



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

Literature Review on 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: In this paper a review is presented about studies involving the fatigue and the corrosion of bridge elements. Reviewed reports include steel structures and steel-reinforced concrete bridges, classified as experimental and theoretical approaches. A special section has been dedicated to particular studies that deny any corrosion – fatigue relationship, thus involving pure corrosion or pure fatigue approaches. Most of the reports deal with the uncoupled corrosion – fatigue, in which the corrosion environment and cyclic loading do no coexist during the experiments. Most of the studies consider the exposition to the aggressive environment, followed by the strength or fatigue testing of the corroded material. Results from these approaches reveal that in some cases the strain level is more significant (up to 85 times more), while in others the corrosion level is the most significant factor (up to 11 times more). The studies that considered the coupled corrosion-fatigue phenomenon, whether circumstantially or systematically, reveal the greatest effects (from 20 to 30% reductions in fatigue strength). Furthermore, it is found that a realistic loading time-history has not been applied, regardless of the approach selected. Future works should focus on coupled corrosion – fatigue phenomenon, proposing standard procedures for structure design. Also, realistic force time-histories should be considered.

KEYWORDS: Corrosion, fatigue, collapse, analytical techniques, structural analysis, bridge failure, infrastructure.

I. INTRODUCTION

Corrosion has been defined as the deterioration of a material by reaction to its environment [1]. Attending the origin of the word “corrosion”, such deterioration would be the literal gnawing of the material [2]. Fatigue of a material, on the other hand, has been described as the process of cumulative damage in a benign environment that is caused by repeated loads [3], which is equivalent to a progressive fracture [4]. If the fatigue occurs under an aggressive environment, that phenomenon is known as corrosion fatigue [3]. Corrosion fatigue is thus the process in which a metal fractures prematurely under conditions of simultaneous corrosion and repeated cyclic loading at lower stress levels or after fewer cycles than would be required in the absence of the corrosive environment [5].

The phenomenon of corrosion fatigue can be described as a type of environmental assisted cracking [6; 7]. In this respect, however, environmental assisted corrosion assumes no influence of variable stresses, and is studied through fracture mechanics approaches [8]. While the phenomenon of corrosion was originally observed in metals, ferrous metals in particular, such phenomenon can occur also in non-metallic materials [9; 10]. The corrosion of metals can be characterized by a chemical reaction that can occur between different metals (electrochemical, fretting, crevice), or between the vulnerable metal and the corrosive media (pitting, etching). In particular, pitting, instead of uniform corrosion, would be the more structure damaging phenomena [11]. Together with Stress Corrosion Cracking, fretting fatigue is another form of corrosion influenced by stresses [5].

In the case of road bridge infrastructure, its elements are exposed to different loads while exposed to corrosive environments [12]. In particular, a highly aggressive situation occurs when salt is used to deice bridge decks, melting the ice and pouring brine into the bridge structure [13]. Bridges over rivers also suffer such exposure to chemically aggressive environments [14]. While loads on the bridge derives from wind, earthquakes and even thermal variations that result in stresses, the most significant force perturbation to the bridges derives from the axle loads associated to the trucks using such infrastructures [15].

Innovative approaches to cope with such infrastructure damage issues include the heating of the bridges [16], dry air ventilation [17], and the use of corrosion resistant materials such as aluminum [18], fiber-reinforced polymers [19; 20], or stainless steel [21]; or protective coatings [22]. On the side of dynamic loads from traversing vehicles and the vibration of bridges, vehicles equipped with bridge friendly suspensions have been proposed [23, 24], as well as bridge vibration suppression active systems [25]. In the case of steel reinforced concrete bridges (RC), the use of corrosion inhibitors has also been considered [26].

Fracture of the materials in the context of road bridges takes different characteristics [27]: brittle fracture due to local corrosion attack or hydrogen embrittlement; stress corrosion cracking, due to anodic stress corrosion cracking or hydrogen induced stress-corrosion cracking; and corrosion fatigue.

Although not always recognized as a coupled phenomenon, fatigue and corrosion of bridges is mentioned as an important cause of bridges collapse [28; 29; 30], or the combination of overloading and fatigue [31]. In the case of the cables that support bridges, a particularly dangerous characteristic of corrosion fatigue is the poor visual evidence of the damage [32]. While in the case of steel bridges the corrosion is associated to the direct attack of the environment, in the case of the steel used as concrete bridges reinforcement, its damage is the result of complex interactions, in which the reinforcing steel will not corrode unless the PH of the concrete drops due to carbonation [33]; or the chloride content of the concrete reaches the corrosion threshold of the reinforcement [34; 35].

II. LITERATURE REVIEW

Nakamura and Suzumura [38] report the laboratory testing of galvanized wires used in suspension and cable-stayed bridges. The testing procedure consisted of producing corroded wires in laboratory, which were testing for fatigue strength in dry and wet conditions. Results validated the effectiveness of the zinc layer to preserve the properties of the wire, and the low concentration of diffusive hydrogen into the material. However, the authors associate the fracture of the specimens to a combination effect, involving corrosion, cyclic stresses and diffusive hydrogen. Comparative fatigue tests under dry and wet conditions revealed the significant effect of corrosion and fatigue coupling (20% reduction of the fatigue strength).

