International Journal of Scientific Research & Engineering Trends
Volume 9, Issue 4, July-Aug-2023, ISSN (Online): 2395-566X

A Review On Use And Performance Of In Steel Highway Bridges

Assistant Professor Bakshetty Snehalatha, Associate Professor Dr. Srikanth Ramvath
Kshatriya College Of Engineering
Armur, Telangana, India,
Chaitanya (Deemed To Be) University
Warangal, Telangana, India, 506001.

Abstract- Uncoated weathering steel (UWS) bridges have been in use in the United States for nearly 50 years, now enabling the long-termperformance of these structures to be assessed. This was accomplished by surveying the varied experiences of 52 U.S. transportation agencies, along with data analysis on all UWS bridges known within these and other agencies, which total nearly 10,000 structures. Climate and age were key considerations in this data analysis. Contrary to previous, more limited research, this analysis showed that there is not a strong trend in UWS bridge performance as a function of climate. A similar climate analysis for non-UWS bridges also showed a counterintuitive relationship be- tween some climate types and these bridges. This suggests that design and maintenance practices may be more influential to UWS performance than climate, and further research to cultivate current best practices in this regard is recommended. Comparison between the UWS and non-UWS data sets also reveals that UWS bridges generally perform well in relation to non-UWS bridges.

Keywords- Steel bridges;Uncoated weathering steel; Ratings; Performance characteristics; Aging; Corrosion; Climates.

I. INTRODUCTION

Bridges in the United States were first constructed with uncoated weathering steel (UWS) in 1964 (Albrecht and Naeemi 1984), and thus there is a significant population of this bridge type that has been in service for an extended period of time. This history has generally revealed that UWS bridges perform well in most cases, but in the 1980s, some states began to experience less than de- sirable performance of their UWS bridges. This prompted the Federal Highway Administration (FHWA) to issue Technical Advisory (TA) 5140.22 in 1989 (FHWA 1989).

This TA gave broad guidance to bridge owners on situations where UWS should not be used, such as coastal, high-humidity, or industrial envi- ronments, grade separations, and low-level water crossings, as well as detailing guidance. A study subsequently conducted by the American Iron and Steel Institute (AISI) in 1995 on a select number of bridges showed that UWS bridges that were designed and de- tailed in accordance with this TA were performing well throughout the United States (AISI 1995), although this work could only assess performance over a relatively short time frame of 6 years. In contrast, this paper presents the results of a study aimed at assessing the overall performance of the national population of UWS bridges over the last 50 years in order to reveal trends in performance so that future research can be better designed to explain and improve on these observed trends and, if deemed necessary, the FHWA TA can be updated based on these findings. Furthermore, given the cost-effectiveness of UWS, which has been demonstrated in both short- and long-term savings and the environmental benefits of this material type (e.g., Missouri Highway and Transportation Department 1996), many owners consider UWS to be an attractive material option for highway bridges, and the rate at which this material is being used is increasing within some agencies. Thus the need for improved understanding of the performance of this material in realistic conditions is vital for efficiently maintaining.

II.UWS IN HIGHWAY BRIDGES

The research presented in this paper is organized by first re- viewing prior work on the performance of UWS bridges, which serves as a foundation for focusing the present work. Next, as a step toward addressing the needs discussed earlier, surveys were con- ducted and bridge records were requested from all 50 states, the District of Columbia, and Puerto Rico (for a total of 52 highway agencies). This paper synthesizes the results of this survey to reveal a broad qualitative understanding of the varied experiences related to UWS performance. The 52 agencies were also asked to identify the bridges within their jurisdictions containing UWS structural elements. Because such information is not stored in national databases, it is highly valuable for facilitating a statistical evalu- ation of UWS performance. With these structures identified, re- gional trends in UWS performance were determined through review of National Bridge Inventory (NBI) records, a national database containing descriptions of the features and condition of all bridges on public roads. These trends are evaluated as a function of climate and age, independently and in comparison with other bridge types, to produce a more quantitative evaluation of UWS performance. This paper concludes with a discussion of key con- clusions of this work and recommended next steps for better un- derstanding the variations in and best practices regarding UWS performance.

