the maintenance and upkeep of these bridges, particularly concrete bridges, which constitute a significant portion of the infrastructure. Constant exposure to environmental factors, material degradation, and the strain of growing traffic, including heavy trucks, lead to the deterioration of bridge conditions over time.

The impact of heavy trucks on bridge infrastructure is particularly pronounced, contributing disproportionately to pavement damage despite constituting a relatively small portion of total traffic volume. This underscores the need for effective management strategies to mitigate the adverse effects of heavy traffic on bridge integrity.

Moreover, the costs associated with bridge repairs are not solely limited to direct repair expenses but also encompass indirect costs stemming from traffic disruptions during repair activities. These disruptions can have significant economic implications, affecting businesses, commuters, and the overall efficiency of transportation networks.

II. METHODOLOGY

The Prototype Bridge

The model scaffold that was embraced for this examination is situated on 104th AVE, over the I-25 Highway Colorado.

Historical Overview

The old bridge with a new one was a significant engineering project. Building bridges according to AASHTO (American Association of State Highway and Transportation Officials) standards ensures that they meet safety and design requirements.

The use of pre-stressed concrete box girders is a common choice for bridge construction due to their strength and durability. Having two spans in a symmetric layout suggests a balanced design, which is important for distributing loads evenly across the structure.

Thornton, Colorado, being just north of Denver, likely sees heavy traffic flow, making the replacement of the bridge a vital infrastructure project to ensure the smooth movement of vehicles and safety for commuters.

Bridge Description and Geometry:

It sounds like a well-designed bridge with careful consideration given to its layout, structural elements, and traffic requirements. Here's a summary of its key features based on the information you provided:

The bridge deck comprises 23 concrete box girders.

Originally constructed as two simple support spans, it was later converted to a continuous connection type by the continuous bridge deck.

Each span is identical, with a length of 127 feet from curb to curb, resulting in a total length of 254 feet.

There are no skewers, indicating that the bridge is perpendicular to the road it crosses.

The bridge accommodates five lanes of traffic in each direction, with each lane being 12 feet wide.

Integrated abutments support the superstructure at the bridge bent.

The superstructure is supported by eight elliptical piers, each measuring 72 inches by 48 inches.

The plan and elevation views of the bridge, as well as a typical cross-section, provide valuable insights into its design and construction.

With such detailed specifications, this bridge appears to be well-suited for handling heavy traffic loads efficiently while ensuring the safety and stability of the structure.

About the materials and design specifications for various components of the bridge. Here's a summary based on the details you provided:

The main superstructure members are made of Class D reinforced concrete and Grade 60 reinforcing steel.

The superstructure consists of two spans, each designed with 23 precast prestressed concrete box girders measuring 72 inches by 46 inches.

The minimum cover for the reinforcing steel is 1 inch.

The harping point, indicating a change in strand geometry and loss in prestress force, is located at 14 feet from the center line of the girder.

The superstructure has a width of 147 feet from out to out and is designed to support ten lanes in total (five lanes in each direction), with each lane being 12 feet wide.

Additionally, there is a 4-foot median and an 8-foot sidewalk in each direction.

The approach slab, which connects the bridge to the roadway, is 12 feet long and 1 foot 3 inches thick, also made of Class D reinforced concrete and Grade 60 reinforcing steel. Detailed sections for the approach slab and caisson details at the abutment and pier are provided in figures 3.5, 3.6, and 3.7, respectively.

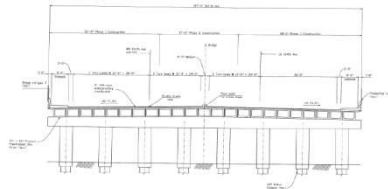


Figure 2.1: Typical Section in the Bridge

III. RESULT AND CONCLUSION

Overall, this detailed analysis provides insights into the dynamic behavior and fatigue performance of the bridge deck under realistic loading conditions. It allows for the identification of critical factors influencing fatigue damage accumulation and aids in the development of maintenance and design strategies to ensure the long-term structural integrity of the bridge.



Figure 3.1A: Joint locations and numbers

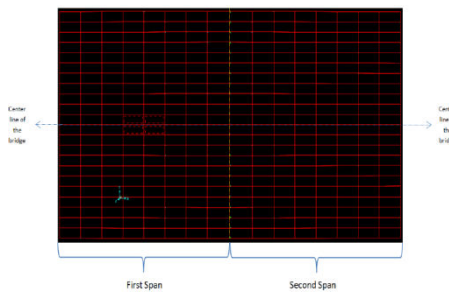


Figure 3.1.B: locations of the elements chosen in this study

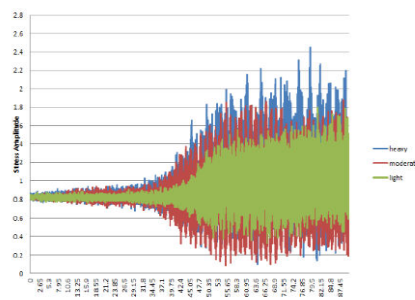


Figure 3.2: Stress amplitudes versus time steps for heavy, moderated and light traffic for joint#1580

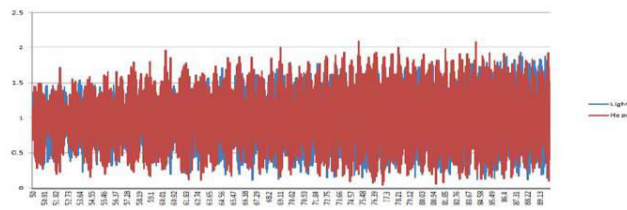


Figure 3.3: Stress amplitudes versus time steps for Heavy, Light traffic under Good Roughness and Medium-Corrosion conditions for joint #1565

