A look at the performance of the national uncoated weathering steel bridge inventory.

TIME Tested

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ALL RESEARCH TAKES PLACE in a lab—of sorts.

For uncoated weathering steel (UWS) bridges, that lab is out in the open, exposed to the elements, in various types of environments across the country.

UWS bridges have now seen domestic use for nearly a half-century, an appropriate time frame for assessing their long-term performance. Such an assessment has been the focus of recent research, "Evaluation of Unpainted Weathering-Steel Highway-Bridge Performance," conducted at the University of Delaware's Center for Innovative Bridge Engineering in partnership with the Federal Highway Administration's (FHWA) Long Term Bridge Performance Program (LTBPP) and Rutgers University. Specifically, UWS performance has been assessed through surveying the varied experiences of 52 US transportation agencies as well as through compiling a national database of UWS bridges and performing a data analysis on the condition of these bridges. In total, the performance of nearly 10,000 structures has been quantified as a result of these efforts.

Qualitative Performance

Through a survey facilitated by the organizational structure of FHWA's LTBPP—which has "state coordinators" in each state, Puerto Rico and the District of Columbia—data has been compiled regarding owners' perceptions on the performance of UWS. Respondents were asked to "briefly describe your general perception of the overall performance of unpainted weathering steel in highway bridges within your agency."

"Overall performance" was defined as performance away from problematic details such as leaking joints, details that trap moisture and debris, etc., because the reasons for inferior performance at the locations of problematic details is relatively well understood and theoretically easy to remedy with sufficient maintenance resources. Rather, a major goal of this survey was to reveal general information on the frequency and characteristics of structures suffering from accelerated corrosion over more widespread areas.

The responses to this question were categorized into the three distinct categories listed below, which emerged as the results were reviewed:

- Entirely Positive (EP): No overall performance problems with UWS indicated.
- Mostly Positive (MP): A generally positive perception of UWS performance was indicated, but some drawbacks were also mentioned.
- Negative: A response indicating a negative perception of UWS performance.

Based on these definitions, Figure 1 (on fthe following page) shows the geographic distribution of the 50 responses to this question (agencies not reporting data for this question are filled with a dashed pattern). The map indicates that 96% of the respondents have a positive perception of the performance of UWS, including 29 of the 50 respondents (58%) being in the EP category. The 38% of respondents in the MP category reported issues typically associated with various specific environments or situations. These

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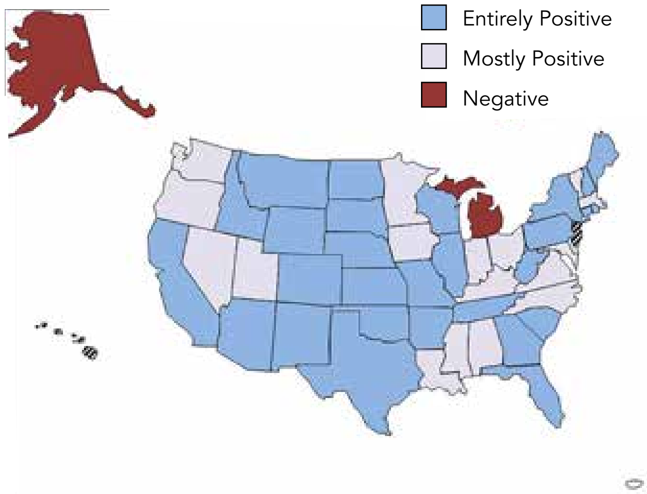


Figure 1. Owners' perception of the performance of UWS bridges in their state.

problematic environments were most often related to the use of deicing agents on underpass roadways. The only two states with a negative perception of UWS were Michigan and Alaska—neither of which has constructed any UWS bridges since guidance on proper UWS maintenance ("Uncoated Weathering Steel in Structures Technical Advisory") was published by FHWA in 1989. (Michigan's newest UWS bridge was constructed in 1983 and all of four of Alaska's UWS bridges were built in 1974 or 1975.)

Quantitative Performance

A national UWS bridge database was created through cooperation with 46 state coordinators and representatives from eight federal agencies who identified the UWS bridges within their inventory. As a relatively simple means to assess the performance of this extensive inventory of UWS bridges, the National Bridge Inventory (NBI) superstructure condition rating (SCR) of each structure was compiled. The SCR is an integer value from 0 to 9 that is meant to describe the overall condition of girders, cross-frames, bearings, etc., with 0 being the worst condition (failed) and 9 being the best condition (excellent). The rating takes several factors into consideration, including fatigue cracks and other visual signs of over-stressed members, damage resulting from vehicular impacts, missing bolts in structural connections and corrosion. From the review of numerous inspection reports of specific structures, it has been observed that the last of these (corrosion) is one of the more common causes of decreasing SCR. Thus, when reviewing these ratings for an extensive sample size of UWS bridges, the authors have shown that these ratings give a general quantitative indication of UWS performance.