III.BACKGROUND

Several previous studies have evaluated the performance of UWS. Most of them have been carried out at the request of federal (e.g., Albrecht and Naeemi 1984; Albrecht et al. 1989; Coomarasamy et al. 2008) or state (e.g., Raman and Nasrazadani 1989; Jobes 1996; Missouri Highway and Transportation Department 1996; McDad et al. 2000; Barth et al. 005; Wiss, Janney, Elstner Asso- ciates, Inc. 2013) agencies. Obviously, the latter of these tends to focus on the performance of UWS within a particular state. In addi- tion to the national reviews of the performance of UWS mentioned earlier, AISI reports on field inspections of UWS bridges over a 13-year period (AISI 1982, 1995). Even though these reviews cover a broad range of climates and geographies, they were limited to a fairly small percentage of the total population of UWS bridges. This work differs from these prior works by reporting on general per- formance trends on the vast majority of the UWS bridges in the United States.

Taken together, prior work on the performance of UWS bridges suggests that these bridges often perform well, but certain situations result in compromised performance. These situations can include issues related to both the geographic location of the structure and the manner in which it is designed and/or maintained. Common main- tenance issues include situations such as leaking joints that fre- quently expose steel elements to runoff (which has resulted in most agencies now painting these isolated areas) or other maintenance or detailing issues causing the steel surface to be frequently wet or in contact with corrosive substances such as bird droppings.

Of the environmental variables that have been identified as being associated with UWS bridges with inferior performance, Albrecht and Naeemi (1984) observed high humidity, or time of wetness (National Association of Corrosion Engineers 2010), as negatively affecting the performance of UWS. However, in contrast, AISI (1982, 1995) inspected several bridges that were located in areas of high rainfall, high humidity, or frequent fog, and no problems were observed with any of these bridges (although no time-of-wetness measurements were taken at any of the bridge sites). Atmospheric contaminants, including chlorides, sulfates, and nitrites, have also been considered for their effects on UWS per- formance. Of these potential contaminants, chlorides (near marine environments) typically pose the greatest concern in the United States (Albrecht and Naeemi 1984), whereas sulfate and nitrite levels from pollution are generally thought to be not high enough to have a detrimental effect.

Deicing salts (which also commonly contain chlorides) have been identified as a primary cause of corrosion in several previous studies (e.g., Culp and Tinklenberg 1980; Coomarasamy et al. 2008; Wiss, Janney, Elstner Associates, Inc. 2013). Deicing salts also have been linked to corrosion on the structure as a whole and at local areas where salt-laden runoff has leaked through joints. Consid- ering the structure as a whole, the influence of deicing salts is most apparent on overpass bridges with limited clearances. This is often referred to as a tunnel situation, which has been quantified as vertical clearance less than 20 ft (which is true for most highway overpasses) and retaining walls near the shoulders (AISI 1982). Bridges in this situation are thought to be exposed to greater levels of moisture and salt spray from the traffic underneath the bridges. The combined influence of deicing salts and air pollution has also been considered, but high sulfate levels (from industrial or auto- motive pollution) did not appear to have an effect on corrosion rates (AISI 1982).

This prior work has identified the environments in which UWS performance is most likely to be compromised as those with high time of wetness, locations with frequent applications of deicing salts in a manner where these salts easily accumulate on the UWS surface, and marine environments. Thus the research discussed herein was framed accordingly. This prior work also shows that there are detailing and maintenance issues over which owners have some degree of control (FHWA 1989; Barth and McConnell 2010). However, the scope of the research presented herein fo- cuses more effort on understanding UWS performance as a function of environmental and geographic influences. Similar consider- ation of design and maintenance issues is recommended for future work.