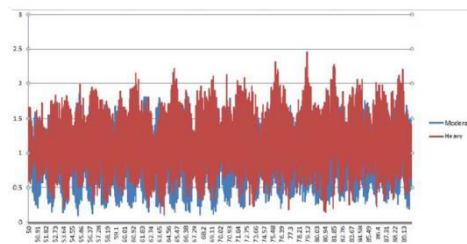


Figure 3.4: Stress amplitudes versus time steps for Heavy, Moderate traffic under Very-Good Roughness and No-Corrosion conditions for joint # 1580

IV. CONCLUSION

1. Impact of Traffic Rates :

- Traffic rates have a clear effect on the dynamic performance of short slab bridges. Higher traffic rates induce higher resultant stress ranges.
- Heavy and moderate traffic conditions generally induce higher damage indexes compared to light traffic conditions. However, heavy traffic rates do not always introduce larger stress-range cycles than moderate traffic rates. Thus, heavy traffic flow may not necessarily result in the largest fatigue damage indexes per hour.

2. Effect of Road Surface Roughness :

- Road surface roughness conditions significantly affect the dynamic performance of short slab bridges. Deteriorated road surface conditions lead to larger stress ranges and more stress-range cycles for each truck passage.
- Consequently, more deteriorated road surface conditions introduce larger fatigue damage indexes per hour.

3. Influence of Reinforcement Bar Corrosion :

- Corrosion of the reinforcement bars in bridge decks influences the fatigue life of short span bridge decks. Corrosion leads to larger stress ranges and more stress-range cycles per hour.
- As the percentage of steel bars affected by corrosion increases, the fatigue damage indexes per hour also increase.

These conclusions highlight the complex interplay between traffic rates, road surface conditions, and reinforcement bar corrosion on the dynamic response and fatigue life of short slab bridge decks. Understanding these factors is crucial for optimizing bridge design, maintenance strategies, and ensuring the long-term structural integrity and safety of bridge infrastructure.

REFERENCES

- [1] International Standard Organization. (1995). Mechanical Vibration - Road Surface Profiles - Reporting of Measured Data. Geneva: ISO 8608.
- [2] J. G. MacGregor, S. A. (1983). Statistical Analysis of Resistance of Reinforced and Prestressed Concrete Members. ACI, 80(3), 167-176.
- [3] Khatri, R., & Sirivatnanon, V. (2004). Characteristic Service Life for Concrete Exposed to Marine Environments. Cement and Concrete Research, 34(5), 745-752.

- [4] Koch, G., P.H.Brongers, M., & Neil G, T. (2002). Corrosion Costs and Preventive Strategies in the United States. Federal Highway Administration FHWA-RD-01-156.
- [5] LeRose, C. (2001). The Collapse of the Silver Bridge. West Virginia Historical Society Quarterly, 15(4).
- [6] Li, C. Z., J., L., W., & Melchers, R. (2007). Concrete Delamination Caused by Steel Reinforcement Corrosion. JOURNAL OF MATERIALS IN CIVIL ENGINEERING, 19(7), 591.
- [7] Liu, Y. (1996). Modeling the Time-to Corrosion Cracking of the Cover Concrete in Chloride Contaminated Reinforced Concrete Structures. Dissertation.
- [8] Lonaker, T. (2006). Silver Bridge Collapse. Retrieved from The Long Day: <http://www.freewebs.com/silverbridgeaccident/thebridgecollapse.htm>
- [9] Lounis, G. M. (2003). A New Approach to Programming Maintenance Activities for Concrete Bridge Decks. National Research Council Canada.
- [10] Masi, D. C. (1997). Simulation of Chloride Penetration in Cement-Based Materials. Cement and Concrete Research, 27(10), 1591-1601.
- [11] M.G. Stewart, J. M. (2007). Spatial Time-Dependent Reliability Analysis of Corrosion Damage and the Timing of First Repair for RC Structures. Engineering Structures, 29(7), 1457–1464.
- [12] Maaddawy, T. E., & Soudki, K. (2007). A Model for Prediction of Time from Corrosion Initiation to Corrosion Cracking. Cement and Concrete Composites, 29(3), 168–175.
- [13] Mangat, P. S., & Molloy, B. T. (1994, July). Prediction of Long Term Chloride Concentration in Concrete. Materials and Structures, 27(6), 338-346.
- [14] Maymon, G. (1998). Some Engineering Applications in Random Vibrations and Random Structures (Vol. 178). American Institute of Aeronautics and Astronautics.
- [15] Mazzolani, F. M. (2000). Moment Resistant Connections of Steel Frames in Seismic Areas: Design and Reliability. (1, Ed.) London: E & FN SPON.
- [16] Mullard, J. A., & Stewart, M. G. (2009). Corrosion-Induced Cover Cracking of RC Structures: New Experimental Data and Predictive Models. University of Newcastle.
- [17] Mullard, J., & Stewart, M. (2009). Stochastic Assessment of Timing and Efficiency of Maintenance for Corroding RC Structures. Journal of Structural Engineering, 135(8), 887–895.
- [18] Nagel, K., & Schreckenberg, M. (1992). A Cellular Automaton Model for Freeway Traffic. J. Phys. I France , 2221-2229.
- [19] Nasvik, J. (2003). Rehabilitation for Our Nation's Bridges: Maintaining Bridges is no Small Task. Here's How We Make Decisions About Repair and Technology That Will Help them Last Longer. Concrete Construction.
- [20] Neville, A. M. (1996). Properties of Concrete (4, illustrated ed.). John Wiley & Sons.
- [21] Oh, B., Lew, Y., & Choil, Y. (2007). Realistic Assessment for Safety and Service Life of Reinforced Concrete Decks in Girder Bridges. Journal Of Bridge Engineering, 12(7), 410.



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