FINAL REPORT

PERFORMANCE OF WEATHERING STEEL BRIDGES IN WEST VIRGINIA

WVDOT/DOH Research Project

by

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16. Abstract

Due to the economical benefits offered by the use of weathering steel in highway bridges, the West Virginia Department of Highways (WVDOH) has constructed approximately 100 weathering steel bridges throughout the state. The majority of these bridges have been constructed over the past decade. Evaluating the performance of weathering steel has become necessary because of the extensive use of this material throughout the state. Thus, this project was initiated with the goals of assessing the corrosion characteristics of weathering steel bridges throughout the state and providing recommendations for the use of weathering steel.

These objectives achieved through the completion of six tasks. First, a literature review was conducted in Task A that focused on general information on weathering steel and on studies similar to this investigation. Second, a database of weathering steel bridges in the WVDOH inventory was developed for Task B. This database contained geographical and geometric data as well as the age of each structure. In addition, a map of the geographical locations of these weathering steel bridges was created.

In Task C, the weathering steel database developed in Task B was used to select a number of bridges for site visitation. A large majority of the bridges were inventoried easily because of their close proximity to each other. In fact, in Task D, site visits were made to 87 of the 98 bridges listed on the weathering steel inventory that was provided by WVDOH. Additionally, site visits were made to two bridges owned by WVDOH (not yet inventoried), two bridges owned by the WV Turnpike Authority, and six bridges owned by the New York Department of Transportation (DOT). In total, 97 weathering steel bridges were inspected during this project. Eleven bridges on the WVDOH inventory list were not visited. These bridges, however, are very similar to other bridges that were inspected. Therefore, a comprehensive evaluation of the use of weathering steel in West Virginia can be made.

Task E consisted of developing project conclusions, guidelines, and recommendations for future design and maintenance efforts related to weathering steel bridges. Finally, the project's progress was reported to WVDOH personnel in Task F.

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Performance of Weathering Steel Bridges
In West Virginia

EXECUTIVE SUMMARY

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This final project report presents the results of these six tasks. The report is organized as follows. Section 1 of this report presents the background, problem statement, and literature review material. Section 2 provides an overview of the weathering steel bridge population in West Virginia. The scope and methodology of the bridge inspections are discussed in Section 3. A summary of the findings from the bridge inspections is subsequently presented in Section 4. Section 5 presents recommendations for future design and maintenance efforts. Finally, the proposed plan for implementation and technology transfer is presented in Section 6. Additionally, the inspection reports from each of the bridge site visits are provided on the enclosed CD-ROM, which serves as Appendix A.

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I. INTRODUCTION

Background

Weathering steel bridges offer the advantage of eliminate the need for painting, leading to more economical structures. Consequently, there are approximately 100 weathering steel bridges throughout the state of West Virginia. However, concerns exist regarding unacceptable levels of corrosion in these unpainted structures. For this reason, the research project described herein was initiated with the goal of providing a comprehensive assessment of the performance of weathering steel bridges in West Virginia.

Problem Statement

The goal of this project is to assess the corrosion performance of weathering steel bridges in West Virginia. This is of importance as the number of weathering steel bridges being constructed continues to increase. Furthermore, the population of weathering steel bridges in the state now contains several structures that have been in service for a significant number of years, making it possible to assess the long-term corrosion performance of weathering steel bridges in West Virginia.

Literature Review

Overview of Weathering Steel

A588 weathering steel is formed by alloying additional elements (2% or less of various combinations of copper, phosphorus, chromium, silicon, and/or nickel) with traditional steels (A36 or A572), which significantly increases the corrosion resistance of the steel.

The behavior of weathering steel exposed to appropriate environments is fundamentally different from that of traditional steel. In contrast to the formation of iron oxide (rust) that occurs when traditional steels are exposed to atmospheric conditions, weathering steel forms a protective oxide coating that reduces the rate of corrosion of the steel. However, this protective oxide coating will form only if the weathering steel is not subjected to extended periods of moisture. Additionally, proper detailing of the structure is critical to maintain the integrity of the protective coating.

Environmental factors may adversely affect the ability of weathering steel to develop a protective oxide coating, particularly the presence of excessive levels of chlorides and sulfur dioxides. Sulfur dioxide levels from pollution are generally not high enough to have a detrimental effect on weathering steel in the United States. Chlorides are a concern, however, because chloride contamination may result from the runoff of deicing salts applied to roadways or from the proximity of the structure to marine environments that have high atmospheric chloride levels. Although the concerns associated with the impacts of a marine environment are not an issue in this study, the West Virginia Department of Highways (WVDOH) uses a large amount of deicing salts for winter roadway maintenance operations.

Previous Studies Focused on Evaluating Weathering Steel Performance

One of the first studies that evaluated weathering steel bridges was conducted by the American Iron and Steel Institute (AISI 1982). At that time, the Michigan Department of Transportation had placed a moratorium on the use of all non-painted weathering steel.

This action was due to the observation that many bridges in the state were developing excessive corrosion. For example, bridges in urban, industrial locations were corroding because the heavy application of deicing salts combined with industrial and automotive pollution was creating an extremely corrosive environment. Overpass bridges with less than 20 ft. under-clearance and with retaining walls near the shoulders, often referred to as a depressed roadways, were also developing excessive corrosion. The salt-spray caused by traffic underneath the bridges in depressed roadways collects on the girders, resulting in a regular application of a highly corrosive solution directly on the bridge superstructure.

As a result of the Michigan moratorium, AISI organized a formal evaluation of weathering steel bridges including the inspection of 49 bridges in seven states (Illinois, Maryland, Michigan, New York, North Carolina, Wisconsin, and New Jersey). The objective of the evaluation was to determine if the problems observed in Michigan were indicative of a general problem or were unique to that state/area (AISI 1982). The bridges were selected for inspection based on two criteria: site characteristics and level of salt use. The site characteristic of a particular bridge was classified as being in one of four categories: (1) urban or industrial grade separation, (2) rural grade separation, (3) stream or railroad crossing, or (4) depressed roadway condition. Bridges were also categorized as having heavy, light, or no salt use. Bridges were then selected with the goal of having several bridges in each combination of categories.

Results of this investigation showed that 30% of the bridges were in good condition in all areas; 58% of the bridges showed moderate corrosion (flaky rust) in some localized areas, but were in generally good condition; and 12% of the bridges exhibited heavy corrosion in some areas, but were in generally good condition. Local areas of corrosion were most often attributed to salt-laden runoff through leaking joints or open expansion dams. The evaluation also found that bridges in depressed roadway conditions generally did not develop the desired protective oxide coating. High sulfate levels (from industrial or automotive pollution) did not appear to have an effect on corrosion rates.

The study concluded that the majority of weathering steel bridges were performing satisfactorily; although, exceptions existed in the state of Michigan (AISI 1982). Since the study has been published, however, other researchers have identified weathering steel bridge structures in which the protective coating did not perform adequately in states other than Michigan.

In 1984, Albrecht and Naeemi also conducted an extensive evaluation of weathering steel performance. This study reviewed the bridges inspected and the states considered in the AISI (1982) study as well as the experiences of other states that had reported less than optimal performance of weathering steel bridges. Specifically, bridges in both Alaska and California that exhibited excessive corrosion were evaluated. This study concluded that the site conditions of heavy rainfall, fog, and high humidity subjected these structures to prolonged periods of wetness and lead to the poor performance of the weathering steel.

Albrecht and Naeemi (1984) also reported that two of Louisiana's sixteen weathering steel bridges were not performing as expected. Both of these bridges were located in close proximity to the Gulf of Mexico. Salt contamination (as a result of salt-laden wind and fog) and high humidity were identified as factors that prevented the formation of a protective oxide coating.

They also reported on several cases of inadequate weathering steel performance in Ohio. The cause of corrosion in these structures was also attributed to prolonged periods of wetness caused by low clearances over underlying streams. A chemical analysis of rust samples taken from one of these bridges showed only trace amounts of sulfates and chlorides. Therefore, the excessive corrosion observed was not caused by salt contamination or pollution.

Conclusions of the Albrecht and Naeemi study (1984) were in general agreement with the findings of the AISI First Phase Report (AISI 1982). Albrecht and Naeemi also state that the majority of weathering steel bridges are in good condition, but local areas of pronounced corrosion exist in several structures.

