5.3. IN-DEPTH INSPECTION RESULTS

The following sections describe the results obtained from Tasks F and H. These tasks were In-Depth Inspections of portions of the below-deck superstructures of STAR Bridge B544 and the U.S. Route 1 Bridge over the Occoquan River, respectively. Detailed descriptions of these bridges and tasks were presented in Chapter 4. Data from these tasks were collected in the form of inspector field notes, inspector responses to questions, and firsthand observations of the inspector performing the inspections. The results for Task F are presented first. The discussion first focuses on the inspection process and the description of the known defects. The known defects are then compared to the inspector-reported defects. To conclude Task F, the factors found to correlate with the inspection results are presented. In a similar manner, the results obtained from Task H are then presented.

5.3.1. Description of In-Depth Inspection

The *Manual for Condition Evaluation of Bridges, 1994* defines "In-Depth Inspection" as follows:[3]

> "An In-Depth Inspection is a close-up, hands-on inspection of one or more members above or below the water level to identify any deficiency(ies) not readily detectable using Routine Inspection procedures. Traffic control and special equipment, such as under-bridge inspection equipment, staging and workboats, should be provided to obtain access, if needed. Personnel with special skills such as divers and riggers may be required. When appropriate or necessary to fully ascertain the existence of or the extent of any deficiency(ies), nondestructive field tests and/or other material tests may need to be performed.
>
> The inspection may include a load rating to assess the residual capacity of the member or members, depending on the extent of the deterioration or damage. Non-destructive load tests may be conducted to assist in determining a safe bridge load-carrying capacity.
>
> On small bridges, the In-Depth Inspection, if warranted, should include all critical elements of the structure. For large and complex structures, these inspections may be

scheduled separately for defined segments of the bridge or for designated groups of elements, connections or details that can be efficiently addressed by the same or similar inspection techniques. If the latter option is chosen, each defined bridge segment and/or each designated group of elements, connections or details should be clearly identified as a matter of record and each should be assigned a frequency for re-inspection. To an even greater extent than is necessary for Initial and Routine Inspections, the activities, procedures and findings of In-Depth Inspections should be completely and carefully documented."

In general, the two In-Depth Inspection tasks were administered and completed according to this definition. In both cases, the tasks were clearly defined inspections of portions of a bridge superstructure that included the use of special access equipment.

5.3.2. Task F

Task F is the In-Depth Inspection of approximately one-fifth of the below-deck superstructure of Bridge B544, a decommissioned bridge at the STAR facility. The bridge and Task F are fully described in Chapter 4.

5.3.2.1. INSPECTION PROCESS

This section provides a general description of how the inspectors completed this task. The data for this discussion come from the pre-task questionnaire, firsthand observation of the inspectors performing the tasks, and the post-task questionnaire.

Forty-two inspectors completed this task. Seven inspectors did not complete this task due to either adverse weather conditions, lift malfunction, or refusal due to minor physical impairment. Inspectors were allowed 3 h to complete the In-Depth Inspection of the superstructure of approximately one-fifth of this bridge. The average time to complete this task was 75 min and the median time was 70 min. The standard deviation was 30 min, with a maximum time to completion of 156 min and a minimum of 29 min. The distribution of actual inspection times is shown in figure 125.

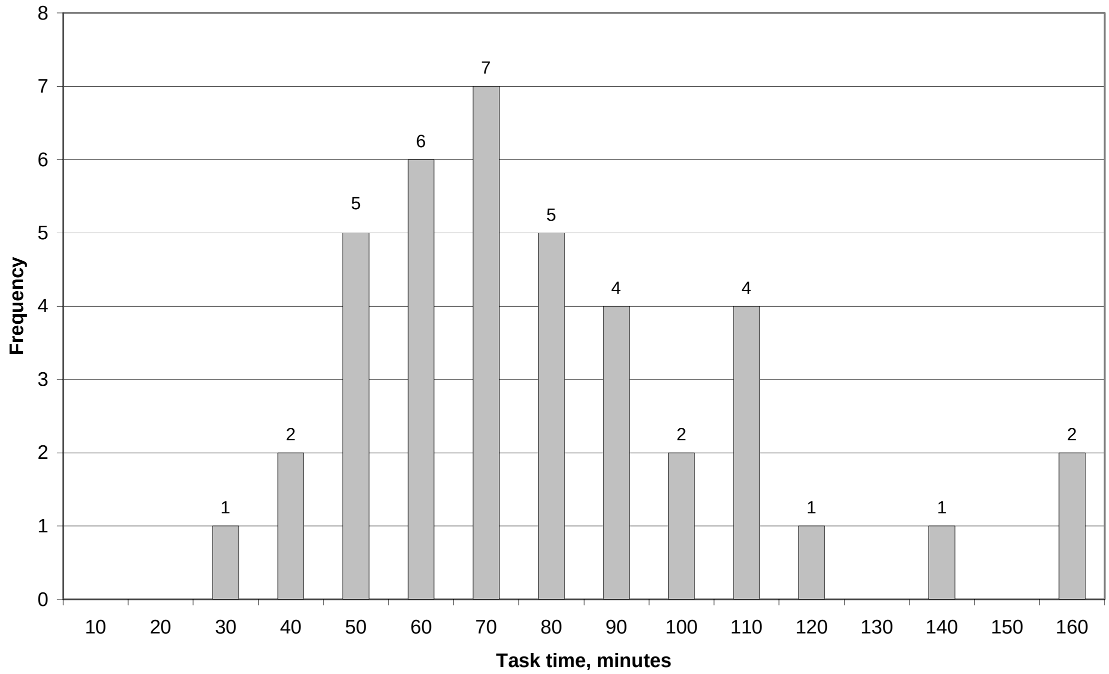


Figure 125. Task F – Actual inspection time.

Table 162 summarizes some of the questions asked in the pre-task questionnaire. These results show that, on average, it has been more than 8 months since an inspector performed an inspection similar to Task F. There was one inspector who had not performed an inspection similar to this one in more than 8 years and two inspectors who had never inspected a structure similar to this one. Figure 126 illustrates the distribution of predicted task times.

For this inspection, inspectors were provided with the full set of inspection tools, as well as a 12.2-m boom lift that could provide hands-on access to the structure. In order to assess what types of access equipment would normally be used for this type of an inspection, inspectors were asked to describe the equipment they would normally have used. Table 163 provides the results of this question. The inspectors' responses to this question indicate that 90 percent of the inspectors would have used a snooper or a lift to access the structure. Ten percent of the inspectors indicated that they would have either used only a ladder or no access equipment at all. This final group of inspectors would have had great difficulty accessing large portions of the bridge while performing a hands-on inspection.

Table 162. Task F – Quantitative pre-task questionnaire responses.

Question	Range of possible answers: Low	Range of possible answers: High	Inspector Response: Average	Median	Standard Deviation	Maximum	Minimum
How long has it been since you completed an In-Depth Inspection of a bridge of this type (in weeks)?	N/A*	N/A	38	21	82	440	1
Given the available equipment and the defined tasks, how long do you think you would normally spend on this inspection (in minutes)?	N/A	N/A	77.1	60.0	41.7	200	30
How rested are you?	1 = very tired	9 = very rested	6.9	7	1.2	9	4

* N/A = Not applicable.

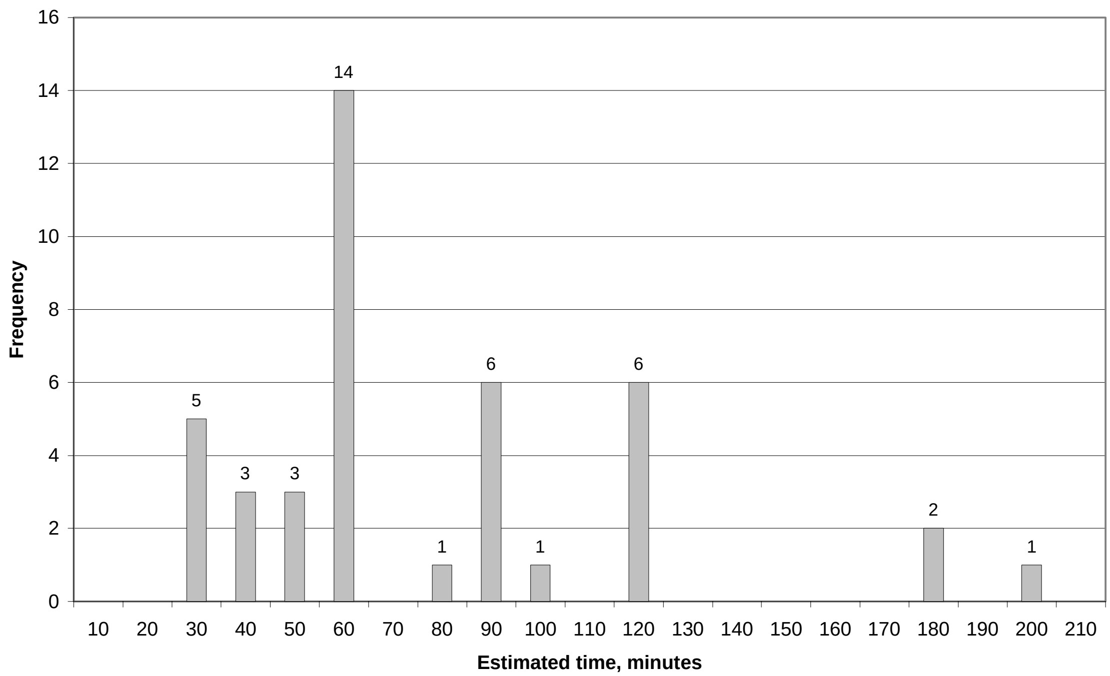


Figure 126. Task F – Predicted inspection time.

Table 163. Task F – Normal access equipment use.

Equipment	Percentage of Respondents
Snooper	55%
Lift	50%
Ladder	21%
Scaffolding	0%
Climbing Equipment	0%
Permanent Inspection Platform	0%
Movable Platform	2%
None	2%
Other	0%
Snooper and/or Lift	90%

Within the pre-task questionnaire, the inspectors were asked to describe the type of construction used on this bridge. The results from this question are presented in table 164. Note that these results are very similar to the results that were presented for this question for Task E. The minor differences are due to seven inspectors who completed Task E, but did not perform Task F, thus leading to a different inspector sample between the two tasks. It is important to note that only 10 percent of the inspectors indicated that the bridge is skewed. In a bridge of this type, skew can lead to out-of-plane distortions and particular types of defects that are only likely to occur if the bridge is skewed. This knowledge may have significant implications on the focus of the inspection, and could lead to less accurate inspection results.

Table 164. Task F – Description of type of construction used.

Bridge Characteristic	Percentage of Respondents
Steel Plate Girder	88%
Riveted	79%
Cast-in-Place (CIP) Concrete Slab	62%
Simply Supported	36%
Floor Beams/Sway Frames	33%
Skewed	10%
Asphalt Overlay	7%
Other	19%

To further assess how inspectors were formulating their approach to the inspection, inspectors were asked to identify problems that they might expect to find on a bridge of a similar type, condition, and age. These responses are summarized in table 165. These results show that inspectors expect relatively few types of problems to exist. Of this list of possible deficiencies, steel corrosion and concrete deterioration were mentioned by approximately three-quarters of the inspectors, while no other defects were cited by more that 40 percent.

Table 165. Task F – Problems expected.

Problem Type	Percentage of Respondents
Steel Corrosion	79%
Concrete Deterioration	69%
Cracked Asphalt	36%
Paint Deterioration	31%
Tack Weld Cracks	24%
Leakage	24%
Leaching	21%
Underside Deck Cracking	21%
Missing Rivets	19%
Inadequate Concrete Cover	17%
Impact Damage	5%
Settlement Cracking of Abutments	5%
Other	14%

As previously mentioned, while the inspector was completing the inspection, the observer recorded environmental conditions, recorded how the inspection was completed, noted what inspection tools were used, and operated the lift. Tables 166 and 167 provide a summary of the environmental conditions that were encountered during this task. As the tables reiterate, this task was performed under normal summer weather conditions. Note that these environmental measurements were gathered at an elevated position just under the southwest quadrant of the bridge.

Table 168 summarizes the portions of the inspection task performed by the inspectors. Specifically, this table lists many of the general components that exist in the bridge and shows the number of inspectors who performed at least a partial inspection of that component. This table is divided into two parts, the first section reporting the items that were inspected in the southwest quadrant of the bridge (referred to as a "lift inspection") and the second section reporting what items were inspected in the northeast quadrant (referred to as a "ladder inspection"). Based on this table, it is clear that some inspectors left this inspection task partially incomplete. For example, although approximately 80 percent of the inspectors inspected the bearings, only about 50 percent of the inspectors inspected behind the end diaphragms.

Table 166. Task F – Direct environmental measurements.

Environmental Measurement	Average	Median	Standard Deviation	Maximum	Minimum
Temperature (°C)	21.7	22.8	5.5	30.0	10.6
Humidity (%)	63.3	64	14.7	96	38
Heat Index (°C)	22	23	5.8	32	11
Wind Speed (km/h)	1.4	0	2.5	11.3	0
Light Intensity (lux)	216	62	330	1390	2

Table 167. Task F – Qualitative weather conditions.

Weather Condition	Percentage of Inspections
0 – 20% Cloudy	40%
20 – 40% Cloudy	7%
40 – 60% Cloudy	5%
60 – 80% Cloudy	10%
80 – 100% Cloudy	17%
Hazy	2%
Fog	0%
Drizzle	10%
Steady Rain	7%
Thunderstorm	0%

Inspector tool use is presented in table 169. This table shows that only 48 percent of the inspectors used a flashlight, even though the light level under the bridge was relatively low as reported in table 166. Also, fewer than half of the inspectors performed any sounding during this task as evidenced by the low usage rate of the sounding tools.