The data summary shown in Figure 2 shows that on average UWS bridges perform quite well, with the most populated SCR being 8, which represents "very good" condition, and 50% of the total inventory of UWS bridges having either a SCR of 8 or 9. Furthermore, 95% of the UWS population has a rating of 6 or better, indicating "satisfactory" performance or better. Note that only 1% of the UWS population received a rating of 4 or less. Furthermore, the SCR values of 0 to 3 were not found to be a direct result of UWS or corrosion-related issues; instead, they were most commonly related to un-arrested fatigue cracks in the sample of bridges for which detailed information has been obtained. Figure 3 shows, perhaps unsurprisingly, that a clear factor affecting SCR is the age of the structures. Specifically, a relatively linear decreasing trend in SCR with increasing age is observed, where the average SCR for bridges 10 years old and younger is 8.0 and is 6.5 for bridges 41 years old and older.

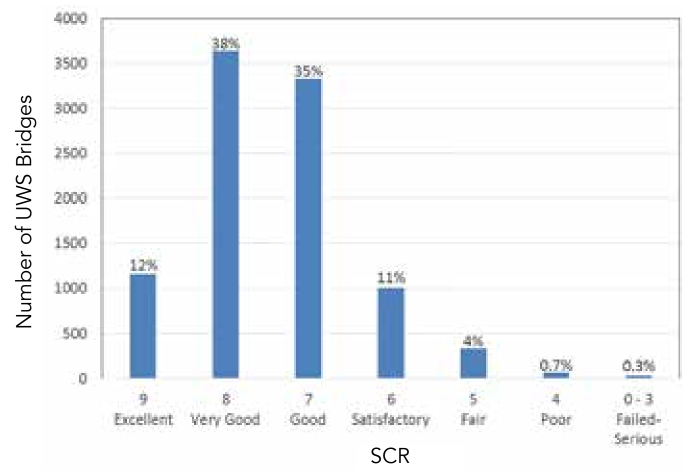
Comparative Performance

The significance of the above data increases when viewed in context relative to other material types. Figure 4 shows the SCR versus age for UWS bridges in two representative agencies (one from an agency in the "entirely positive" category and the other from the "mostly positive" category based on the survey results discussed above) plotted relative to the other steel (OS) bridges in these same agencies. As a simple means to aid in interpretation of and comparison between data sets, trend lines based on linear regression analysis of each data set are added to each of these data series.

In comparing the performance of the UWS and OS data sets, it is observed that in the entirely positive category, the performance trend of the UWS data set is similar to the performance trend of the OS data set, with UWS tracking slightly above. This difference is more pronounced for younger bridges, although even UWS bridges designed prior to the publication of the FHWA UWS technical advisory outperform their OS counterparts. For the mostly positive performance category, it is also observed that the UWS bridges display similar performance relative to their OS counterparts. For these two data sets, the trend lines are very similar, with the UWS trend line being slightly superior to the OS trend line for ages between 1 and 25 years and the OS data set being slightly superior otherwise. However, this finding should be viewed in light of two facts. The first is that even though data is plotted here for ages 1 through 49, there are relatively few (only nine) bridges older than 35 years old, so data for these structures is not statistically

Favorable performance of a UWS overpass.

➤ Figure 2. Distribution of UWS population by SCR.

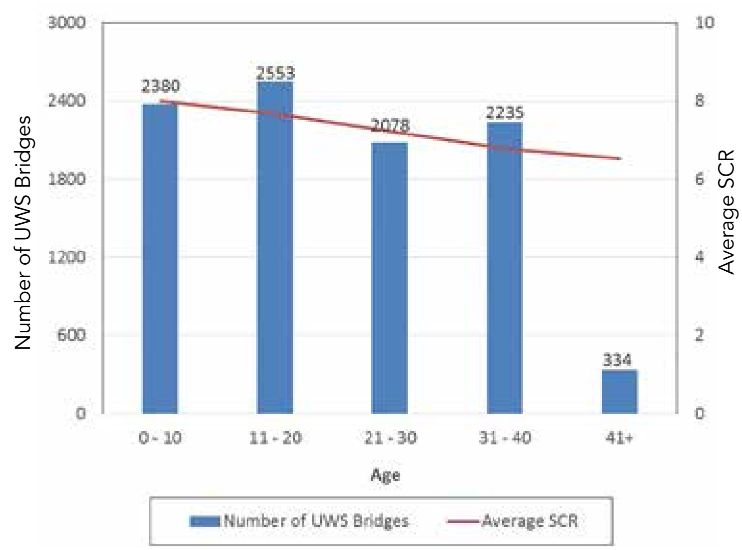


significant in light of the total number of bridges considered in this figure (12,000). The second is that it has been 25 years since the FHWA UWS technical advisory was published. Thus, it is possible that design or maintenance practices implemented since that time would change these trend lines as the newer bridges in this population age in the future.