Subsequent to the initial investigation on weathering steel bridges by AISI, a second study was conducted and the results are summarized in "Performance of Weathering Steel in Highway Bridges: A Third Phase Report" (AISI 1995). In this study, researchers from AISI revisited the bridges that were initially inspected in the Phase I Report (AISI

1982, referenced above) and also inspected several additional bridges. These bridges are located in West Virginia, Louisiana, Iowa, California, and Puerto Rico.

The results of this evaluation indicated that weathering steel bridges that are designed and detailed in accordance with the FHWA Technical Advisory on weathering steel bridges (T 5140.22, FHWA 1989) were performing well throughout the United States, including those in marine and industrial environments. However, other researchers have found that the distribution of airborne salts in marine environments may vary greatly from location to location and have noted structures in these environments where the weathering steel has not performed adequately.

AISI also reports that several of the bridges that were inspected were located in areas of high rainfall, high humidity, or frequent fog. Despite these environmental factors, no problems were observed with any of these bridges. The only weathering steel bridges that were found to be performing unsatisfactorily were those located in the metropolitan Detroit area. The negative performance of these bridges was believed to be caused by the amount and frequency of deicing salts used in the Detroit area, the chemical composition of these salts, or a combination of both of these factors. Additionally, local areas of corrosion were reported for some bridges; the most common causes of these problems were reported to be leaky deck joints and clogged scuppers.

In addition to the previously mentioned studies, several states—such as Louisiana, Idaho, and Texas—have independently evaluated weathering steel bridges in their inventory.

Louisiana has cited corrosion problems caused by airborne salts in some of its weathering steel bridges, particularly those along the Gulf Coast (Raman and Naszrazadani 1989). Excessive corrosion was found to occur in the following primary locations: (1) near piers, (2) where wildlife (particularly birds) sheltered, (3) where condensed water collected and pooled, and (4) at locations with accumulated debris. In their research, Raman and Naszrazadani cite instances in which the application of a tannic acid solution was found to stabilize the corrosion rate (1989). However, whether this method would be acceptable as a general practice is not yet known.

In 1995, the Idaho Transportation Department inspected 12 of its 40 unpainted weathering steel bridges (Jobes 1996). A protective oxide coating was observed on all 12 of these bridges, and the continued use of weathering steel bridges in appropriate environments was recommended.

The Texas Department of Transportation (TxDOT) also recently completed a study focusing on the performance of weathering steel used in bridges in Texas (McDad et al. 2000). During this project, 40 weathering steel bridges throughout the state were independently inspected. The bridges were selected to represent five different site conditions: coastal, industrial, urban, suburban, and rural. The inspections revealed similar findings for all of the bridges except for those in coastal areas. In particular, the interior surfaces of bridges in coastal areas had larger flakes than the other inspected bridges; the exterior surfaces of the coastal bridges were similar to those of the other bridges in the evaluation sample.

McDad et al. (2000) concluded that the use of weathering steel bridges in Texas was generally a cost-effective alternative. However, they did not recommend using weathering steel: (1) in the presence of corrosive industrial or chemical pollution, (2) in locations with heavy salt-water spray or salt-laden fog, (3) in conjunction with timber decking, and (4) in depressed roadway conditions over roadways on which deicing salt is used.

While these studies confirm that weathering steel bridges perform favorably in most locations in the United States, the results indicate that weathering steel may not perform as intended at some sites. Weathering steel should be used cautiously in these specific areas: (1) locations with frequent rainfall, fog, or high humidity, (2) sites with topography that may subject the steel to excessive periods of wetness, (3) low-level water crossings, (4) marine environments, (5) locations where concentrated chemical pollution may drift directly onto the structure, and (6) in depressed roadways.

The studies discussed in this section have also attributed the excessive, local corrosion of some weathering steel bridges to problems with design details. One of the most significant sources of this type of corrosion is caused by leaky bridge joints. Similarly, controlling drainage on and around a weathering steel bridge is of utmost importance.

II. WEST VIRGINIA WEATHERING STEEL BRIDGE POPULATION

The project sponsor provided information on each weathering steel bridge inventoried by WVDOH to the research team. This information included the name, location, crossing, length, width, construction date, span type, and ADTT of 98 bridges as presented in Table 1. The bridges were then classified by each of these categories to obtain a better understanding of the population of weathering steel bridges within the state.

Location

The geographic location of each weathering steel bridge is illustrated in Fig. 1. Each bridge is represented by a pin in this figure. As Fig. 1 shows, weathering steel bridges are well distributed throughout the state. In addition, the urban areas of Bluefield/Princeton, Huntington, and Morgantown contain several weathering steel bridges that are in close proximity to one another.

Crossing

The weathering steel bridges contained in the WVDOH inventory cross either bodies of water, roadways, railroads, or a combination of the three. Fig. 2 categorizes the WV weathering steel bridge population by crossing type. The majority of the bridges (68%) only cross bodies of water. Furthermore, 89% of the bridges cross water, 26% cross highways, and 15% cross railroads. Note that the sum of these percentages exceeds 100% because several bridges fall into more than one of these categories.

Length

Four categories for bridge length were created for the purpose of describing the WV weathering steel inventory. These categories are: less than 100 ft, between 100 and 250 ft, between 250 and 500 ft, and greater than 500 ft. Fig. 3 shows the population of bridges