IV.METHODOLOGY

Two key parameters were considered for each UWS bridge that was considered in this study: superstructure condition rating (SCR), as recorded in the NBI, and the structure’s age. The treat- ment of these variables is discussed in this section. Specific details on the methodology of the survey and assembly of the national database of UWS bridges are discussed later in those respective sections. The SCR is an integer value from 0 to 9 that is meant to describe the overall condition of girders, cross-frames, bearings, and so on, with 0 being the worst condition (failed) and 9 being the best con- dition (excellent). Separate categories of ratings quantify the con- dition of the deck and the substructure in the same manner. The SCR takes several factors into consideration, including fatigue cracks and other visual signs of

International Journal of Scientific Research & Engineering Trends
Volume 9, Issue 4, July-Aug-2023, ISSN (Online): 2395-566X

overstressed members, damage resulting from vehicular impacts, missing bolts in structural connections, corro- sion, and so on. Corrosion is one of the more common issues but obviously not the only cause of decreasing SCR. Thus, despite the fact that there is likely variability in the SCR arising from differing procedures in different agencies or even different inspectors within the same agency, the SCR is the best measure available to quantify UWS performance on the widespread level desired in this work. Considering the extensive sample size of UWS bridges reviewed herein, these ratings give a general view of UWS performance.

This was confirmed by comparing the qualitative performance de- scribed by each agencies' responses to the survey described herein (Question 2 specifically) and the SCRs of the bridges within the corresponding agency (McConnell et al. 2014). The comparison showed a strong correlation between these two indicators of UWS performance. However, it should be noted that on review of detailed data from several agencies, it was observed that the very low SCRs (values of 0–3) associated with some UWS bridges are not a result of UWS or corrosion-related issues. Age is a second key parameter considered in this work because a clear known relationship between age and condition exists. Be- cause the age of interest is the age of the UWS components rather than the age of the structure as a whole, both the year built and year reconstructed entries in the NBI were considered.

Because it is impossible to know whether the UWS components of these struc- tures were built during the initial construction or the reconstruction, the more recent of these two dates was used in statistical analyses of the resulting UWS database. This is both conservative (i.e., would overestimate the decrease in SCR with respect to time if this as- sumption is incorrect) and most consistent with actual practice; i.e., girders are often replaced during a reconstruction. The age of the structure was then calculated relative to 2013 (the current date at the time of this writing).

When specific bridges of interest were iden- tified, an attempt was made to determine the exact age of the UWS components through additional correspondence with the owners. Furthermore, the date when UWS is first known to have been used inn highway bridges is 1964, so bridges having both a year built and year constructed (where applicable) prior to 1964 were removed from data sets because these are most likely not representative of modern UWS (although it is possible that some agencies adopted the use of UWS slightly before this time). These will be referred to as pre-1964 bridges in the following sections.

V.NATIONAL SURVEY OF BRIDGE OWNERS

Description of Survey

A survey was sent to representatives at state DOTs in all 50 states, Puerto Rico, and the District of Columbia. This effort was facili- tated by the structure of FHWA's Long Term Bridge Performance Program (LTBPP) (Friedland et al. 2007), which has liaisons (to whom the survey was sent) in each of these agencies.

The purposes of this survey were to compile data on the historical use of UWS throughout the United States, the owners' perceptions of the per- formance of UWS, and the conditions under which poor overall performance was observed. Overall performance was defined as performance away from problematic details, leaking expansion joints, and so on. Last, the survey asked about the agencies' records on use of deicing agents because it was foreseen that this may be an important variable affecting UWS performance to be included in future work. The survey questions relevant to this work are listed next. The survey also included instructions to direct the respondents to the appropriate questions because not all are applicable to any given agency depending on its practices.