The observers made a number of observations regarding inspector behavior during this task. These results are presented in table 170. Note that, on average, very few of the inspectors seemed rushed while completing the task and most inspectors seemed relatively comfortable with the lift.

After completion of the task, the inspectors were again asked a series of questions. These questions were typically related to the inspector's impression of the inspection they just completed and to their general physical and mental condition. In all, 15 questions were asked, with the results presented in table 171.

Table 168. Task F – Bridge component inspection results.

	Inspection Item	Percentage of Inspectors
Lift Inspection	Outer Bearing	88%
	Middle Bearing	86%
	Inner Bearing	86%
	Fascia Girder	83%
	Middle Girder	88%
	Inner Girder	86%
	End Diaphragm Connections	60%
	Intermediate Diaphragm – Web Connections	79%
	Sway Frame – Web Connections	79%
	Bottom Flange Rivets	50%
	Behind End Diaphragm	48%
Ladder Inspection	Outer Bearing	83%
	Middle Bearing	76%
	Inner Bearing	79%
	Fascia Girder	71%
	Middle Girder	67%
	Inner Girder	67%
	End Diaphragm Connections	62%
	Intermediate Diaphragm – Web Connections	21%
	Sway Frame – Web Connections	31%
	Bottom Flange Rivets	31%
	Behind End Diaphragm	55%

Table 169. Task F – Use of inspection tools.

Tool	Percentage of Inspectors
Tape Measure	36%
2.4-m Stepladder	0%
9.75-m Extension Ladder	79%
Any Flashlight	48%
Two AA-Cell Flashlight	12%
Three D-Cell Flashlight	21%
Lantern Flashlight	19%
Any Sounding Tool	38%
Masonry Hammer	38%
Chain	0%
Level as a Level	5%
Level as a Straightedge	5%
Binoculars	0%
Magnifying Glass	5%
Engineering Scale	7%
Protractor	7%
Plumb Bob	2%
String	0%
Hand Clamp	0%

Table 170. Task F – Summary of quantitative observations.

Question	Range of possible answers		Observer Assessment				
	Low	High	Average	Median	Standard Deviation	Maximum	Minimum
Was the inspector focused on the task?	1 = very unfocused	9 = very focused	6.6	7	1.7	9	3
Did the inspector seem rushed?	1 = not rushed	9 = very rushed	2.6	2	1.7	7	1
How comfortable was the inspector with the working height?	1 = very uncomfortable	9 = very comfortable	7.9	9	1.5	9	3
How comfortable was the inspector with the lift?	1 = very uncomfortable	9 = very comfortable	7.7	9	1.9	9	1
What was the quality of lift operation?	1 = very poor	5 = very good	3.5	3	0.8	5	2

Table 171. Task F – Qualitative post-task questionnaire responses.

Question	Range of possible answers		Inspector Response				
	Low	High	Average	Median	Standard Deviation	Maximum	Minimum
How similar was this task to the tasks performed in your normal In-Depth Inspections?	1 = not similar	9 = very similar	7.3	7.5	1.7	9	3
Did this task do an accurate job of measuring your inspection skills?	1 = not accurate	9 = very accurate	7.3	7	1.6	9	4
How rested are you?	1 = very tired	9 = very rested	6.4	6.5	1.5	9	2
How well did you understand the instructions you were given?	1 = very poorly	9 = very well	8.4	9	.8	9	6
How accessible do you feel the various bridge components were?	1 = very inaccessible	9 = very accessible	8.1	8	1.0	9	5
How well do you feel that this bridge has been maintained?	1 = very poorly	9 = very well	4.4	4	1.8	7	1
How complex was this bridge?	1 = very simple	9 = very complex	4.9	5	1.8	8	1
Do you think my presence as an observer had any influence on your inspection?	1 = no influence	9 = great influence	2.7	2	2.1	7	1
Do you feel that the working height influenced your performance?	1 = no influence	9 = great influence	1.5	1	1.0	6	1
How adequate do you feel the light level was?	1 = very inadequate	9 = very adequate	7.3	8	1.3	9	4
On average, how close do you think you got to the welds you were inspecting (in meters)?*	N/A**	N/A	0.52	0.61	0.33	1.52	0.25
Do you feel you were able to get the proper viewing angle for the components you were inspecting?	1 = never	9 = always	7.8	8	0.9	9	6
Did you feel rushed while completing this task?	1 = not rushed	9 = very rushed	2.5	1	2.1	7	1
What was your effort level on this task in comparison with your normal effort level?	1 = much lower	9 = much greater	5.2	5	1.1	9	3
How thorough were you in completing this task in comparison to your normal inspection?	1 = less thorough	9 = more thorough	5.2	5	0.8	7	3

* Inspector responses were originally given in English units and have since been converted into metric.
** N/A = Not applicable.

5.3.2.2. COMPARISON OF KNOWN AND INSPECTOR-REPORTED DEFICIENCIES

Many reportable defect indications exist within the portion of STAR Bridge B544 that was inspected in Task F. Inspectors performing this task were asked to note any defects that they found during their inspection. These defect indications (hereafter referred to as defects) can be categorized into two main types: global and local. The following section will discuss the known defects as compared to the defects that were reported by the inspectors.

5.3.2.2.1. Global Defects

The “Global Defect” category encompasses deficiencies in the bridge that pertain to general sections of the bridge, not to specific locations. This type of defect includes paint system failure, moderate to severe corrosion of girders and secondary members, rivet section loss, and efflorescence. These four defects are present throughout Bridge B544.

The paint system failure is prevalent throughout the test specimen. This type of defect includes locations where the paint has failed, probably due to poor bonding between the paint and the steel surface at locations of severe corrosion. Figure 127 is indicative of the extent of this deficiency. All 42 inspectors who performed this task indicated that there was some level of paint system failure.

Figure 127. Paint system failure and moderate to severe corrosion.

The moderate to severe corrosion of girders and secondary members also occurs at numerous locations throughout the test specimen. This deficiency includes corrosion ranging from minor corrosion over a large area to severe corrosion that has caused measurable section loss. Figure 127 also illustrates a portion of this global defect. Ninety-eight percent of the inspectors who performed this task noted corrosion problems.

Extensive corrosion of rivets and rivet heads can lead to fastener section loss and eventually a decrease in member capacity. This deficiency is present at various locations throughout the bridge. Figure 128 illustrates an example of this deficiency. Forty-five percent of the inspectors who performed this task noted the severe rivet head corrosion.

Figure 128. Severe corrosion of rivet heads.

Finally, efflorescence, due primarily to deck-related deterioration, has crystallized on the superstructure in many locations. Sixty-nine percent of the inspectors noted this effloresence, represented in figure 129.

Figure 129. Typical efflorescence.

5.3.2.2.2. Local Defects

Local defects are deficiencies that occur at discrete locations within the structure. These types of problems include a crack indication at a tack weld, localized member distortion due to impact, a missing rivet head, and bearings displaying abnormal rotations. Note that the tack weld crack indication and the missing rivet head were defects implanted by the NDEVC.

Tack welds exist at a number of locations in this bridge. This type of weld results in a fatigue-sensitive detail. A crack indication was implanted at the root of one of these welds. The schematic drawing shown in figure 130 indicates the location of this defect, while figure 131 shows this defect. The crack indication was identified by 3 of the 42 inspectors (7 percent) who performed this task.

A rivet head was removed to simulate another common deficiency. The location of this defect is indicated in figure 130 and the defect can be seen in figure 132. Two of the inspectors (5 percent) identified the missing rivet head.

There are two locations on the bridge that have impact damage. The first, a localized flange distortion, is located on a sway frame just inside the northern girder near the west abutment.

This defect probably occurred during erection of the superstructure. Figure 130 denotes the location of this defect. Two inspectors (5 percent) noted this impact damage. Impact damage is also present on the bottom flange of the southern girder, as indicated in figure 130. Scrapes are present on the bottom flange, indicating that an overheight vehicle may have damaged the girder. Six of the inspectors (14 percent) noted the impact damage on this girder. In total, seven different inspectors (17 percent) noted impact damage to this bridge.

The rocker bearings on the eastern abutment of the southern half of this bridge display an abnormal setting given the thermal conditions surrounding the bridge. First, the three bearings exhibit overly expanded positions. Also, the southern bearing has rotated more than the other two, indicating a possible planar rotation of the bridge. Figure 133 shows one of the rocker bearings when the air temperature is approximately 24 °C. Twenty-one of the inspectors (50 percent) noted this bearing abnormality.

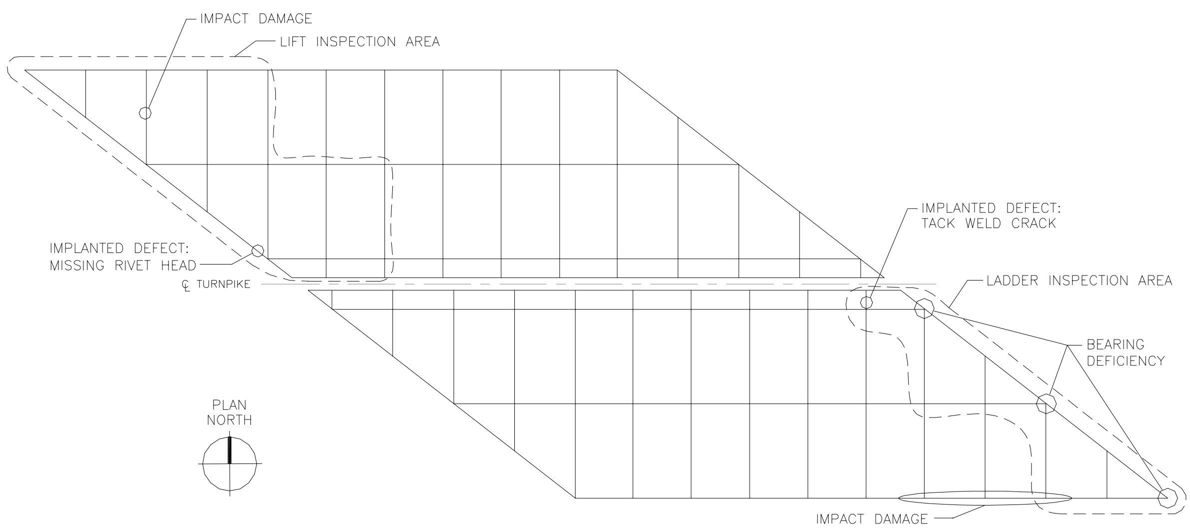


Figure 130. Schematic of the locations of local defects.

a. General location of implanted defect.

b. Close-up of defect.

Figure 131. Crack indication at the root of a tack weld.

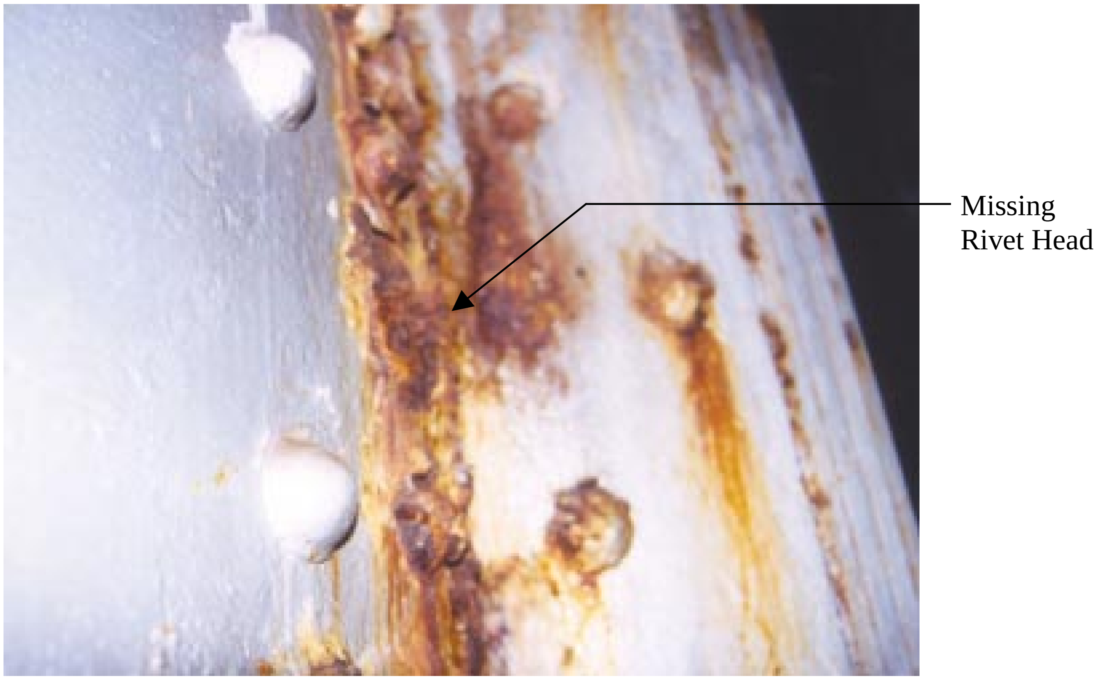


Figure 132. Missing rivet head defect.