Table 1: West Virginia Weathering Steel Bridge Inventory

Bars#	County	CO-RT-MP	Local Name	Crossing	Location	Length	Width	Yr Built	Yr Recon	Main Span Type	Dist	Inspected?
01A037	Barbour	01-024/00-005.01	LAUREL CREEK W-BM	LAUREL CREEK	0.02 MI E OF CO RT 12 SLS	83.9	16	1980	0	STEEL STRINGER	7	YES
02A123	Berkeley	02-018/00-000.87	SHANGHAI BRIDGE	BACK CREEK	0.05 MI WEST OF CR 20SLS	252	32.5	2001	0	STEEL STRINGER	5	YES
03A170	Boone	03-003/00-020.32	PEYTONA BRIDGE 4550	BIG COAL RIVER	0.01 MILE W OF CR 119/21	314.9	31.3	2000	0	STEEL STRINGER	1	YES
04A020	Braxton	04-001/03-000.08	ROAD RUN W-BEAM	OIL CREEK	0.08MI S OF CO 1	60	15.2	1980	0	STEEL STRINGER	7	YES
04A061	Braxton	04-019/00-027.48	BULLTOWN BRIDGE	LITTLE KANAWHA RIVER	0.20 MI S OF CO 19/12	409.3	46.7	1978	0	STEEL STRINGER	7	YES
04A180	Braxton	04-004/00-016.91	LOWER GASSAWAY GIRDER	ELK RIVER	0.15 MI N OF CO 4/24 SLS	453	35.2	2001	0	STEEL STRINGER	7	YES
05A079	Brooke	05-001/08-000.03	COLLIERS BRIDGE	HARMON CREEK	0.03 MILE N. OF CR 1	259.7	30.6	2000	0	STEEL STRINGER	6	YES
06A242	Cabell	06-064/00-021.75	HOWELLS MILL OVERPASS EB	MUD RIVER & CR 1	1.75 MI. E. OF CR 60/89	373.8	35.5	1998	0	STEEL STRINGER	2	YES
06A243	Cabell	06-064/00-021.75	HOWELLS MILL OVERPASS WB	MUD RIVER & CR 1	1.75 MI. EAST OF CR 60/89	368.2	35.5	1998	0	STEEL STRINGER	2	YES
06A244	Cabell	06-064/00-022.39	ONA RAILROAD OVERPASS EB	CSX RAILROAD	1.93 MI. EAST OF CR 60/89	374.8	35.5	1998	0	STEEL STRINGER	2	YES
06A245	Cabell	06-064/00-022.39	ONA RAILROAD OVERPASS WB	CSX RAILROAD	1.93 MI. EAST OF CR 60/89	374.8	35.5	1998	0	STEEL STRINGER	2	YES
06A260	Cabell	06-017/25-000.01	BLUE SULPHUR BRIDGE	MUD RIVER;CR 17/10;CSXRR	0.01 MILE NORTH OF US 60	747	38.7	2001	0	STEEL STRINGER	2	YES
07A064	Calhoun	07-005/00-006.11	BROOKSVILLE BRIDGE	YELLOW CREEK	O.02 MILE EAST OF CR 4	134	33	1998	0	STEEL STRINGER	3	YES
08A057	Clay	08-028/00-007.78	NEW PISGAH BRIDGE	ELK RIVER	0.27 MI N OF CR 28/1	279.7	31.8	1996	0	STEEL STRINGER	1	YES
10A214	Fayette	10-019/00-015.37	NEW RIVER GORGE BRIDGE	NEW RIVER ,CSX RR,WV 82	1.16 MI N OF WV 16	3036.5	73.4	1977	0	STEEL DECK ARCH	9	YES
11A010	Gilmer	11-005/00-010.64	LEADING CK W-BM	LEADING CREEK	0.01 MI E OF CO 12	212.2	32.4	2001	0	STEEL STRINGER	7	YES
11A113	Gilmer	11-040/01-000.10	LTL BULL RUN W-BM	LITTLE BULL RUN	0.10 MI E OF CO 40	30	13.9	1979	0	STEEL STRINGER	7	YES
11A121	Gilmer	11-040/00-007.24	STOUT'S MILL W-BEAM	LITTLE KANAWHA RIVER	0.09 MI W OF WV 5 T	173.2	27.5	1997	0	STEEL STRINGER	7	NO
	Gilmer	11-17/6-0.01		CEDAR CREEK	0.01 MI S OF CR 17		?	1996		STEEL STRINGER	7	YES
13A122	Greenbrier	13-060/07-000.61	LOUDERMILK ROAD BRIDGE	I 64	0.61 MI N US 60	345.5	36.6	1972	0	STEEL ORTHO	9	YES
13A221	Greenbrier	13-064/00-180.29	WADES CREEK BRIDGE	US 60 & WADES CREEK	3.10 MI W OF WV 311	354	35.3	1999	0	STEEL STRINGER	9	NO
13A222	Greenbrier	13-064/00-180.29	WADES BREEK BRIDGE	US 60 & WADES CREEK	3.10 MI W OF WV 311	354	35.2	1999	0	STEEL STRINGER	9	NO
14A098	Hampshire	14-127/00-000.28	NORTH RIVER BRIDGE	NORTH RIVER	0.28 MI EAST OF WV 29 F	183.7	32.9	1960	2002	STEEL STRINGER	5	YES
16A109	Hardy	16-220/00-002.38	DURGON STORE BRIDGE	DURGON RUN	0.02 MI N OF CR 220/5 SLS	41.7	34.9	1998	0	STEEL STRINGER	5	YES
17A106	Harrison	17-020/00-025.38	HAYWOOD BRIDGE	WEST FORK RIVER & CSX RR	0.04 MI NORTH CO RT 20/69	634.8	39.3	1981	0	STEEL STRINGER	4	YES
17A316	Harrison	17-079/00-121.32	MEADOWBROOK ROAD OP	HARRISON CO RT 24	2.06 MI NORTH US RT 50	219.4	60.5	2002	0	STEEL STRINGER	4	YES
17A317	Harrison	17-079/00-121.32	MEADOWBROOK ROAD OP	HARRISON CO RT 24	2.06 MI NORTH US RT 50	219.4	60.5	2002	0	STEEL STRINGER	4	YES
17A922	Harrison	17-N03/10-000.06	DUBLIN BRIDGE	ELK CREEK	ON BUCKHANNON AVENUE	101.8	26	1949	1998	STEEL STRINGER	4	YES
19A037	Jefferson	19-340/00-014.66	HARPERS FERRY BRIDGE	SHEN R;CSX RR PK ACC RD	0.08 MI N OF CR 340/9 SLS	1427.1	52.9	2000	0	STEEL STRINGER	5	YES
20A236	Kanawha	20-077/00-117.30	I-77 BR NO 2187 NBL	CR 19,ALLEN FORK	1.28 MI N OF CR 21/17	264.6	35.5	1959	1999	STEEL STRINGER	1	YES
20A453	Kanawha	20-077/00-117.30	I-77 BR NO 2187 SBL	CR 19,ALLEN CREEK	1.28 MI N OF CR 21/17	264.6	35.5	1959	1999	STEEL STRINGER	1	YES
20A775	Kanawha	20-061/00-011.50	SLAUGHTER CREEK BR	SLAUGHTER CREEK	0.04 MI N OF CR 72	113.4	31.5	1954	2000	STEEL STRINGER	1	YES
21A157	Lewis	21-001/07-001.85	DUTCH HOLLOW W-BM	DUTCH HOLLOW CREEK	0.04 MI E OF CO 1/11	30.2	13.2	1980	0	STEEL STRINGER	7	YES
21A166	Lewis	21-019/10-003.60	MUDLICK ROAD GRD	SAND FORK	0.07 MI W OF US 19 SLS	120.6	29.5	1982	0	STEEL STRINGER	7	YES
21A174	Lewis	21-019/43-000.01	LCHS ACCESS BRIDGE	WEST FORK RIVER	0.01 MI W OF US 19 SLS	149	35.8	1994	0	STEEL STRINGER	7	NO
21A181	Lewis	21-908/00-000.13	BEALL'S MILL BRIDGE	SAND FORK	0.13 MI S OF CO 17	78.4	14	1997	0	STEEL STRINGER	7	NO
22A137	Lincoln	22-907/00-000.01	BEAR WALLOW BRIDGE	BEAR WALLOW CREEK	0.01 MI NORTH OF CR 52/1	23.7	16	2003	0	STEEL STRINGER	2	NO
23A253	Logan	23-119/00-005.14	STAFF SGT FRANKIE MELNAR	MUD FORK & CR 5	0.90 MILE SOUTH OF WV 73	1530	76.4	1996	0	STEEL GIR/FB	2	YES
23A266	Logan	23-110/20-000.01	J.T. FISH MEMORIAL BRIDG	GUYANDOTTE RIVER	0.01 MILE EAST OF WV 10	249	35.7	1998	0	STEEL STRINGER	2	YES
23A302	Logan	23-010/10-000.01	MALLORY BEAM SPAN	HUFF CREEK	0.01 MILE WEST OF WV 10	83	32.7	2002	0	STEEL STRINGER	2	NO
25A231	Marion	25-079/00-129.84	DANA LEE LYNCH JR BRIDGE	MARION 73/73 & BOOTHS CK	2.23 MI SOUTH US RT 250	285.2	35.6	1966	1998	STEEL STRINGER	4	YES
25A233	Marion	25-019/00-000.01	KENNETH RILEY BRIDGE	BINGAMON CREEK	0.04 MILES SOUTH CO RT 48	145.8	42.7	1999	0	STEEL STRINGER	4	YES
25A237	Marion	25-250/00-019.38	NORVILLE CLINTON SHOCK	BUFFALO CREEK & CSX RR	0.03 MI NORTH CO RT 250/7	332.1	40.7	2000	0	STEEL STRINGER	4	YES
27A142	Mason	27-035/00-017.02	HENDERSON BRIDGE	CR 25, CSX RAILROAD	2.08 MI N OF CR 17/5	399.9	87.6	1997	0	STEEL STRINGER	1	YES
24A250	McDowell	24-001/00-008.55	D C PERRY MEMORIAL BR	TUG FORK	0.01 MI EAST OF CO 1/14	595.7	40.7	1997	0	STEEL STRINGER	10	YES
24A268	McDowell	24-052/00-031.89	ECKMAN OVERHEAD	CO52/9,NS RR,ELKHORN CK	0.09 MI W OF CO 52/9	585.2	40.7	1999	0	STEEL STRINGER	10	YES
24A278	McDowell	24-080/05-000.01	SANDY RIVER MID SCHOOL	DRY FORK	0.01 MILE E OF WV 80	167.2	37.2	1998	0	STEEL STRINGER	10	NO
24A293	McDowell	24-052/19-000.01	NORTHFORK BRIDGE	ELKHORN CREEK	0.01 MI NORTH OF US 52	51.5	30.8	2000	0	STEEL STRINGER	10	YES
28A113	Mercer	28-077/00-002.95	EAST RIVER BR.	CR.38/5 E.RV. &NSRR	2.12 MI. S. WV.112	492.5	36.1	1972	1999	STEEL STRINGER	10	YES
28A176	Mercer	28-077/00-002.95	E. RIVER BR.	CR.38/5 E. RV.$ NSRR	2.12 MI. S. OF WV. 112	461.5	36.1	1972	1999	STEEL STRINGER	10	YES
28A186	Mercer	28-019/00-017.77	LAKE SHAWNEE BRIDGE	BLUESTONE RIVER	0.14 MI S OF CO 19/13	150	31	1996	0	STEEL GIR/FB	10	YES
28A187	Mercer	28-019/00-020.58	GARDNER BRIDGE	BLUESTONE RIVER	0.03 MI S OF CR 7	125	32	1996	0	STEEL GIR/FB	10	YES
28A188	Mercer	28-019/00-022.03	SPANISHBURG BRIDGE	RICH CREEK	0.12 MI S OF CR 5	77	32	1996	0	STEEL STRINGER	10	YES