Ahn and Reddy [39] report a study aimed at assessing the effect of type of loading (static, fatigue) and water/cement ratios on the durability of steel reinforced concrete beams. They find that cyclic loading and corrosion duration influences the ultimate strength of the elements, in a range from 22 to 14%, as a function of the corrosion environment. Also, that beams subjected to fatigue loading deteriorated faster than those statically loaded. The experimental setup was based upon simply supported beams.

Bastidas-Arteaga et al. [40] propose a probabilistic model for RC structures, stressing the concept of a coupled effect of corrosion and cycle loading on the reinforce steel life. They assume three stages for steel deterioration, with two of them being influenced by the stresses applied, as follows: corrosion initiation and pit nucleation, with no effect of applied stresses; pit-to-crack transition, and crack growth, which are influenced by the stress level. For the first stage of material deterioration, authors consider the inclusion of chloride into the material structure, causing pitting of the material as a function of the level of environment aggressiveness. Such level of aggressiveness is defined in terms of the distance from the coast, from a low aggressiveness (at 2.8 km from the coast) to extreme aggressiveness, in which the structure is subjected to wetting and drying cycles. Such distance from the coast was characterized in terms of different properties, as follows: (1) a chloride surface concentration (CSC), (2) an expected threshold corrosion rate (TCR), and (3) a concrete cover (CC). The magnitudes of these properties varied from low to high as follows: CSC from 0.35 to 7.35 kg/m³; TCR from 0.5 to 10 μ A/cm²; and CC from 40 to 55 mm, signifying percentage increments of 2000, 1900 and 37.5%, respectively. For such levels of aggressiveness, different loading cycles were considered, and applied in long term perspective (hundreds of years), at a rate from 0 cycles per day, to 2000 loading cycles per day.

Maes et al. [41] propose a model of corrosion fatigue for the bonded prestressing strands of post-tensioned concrete bridge decks, based upon a 21-parameter formulation involving loading, bridge design and environment. Aggressiveness of environment is characterized in terms of temperature, conductivity of the fluid surrounding the strands, and oxygen concentration (creating from a neutral to an extremely aggressive environment). Failure of the reinforcement is characterized in terms of the number of broken strands. Simulated results from this research consider the broken strands as a function of time and level of environmental aggressiveness. Figure 4 illustrates the effect of corrosion level and corrosion duration on the number of broken strands. While part (a) of this figure takes

the broken strands as the independent variable, part (b) takes the time as the independent variable. These figures thus illustrate the corrosion duration to produce the same damage, and the damage variation with corrosion duration.

Hwan-Oh et al. [43] propose a comprehensive methodology to assess reinforced concrete decks considering traffic loads and the environmental effect, to assess the reliability of such structures. In the paper a mixed approach is considered, including coupled and un-coupled corrosion-fatigue phenomenon as a function of the type of stress (bending and shearing). For the bending stresses an uncoupled corrosion-fatigue approach is considered, collecting corrosion initiation and reduction-of-area equations for the reinforce steel, in terms of corrosion parameters such as diffusion coefficient and surface concentration. For such reduction of area of the steel, the variation of bridge deck strength is calculated.

Lindquist et al. [34] report measurements of chloride concentration in concrete bridge decks, characterizing the effect of cracks on the diffusion of chloride in concrete. While the authors recognize the influence of different factors for concrete cracking, including load, they infer that shrinkage and settlement are the dominant causes. They find cracks as the medium for chloride diffusion and reinforce damage.

Shi and Zhang [44] propose a formulation thorough which they assess the effect of corrosion and fatigue on bond strength, including the damage of the steel and the damage of the concrete, separately or together. The damage of the concrete would be a consequence of the damage of the reinforce steel. It is defined an environmental acceleration factor, as a function of loading frequency and stress ratio. According to its formulation debond length increases in about 10% when corrosion fatigue is considered.

De Corte et al. [45] theoretically analyze the fatigue failure of ribs in orthotropic plated bridge decks, in particular, the rib to the floorbeam joint. The authors identify some stress concentrations potentially leading to fatigue, as the result of tire loads applied at certain locations on the structure. The reason for neglecting any corrosion contribution for such orthotropic all-steel bridges decks seems to derive from design measures undertaken specifically to prevent any humidity in the structure, even through the use of dehumidification techniques [12].

Issa et al., [46] report the full scale testing of overlays installed on bridge decks, considering bonding properties of the overlays after being subject to temperature variations. Acceptable performance during static testing of a prototype is reported, once that cycle loading was applied.

Sih et al. [47] report and analytical/experimental study, to characterize the effect of crack shape and size on the fracture strength and crack growth fatigue life of bridge cable steel wires. They calibrate a theoretical model, identifying stages of microcracking and macrocracking.

Siegert et al. [48] report field strain measurements in concrete prestressed short span bridges, during a 256-day period. The bridges were heavily trafficked. With these data the authors extrapolate expectance results for more than 50 years. A linear relationship is found between the total weight of the vehicle and the strain at the mid-span portion of the bridges. Extrapolation of results reveals that the bridge will have an acceptable performance, beyond 100-year horizon.