(a) Does your agency have bridges using unpainted weathering steel in its inventory? (b) If so, does your agency continue to construct bridges using unpainted weathering steel? Briefly describe your general perception of the overall per- formance of unpainted weathering steel in highway bridges within your agency. Note that by overall performance, we are interested in performance away from problematic details such as leaking joints, details that trap moisture and debris, etc. Identify which of your bridges using unpainted weathering steel are exhibiting the worst overall performance (approxi- mately one to three bridges would be most helpful to us). For the bridges identified in Question 3, briefly elaborate on the condition of these bridges and the environment (i.e., climate, physical surroundings, exposure to deicing agents) in which they are located. Briefly describe the reasons why your agency does not use unpainted weathering steel in highway bridges.

VI.SURVEY RESULTS

As a result of the cooperation of all state coordinators, a 100% response rate was obtained from the survey. However, not all respondents an- swered every question. Generally, these questions are left blank, and the sample size for that question is decreased accordingly unless other means were available to answer the question using factual information (e.g., NBI data on year built). The results of the first question of the survey are summarized by Fig. 1. As will be typical for presenting the results of all survey questions, both percentages and geographic distributions of the responses are shown because of the interest in influence of climate on UWS performance.

Fig. 1 shows that all but one agency, Hawaii, has UWS bridges. Reasons for the lack of use of UWS in Hawaii's bridges were cited as being a combination of maintenance issues with steel structures in general and past performance issues of UWS in other applications in Hawaii. There are five agencies that indicated that they have discontinued their use of UWS. Reasons given for this practice were poor performance ranging from isolated to local to widespread problems (Mississippi, Alaska, and Michigan, respec- tively), perceived maintenance requirements (Georgia), aesthetics (Mississippi), and availability (Puerto Rico). The free responses to Question 2, inquiring about general per- ceptions of overall performance of UWS, were converted to a 1- to 5-point Likert-type scale using the following conversion: A completely negative perception of UWS performance indicated; A somewhat negative perception of UWS performance indicated;

A generally positive perception of UWS performance but three or more problems indicated; A generally positive perception of UWS performance with only one or two specific negative issues indicated; and No overall performance problems with UWS indicated Based on these definitions, **the numerical and geo- graphic analysis of the 50 responses** Agencies not reporting data for this question are filled with a dashed pattern in Fig. 2. Subsequent figures will also represent a lack of data in this way. Fig. 2 shows that 96% of the respondents have a positive per- ception of the performance of UWS, including 58% of the respon- dents indicating that they have no problems with UWS performance. However, 38% of respondents reported some drawback to UWS performance, typically associated with various specific environments or situations. The two states with a negative perception of UWS were Michigan, which has a long-standing history of problems with UWS, and Alaska, whose four older UWS bridges contained timber decks, which is now a discouraged practice.

Looking at the geographic distribution of the responses to Question 2 regarding the perceived performance of UWS shows that UWS is perceived to perform best in the western half of the conti- nental United States, with only Washington, Oregon, Nevada, and Utah expressing any reservations regarding the performance of UWS over this broad geographic region. Perceptions of the per- formance of UWS in the eastern half of the United States are more varied. Whereas UWS generally has a good reputation in this area, the regions reporting concerns are the northern Gulf Coast region, mid-Atlantic region, the northern Midwest, and New England. The two agencies (Alaska and Michigan) expressing negative percep- tions regarding the performance of UWS are located in northern climates.

The responses to Questions 3 and 4, where bridges with overall performance issues were identified and described, are summarized.

(1) an answer directly expressing that the agency had no bridges with an overall performance issue with UWS,

(2) a listing of one or more bridges whose inferior performance reportedly stemmed from known problematic details such as leaking joints, timber decks, and so on (i.e., a detailing and/or maintenance issue),

(3) a description of one or more specific bridges with an overall performance issue related to UWS, or

(4) general information implying an overall performance issue without identifying any information on specific bridges and their environments. Responses relating to detailing and/ or maintenance issues were somewhat unexpected because the survey intended to specify a clear definition of overall performance and focus responses to these questions accordingly. In at least some cases, it was stated that these agencies simply had no bridges with inferior overall performance, and thus the most relevant information was provided.