Table 1, continued: West Virginia Weathering Steel Bridge Inventory

Bars#	County	CO-RT-MP	Local Name	Crossing	Location	Length	Width	Yr Built	Yr Recon	Main Span Type	Dist	Inspected?
28A193	Mercer	28-010/00-000.51	SHAWNEE BRIDGE	BLUESTONE RIVER	0.36 MI N. OF WV 10 WYE	167.8	35	1997	0	STEEL STRINGER	10	YES
28A215	Mercer	28-077/00-017.52	CORNELIUS CHARLTON BR	BLUESTONE RIVER & CR. 3	2.20 MI. S. OF US 19	1511.7	44.6	1979	0	STEEL DECK TRUSS	10	YES
	Mercer	28-052/00-???.??		NS RR, UNKNOWN HIGHWAY	NEAR 19 INTERSECTION?	?	?	2000	?	STEEL STRINGER	10	YES
29A062	Mineral	29-042/03-001.88	PAUGHTOWN RD BRIDGE	DEEP RUN	0.04 MI SOUTH OF WV 46 F	62.7	22.3	1997	0	STEEL STRINGER	5	YES
29A063	Mineral	29-042/03-001.19	DEEP RUN BRIDGE	DEEP RUN	0.20 MI N OF CR 42/4 SLS	61.2	22.3	1997	0	STEEL STRINGER	5	YES
30A187	Mingo	30-052/00-018.21	KY 292 OVERPASS BRIDGE	KY 292;TUG FORK RIVER	0.01 MILE WEST OF US 52	1033.5	93.5	1996	0	STEEL STRINGER	2	YES
30A188	Mingo	30-052/00-017.40	BORDERLAND TUG FORK BRID	TUG FORK RIVER	0.01 MI WEST OF CR 52/96	1289.5	93.5	1997	0	STEEL STRINGER	2	YES
30A216	Mingo	30-052/00-029.21	CECIL DIAMOND MEMORIAL	PIGEON CREEK	0.40 MI. EAST OF CR 65/12	130.7	42.9	1999	0	STEEL STRINGER	2	YES
30A239	Mingo	30-003/05-020.12	NORTH LOWNEY BEAM SPAN	WEST FK TWELVEPOLE CK	0.59 MILE NORTH OF CR 3/1	150.8	28.4	2002	0	STEEL STRINGER	2	YES
30A241	Mingo	30-065/79-000.01	LENORE SCHOOL BRIDGE	PIGEON CREEK	0.01 MILE SOUTH OF WV 65	183	35.2	2002	0	STEEL STRINGER	2	YES
31A016	Monongalia	31-007/00-000.02	WALNUT STREET BRIDGE	DECKERS CREEK	0.02 MI WEST WV RT 7	499.7	38.5	1979	0	STEEL STRINGER	4	YES
31A114	Monongalia	31-045/00-010.07	HARMONY GROVE OVERPASS	INTERSTATE 79	0.10 MI EAST CO RT 45/15	230.5	46.6	1971	0	STEEL DECK ARCH	4	YES
31A275	Monongalia	31-007/00-021.96	CORE W-BEAM	DOLLS RUN	0.01 MI EAST MON CO 7/27	48.5	42.7	1999	0	STEEL STRINGER	4	YES
31A281	Monongalia	31-119/39-000.12	SOUTH HIGH STREET BRIDGE	DECKERS CREEK	0.12 MILES NORTH US 119	550.5	42	2001	0	STEEL STRINGER	4	YES
31A283	Monongalia	31-014/00-000.01	MACDALE BRIDGE	DUNKARD CREEK	0.01 MI NORTH WV RT 7	122.8	32.6	2002	0	STEEL STRINGER	4	YES
31A906	Monongalia	31-N00/99-000.06	KNOCKING RUN BRIDGE	KNOCKING RUN	0.05 MI EAST CO RT 7/40	35	25.7	1974	0	STEEL STRINGER	4	YES
34A106	Nicholas	34-019/00-017.93	MUDDLETY BRIDGE N.B.L.	WV 55	1.25 MI. S OF CR 19/57	1370.8	44.6	1997	0	STEEL STRINGER	9	YES
34A107	Nicholas	34-019/00-017.93	MUDDLETY BRIDGE S.B.L.	WV 55	0.87 MI. S OF CR 43/1	137.8	44.6	1997	0	STEEL STRINGER	9	YES
34A113	Nicholas	34-041/00-000.14	YOUNGS CREEK BRIDGE	YOUNGS CREEK	0.21 MI S OF CR 41/10	45.4	34.7	1999	0	STEEL STRINGER	9	YES
35A102	Ohio	35-006/00-000.28	CHAPEL ROAD BRIDGE	INTERSTATE 470	0.28 MI NORTH WV 88	502.3	35.3	1972	0	STEEL FRAME	6	YES
35A136	Ohio	35-024/00-001.02	MARKET ST. BRIDGE	BIG WHEELING CREEK	0.11 MI. SO. JCT OF WV 2	180.5	56	2001	0	STEEL BX BM/GIR	6	YES
36A140	Pendleton	36-025/00-005.43	CAVE BRIDGE	WHITETHORN CREEK	0.52 MI. W. JCT. CR 23	103.5	30.8	2000	0	STEEL STRINGER	8	YES
37A030	Pleasants	37-018/00-000.30	FRENCH CREEK BRIDGE	FRENCH CREEK	0.30 MILE EAST OF CR 1	114.5	19	1998	0	STEEL STRINGER	3	YES
38A111	Pocahontas	38-250/00-009.23	BARTOW BRIDGE	E. FORK GREENBRIER RIVER	0.03 MI. N. JCT. WV 28	122.3	45.5	1997	0	STEEL STRINGER	8	NO
39A017	Preston	39-007/00-015.40	PRE CO VETERANS BRIDGE	CR 7/26 CSX RR CHEAT RIV	0.03 MI EAST WV RT 72	949.7	34	1978	0	STEEL STRINGER	4	YES
39A215	Preston	39-092/00-007.58	J. RICHARD TAYLOR BRIDGE	RACCOON CREEK & CSX RR	0.08 MI NORTH CO RT 33	318	40.7	2001	0	STEEL STRINGER	4	YES
40A123	Putnam	40-869/00-000.27	LOWER BUFFALO BRIDGE	US 35 & KANAWHA RIVER	0.27 MI E OF US 35	1877.7	39.2	1998	0	STEEL BX BM/GIR	1	YES
40A128	Putnam	40-034/00-019.87	LITTLE HURRICAN CK. BR	LITTLE HURRICANE CK	0.30 MI. S. OF US 35	181	35	1949	1998	STEEL STRINGER	1	YES
42A137	Randolph	42-219/00-033.10	FILES CREEK BRIDGE	FILES CREEK	0.24 MI. S.JCT.CR.37/8	84	32.4	1980	0	STEEL STRINGER	8	YES
42A210	Randolph	42-001/99-000.01	CR 1 CONNECTOR BRIDGE	PEARCY RUN	0.01 MI. EAST JCT. CR 1	298.9	34.2	2001	0	STEEL STRINGER	8	YES
43A177	Ritchie	43-047/00-007.20	LAUREL RUN BRIDGE	SOUTH FORK HUGHES RIVER	0.02 MILE EAST OF CR 32	232.9	30.1	2001	0	STEEL STRINGER	3	YES
43A183	Ritchie	43-005/00-009.13	THIRD RUN BRIDGE	THIRD RUN	0.22 MILE EAST OF CR 31/1	444.8	33.6	2002	0	STEEL STRINGER	3	YES
44A149	Roane	44-033/00-006.65	STEINBECK BRIDGE	LEFT FORK OF REEDY CREEK	0.10 MILE EAST OF CR 5/8	75.7	38.7	2000	0	STEEL STRINGER	3	YES
46A079	Taylor	46-050/00-010.33	JOHN F BENNETT BRIDGE	TYGART RIVER;CSX RR & ST	0.03 MI EAST CO RT 40	861.4	51.5	2001	0	STEEL STRINGER	4	YES
46A080	Taylor	46-119/00-004.91	ANISSA ANN SHERO BRIDGE	CSX RAILROAD	0.01 MI NORTH CR 119/36	262.5	36.5	2001	0	STEEL STRINGER	4	YES
48A088	Tyler	48-010/00-001.55	PATTERSON BRIDGE	MIDDLE ISLAND CREEK	0.61 MI NORTH CR 10/1	255.9	17.6	2002	0	STEEL STRINGER	6	YES
48A089	Tyler	48-010/01-003.60	KILE BRIDGE	MIDDLE ISLAND CREEK	0.27 MI. SO. JCT. CR 12	262.4	24.3	2002	0	STEEL STRINGER	6	YES
49A060	Upshur	49-030/19-004.55	TROUT REARING POND	RT FORK MIDDLE FORK RIV	0.11 MI S OF CO RT 30SLS	29.8	16	1982	0	STEEL STRINGER	7	YES
50A010	Wayne	50-007/00-014.45	BUFFALO HARDWARE BRIDGE	BUFFALO CREEK	0.08 MI SOUTH OF WV 75	75.2	21.7	1978	0	STEEL STRINGER	2	YES
50A017	Wayne	50-012/00-004.65	LAVELETTE BRIDGE	TWELVEPOLE CREEK	0.01 MI SOUTH OF WV 152	164	29.5	1980	0	STEEL STRINGER	2	YES
51A003	Webster	51-003/04-000.01	HANGING ROCK	LEFT FORK OF HOLLY RIVER	0.01 MI S JCT CO 3	85.4	12	1979	0	STEEL STRINGER	7	YES
51A045	Webster	51-020/09-000.10	MUDLICK W-BEAM	RIGHT FORK HOLLY RIVER	0.10 MI E WV 20	40.2	16	1989	0	STEEL STRINGER	7	YES
51A087	Webster	51-015/00-008.40	DIANA W-BEAM	RIGHT FORK HOLLY RIVER	0.07 MI W OF CO 5/4	160	30.7	1998	0	STEEL STRINGER	7	NO
51A090	Webster	51-048/00-000.37	CAMDEN ON GAULEY GIRDER	GAULEY RIVER	0.02 MI E OF CO 48/2	258.9	28.8	2001	0	STEEL STRINGER	7	NO
52A129	Wetzel	52-007/00-018.78	T. A. SHUMAN BRIDGE	STEEL RUN	0.02 MI W OF JCT CR 7/8	60	32.5	2001	0	STEEL STRINGER	6	YES
52A134	Wetzel	52-020/00-016.81	NORTH END BRIDGE	FISHING CREEK	0.17 MI SO JCT CR 20/14	182.7	47.2	2003	0	STEEL STRINGER	6	YES
53A059	Wirt	53-005/00-000.34	WWII VETERANS MEM BRIDGE	LITTLE KANAWHA RIVER	0.14 MILE EAST OF WV 53	539	40.5	2001	0	STEEL STRINGER	3	YES