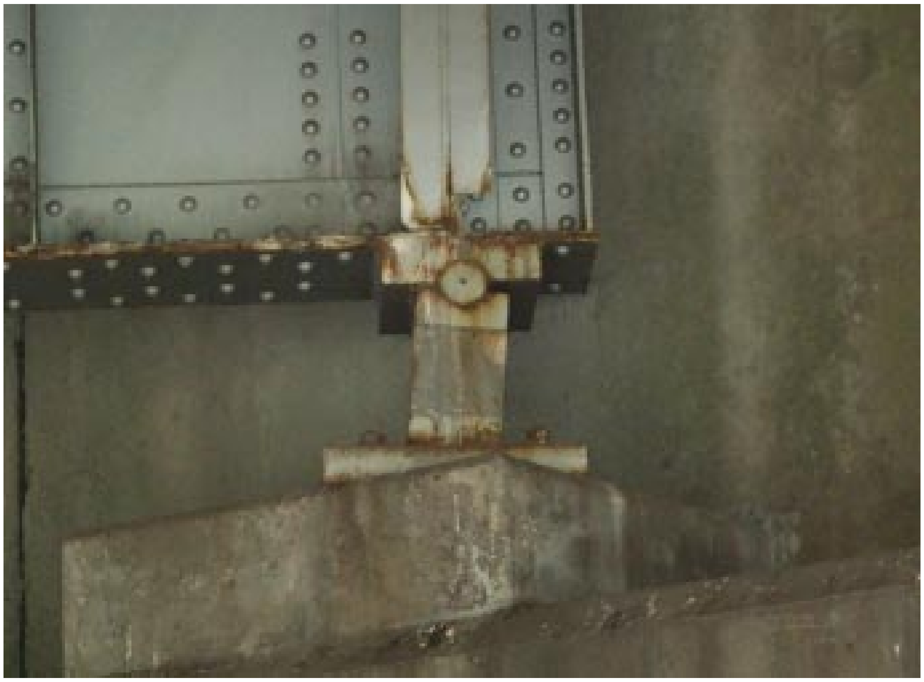


Figure 133. Rocker bearing rotation.

5.3.2.3. FACTORS INFLUENCING INSPECTION

A number of factors may affect an inspector's ability to correctly locate a deficiency during an inspection. The following discusses some of these factors with regard to the inspectors and defects studied in Task F. Note that only a portion of the overall set of factors that could affect the inspection results are discussed. In general, these are the factors found to correlate well with the inspection findings. A few additional factors that do not correlate strongly are also discussed. These factors are either commonly perceived to be important to bridge inspection or are factors that provided strong correlation with Task H and are therefore presented here for comparison. In total, approximately 20 of the factors are discussed. The remaining factors not discussed here were found to provide little correlation with the inspection results.

For the purpose of this discussion, the inspectors who correctly identified the previously mentioned defects are grouped into four subsets: inspectors who identified the rivet corrosion defect, the bearing rotation defect, either implanted defect, or either impact damage defect. Note that individual inspectors may be included in more than one of these subsets. A fifth subset, the subset of inspectors who indicated there were no deficiencies in the bridge other than coating or general corrosion defects, is also discussed. The paint and efflorescence defects are not discussed here as they were noted by most inspectors. Finally, the subset of all inspectors that completed the task is also presented. Also note, Task E, a Routine Inspection of the same bridge, was always completed prior to Task F. The inspector notes for both Tasks E and F were used to determine which defects the inspector reported.

The following results are presented in terms of a comparison between the mean values of the various factors for the subsets of the inspectors. The t-test was used to determine whether the particular inspector subset could be considered to be significantly different from the remainder of the inspectors who did not fit the criteria for inclusion in the subset. To reiterate, the t-test was not used to compare the inspector subsets to the overall inspector sample, but to the set of inspectors who did not fit the criteria for the subset. This is due to the t-test providing information regarding whether a set of data can or cannot be considered to be the same as another set of data. Using the t-test to compare the subset to the overall sample would weaken the results because, clearly, the subset does originate from the overall set. The t-test results for the 5 and 10 percent significance levels are presented in the tables that accompany most of the factor discussions.

5.3.2.3.1. Time

The amount of time an inspector is allotted in order to perform an inspection will probably affect the results of the inspection. A rushed inspector may provide a more focused inspection, but may also miss some deficiencies due to lack of time. In addition, if the time limit is sufficiently long, inspectors may spend more time than normal searching for defects. Finally, if an inspector begins to find defects, he may spend more time looking for these particular types of defects, extending the time spent on the inspection.

Table 172 presents the "Actual Time to Complete Task" information for the subsets of inspectors studied. The one notable tendency is for inspectors who correctly identified defects to spend longer than average on the inspection, with times ranging from 75 to 84 min for the subsets of inspectors who found defects. Note, however, that these results should only be viewed as general trends since most of the subsets do not pass the t-test.

Table 172. Task F – Actual Time to Complete Task (in minutes).

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	75	29	N/A*	N/A
Rivet Corrosion Defect	84	35	Yes	Yes
Implanted Defect	81	19	No	No
Bearing Defect	75	29	No	No
Impact Damage	79	33	No	No
No Deficiencies	68	22	No	No

* N/A = Not applicable.

Tables 173 and 174 present the results with regard to Observed Inspector Rushed Level and Reported Rushed Level. In general, these tables show that inspectors who noted defects tended to both act and report feeling slightly more hurried than the overall average of the sample. In addition, inspectors who did not note any of the deficiencies discussed here both reported being and were observed to act less hurried than average. Again, note that these are solely general trends because much of the data did not pass the t-test at either the 5 or 10 percent significance levels.

Table 173. Task F – Observed Inspector Rushed Level.

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	2.6	1.7	N/A*	N/A
Rivet Corrosion Defect	3.1	1.8	No	Yes
Implanted Defect	3.0	1.4	No	No
Bearing Defect	2.5	1.9	No	No
Impact Damage	3.6	1.9	Yes	Yes
No Deficiencies	1.7	0.7	No	Yes

* N/A = Not applicable.

Table 174. Task F – Reported Rushed Level.

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	2.5	2.1	N/A*	N/A
Rivet Corrosion Defect	3.2	2.6	Yes	Yes
Implanted Defect	4.0	2.9	No	Yes
Bearing Defect	2.6	2.2	No	No
Impact Damage	3.0	2.2	No	No
No Deficiencies	1.9	1.6	Yes	Yes

* N/A = Not applicable.

5.3.2.3.2. Comfort Level During Inspection

Portions of Task F were completed at low to moderate heights. For this reason, a number of factors related to the inspector's comfort level during the inspection were studied. These included Fear of Heights, Observed Comfort With Heights, and Observed Comfort With Lift. The inspectors tended to be very comfortable with the heights and the lift. With regard to the inspector's comfort level during the inspection, no correlations are evident between any of the data collected and the various subsets of inspectors. This is probably due to the maximum height of this inspection being only 9 m, with the majority of the inspection performed at even lower heights.

5.3.2.3.3. Mental Focus

Inspector mental focus may affect inspection results. This factor was quantified twice, once in the SRQ as "General Mental Focus" and once by the observer during the task as "Observed Inspector Focus Level". None of the inspector subsets studied for either of these factors pass the t-test at the 10 percent significance level, thus the data will only be discussed in general terms. With regard to General Mental Focus, the inspector subsets who identified the rivet corrosion defect, the implanted defects, or the impact defects tend to have reported a slightly above average mental focus on the SRQ. Inspectors who noted the bearing defect reported a value consistent with the average and inspectors who did not note any deficiencies aside from the coating and corrosion defects reported a mental focus level slightly below average. The Reported Inspector Focus Level values do not necessarily follow the same trend, with some subsets of inspectors who noted deficiencies being above and some being below the overall average. The subset of inspectors who did not note any deficiencies received an Observed Inspector Focus Level average score of slightly above the overall average.

5.3.2.3.4. Inspector-Reported Thoroughness and Effort Level

Inspectors did not necessarily perform the inspection in Task F in the same way that they would normally perform a similar inspection during their normal duties as a bridge inspector. For this reason, the inspectors were asked to rate their thoroughness and effort level compared to their normal effort level. The majority of inspectors reported that they performed this task to the same degree of thoroughness as they would perform a similar task during their normal duties as a bridge inspector. The overall average inspector-reported thoroughness level was 5.2 on a scale of 1 to 9. All five subsets of inspectors had reported thoroughness level averages between 5.0 and 5.6. The majority of the inspectors also indicated that their effort level was the same as their normal effort level. Again, the overall average effort level was 5.2 on a 1 to 9 scale. Except for the inspectors who located an implanted defect (average of 6.3), the other four subsets of inspectors provided an average effort level of between 4.4 and 5.6.

5.3.2.3.5. Reported Bridge Description and Expected Bridge Defects

Prior to Task E, inspectors were asked to both provide a description of the construction of the bridge and to state any defects that they would expect to encounter on a similar bridge. The overall findings from this question were presented previously in this chapter. No specific correlations between inspector subsets and inspector descriptions resulted from these questions. With regard to expected defects, two deficiency types were of interest. First, overall, only 5 percent of the inspectors expected any sort of impact damage and none of the inspectors who noted impact damage stated, prior to the task, that they expected it. Second, while only 24 percent of the inspectors mentioned the possibility of weld crack indications, 50 percent of the inspectors who noted at least one of the implanted deficiencies had mentioned this possible problem. However, in neither case do the results pass the t-test with 10 percent significance.

5.3.2.3.6. Reported Structure Complexity, Accessibility, and Maintenance Levels

The complexity of the bridge, as reported by the inspector, may have an effect on the way the inspector performs the inspection and also on the results of the inspection. The inspector subset ratings of the complexity of the bridge are presented in table 175. Overall, the average bridge complexity rating was 4.7 on a scale of 1 to 9. Inspector subsets for most defects provided an average rating of near, or slightly above, the overall average; however, the inspectors who noted the implanted defects provided an average response of 7.0. Inspectors who noted no defects aside from the general coating and corrosion problems provided an average complexity response of 4.2. Although this value did not pass the t-test, the general trend still indicates that inspectors who felt that the bridge was less complex correlated with the location of fewer defects. The converse also seems to be true.

The Reported Structure Accessibility Level is a factor quite similar to Reported Structure Complexity Level. It is likely that the ease of access to the areas of the bridge to be inspected may affect the methods an inspector uses to perform the inspection. Overall, the average reported bridge accessibility response was 8.1 (i.e., very accessible). All inspector subsets provided average ratings between 8.0 and 8.3, thus no direct correlations are evident.

Table 175. Task F – Reported Structure Complexity Level.

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	4.7	1.9	N/A*	N/A
Rivet Corrosion Defect	5.1	2.0	No	No
Implanted Defect	7.0	0.8	Yes	Yes
Bearing Defect	4.7	1.8	No	No
Impact Damage	4.7	1.3	No	No
No Deficiencies	4.2	1.6	No	No

* N/A = Not applicable.

The Reported Structure Maintenance Level may distort the inspector's perception of the bridge, changing the way he performs his inspection. The average inspector subset responses are presented in table 176. Inspector subsets who noted rivet corrosion and impact damage rated the maintenance level a 3.9 and inspectors who noted no deficiencies rated it a 4.0. Inspectors who identified the bearing defect and the implanted defect rated the maintenance level a 4.9 and a 5.5, respectively. Thus, inspectors who felt that the bridge was better maintained tended to correlate well with the identification of a larger number of specific defects.

Table 176. Task F – Reported Structure Maintenance Level.

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	4.4	1.8	N/A*	N/A
Rivet Corrosion Defect	3.9	2.0	No	Yes
Implanted Defect	5.5	1.9	No	Yes
Bearing Defect	4.9	1.8	Yes	Yes
Impact Damage	3.9	1.5	No	No
No Deficiencies	4.0	1.6	No	No

* N/A = Not applicable.

5.3.2.3.7. Tool Use

The tools that an inspector uses to perform an inspection are indicative of the type of deficiencies that the inspector is looking for and, possibly, the types of defects that the inspector will find. Of the tools provided to the inspector, the flashlight and the extension ladder stand out as two tools that may aid in the identification of defects. The results for flashlight use are presented in table 177. Overall, 48 percent of the inspectors used a flashlight during this task, while the usage rate was 75 percent for the inspectors who identified either of the implanted defects and 71 percent for the inspectors who identified an impact damage defect. Only 22 percent of the inspectors who indicated that there were no deficiencies other than corrosion and coating failure used a flashlight. With regard to the ladder, some of the defects present in the bridge are extremely difficult to identify without the use of a ladder. Overall, 79 percent of the inspectors used this tool, while 100 percent of those identifying an implanted defect used it. Although this does not necessarily indicate that the use of tools aids in the identification of defects, this does show that some particular methods used by inspectors may have an effect on the results of the inspection.

Table 177. Task F – Tool Use: Flashlight.

Inspector Subset	Average
Overall Sample	48%
Rivet Corrosion Defect	47%
Implanted Defect	75%
Bearing Defect	48%
Impact Damage	71%
No Deficiencies	22%

5.3.2.3.8. Inspector Age and Experience in Bridge Inspection

The overall average inspector age was 40. All of the inspector subsets had average ages between 39 and 41, except for the set of inspectors who noted no deficiencies beyond the general corrosion and coating defects. These inspectors had an average age of 43. The results with regard to inspection experience are presented in table 178. Inspectors who noted impact damage, bearing rotation, or implanted defects averaged between 7.4 and 8.8 years of experience in bridge inspection. The inspectors who did not note any specific defects averaged 11.9 years of experience. These results indicate that the more experienced inspectors may report fewer defects.

Table 178. Task F – Experience in Bridge Inspection (in years).

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	9.2	6.2	N/A*	N/A
Rivet Corrosion Defect	10.5	5.2	No	No
Implanted Defect	7.4	3.1	No	No
Bearing Defect	8.8	5.1	No	No
Impact Damage	8.4	4.7	No	No
No Deficiencies	11.9	9.0	No	No

* N/A = Not applicable.