That if the third and fourth categories are considered together as agencies reporting an overall performance issue, ap- proximately one-third of the agencies falls into each of these three categories (i.e., no issues, detailing/maintenance-related issues, and overall issues).

When considering the geographic distribution of the bridges in each of these three categories, it is not surprising that there are similarities between the trends shown here and those shown in **which pertains to the general perception of the performance of UWS within each agency.** Specifically, **reinforces that UWS bridges have no significant performance issues in most of the western United States and the Southeast**. The agencies reporting overall performance issues are generally located in northern climates in the eastern United States. This is also the region with the lowest perception of the performance of UWS, as shown **in** and three states in the western half of the United States: Washington, Colo- rado, and Wyoming. quadrant of the United States; however, these are typically attributed to problematic details, which most often consist of failed joints.

by a description of their environment, all but two are affected by either a combination of a coastal and humid location (coastal cat- egory, two agencies); deicing salts, particularly in overpass sit- uations (deicing category, eight agencies); or both these issues (coastal and deicing category, three agencies). It is noted that Rhode Island and Connecticut were categorized as coastal by their owners, and the Massachusetts bridges were added to this category after observing that they had similar distances to coastlines as those identified by Rhode Island and Connecticut (McConnell et al. 2012). More unique situations or those with not readily apparent causes for inferior UWS performance are placed in separate categories, as shown in In addition to identifying the environment in which the UWS bridges of most concern are located, their condition, which should be considered relative to the year built, is shown in Table 1. Relative to the year 2013, at the time of this writing, the ages of these structures range from 7 to 42 years. Table 1 also shows that there is a significant range in the condition of the UWS bridges with performance concerns, with specific bridges having SCRs from 3 to 8 and the Ohio bridges have ratings less than or equal to 3. The bridges less than 30 years old have SCRs of 7 (defined as good condition) (FHWA 1995) or better.

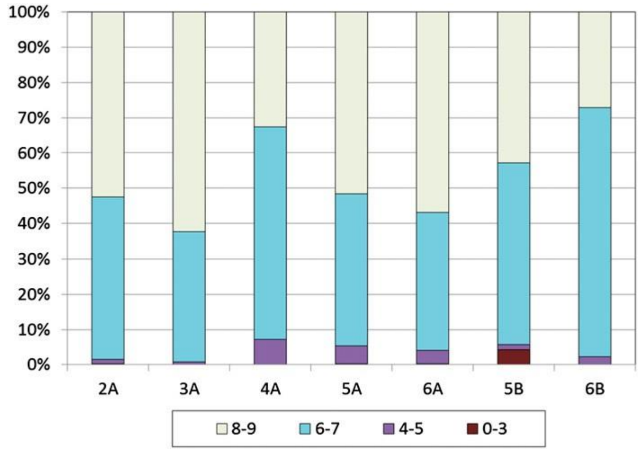

Fig. 1. Distribution of superstructure condition rating (SCR) by climate

VI.INFLUENCE OF AGE ON CLIMATE ANALYSIS

To evaluate the influence of age on the SCRs presented in the pre- ceding section, the SCRs for selected UWS bridges were plotted versus age (calculated as described in the "Introduction") for se- lected bridges, as shown **o**rder to focus this task to a manageable scope, the two best (3A and 6A) and two worst (6B and 4A) climate categories identified in the preceding section were considered in this evaluation.