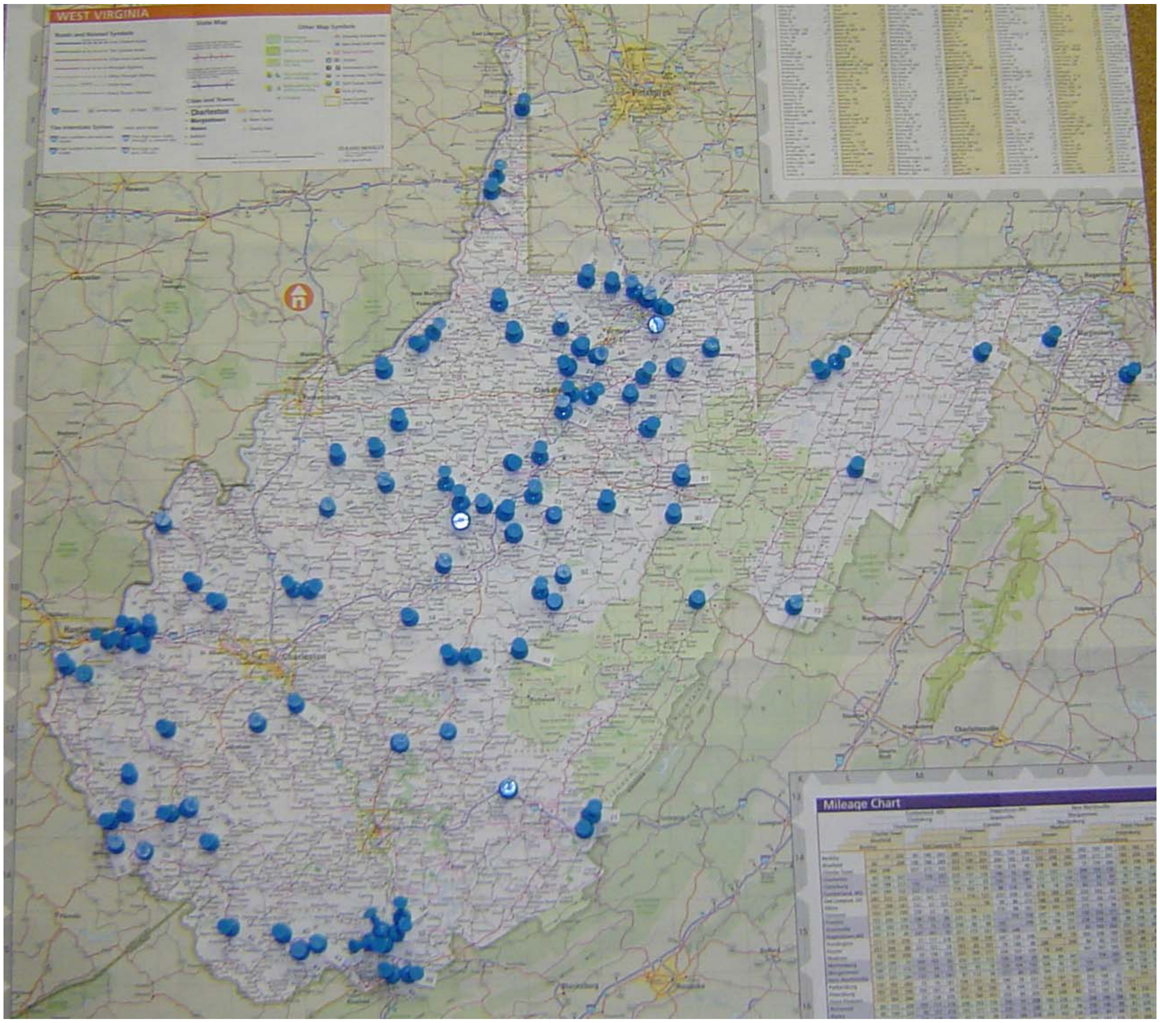

Figure 1 Location of WV Weathering Steel Bridges

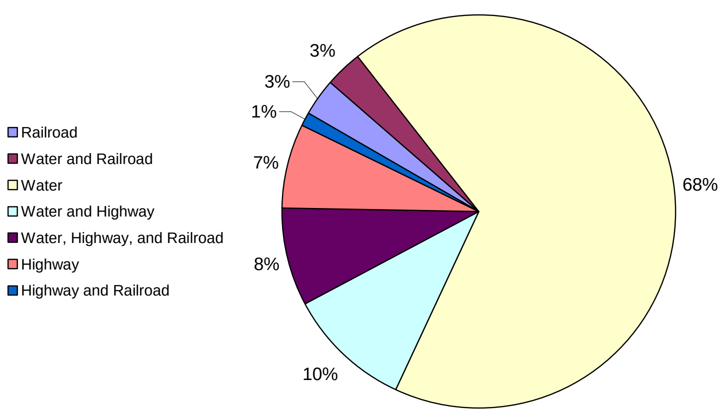

Figure 2 Categorization of WV Weathering Steel Bridges by Crossing

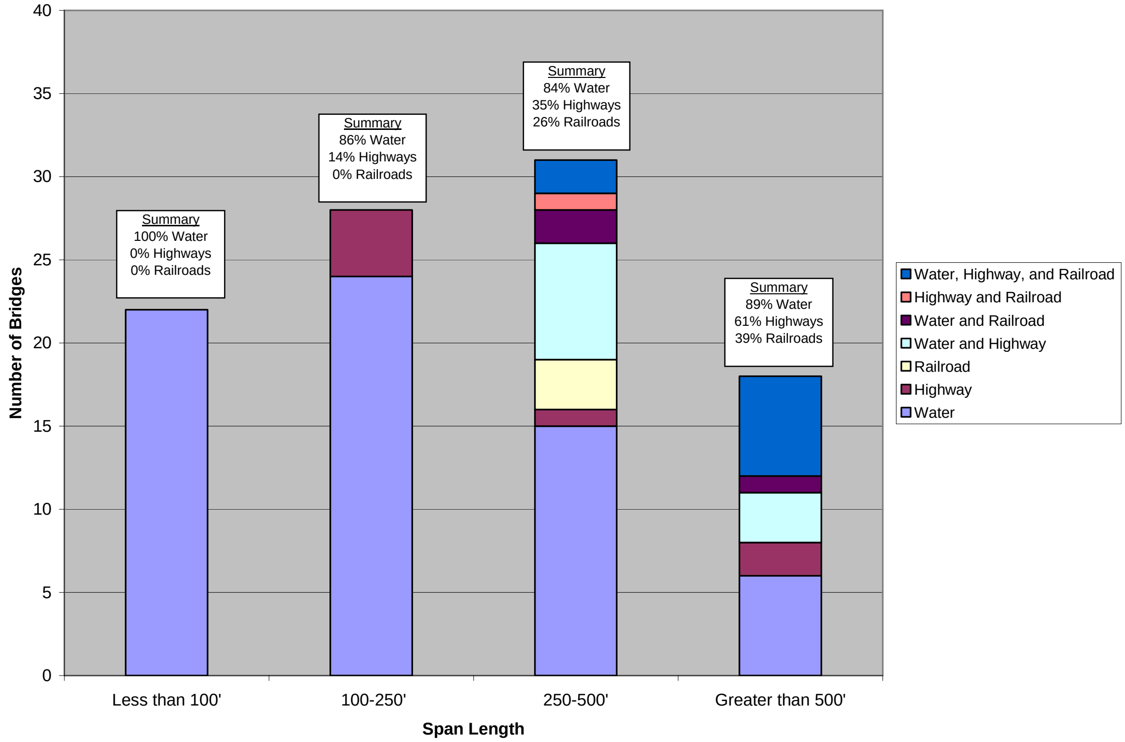

Figure 3 Categorization of WV Weathering Steel Bridges by Length and Crossing

in each of these four categories. Each category has a significant number of bridges. Fig. 3 also shows the relationship between length and crossing type. Bridges with shorter spans tend to cross over water only, while bridges with longer span lengths tend to also cross over highways and/or railroads.

Width

The weathering steel bridges are also classified by width (in 10-ft increments). As shown in Fig. 4, the majority of the bridges have widths between 30 and 40 ft, and 90% of the bridges have a width less than 50 ft. These results indicate that most of the weathering steel bridges are two-lane bridges.

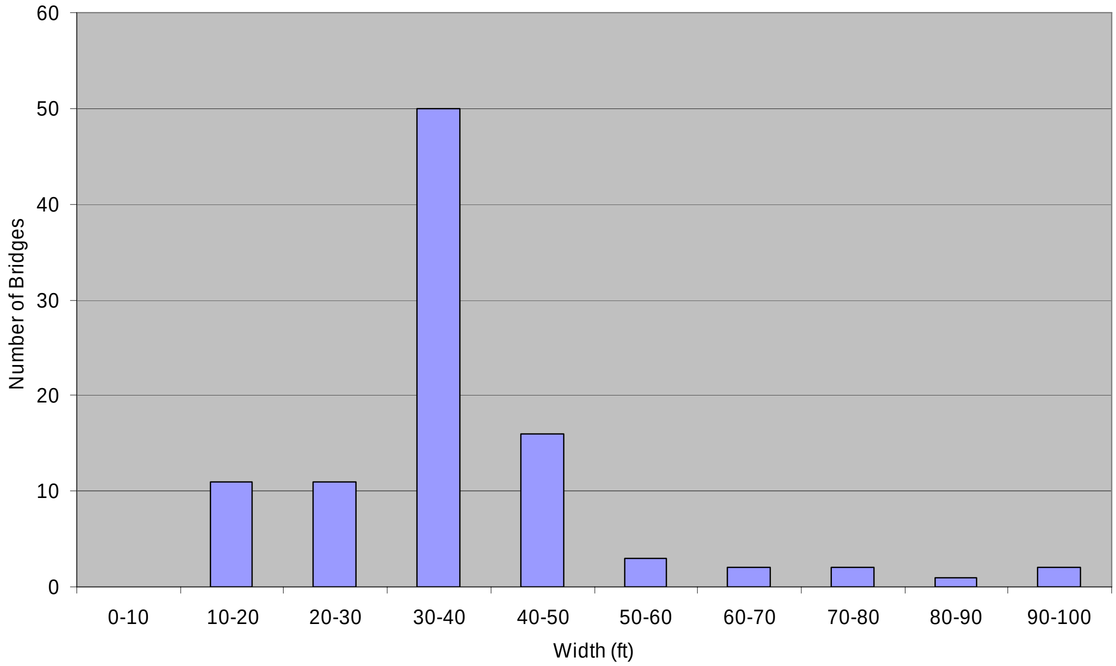

Figure 4 Categorization of WV Weathering Steel Bridges by Width

Age