5.3.2.3.9. General Education Level and Formal Bridge Inspection Training

The education level and formal training of inspectors are both factors that may affect the work an inspector performs. For this task, the General Education Level of the inspector does not seem to correlate with any set of inspection results. However, the results from the overall formal bridge inspection training courses completed do correlate with some subsets of inspectors. These results are presented in table 179. They indicate that inspectors who have completed more formal training courses tend to correlate well with the correct location of more defects. Correspondingly, inspectors who noted no defects outside of the coating and corrosion defects tended to have completed fewer formal training courses. Thus, inspector training may influence the types of defects that are located.

Table 179. Task F – Formal bridge inspection training courses completed.

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	3.3	1.7	N/A*	N/A
Rivet Corrosion Defect	4.0	1.5	Yes	Yes
Implanted Defect	3.5	2.4	No	No
Bearing Defect	3.7	1.6	No	Yes
Impact Damage	3.0	1.9	No	No
No Deficiencies	2.3	1.3	Yes	Yes

* N/A = Not applicable.

5.3.2.3.10. Professional Engineer License

Following the study, inspectors were contacted to determine whether they held a Professional Engineer (PE) license. Table 180 provides the corresponding results in terms of the subsets of inspectors defined for this task. These results show no clear correlation between this factor and the inspection results. However, the small size of the sample, along with the small size of most of the inspector subsets, makes interpreting these results difficult.

Table 180. Task F – Inspectors holding a PE license.

Inspector Subset	Average
Overall Sample	17%
Rivet Corrosion Defect	11%
Implanted Defect	0%
Bearing Defect	10%
Impact Damage	14%
No Deficiencies	33%

5.3.2.3.11. Management Inspection Philosophy and Control Over Inspection Process

The SRQ contained a question regarding whether the management philosophy of the inspector's State focused more on locating all defects in the bridge or on complying with the NBIS regulations (SRQ24). Overall, 30 percent of the inspectors reported that their State focused on complying with the NBIS regulations, while the remainder focused on finding all of the defects. Similar percentages held for most of the other subsets of inspectors. The exceptions are the inspectors who found an implanted deficiency or noted impact damage — 86 and 100 percent, respectively, reported that their State focused on finding defects.

The SRQ also asked inspectors to report the level of control that management typically exercised over their inspections. Overall, 29 percent of the inspectors stated that they were provided with a detailed checklist for their inspections, 29 percent were provided with loose guidelines, and 43 percent were allowed to inspect according to their own inspection knowledge and techniques. Except for the subset of inspectors who identified implanted defects, these percentages approximately stayed the same across the various subsets of inspectors. However, 75 percent of the inspectors who noted implanted defects reported that their supervisors provide a detailed checklist.

These results indicate that States that focus on finding defects may, in fact, locate more of the defects that occur in their bridge population. In addition, it is possible that management's role in how the inspection is performed may affect the inspection results.

5.3.2.3.12. Vision

The near and far visual acuity of each inspector was quantified, with the overall data presented previously. With regard to this task, the inspector visual acuity did tend to correlate with one subset of inspectors. Specifically, the inspectors who noted implanted defects tended to have exceptional visual acuity, with the worst eye of one inspector having a visual acuity of 20/25. The inspectors who are grouped into the other subsets tended to have visual acuities that fell within the overall visual acuity of the sample. The correlation between visual acuity and the inspectors who found implanted defects may indicate that these types of defects are more likely to be located by inspectors who possess better eyesight. Note, however, that these results were not tested with the t-test due to difficulties in implementing the t-test with this data set.

5.3.2.3.13. Inspector-Rated Importance of Bridge Inspection

In the SRQ, inspectors were asked to rate both the importance of bridge inspections to public safety and their general feelings on the importance of bridge inspections. Overall, the responses to these two questions showed that most inspectors feel that bridge inspections are very important, with average ratings of 4.6 (standard deviation of 0.5) and 4.5 (standard deviation of 0.9), respectively, on scales of 1 to 5. However, one specific subset of inspectors, those inspectors who located an implanted defect, provided an average rating of 5.0 (standard deviation of 0.0) to both questions. The strong feelings that these inspectors have toward the importance of their work may tend to encourage them to conduct a more thorough inspection than average.

5.2.3.2.14. Environmental Factors

The environmental factors did not have any discernible impact on the findings of this inspection. Granted, factors such as these could adversely affect an inspection; however, the results obtained in this study provided no specific data to support this supposition.

5.3.3. Task H

Task H is an In-Depth Inspection of a portion of the superstructure of the Route 1 Bridge. The bridge and Task H are both fully described in Chapter 4. The results from this task are presented in a manner similar to that used for Task F. First, information regarding the inspection process is provided. Following this, the known and reported defects are described, along with the accuracy results regarding the detection of these defects. Finally, the factors that tend to correlate with the inspection results are presented.

5.3.3.1. INSPECTION PROCESS

This section provides a general description of how the inspectors completed this task. The data for this discussion come from the pre-task questionnaire, firsthand observation of the inspectors performing the tasks, and the post-task questionnaire.

Forty-four inspectors completed this task. The reasons five inspectors did not complete this task included refusal due to fear of heights, lift unavailability, and unavailability of required safety equipment. In addition, 2 of the 44 inspectors only partially completed the task. This was due to a lift malfunction. The fact that these inspectors only partially completed the task has been accounted for in their results.

Inspectors were allowed 2 h to complete the In-Depth Inspection of one bay of one span of the superstructure of this bridge. The average time to complete this task was 64 min, with the median time being 60 min. The standard deviation was 28 min, with a maximum time to completion of 115 min and a minimum time of 6 min. Also note that some minor additional variability is included in these times due to the lift equipment and its operation by two different observers. Figure 134 illustrates the distribution of the inspection times.

Table 181 summarizes some of the questions asked in the pre-task questionnaire. These results show that, on average, it had been more than 7 months since an inspector performed an inspection similar to Task H; however, there were two inspectors who had not performed an inspection similar to this in more than 5 years. Also, the inspection at heights question demonstrates that, on average, the inspectors perform 28 inspections per year at heights of greater than 12.2 m (40 ft). Some inspectors perform very few of these types of inspections, including two inspectors who, on average, do not perform any inspections above this height. Figure 135 illustrates the distribution of predicted inspection times.

For this inspection, inspectors were provided with the full set of inspection tools, as well as an 18.3-m boom lift that could provide hands-on access to the structure. In order to assess what types of access equipment would normally be used for this type of an inspection, inspectors were asked what type of equipment they would normally use to access the structure. Ninety-six percent of the inspectors stated that they would use a snooper to access the structure. Other responses included a lift (2 percent), permanent inspection platform (4 percent), and movable platform (2 percent). Finally, one inspector said that he would not normally use any access equipment to access this bridge. During his subsequent inspection, he declined the use of the lift and performed the task using binoculars.

In the pre-task questionnaire, the inspectors were asked to describe the type of construction used on this bridge. The results from this question are presented in table 182. Note that these results are the same as were presented for this question in Task G due to the question being bridge-specific. The table shows that only 52 percent of the inspectors indicated that the bridge is continuous. Although this should not be construed to mean that only half of the inspectors were able to make this distinction, it is true that only about half thought to mention it during the pre-task questionnaire. This knowledge can have great bearing on the focus of portions of the inspection. Clearly, if an inspector was unable to recognize this fact, less accurate inspection results could be produced.

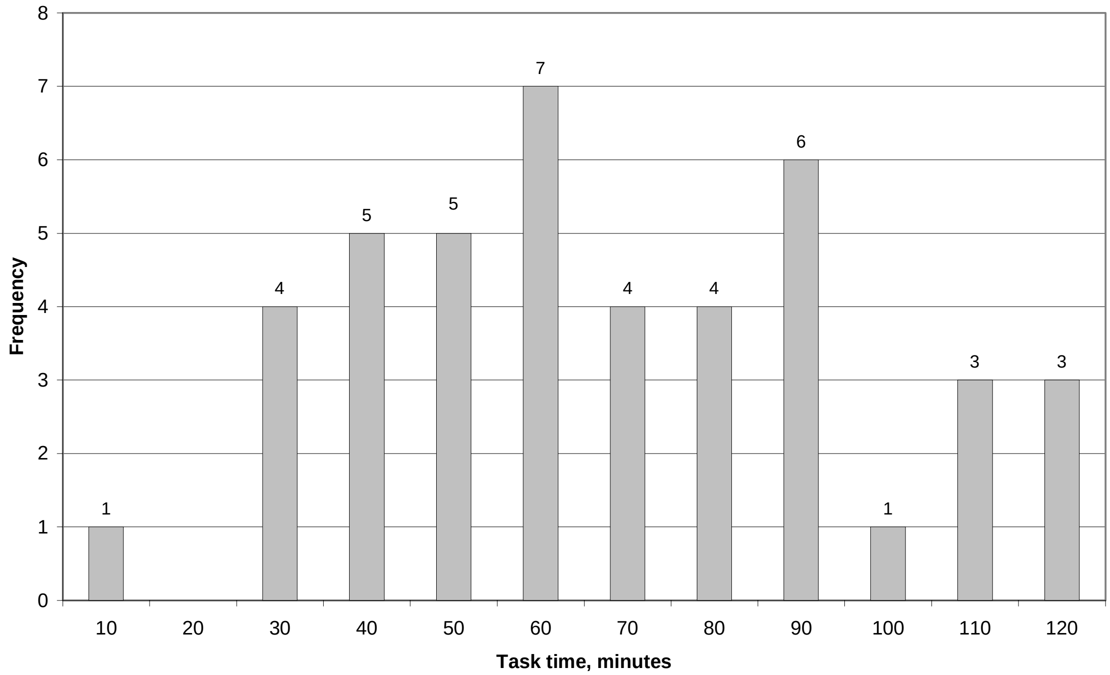


Figure 134. Task H – Actual inspection time.

Table 181. Task H – Qualitative pre-task questionnaire responses.

Question	Range of possible answers		Inspector Response				
	Low	High	Average	Median	Standard Deviation	Maximum	Minimum
How long has it been since you completed an In-Depth Inspection of a bridge of this type (in weeks)?	N/A*	N/A	34.3	16.0	58.5	300	1
How often per year do you perform inspections at heights above 40 feet?	N/A	N/A	28.3	20	31.6	150	0
Given the available equipment and the defined tasks, how long do you think you would normally spend on this inspection (in minutes)?	N/A	N/A	67.8	60.0	37.6	180	5
How rested are you?	1 = very tired	9 = very rested	7.0	7	1.4	9	3

* N/A = Not applicable.

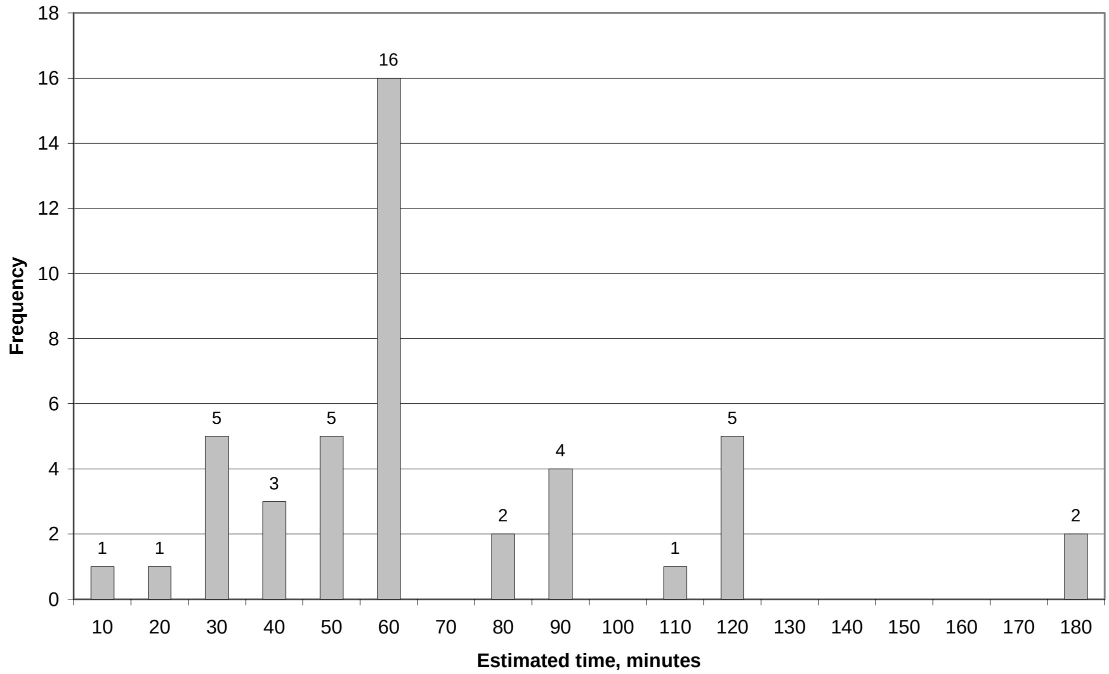


Figure 135. Task H – Predicted inspection time.

Table 182. Task H – Description of type of construction used.

Bridge Characteristic	Percent of Respondents
Steel Girder	82%
Welded Plate Girder	52%
Multi-Girder	41%
Reinforced Concrete Deck	73%
Continuous	52%
Rocker Bearing	7%
Concrete Piers	57%
Single-Angle Cross-Bracing	14%
Composite Construction	5%
Other	18%

To further assess how inspectors were formulating their approach to the inspection, they were asked to identify problems that they might expect to find on a bridge of a similar type, condition, and age. These responses are summarized in table 183. These results indicate that inspectors expect to find relatively few problems. Of this list of possible deficiencies, only steel corrosion and fatigue cracks were mentioned by more than half of the inspectors and no defects were mentioned by more that 60 percent of the inspectors.