Mahmoud [49] reports a fracture mechanics approach to model the failure of cable wires for suspension bridges. The author finds that fracture toughness criterion is more realistic than fracture strength of the wire.

III. CONCLUSION

In this paper a critical review has been presented about studies involving the fatigue and the corrosion of bridge elements. Reports include steel structures and steel-reinforced concrete bridges, classified as experimental and theoretical approaches. A special section has been dedicated to particular studies that deny any corrosion – fatigue relationship, involving pure corrosion or pure fatigue studies.

So, the investigations have included the analysis of different phenomena: coupled corrosion – fatigue; uncoupled corrosion – fatigue, and isolated studies of corrosion and fatigue.

Most of the reports, however, deal with the uncoupled corrosion – fatigue phenomena, in which the corrosion environment and cyclic loading do not coexist during the experiment. Most of the studies consider the exposition to the aggressive environment, followed by the strength or fatigue testing of the corroded material. Results from these approaches reveal that in some cases the strain level is more significant (up to 85 times more), while in others the corrosion level is the most significant factor (up to 11 times more). The studies that considered the coupled corrosion-fatigue situation, whether circumstantially or systematically, reveal greater effects on fatigue strength, with reductions in the order of 30% when compared with the uncoupled situation.

A realistic loading history, however, has not been considered, regardless of the approach selected (experimental or theoretical). Future research should focus on objectively determining the significance of the corrosion – fatigue phenomenon, potentially proposing standard procedures for bridge structures design. Also, realistic force histories should be considered.

REFERENCES

- [1] American Society for Testing and Materials. (2011). Standard Practices for Cycle Counting in Fatigue Analysis I. E1049 – 85.
- [2] National Research Council . (2000). Highway Capacity Manual.
- [3] A.D. Pelton, T. E. (1972). Analytical Solution of Fick's Second law when the Diffusion Coefficient Varies Directly as Concentration. *Acta Metallurgica*, 20(11), 1269.
- [4] ASTM. (1985). Standard Practices for Cycle Counting in Fatigue Analysis. American Society for Testing and Materials Standard .Baboian, R. (2005). Corrosion Tests And Standards: Application And Interpretation (Vol. 20). ASTM International.
- [5] Bamforth, P. B. (1999). The Derivation of Input Data for Modelling Chloride Ingress from Eight-year UK Coastal Exposure Trials. *Magazine of Concrete Research*, 51(2), 87 –96.
- [6] Bazant, H. O. (1983). Uncertainty Analysis of Creep and Shrinkage Effects in Concrete structures. *ACI*, 80(2), 116.
- [7] Bazant, Z. P. (1979). Physical Model for Steel Corrosion in Sea Structures Theory. *Journal of the Structural Division*, 105(6), 1137-1153.
- [8] Bond, A., & Harris, A. (2008). Decoding Eurocode 7.
- [9] Cai, C. C., & Chen, S. (2004). Framework of Vehicle–Bridge–Wind Dynamic Analysis. *Journal of Wind Engineering and Industrial Aerodynamics*, 92(7-8), 579–607.
- [10] Chen, S. R., & Cai, C. S. (2007). Equivalent wheel load Approach for Slender Cable-Stayed Bridge Fatigue Assessment under Traffic and Wind: Feasibility Stud. *J. Bridge Eng*, 12(6), 755–764.
- [11] Chen, S. R., & Wu, J. (2010). Dynamic Performance Simulation of Long-Span Bridge under Combined Loads of Stochastic Traffic and Wind. *J. Bridge Eng*, 15(3), 219–230.
- [12] Chen, S., & Wu, J. (2011). Modeling Stochastic Live Load for Long-Span Bridge Based on Microscopic Traffic Flow Simulation. *Computers & Structures*, 89(9-10), 813–824.
- [13] Dimitri V. Val, M. G. (2003, October). Life-cycle Cost Analysis of Reinforced Concrete Structures in Marine Environments. *Structural Safety*, 25(4), 343-362.
- [14] DuraCrete. (2000). Statistical Quantification of the Variables in the Limit State Functions. Project No.BE95-1347: The European Union - Brite EuRam III.
- [15] Feldmann, G. C. (2008). Concrete Repair Basics. From Structural Practices: <http://www.structuremag.org/article.aspx?articleid=590>
- [16] Guo, G. (2006). Laboratory and Field Tests of Multiple Corrosion Protection Systems for Reinforced Concrete Bridge Components and 2205 Pickled Stainless Steel. Lawrence, Kansas, University of Kansas Center for Research, Inc: ProQuest.
- [17] High-Cycle Fatigue (HCF) Testing. Retrieved 2012 14-feb from MTS Systems Corporation: <http://www.mts.com/en/products/application/materials-testing/metals/high-cycle-fatigue/index.htm>
- [18] International Standard Organization. (1995). Mechanical Vibration - Road Surface Profiles - Reporting of Measured Data. Geneva: ISO 8608.



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