The age of the weathering steel population is shown in Fig. 5. The age of these bridges is consistent with past and current trends in the development of weathering steel. The oldest weathering steel bridge in the state was built in 1971 when weathering steel was first starting to emerge in bridge applications. A total of 20 bridges were then built prior to 1985 when concerns regarding acceptable performance of weathering steel in some environments became publicized; consequently, only two weathering steel bridges were built in the ten-year period between 1985 and 1995. Weathering steel is again gaining popularity, and a large number of the weathering steel bridges (76) have been constructed in West Virginia within the last ten years. The most current category of construction dates ranges from 2000 to 2003 (when this project was initiated). Therefore, the decreasing trend in the number of weathering steel bridges being constructed, which is

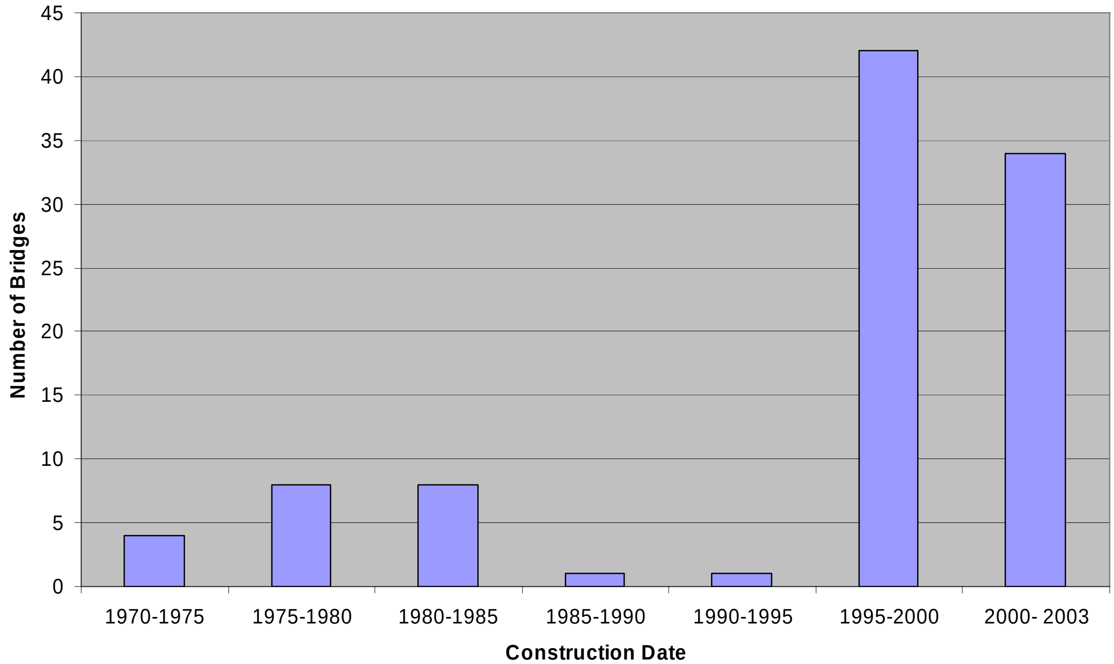

Figure 5 Categorization of WV Weathering Steel Bridges by Construction Date

shown in Fig. 5, is not necessarily occurring because the most current data are based on a shorter period of time compared with the other categories of construction dates.