As previously mentioned, while the inspector was completing the inspection, the observer recorded environmental conditions, recorded how the inspection was completed, noted what inspection tools were used, and operated the lift. Tables 184 and 185 provide a summary of the environmental conditions that were encountered during this task. These measurements were taken at an elevated position immediately under the superstructure. As the tables reiterate, this task was performed under normal summer morning weather conditions. Also, note the variation that was encountered in both wind and light levels.

Table 183. Task H – Problems expected.

Problem Type	Percentage of Respondents
Fatigue Cracks	57%
Steel Corrosion	55%
Concrete Deterioration	52%
Underside Deck Cracking	27%
Deck Delaminations	27%
Locked Bearings	23%
Missing or Loose Bolts	23%
Leaching	18%
Paint Deterioration	16%
Leakage	7%
Impact Damage	7%
Other	46%

Table 184. Task H – Direct environmental measurements.

Environmental Measurement	Average	Median	Standard Deviation	Maximum	Minimum
Temperature (°C)	22.6	22.8	4.9	30.6	10.6
Humidity (%)	68.2	68.0	10.8	89.0	46.0
Heat Index (°C)	23	24	5.8	37	11
Wind Speed (km/h)	5.2	2.4	6.8	25.7	0.0
Light Intensity (lux)	374	366	281	1160	34

Table 186 summarizes the portions of the inspection task performed by the inspectors. This table is divided into two parts, the first section reporting the items that were visually inspected and the second part reporting what items were inspected through sounding. It is important to note that for this task, the level of inspection for certain components was also recorded. Based on this table, it is clear that some inspectors left this inspection task partially incomplete. Only 56

Table 185. Task H – Qualitative weather conditions.

Weather Condition	Percentage of Inspections
0 – 20% Cloudy	49%
20 – 40% Cloudy	2%
40 – 60% Cloudy	4%
60 – 80% Cloudy	7%
80 – 100% Cloudy	24%
Hazy	2%
Fog	4%
Drizzle	2%
Steady Rain	4%
Thunderstorm	0%

Table 186. Task H – Bridge inspection completion results.

	Inspection Item	Percentage of Inspectors
Visual	North Flange Transitions	36%
	South Flange Transitions	33%
	Girder #3 Splice, North	82%
	Girder #4 Splice, North	87%
	Girder #3 Splice, South	82%
	Girder #4 Splice, South	82%
	Girder #4 Stiffener Retrofits	53%
	No Utility Bracket Welds	42%
	1-25% Utility Bracket Welds	0%
	26-75% Utility Bracket Welds	20%
	76-100% Utility Bracket Welds	38%
	No Drain Tack Welds	22%
	Non-Thorough Inspection of Drain Tack Welds	31%
	Thorough Inspection of 3 Drain Tack Welds	47%
	No Lateral Gusset Connection Welds	4%
	1-25% Lateral Gusset Connection Welds	22%
	26-75% Lateral Gusset Connection Welds	18%
	76-100% Lateral Gusset Connection Welds	56%
	Stiffener to Web Connection at Top Flange	69%
	Stiffener to Web Connection at Bottom Flange	53%
Sounding	No Bolts per Splice	84%
	1-3 Bolts per Splice	2%
	4-9 Bolts per Splice	7%
	10+ Bolts per Splice	7%
	No Lateral Connection Bolts	73%
	Bolts on 1-50% of Lateral Connections	22%
	Bolts on 51-100% of Lateral Connections	4%

percent of the inspectors inspected more than 75 percent of the lateral gusset plate connection inspection areas and only 47 percent of the inspectors thoroughly inspected all three drain tack weld inspection areas.

Inspector tool use is presented in table 187. This table shows that only 58 percent of the inspectors used a flashlight. Also, as could be inferred from table 186, very few inspectors performed any sounding during this task as evidenced by the low usage of sounding tools.

The observers reported on a number of observations regarding inspector behavior during this task. These results are presented in table 188. Note that, on average, very few of the inspectors seemed rushed while completing the task and most inspectors seemed relatively comfortable with the lift.

After completion of the task, the inspectors were again asked a series of questions. These questions were typically related to the inspector's impression of the inspection they just completed and to their general physical and mental condition. In all, 15 questions were asked

Table 187. Task H – Use of inspection tools.

Tool	Percentage of Inspectors
Tape Measure	18%
2.4-m Stepladder	0%
9.75-m Extension Ladder	0%
Any Flashlight	58%
Two AA-Cell Flashlight	20%
Three D-Cell Flashlight	24%
Lantern Flashlight	18%
Any Sounding Tool	29%
Masonry Hammer	29%
Chain	0%
Level as a Level	0%
Level as a Straightedge	0%
Binoculars	4%
Magnifying Glass	16%
Engineering Scale	2%
Protractor	0%
Plumb Bob	0%
String	0%
Hand Clamp	0%

and the results are presented in table 189. The results show that, in general, the inspectors felt that they were slightly more thorough and provided slightly more effort than they would on a normal inspection. Also, on average, inspectors felt that they were about 630 mm away from any welds that they were inspecting. This result contrasts with the observer value from table 188 that shows the inspectors were about 1.2 m away from any welds that they were inspecting.

Table 188. Task H – Summary of quantitative observations.

Question	Range of Possible Answers		Observer Assessment				
	Low	High	Average	Median	Standard Deviation	Maximum	Minimum
Was the inspector focused on the task?	1 = very unfocused	9 = very focused	5.9	6	1.6	9	2
Did the inspector seem rushed?	1 = not rushed	9 = very rushed	2.2	2	1.6	8	1
How close did the inspector get to the welds he was inspecting (in meters)?*	N/A**	N/A	1.17	0.61	2.27	15.2	0.15
Was the inspector's viewing angle varied while inspecting the welds?	1 = never	9 = always	5.4	6	2.3	9	1
How comfortable was the inspector with the working height?	1 = very uncomfortable	9 = very comfortable	7.1	8	1.6	9	3
How comfortable was the inspector with the lift?	1 = very uncomfortable	9 = very comfortable	6.2	7	2.2	9	1
What was the quality of lift operation?	1 = very poor	5 = very good	3.4	3	0.7	5	2

* Observer responses were originally given in English units and have since been converted into metric units.
** N/A = Not applicable.

5.3.3.2. COMPARISON OF KNOWN AND INSPECTOR-REPORTED DEFICIENCIES

Many reportable deficiencies exist within the inspected portion of the superstructure of the Route 1 Bridge. Inspectors performing this task were asked to note any defects they found during their inspection. The defects can be categorized into three main types: general defects, welded connection defects, and bolted connection defects. Thirty-six of the 44 inspectors performing this task noted at least one of these deficiencies. The following section will discuss the known deficiencies, as compared to the inspector-reported deficiencies.

Table 189. Task H – Quantitative post-task questionnaire responses.

Question	Range of Possible Answers: Low	Range of Possible Answers: High	Inspector Response: Average	Inspector Response: Median	Inspector Response: Standard Deviation	Inspector Response: Maximum	Inspector Response: Minimum
How similar was this task to the tasks performed in your normal In-Depth Inspections?	1 = not similar	9 = very similar	7.5	8	1.4	9	5
Did this task do an accurate job of measuring your inspection skills?	1 = not accurate	9 = very accurate	7.9	8	1.0	9	5
How rested are you?	1 = very tired	9 = very rested	7.0	7	1.4	9	3
How well did you understand the instructions you were given?	1 = very poorly	9 = very well	8.5	9	0.6	9	7
How accessible do you feel the various bridge components were?	1 = very inaccessible	9 = very accessible	7.8	8	1.4	9	4
How well do you feel that this bridge has been maintained?	1 = very poorly	9 = very well	7.3	7	0.8	9	5
How complex was this bridge?	1 = very simple	9 = very complex	6.0	6	1.5	9	1
Do you think my presence as an observer had any influence on your inspection?	1 = no influence	9 = great influence	2.5	2	2.0	9	1
Do you feel that the working height influenced your performance?	1 = no influence	9 = great influence	1.8	1	1.3	6	1
How adequate do you feel the light level was?	1 = very inadequate	9 = very adequate	7.2	7	1.4	9	4
On average, how close do you think you got the welds you were inspecting (in meters)?*	N/A**	N/A	0.63	0.61	0.38	1.83	0.08
Do you feel you were able to get the proper viewing angle for the components you were inspecting?	1 = never	9 = always	7.3	7	1.0	9	5
Did you feel rushed while completing this task?	1 = not rushed	9 = very rushed	2.0	1	1.5	6	1
What was your effort level on this task in comparison with your normal effort level?	1 = much lower	9 = much greater	5.2	5	0.7	7	4
How thorough were you in completing this task in comparison to your normal inspection?	1 = less thorough	9 = more thorough	5.5	5	1.0	8	4

* Inspector responses were originally given in English units and have since been converted into metric units.
** N/A = Not applicable.

5.3.3.2.1. General Defects

The General Defect category encompasses structural deficiencies in the bridge that do not pertain to welded or bolted connections. This type of deficiency includes paint system failure, corrosion, member distortions, and fabrication errors. All four of these types of deficiencies are present within the test specimen portion of this bridge.

Paint system failure and corrosion are present in various locations throughout the test specimen. Figures 136 and 137 show typical examples of this deficiency. Of the inspectors who completed this task, 66 percent specifically indicated some sort of paint system failure. Corrosion is a bridge defect that is generally directly linked to the paint system failure. Minor localized corrosion, also known as speckled rust, has occurred in various locations throughout the specimen. Fifty-five percent of the inspectors noted that corrosion was present in the test specimen. Hereafter, paint system failure and corrosion will be combined into a general coating deficiency. Sixty-six percent of the inspectors noted the coating deficiency.

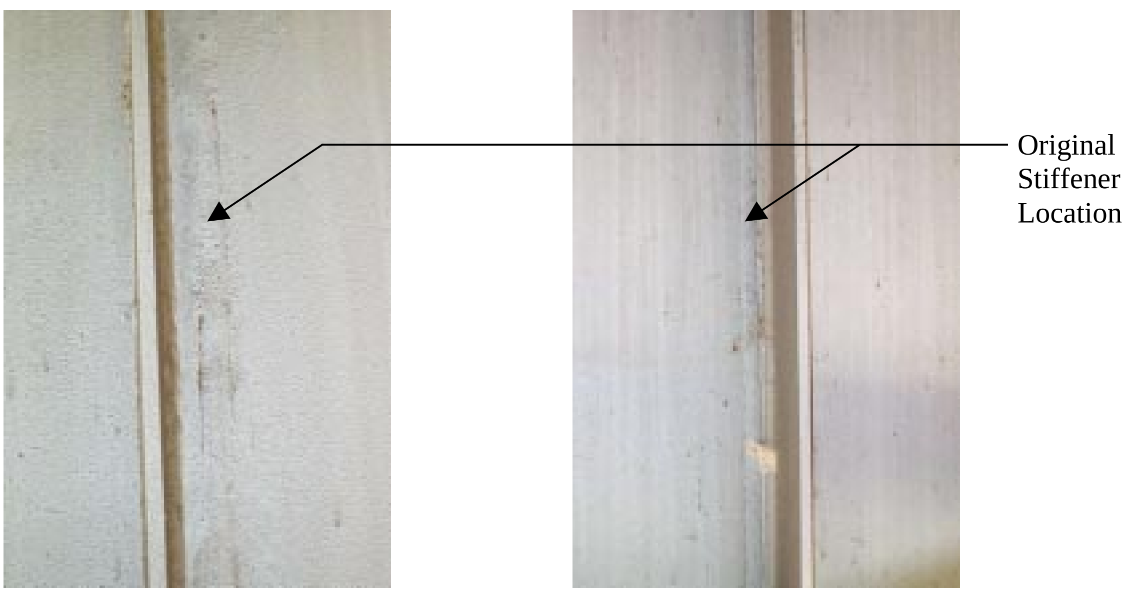
Figure 136. Paint failure on girder web.

Figure 137. Localized corrosion on flange and web near the drain-to-girder web connection.

Member distortions can be indicative of, or may lead to, overall problems with the structure. As shown in figure 138, the bottom flange of the interior girder in the test specimen is not entirely straight, having a “wavy” nature between midspan and pier 5. Eleven percent of the inspectors noted this defect.

Fabrication errors, due to the nonhomogeneity they introduce into the structure, have the possibility of later developing into more serious defects. Frequently, these errors are difficult to detect; however, in some instances, depending on the repair that was employed, they may be detected by normal visual means. In this test specimen, there are two locations where vertical stiffeners were installed at incorrect locations, removed, and replaced at nearby locations. Figure 139 shows the two locations of fabrication errors. Only one inspector noted the fabrication error in the interior girder and no inspectors noted the defect in the exterior girder.

Figure 138. Flange distortion.



a. Interior Girder.   b. Exterior Girder.

Figure 139. Misplaced vertical stiffeners on interior and exterior girders.

5.3.3.2.2. Welded Connection Defects

Welded connection defects consist of cracks or crack indications that occur in or close to a weld. Within the test specimen for Task H, the welded connections were divided into four groups of locations that were most likely to produce crack indications, either due to poor workmanship or low fatigue resistance. These locations include the stiffener-to-girder connections, the lateral bracing-to-girder connections, the drain-to-girder connections, and the utility bracket-to-girder connections. In total, seven weld crack indications are present within the portion of the bridge inspected in Task H. Figure 140 shows a line drawing of the test specimen for Task H, including the locations of the seven indications.