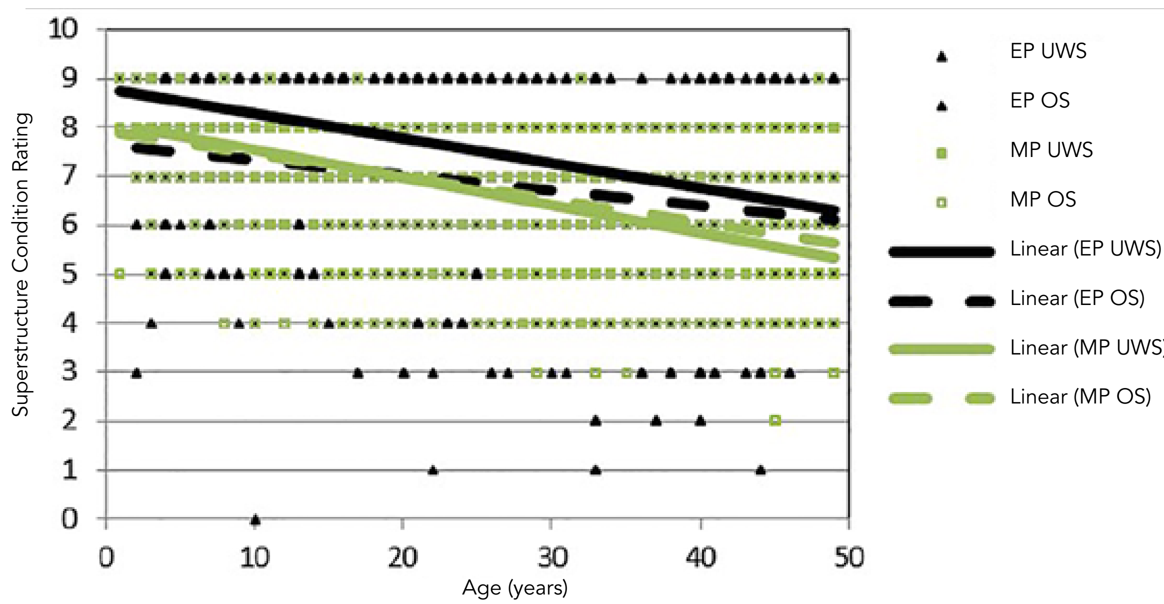
Further Work

As a result of the data presented herein, we have concluded that UWS generally provides reliable performance in highway bridge applications throughout the U.S. Specifically, as a result of the survey of bridge owners, it was found that 96% of the respondents have a positive perception of UWS performance within their inventory and that the remaining two agencies had not built any UWS bridges since 1983—which was, again, prior to the FHWA guidance on this topic being published in 1989. When reviewing the NBI ratings of the structures in the newly created national UWS bridge inventory, it was found that the superstructure condition ratings of the majority of UWS bridges are classified as excellent or very good. While these tend to be newer UWS bridges, UWS bridges that

➤ Figure 3. Distribution of UWS population by age with corresponding SCR.



➤ Figure 4. Superstructure condition rating vs. age, UWS vs. other steel bridges.



have been in service for over 40 years were shown to be also generally performing well.

Furthermore, based on the fact that Figure 4 shows the average performance of UWS is on par with or better than the average performance of painted steel superstructures for the representative agencies evaluated here, we can conclude that when choosing between these two corrosion-control strategies and considering the economic and environmental benefits of UWS bridges, UWS is a sound choice in many different environments. That said, complementary research is recommended to more carefully evaluate potential exceptions to this general statement.

One such research topic has been to analyze UWS performance as a function of climate (see "National Review on Use and Performance of Uncoated Weathering Steel Highway Bridges" in ASCE's *Journal of Bridge Engineering*). This work revealed that UWS bridges generally performed well across all climate categories and suggested that maintenance practices may be a more influential indicator of UWS performance than climate; this latter hypothesis is of interest for future evaluation. Furthermore, the climate analysis to date has consisted of broadly categorizing bridges into regional climate categories. However, recent creation of a geographic information system (GIS) database combining the UWS inventory, climate data and atmospheric chemical concentrations now allows the specific climate conditions (e.g., monthly humidity values, annual snowfall and atmospheric chloride levels) of each UWS bridge to be known, which could reveal new insights on the effects of local climates.

Lastly, field work to more rigorously evaluate specific UWS bridges is also underway, along with a complementary effort to obtain as much information as possible from existing inspection reports of additional UWS bridges so that additional metrics beyond SCR, such as element-level condition state data and visual observations, can be considered. Through such efforts, guidance on expected UWS performance in representative realistic conditions can be obtained, which can ultimately lead to the development of UWS best practices and guidelines. ■