Span Type

The majority of the weathering steel bridges, 89 bridges (91%), are steel stringer bridges. Additionally, the sample includes two deck arches, one deck truss, three girder and floorbeams, one box beam, and two steel frame bridges.

III. INSPECTION OF WEATHERING STEEL BRIDGES

Inspections were conducted on 87 of the 98 bridges listed on the weathering steel inventory provided by WVDOH. Additionally, site visits were made to two bridges owned by WVDOH (that have not yet been inventoried), two bridges owned by the WV

Turnpike Authority, and six bridges owned by the New York DOT. A total of 97 weathering steel bridges were inspected during this project. Inspections were not conducted on eleven bridges on the WVDOH inventory list. These bridges, however, are very similar to other bridges that were inspected. Therefore, a comprehensive evaluation of the use of weathering steel in West Virginia can be made.

The inspection of each bridge consisted of evaluating weathering steel performance, determining what factors lead to excessive corrosion (if applicable), and recording observations. A standard report form was developed to assist with compiling the data obtained during each inspection. Completed forms for each bridge site visited are contained in Appendix A. In summary, these forms identify the bridge of interest and provide a detailed description of the bridge including: general structure configuration, bridge environment, and corrosion performance. Each inspection report also contains numerous photographs of the inspected bridge to adequately depict key observations and characteristics of the structure.

IV. SUMMARY OF FINDINGS FROM BRIDGE INSPECTIONS

In this study, the corrosion performance of the inspected bridges' weathering steel members varied considerably from one bridge to another and between different components of a given bridge. The majority of the bridges are in good condition with few corrosion problems; however, exceptions do exist. Based on a critical review of the inspected bridges' corrosion performance, the following three factors have been identified as being most influential to the performance of weathering steel bridges: deck type, span type (e.g., stringer, arch, frame, etc.), and crossing type.

Other researchers have set forth various additional factors relating to the environment of a bridge site that influence the performance of weathering steel. Some of these environmental factors include: proximity to industrial locations, surrounding vegetation, clearance over bodies of water, and constant shade. Bridges in a broad range of site environments were investigated in this study such as bridges that were: near two different power plants, immediately adjacent to a coal field, situated in urban environments, located in rural areas, and densely sheltered by terrain and vegetation. Although these factors may affect corrosion characteristics, the results of this study indicate that these factors alone are not sufficient to create a situation in which the performance of the weathering steel is unsatisfactory. Instead, these factors may only intensify a corrosion problem caused by some other source.

Deck Type

The following deck types were found to be used in conjunction with weathering steel bridges: reinforced concrete decks, reinforced concrete with stay-in-place (SIP) metal deck forms, concrete-filled metal grid decks, and timber decks.

Reinforced – Concrete Decks

Bridges with reinforced concrete decks exhibit the fewest corrosion problems. Concrete decks are generally a continuous surface; therefore, water does not penetrate the deck and does not reach the steel elements below. These two factors reduce the rate of corrosion. However, when cracks or inadequately sealed construction joints are present in the surface of the deck, corrosion problems frequently occur beneath these cracks and joints. One such situation is shown in Fig. 6

Concrete decks with relatively wide overhangs exhibit significantly less corrosion on the exterior girders. Corrosion on the bottom flanges and on the bottom of the webs of exterior girders is common in cases where the depth of the girder is greater than the width of the overhang. The corrosion is caused by the lack of shelter to the exterior girder. The horizontal surface of the bottom flange then allows water to accumulate, and capillary action draws this moisture up the height of the web. An example of this situation is

(a) Deck Joint (b) Corrosion Beneath Joint

Figure 6 Corrosion Caused by Open Deck Joint shown in Fig. 7a. This water also flows along the bottom surface of the bottom flange leading to corrosion, as depicted in Fig. 7b.

Reinforced-Concrete Decks With Stay-In-Place Metal Deck Forms

Bridges with reinforced-concrete decks and with stay-in-place (SIP) metal deck forms have corrosion characteristics similar to the reinforced-concrete decks previously mentioned. One difference between the two is that the SIP forms would provide an additional barrier for the water if the deck were to be become cracked in any way. However, this barrier would lead to corrosion of the SIP forms and would only delay the corrosion of the girders.

Concrete-Filled Metal Grid Decks

Several bridges were inspected that had bridge decks comprised of concrete-filled metal grid decks. All of these decks had been in service for several years, and all were leading to corrosion problems on the weathering steel members. Typical photographs of this type

(a) Corrosion of Bottom Flange and Web　　(b) Corrosion of Bottom Flange

Figure 7 Corrosion due to Narrow Overhang of bridge deck are shown in Fig. 8. The figure shows that this deck type consists of three components: a geometric steel grid, a stiffened bottom plate, and the concrete in-fill. Water is able to pass through the filled grid deck, which eventually deteriorates the underlying stiffened plate and allows run-off to flow over the weathering steel members. Thus the weathering steel is frequently exposed to moist conditions, which results in excessive corrosion.

Timber Decks

All of the inspected bridges having timber decks displayed serious corrosion issues. Similar to the problems with concrete-filled metal grid decks, water easily penetrates between each joint of the timbers, providing little shelter to the weathering steel. Furthermore, the timber deck also retains moisture, which worsens the already severe corrosion of the top flange. Fig. 9 shows typical corrosion of a weathering steel bridge with a timber deck. It should be noted that many of these bridges have been painted, and the paint systems are also failing.

(a) Grid Deck From Above

(b) Grid Deck From Below

Figure 8 Concrete-Filled Metal Grid Deck

(a) General View (b) Pack Rust on Top Flange

Figure 9 Typical Corrosion on Bridges With Timber Decks

Span Type

For the purposes of this discussion, the weathering steel bridges in the WVDOH inventory are classified into the following three span types: stringer, box girder, and arch or frame bridges. The following discussion focuses on the influences of each of these span types on corrosion.

Stringer

Stringer bridges are classified as bridges in which the main superstructure elements are I-girders or rolled beams supported by concrete abutments. In general, the weathering steel stringer bridges exhibited the most favorable performance because, in this type of bridge, all of the members are sheltered to some degree from the elements.

Box Beam

Only one box beam weathering steel bridge is located in West Virginia. The suitability of this type of bridge has been a concern because of the potential for water to collect inside the box beams. An inspection of this bridge, however, revealed that the design was not detrimental to corrosion performance. The inside surfaces of this bridge are painted, and adequate drainage is provided for water that accumulates inside the box girder.

Arch and Frame

Arch and frame bridges contain an unavoidable negative aspect because numerous members are completely exposed to the elements. This type of bridge has three problems: (1) ponding of water can occur on the horizontal members, (2) the orientation of inclined members, particularly at the bearings, allows water to collect in places that do not have any mechanisms for drainage, and (3) open cross-sections allow moisture to enter the section, particularly in combination with the connections. Examples of each of these three conditions are shown in Figs. 10-12. Fig. 10 shows a heavily pitted horizontal member of a steel deck truss. Fig. 11 shows the bearing of a steel frame, which was filled with debris immediately before this photograph was taken. The accumulated debris and moisture lead

Figure 10 Horizontal Member of Deck Truss

Figure 11 Bearing Corrosion on Steel Frame Bridge

Figure 12 Corrosion Inside Open Truss Member

to significant bearing corrosion, as shown in Fig. 11. The excessive corrosion in the interior of an open truss member is shown in Fig. 12. The substantial corrosion of the bottom bolts are also shown in this figure.

Crossing

The inspected bridges serve to cross bodies of water, highways, railroads, or a combination of these three types of crossings. The weathering steel population with respect to crossing type was previously discussed in Section 2, where it was shown that 89% of the bridges cross water, 26% cross highways, and 15% cross railroads. The following discussion focuses on the influence of crossing type on corrosion performance.

Water Crossings

Water crossings do not adversely affect corrosion performance. Although previous studies have cited that low clearances over bodies of water (particularly stagnant bodies of water) may cause poor corrosion performance, our research did not support this theory. Water crossings were not solely responsible for excessive corrosion of any of the bridges inspected in our evaluation.