Following the field trials, the seven weld crack indications were thoroughly investigated through the use of visual, dye penetrant, and magnetic particle inspection techniques. None of the indications responded to any of the techniques used, with the exception of Visual Inspection. This indicates that it is unlikely that any of these defect indications are actual weld cracks.

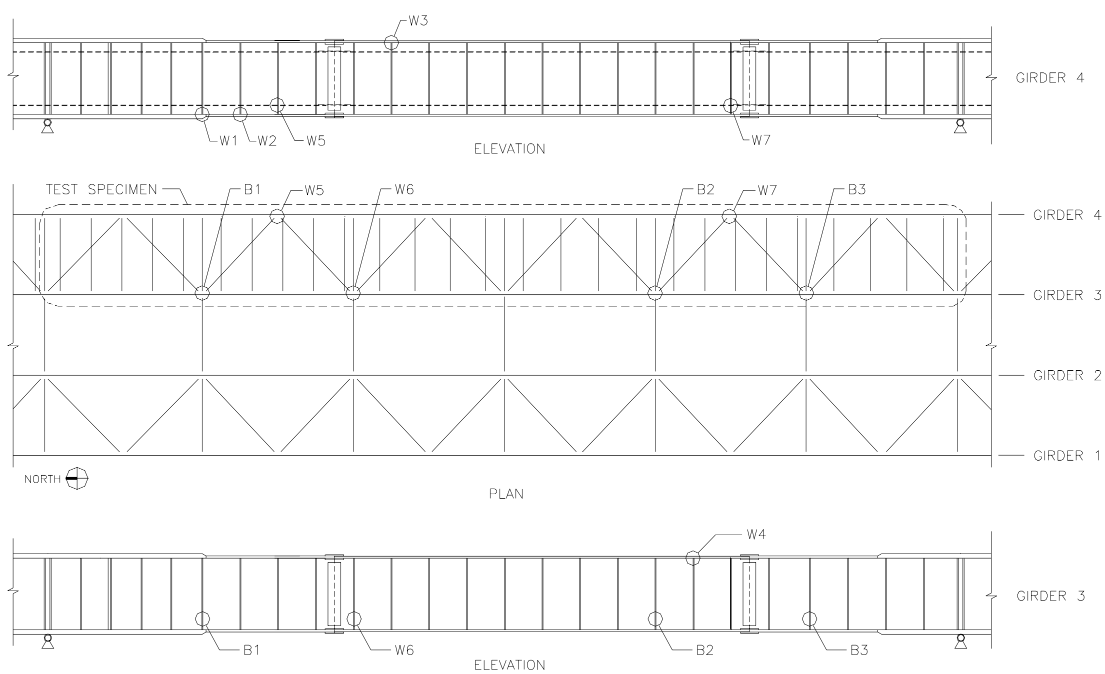


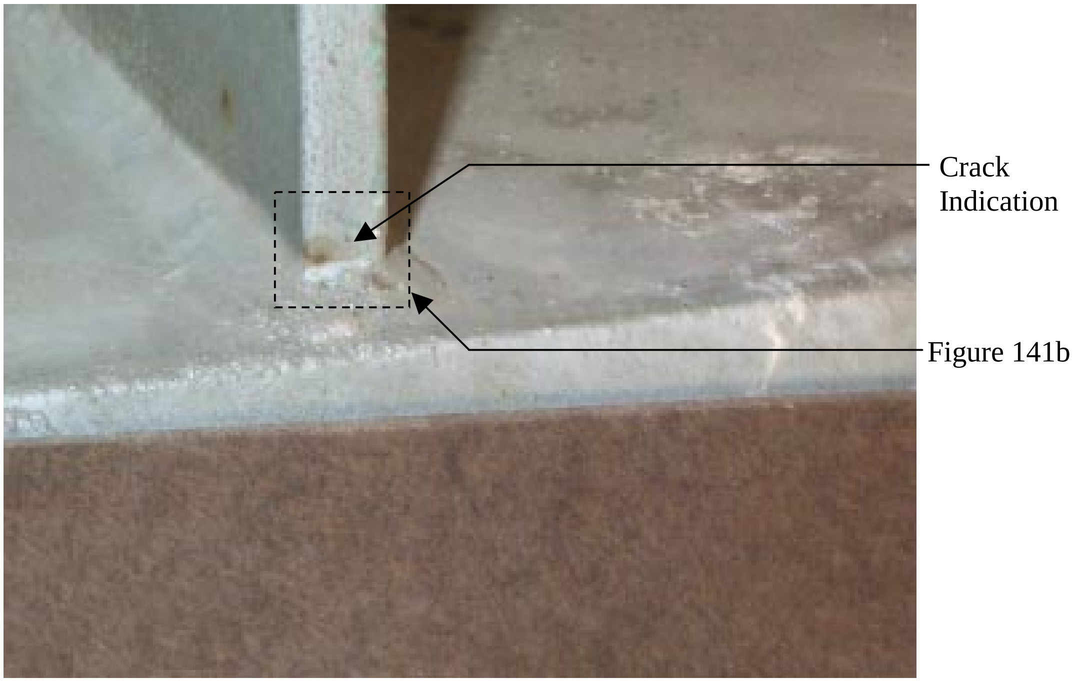
Figure 140. Schematic of the locations of welded and bolted connection defects.

The first critical welded connection location is at the stiffener-to-girder connection. The welds near both the top and bottom flanges at every vertical stiffener were defined to be inspection areas. This includes welds between the stiffener and the web, as well as the welds between the stiffener and the flange, if present. The test bed for Task H contained 104 total inspection areas for this type of connection. Weld crack indications were present in 4 of the 104 inspection areas. Weld crack indication W1 is shown in figure 141. This deficiency is a 5-mm-long indication in the paint at the base of a vertical stiffener. One inspector correctly identified this defect. Another indication, weld crack indication W2, is shown in figure 142. This deficiency is a 12-mm-long indication in the paint in the bottom flange-to-web weld directly under a vertical stiffener. Two inspectors correctly identified this defect.

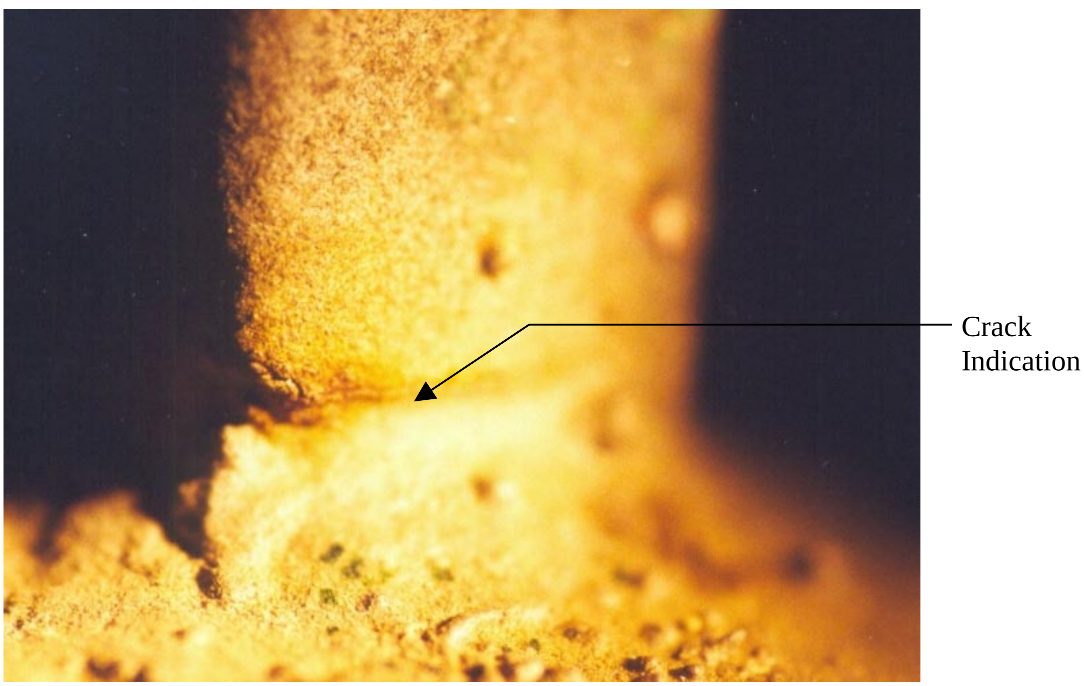
Crack indications exist in two locations at the vertical stiffener-to-top flange connection. The first defect, W3, can be seen in figure 143. This defect is a 30-mm-long indication surrounded by corrosion staining. Three inspectors correctly identified this indication. Weld crack indication W4 is shown in figure 144. It is a 25-mm-long indication also surrounded by corrosion staining. One inspector correctly identified this indication.

A number of false calls were also made with regard to the vertical stiffener-to-girder web connection. In total, 27 false calls were reported. However, a single inspector reported 11 of these false calls, with the remaining 16 being made by 6 other inspectors. To be clear, the inspector who made the majority of the false calls was primarily indicating welds on which he would have requested further testing, not welds that he was sure contained defects.

The welds connecting the lateral bracing gusset plate to the girder web and vertical stiffeners are also likely locations for cracks to occur. Thirteen inspection areas of this type exist within the test bed for Task H. Each inspection area contained two gusset plates, one welded to each side of a vertical stiffener. Figure 145 shows half of one inspection area for this type of connection. Crack indications were contained in 3 of the 13 inspection areas.



a. Stiffener-to-flange connection.



b. Crack indication enlarged for clarity.

Figure 141. Weld crack indication W1 at the base of a vertical stiffener.

a. Web-to-flange connection.

b. Crack indication enlarged for clarity.

Figure 142. Weld crack indication W2 near the base of a vertical stiffener.

Figure 143. Weld crack indication W3 at vertical stiffener-to-top flange connection.

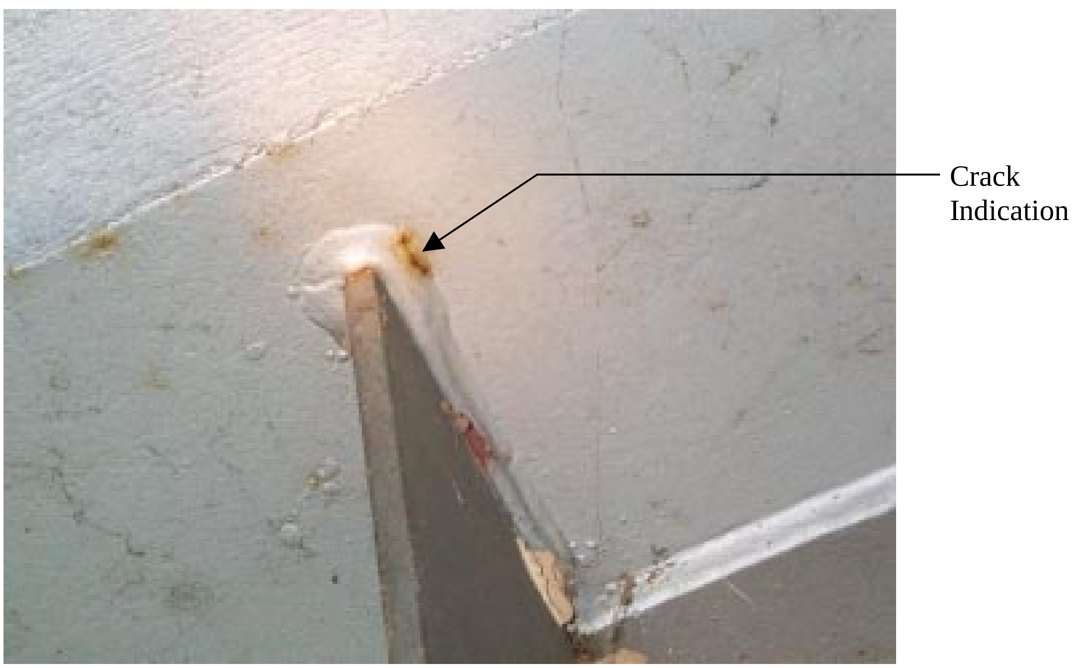


Figure 144. Weld crack indication W4 at vertical stiffener-to-top flange connection.

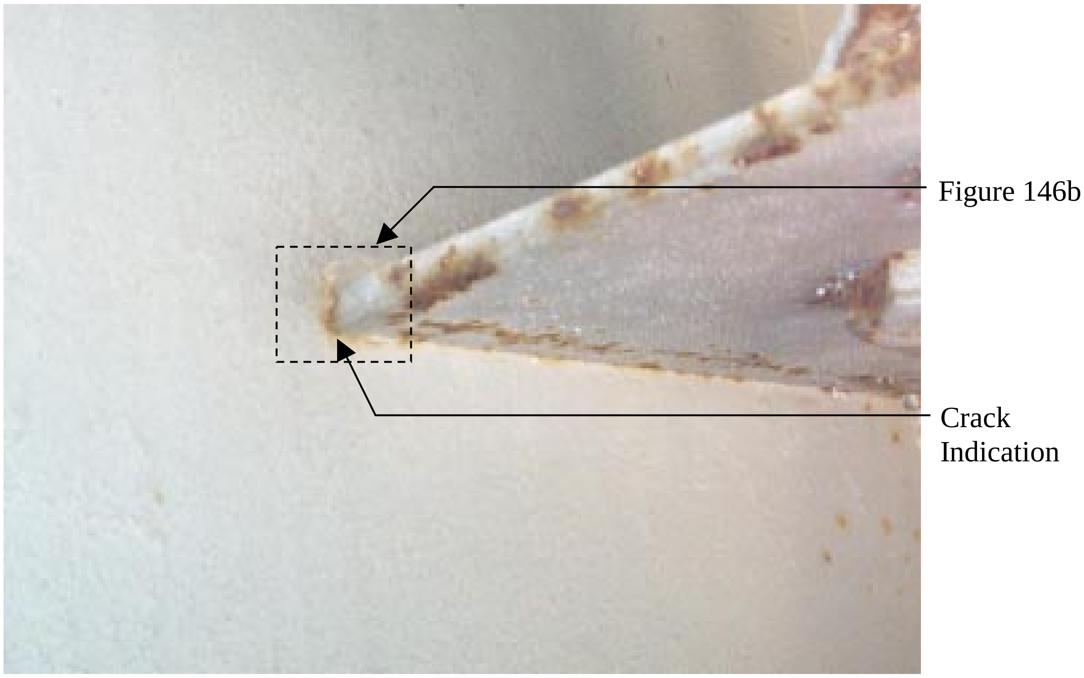
Figure 145. One-half of the lateral gusset plate-to-girder web and vertical stiffener inspection area.