Then one state with a statistically significant number of UWS bridges within each of these climate categories was selected for detailed evaluation (i.e., the UWS populations within four state agencies were reviewed). Because the purpose of this evaluation is simply to evaluate differences resulting from climate versus specific design or maintenance practices of any specific state, these states are referenced by climate category only. To most clearly present this large volume of results so that the effects of climate type can be assessed, the data are divided between two figures. Data from Climate Categories 6A and 6B are presented in Fig. 7(a), and data from the remaining two climate categories are shown in Then, in order to determine whether the observed trends here are indicative of UWS or other causes, other steel (OS) bridges are also included and will be discussed in a subsequent section. there is a large amount of scatter in these data given the significant number of variables that factor into a single SCR describing any given structure, but as expected, a trend of decreasing SCR with increasing age is observed. Thus, as a simple means to aid in data interpretation, linear trend lines are added to each of these data series. It is acknowledged that the relationship between SCR and age may be better described by a higher-order equation, but linear trend lines are sufficient for the present purposes of comparing these data sets.

REFERENCES

[1]. Albrecht, P., Coburn, S. K., Wattar, F. M., Tinklenberg, G. L., and Gallagher,
W. P. (1989). "Guidelines for the use of weathering steel in bridges." National Cooperative Highway Research Program Rep. 314, Trans- portation Research Board, Washington, DC.
[2]. Albrecht, P., and Naeemi, A. H. (1984). "Performance of weathering steel in bridges." National Cooperative Highway Research Program Rep. 272, Transportation Research Board, Washington, DC. American Iron and Steel Institute (AISI). (1982). Performance of weath- ering steel in highway bridges: A first phase report, Pittsburgh.
[3]. American Iron and Steel Institute (AISI). (1995). Performance of weath- ering steel in highway bridges: A third phase report, Pittsburgh.
[4]. Barth, K., Albrecht, P., and Righman, J. (2005). Performance of weathering steel bridges in West Virginia: Final report, West Virginia Department of Highways, Charleston, WV.
[5]. Barth, K., and McConnell, J. (2010). "An assessment of weathering steel bridges in West Virginia." Proc., Int. Conf. on Short and Medium Span Bridges, Canadian Society for Civil Engineering, Montreal, 361-1– 361-10.Coomarasamy A., et al. (2008), "Analysis of corrosion products formed on some of Ontario's weathering steel bridges" Paper No. 08199, Ministry of Ontario Transportation, Toronto.
[6]. Culp, J. D., and Tinklenberg, G. L. (1980). "Interim report on effects of corrosion on bridges of unpainted A588 steel and paint types." Research Rep. No. R-1142, Michigan Transportation Commission, Lansing, MI. Federal Highway Administration (FHWA). (1989). "Uncoated weathering steel in structures." Technical Advisory 5140.22, Washington, DC.
[7]. Federal Highway Administration (FHWA). (1995). "Recording and coding guide for the structure inventory and appraisal of the nation's bridges." Rep. No. FHWA-PD-96-001, Office of Engineering, Bridge Division, Bridge Management Branch, Washington, DC.
[8]. Friedland, I., Ghasemi, H., and Chase, S. (2007). The FHWA long-term bridge performance program, Turner-Fairbank Highway Research Center, McLean, VA.

[9]. International Code Council. (2012). 2012 International energy conservation code, Washington, DC. Jobes, R. A. (1996). Evaluation of unpainted weathering steel bridges in Idaho, Idaho Transportation Department and FHWA, Washington, DC. McConnell, J., Mertz, D., Shenton, H., Lee, S., and Roda, A. (2012). Long-term bridge performance (LTBP) program: Evaluation of unpainted weathering steel highway bridge performance: Phase I report, Center for Innovative Bridge Engineering, Univ. of Delaware, Newark, DE.

[10]. McConnell, J., Shenton, H., Mertz, D., and Kaur, D. (2014). "Performance of uncoated weathering steel bridges throughout the United States." Annual Meeting Compendium of Papers, Transportation Research Board, Washington, DC, in press.

[11]. McDad, B., Laffrey, D. C., Dammann, M., and Medlock, R. D. (2000). "Performance of weathering steel in TxDOT bridges." Project 0-1818, Texas DOT, Austin, TX.

[12]. Missouri Highway and Transportation Department. (1996). Task force report on weathering steel for bridges, Missouri Highway and Trans- portation Department, Jefferson City, MO.