Highway Crossings

Highway crossings generally have an acceptable corrosion performance. The exception to this rule lies in bridges with relatively low clearances over roadways that are heavily treated with deicing salts and that also experience heavy truck traffic (e.g., bridges over interstates). In these cases, the influence on corrosion seems to be directly related to the amount of salt applied to the roadway and to the proximity of the members to the roadway. Highway crossings resulted in excessive corrosion in a limited number of cases.

Railroad Crossings

Based on the observations in this study, railroad crossings did not have any negative effects on corrosion performance.

New York Bridges

The inspections of weathering steel bridges in West Virginia were used as the basis for the findings outlined above. However, several bridges in the Rochester, New York area were also inspected in order to compare the performance of weathering steel bridges in West Virginia to the performance of other weathering steel bridges. While numerous bridges in the Rochester area were examined, the focus of this trip was six bridges that had previously been identified as experiencing corrosion problems. Four of these six bridges are located in a tunnel-like situation over interstate (I-390) traffic. The remaining two bridges are also in a tunnel-like situation, but over a less heavily traveled roadway.

Three of the four bridges over I-390 show significant signs of corrosion with various levels of pitting on nearly all members. The fourth of these bridges has recently been treated with an acid wash solution that appears to be arresting future corrosion. The two other bridges inspected show less significant steel corrosion, which is attributed to the reduced traffic volumes and salt spray under these bridges. However, these two bridges have badly deteriorated expansion joints.

Based on these inspections it was concluded that the weathering steel bridges in West Virginia have much better performance than the weathering steel bridges inspected in the Rochester area. Detailed inspection reports of these bridges are also given in Appendix A.

V. CONCLUSIONS AND RECOMMENDATIONS

Literature on weathering steel frequently makes reference to the concept of wet-dry cycles. However, the dry phase of this cycle if of the utmost importance. Exposing weathering steel to so-called wet cycles has little merit or benefit. Rather, the most desirable situation is one in which the steel is perpetually dry because corrosion will not occur in the absence of water. This expectation is unrealistic for materials exposed to the elements, and the presence of moisture is inevitable; therefore, wet-dry cycles will occur. However, the most general recommendation is to make every reasonable effort to keep water from reaching weathering steel members so that the wet cycle is minimized to the fullest extent possible. With this important goal of minimizing the amount and duration of moisture on weathering steel members, the following recommendations are provided for the design and maintenance of weathering steel bridges. Additionally, recommendations for continued evaluation of weathering steel performance are given.

Design

Deck Design

Bridges should have decks consisting of a continuous, solid surface. Reinforced concrete decks with or without stay-in-place metal deck forms are recommended. Conversely, using timber decks and metal grid decks (either filled or not filled with concrete) is highly discouraged for two reasons. First, these decks do not prevent water from reaching the girders. Second, in many cases, water becomes trapped on the top flange of the girders.

Construction joints in concrete decks should be grouted. These joints should be carefully inspected during biennial inspections to monitor water penetrability. Construction joints located approximately 10 ft from the abutments were observed in many newer bridges. Design practices should be revised to eliminate these joints.

The overhang width should be extended as wide as feasible to provide additional shelter to exterior girders. This recommendation is based on the high number of girders that had corrosion on the bottom flange and on the bottom of the web of the exterior girders. Inspection results suggest that this problem can be avoided when an overhang width equal to at least the depth of the girder is provided.

Drainage

Careful consideration should be given to the drainage system for the bridge. Joints should be eliminated wherever possible, and the use of integral or semi-integral abutments is highly recommended where appropriate. Consideration should also be given to drainage for individual members, particularly those that are completely exposed to the elements. Water should be prevented from collecting on members, and methods for allowing water to drain where it collects (e.g., bearings of inclined members) should be provided.

Painting

The bridge inspections revealed that girder ends are typically painted in newer weathering steel bridges. Comparing these bridges with older bridges without paint suggests that this practice is beneficial. The length of the girder that is painted varied considerably and ranged between a few inches to several feet. Based on the field observations, painting the ends of the girders over a length equal to the depth of the girders is recommended.

Connections

The continued use of bolt spacings that provide water tight connections is recommended.

Drip Bars

The use of drip bars is discouraged. These features tend to trap water and debris and are thus counterproductive to their intended purpose.

Sheltering Exterior Girders

As previously mentioned, as a rationale for providing relatively wide overhangs, the exterior girders are typically subjected to the elements to a higher degree than the interior girders. Consequently, increased corrosion typically results in exterior girders. This situation can be prevented by providing wider overhangs; however, this method may not be feasible for girders with large web depths. A novel approach to this problem was encountered during the inspection of a weathering steel bridge with a fiber-reinforced polymer (FRP) deck. In addition to the structural FRP components, this bridge also displayed decorative FRP sheets on the exterior surfaces (see Fig. 13). These sheets provide a significant increase in the amount of shelter given to the exterior girder. Such an approach may be adopted in future efforts to minimize corrosion of the exterior girders.

Maintenance

Decks

Decks should be periodically inspected for cracks, open joints, and for signs of moisture penetrating through the deck. Observations of these occurrences should be reported, and repairs should be initiated. Caulked joints encountered during the bridge inspections appear to be adequate for preventing future corrosion.

Figure 13 FRP Panels Sheltering Exterior Girders

Drainage

The drainage system of the bridge should be inspected and assessed as to its functionality. Drains should be cleaned, and any other components of the drainage system that are not functioning as intended should be cleaned or otherwise repaired.

Flooding

When flood waters reach the superstructure, various sediments and debris will inevitably be deposited onto the weathering steel members. Debris ranging from fine silt to large trees was observed lodged on girders and in cross-frames. This debris should be removed because of its tendency to trap moisture onto the surfaces of the steel.

Deicing Salts

Alternatives to deicing salt that have less severe effects on corrosion are recommended in tunnel situations with large amounts of truck traffic.

Graffiti

One instance of a graffiti substance that was causing significant corrosion was observed during the bridge inspections. In this type of situation, an effort should be made to remove the corrosive substance.

Acid Solutions

In cases of severe, progressive corrosion, consideration may be given to treating the affected members with an acid solution wash. Limited results suggest that such methods may be successful in arresting corrosion.

Continued Evaluation

Based on the inspections completed during this research, it has been concluded that the performance of the majority of weathering steel bridges is satisfactory and that there is no cause for concerns related to the corrosion of these bridges. However, there are bridges that have appreciable levels of corrosion and it is recommended that these bridges should be continually monitored to assess the corrosion rate of these bridges. The bridges of concern are the Tamarack Access Bridge over I-64/77 and the following bridges with timber decks: Road Run W-Beam, Little Bull Run W-Beam, Dutch Hollow W-Beam, Trout Rearing Pond, Hanging Rock, and Mudlick W-Beam.

VI. PLAN FOR IMPLEMENTATION AND TECHNOLOGY TRANSFER

It is recommended that the findings of this study be implemented through dissemination of this report to WVDOH personnel involved in the design and maintenance of weathering steel bridges as well as applicable consultants.

REFERENCES

Albrecht, P., and Naeemi, A. H. (1984). “Performance of Weathering Steel in Bridges,” National Cooperative Highway Research Program, Report 272.

American Iron and Steel Institute (1995). “Performance of Weathering Steel in Highway Bridges: A Third Phase Report,” 1995.

Federal Highway Administration (1989). “Uncoated Weathering Steel in Structures,” Technical Advisory T 5140.22, October 3, 1989.

Jobes, R. A. (1996). “Evaluation of Unpainted Weathering Steel Bridges in Idaho,” Final Report, Idaho Transportation Department.

McDad, B., Laffrey, D. C., Dammann, M. and Medlock, R. D. (2000). “Performance of Weathering Steel in TxDOT Bridges,” Texas Department of Transportation, Project 0-1818.

McKenzie, M. (2000). “The Performance of In-Situ Weathering Steel Bridges,” *Proceedings of the Fourth International Conference on Bridge Management*, University of Surrey, Guildford, United Kingdom, April 2000, p. 308-314.

Raman, A. and Naszrazadani, S. (1989). “Corrosion Problems in Some Louisiana Bridges and Suggested Remedies,” Paper No. 165 Louisiana State University, Department of Mechanical Engineering, Baton Rouge, LA.

APPENDIX A

BRIDGE INSPECTION REPORTS

This enclosed CD-ROMs contains the bridge inspection reports for each weathering steel bridge that was inspected during this study. The bridges in West Virginia are identified by the name of the county in which the bridge is located and then by the local name of the bridge. The New York bridges are identified by the label “NY” followed by the intersection at which the bridge is located.