The first defect of this type, weld crack indication W5, is shown in figure 146. This defect is a 16-mm-long crack indication at the termination of the gusset plate-to-web weld. Two inspectors correctly identified this defect. The second defect of this type is weld crack indication W6. It can be seen in figure 147. This defect is a 19-mm-long indication at the termination of the gusset plate-to-web weld. One inspector correctly identified this defect. The final defect of this type is weld crack indication W7, shown in figure 148. It is a 10-mm-long indication, also located at the termination of the gusset plate-to-web weld. Two inspectors correctly identified this defect. The lateral gusset plate-to-girder web connection detail also produced some false calls. In total, four different inspectors made a total of four false calls regarding this connection detail.

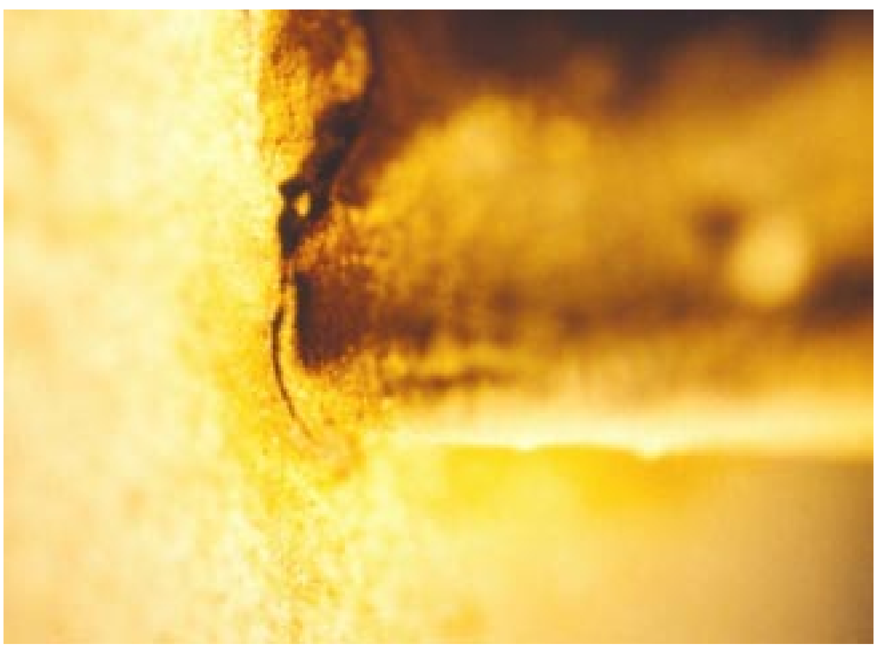
This test bed contained two other areas that are considered to be likely locations for the development of weld cracks. Tack welds were used to connect drain pipes to the exterior girder web. This type of connection occurs three times within the Task H portion of the bridge. Figure 137 shows a photograph of this type of detail. Although the welds are generally of poor quality, no crack indications were present within these connections. Five inspectors made a total of five false calls. Note, however, that these welds are of very poor quality, poor enough that some people may consider them defective even without a crack indication.

The final suspect welded connection pertains to the utilities that run the length of the bridge. After installation of the main girders of the bridge, brackets were field-welded to the girder web to create a support system for the utilities. This type of connection occurs 54 times within the test specimen; thus, there are 54 inspection areas. Figure 149 shows a photograph of this type of detail. Although the welds are generally of poor quality, no defects were present within these connections. Five inspectors made a total of seven false calls.

In summary, there were 174 possible weld inspection areas in the test specimen. A total of 7,538 weld inspection areas should have been inspected by the sample of inspectors. Of these areas, seven contained crack indications. In total, 304 inspections should have been performed on these defects. A total of 12 weld crack indications were correctly identified. Thus, the overall accuracy rate for correctly identifying crack indications is 3.9 percent. In the remaining 167 weld inspection areas that contained no crack indications, 43 false calls were made during the 7,234 inspections of these areas. Therefore, the overall false call rate for identifying good welds as containing indications is 0.6 percent. Combining correct and false calls, 55 crack indication calls were made, indicating that calls were correct only 22 percent of the time. Finally, note that only 41 percent of the inspectors indicated the presence of any type of weld crack indication within the test bed.

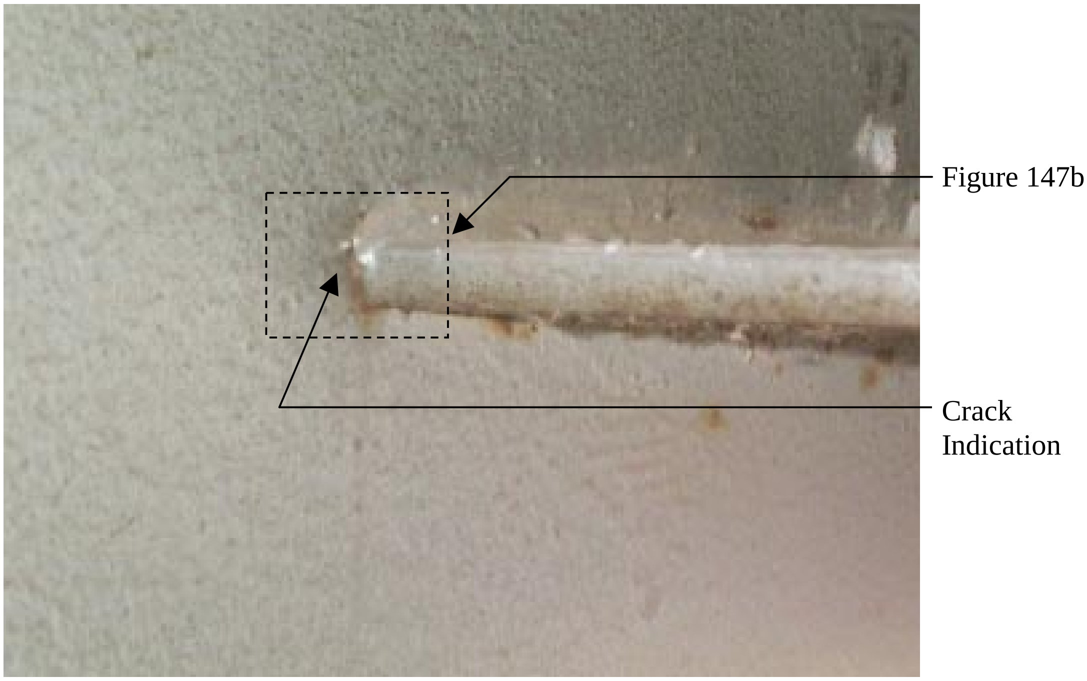


a. Gusset plate-to-web connection.

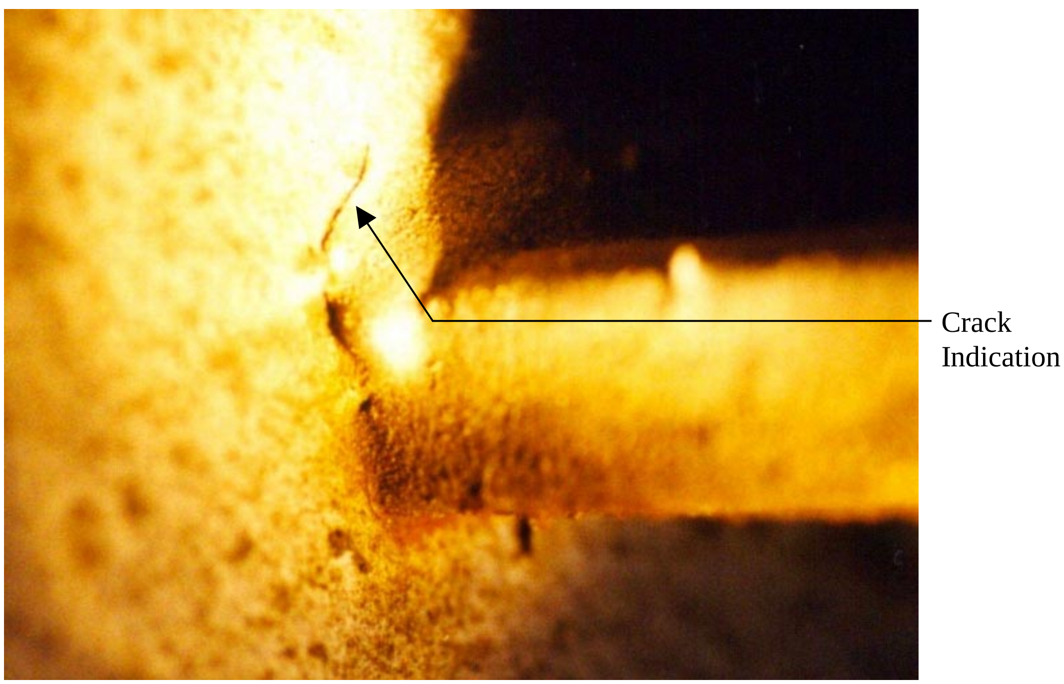


b. Crack indication enlarged for clarity.

Figure 146. Weld crack indication W5 at the lateral bracing gusset plate-to-web connection.

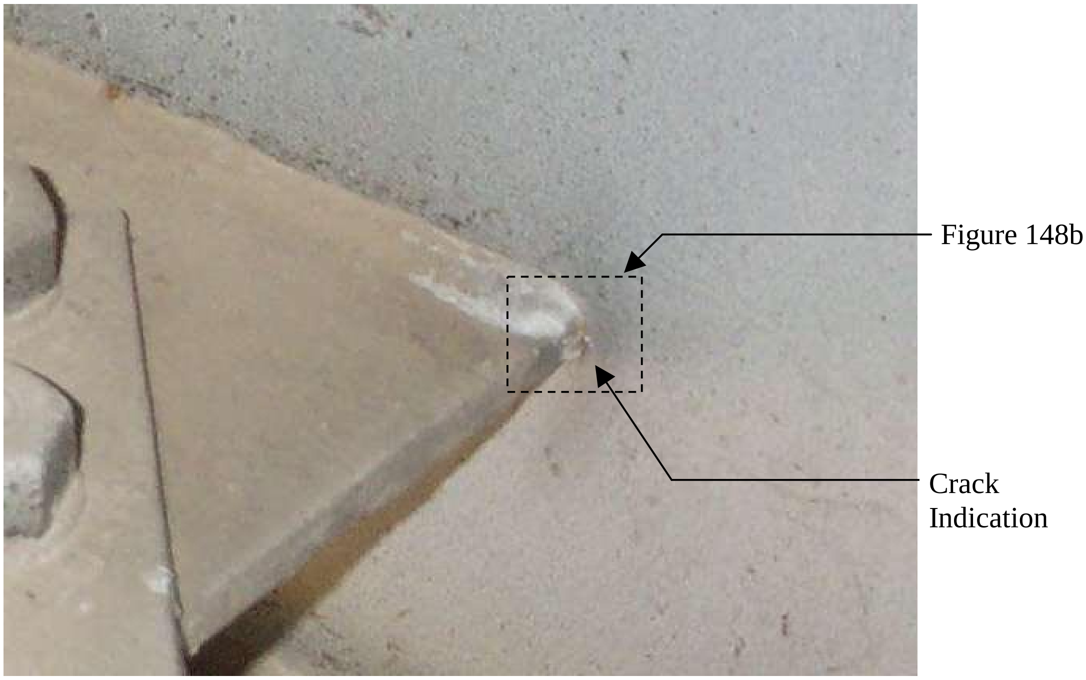


a. Gusset plate-to-web connection.

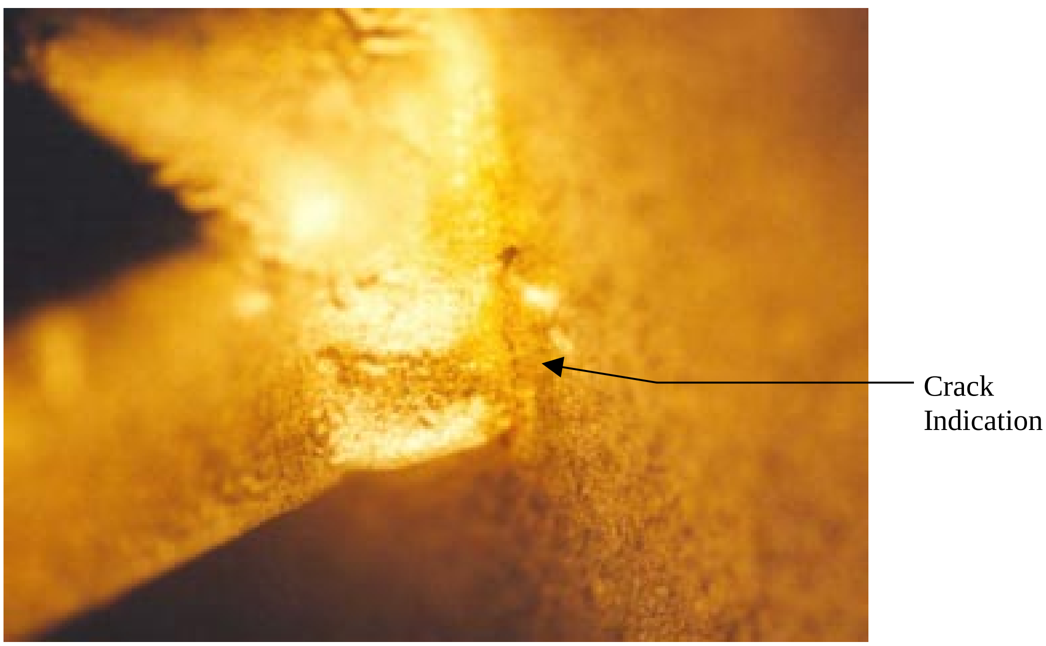


b. Crack indication enlarged for clarity.

Figure 147. Weld crack indication W6 at the lateral bracing gusset plate-to-web connection.



a. Gusset plate-to-web connection.



b. Crack indication enlarged for clarity.

Figure 148. Weld crack indication W7 at the lateral bracing gusset plate-to-web connection.

Figure 149. Typical utility bracket-to-web welded connection.

5.3.3.2.3. Bolted Connection Defects

This bridge contains bolted connections at cross-frame-to-vertical stiffener connections and at girder splices. As with the welded connections, these bolted connections were divided into inspection areas. The girder splices were divided with an inspection area defined for each top flange splice, web splice, and bottom flange splice. The cross-frame-to-vertical stiffener connections were divided such that the bolted connections at any vertical stiffener were considered to be one inspection area. In total, this created 37 potential defect-containing locations within the test specimen.

Three bolted connection defects were present in the test specimen. These defects all occurred at cross-frame-to-vertical stiffener connections and all exhibited themselves as bolts whose nuts were at least 4 mm removed from the plate that they were to be bearing against. The locations of the defects, identified at defects B1, B2, and B3, are illustrated in figure 140. Figure 150 shows one of the three bolted connection defects.

Figure 150. Representative bolted connection defect.

The accuracy of the detection of bolted connection defects was as follows: Defect B1 was correctly identified by 14 inspectors (32 percent), while B2 and B3 were correctly identified by 8 (19 percent) and 9 (21 percent) inspectors, respectively. In total, 31 correct bolted connection defect calls were made throughout the 128 inspections of these inspection areas. Thus, the overall accuracy rate for correctly identifying defective bolted connections is 24 percent. A total of 6 bolt locations (8 total calls) were falsely identified as being defective, while inspections were performed on a total of 1,468 bolted connections classified as non-defective. Therefore, the false call rate for incorrectly identifying non-defective bolts as defective is 0.5 percent. Combined, a total of 39 defective bolted connection calls were made, indicating that calls were correct 79 percent of the time. In addition, note that only 48 percent of the inspectors identified any bolted connections as defective.

5.3.3.3.   FACTORS INFLUENCING INSPECTION

The following discusses factors that may have influenced the results of Task H. First, a discussion parallel to the factor presentation from Task F is provided. Following this, results based on the thoroughness with which the inspectors completed the weld inspection portion of the task are presented.

5.3.3.3.1. Individual Factors

A number of factors affect an inspector's ability to correctly locate a defect during a bridge inspection. The following discusses some of these factors with regard to the inspectors and deficiencies studied in Task H. The set of factors presented, although not the complete set of factors studied within this research, does represent the factors that provide the best correlations with the inspection data. A few additional factors that do not correlate strongly are also discussed. These factors are either commonly perceived to be important to bridge inspection or are factors that provided strong correlation in Task F and are presented here for comparison. In total, approximately 20 of the factors are discussed. The remaining factors not discussed here were found to provide little correlation with the inspection results.

For the purposes of this discussion, the inspectors who correctly identified the deficiencies mentioned previously are grouped into six subsets: inspectors who identified a weld crack indication, multiple weld crack indications, bolt defects, multiple bolt defects, coating defects, and the flange distortion defect. Note that individual inspectors may be included in more than one of these subsets. A seventh subset, the subset of inspectors who indicated that there were no deficiencies in the bridge, is also discussed. All inspectors are included in at least one of the seven subsets. The fabrication error defect is not discussed here since only one inspector noted it.

In general, the following results are presented in terms of a comparison between the mean value of a factor for each subset of inspectors and the mean value of the factor for the overall sample of inspectors who completed the task. As in Task F, the t-test was used to determine whether the particular inspector subset can be considered to be significantly different than the remainder of the inspectors who did not fit the criteria for inclusion in the subset. The t-test results for the 5 and 10 percent significance levels are presented in the tables that accompany most of the factor discussions. In addition, these tables also contain the average and standard deviation values for each subset of inspectors.

TIME: As discussed previously, the amount of time an inspector uses to perform an inspection is likely to affect the results of the inspection. Table 190 presents the average and the standard deviation of the Actual Time to Complete Task for the overall sample of inspectors, as well as the subsets of inspectors. In a manner similar to the information presented in table 190, table 191 presents the differences between the Estimated Time for Task and the Actual Time to Complete Task.

Table 190. Task H – Actual Time to Complete Task (in minutes).

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	66	28	N/A*	N/A
Weld Crack Indication	67	25	No	No
Multiple Crack Indications	88	17	No	Yes
Bolt Defect	78	22	Yes	Yes
Multiple Bolt Defects	85	13	Yes	Yes
Coating Defect	70	29	No	Yes
Distortion Defect	76	12	No	No
No Deficiencies	43	21	Yes	Yes

* N/A = Not applicable.

Table 191. Task H – Actual Time to Complete Task minus Estimated Time for Task.

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	-3	44	N/A*	N/A
Weld Crack Indication	11	43	No	No
Multiple Crack Indications	38	13	Yes	Yes
Bolt Defect	11	43	No	Yes
Multiple Bolt Defects	33	20	Yes	Yes
Coating Defect	-2	42	No	No
Distortion Defect	19	10	No	No
No Deficiencies	-25	50	No	Yes

* N/A = Not applicable.

The average Actual Time to Complete Task for this task was 66 min. The average Estimated Time for Task was 69 min. With regard to weld crack indications, the subset of inspectors who noted this defect spent an average of 67 min on this task, while the three inspectors who noted multiple weld crack indications spent an average of 87 min on the task. The inspectors who found a weld crack indication tended to underestimate their time by 11 min, while the inspectors who found multiple weld crack indications tended to underestimate by 38 min. With regard to bolt defects, the amount of time spent on this inspection by inspectors who found defects varied from 22 to 113 min, with an average of 78 min. However, of the 33 correct bolt defect identifications, 29 were made by inspectors spending at least 72 min on the task. Also, the inspectors who noted multiple bolt defects tended to spend 85 min on the task. Inspectors who found bolt defects tended to underestimate their time by 11 min and inspectors who found multiple bolt defects tended to underestimate by 33 min.

Inspectors who did not note any deficiencies tended to spend 43 min on this task. On average, these inspectors performed the inspection in 25 min less time than they predicted. The results from the coating and distortion defect subsets of inspectors do not show significant deviation from the overall averages.

The results presented above show that there is good correlation between inspectors finding specific defects and spending more time completing the inspection. Clearly, the inspectors who did not note any deficiencies tended to perform the inspection faster than the average and faster than they predicted that they would. The inspectors who noted weld or bolt defects, especially the inspectors who noted multiple defects, tended to spend much longer on the inspection.

Also with regard to time, both the inspector and the observer were asked to rate the Rushed Level of the inspector during the task. These results are relatively minor and thus will not be presented in tabular form. As was reported previously, no inspectors said they were overly rushed; however, the observers reported that four inspectors seemed very rushed. None of these four inspectors correctly identified the weld or flange distortion defects; however, two of the four inspectors did note one of the bolt defects. Inspectors who reported no deficiencies were both observed to be, and reported being, less rushed than average. These results provide some evidence that a more hurried inspector may locate fewer deficiencies.

COMFORT LEVEL DURING INSPECTION: Task H was completed at a moderate height using access equipment that was relatively unfamiliar to most of the inspectors. The inspector’s comfort level with working at heights and with the operation of the lift may have an effect on the results of the inspection. In this regard, the inspectors were asked to rate their personal fear of heights in the SRQ and the observers were asked to rate the inspectors' comfort both with heights and with the lift vehicle. Tables 192 through 194 present an analysis using this information. Note that Reported Fear of Heights is rated on a 1 to 4 scale, while Observed Inspector Comfort With Heights and With Lift are rated on a 1 to 9 scale.

These tables show a few clear trends with regard to inspector comfort during the inspection and the inspection results that the inspector provides. First, all correct weld crack indication calls were made by inspectors who stated that they were "Mostly Fearless" or had "No Fear" with regard to Fear of Heights. Overall, only 68 percent of the inspectors fell into these categories. The average response to this question was 3.4 for inspectors who found a weld crack indication, while it was 2.9 overall. The observed inspector comfort with height averaged 8.0 for inspectors who found a weld defect indication, but averaged only 7.1 overall. The observed inspector comfort with the lift was 7.1 for these inspectors, while the overall average was 6.2.

The inspectors who identified the flange distortion were also relatively comfortable during the inspection. Even though these inspectors reported varying levels of fear of heights in the SRQ, the observer reported that comfort with lift and height were both 7.8, above the overall average. The inspectors who indicated that there were no deficiencies during this task were less

Table 192. Task H – Reported Fear of Heights.

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	2.9	0.76	N/A*	N/A
Weld Crack Indication	3.4	0.53	Yes	Yes
Multiple Crack Indications	3.3	0.58	No	No
Bolt Defect	3.1	0.75	No	No
Multiple Bolt Defects	3.1	0.57	No	No
Coating Defect	3.1	0.75	No	Yes
Distortion Defect	3.0	1.00	No	No
No Deficiencies	2.1	0.35	Yes	Yes

* N/A = Not applicable.

Table 193. Task H – Observed Inspector Comfort With Height.

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	7.0	1.57	N/A*	N/A
Weld Crack Indication	8.0	0.82	Yes	Yes
Multiple Crack Indications	7.7	0.58	No	No
Bolt Defect	6.8	1.52	No	No
Multiple Bolt Defects	6.9	1.37	No	No
Coating Defect	7.2	1.61	No	No
Distortion Defect	7.8	0.45	No	No
No Deficiencies	6.4	1.99	No	No

* N/A = Not applicable.

Table 194. Task H – Observed Inspector Comfort With Lift.

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	6.2	2.77	N/A*	N/A
Weld Crack Indication	7.1	1.68	No	No
Multiple Crack Indications	7.0	2.00	No	No
Bolt Defect	6.4	2.32	No	No
Multiple Bolt Defects	6.4	2.46	No	No
Coating Defect	6.1	2.26	No	No
Distortion Defect	7.8	0.45	Yes	Yes
No Deficiencies	5.0	2.58	No	Yes

* N/A = Not applicable.

comfortable while performing the task. Their average for Fear of Heights was 2.1. For these inspectors, the Observer-Reported Comfort With Height average was 6.4 and the Comfort With Lift average was 5.0.

The results presented above show that the inspector comfort during the task can correlate with the inspection findings. Specifically, inspectors who identified the weld or the flange distortion defects tended to be much more comfortable while performing the inspection. The inspectors who did not note any deficiencies tended to be less comfortable and also reported having a stronger than average fear of heights.

MENTAL FOCUS: Inspector mental focus may also affect inspection results. This factor was measured through inspector responses on the SRQ, as well as through observations during the execution of this task. Results of the analyses with these data are presented in tables 195 and 196.

Table 195. Task H – General Mental Focus.

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	4.4	0.72	N/A*	N/A
Weld Crack Indication	4.6	0.53	No	No
Multiple Crack Indications	4.7	0.58	No	No
Bolt Defect	4.3	0.85	No	No
Multiple Bolt Defects	4.4	0.84	No	No
Coating Defect	4.6	0.69	Yes	Yes
Distortion Defect	4.6	0.55	No	No
No Deficiencies	4.0	0.53	Yes	Yes

* N/A = Not Applicable.

Table 196. Task H – Observed Inspector Focus Level.

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	5.9	1.53	N/A*	N/A
Weld Crack Indication	7.0	0.82	Yes	Yes
Multiple Crack Indications	7.3	0.58	No	Yes
Bolt Defect	5.9	1.50	No	No
Multiple Bolt Defects	6.5	1.43	No	Yes
Coating Defect	5.9	1.73	No	No
Distortion Defect	5.6	1.95	No	No
No Deficiencies	5.5	0.93	No	No

* N/A = Not Applicable.

These results indicate that the mental focus level of the inspector may correlate with the results obtained in an inspection of this type. Specifically, inspectors who identified no deficiencies during this task reported an SRQ mental focus of 4.0, well below the overall average. Although possibly not significant, inspectors who identified a weld crack indication, the flange distortion, or the coating defect reported a mental focus above the overall average of 4.4. In addition, the observer-reported mental focus on the task shows that inspectors who noted a weld crack indication tended to exhibit a significantly higher mental focus level than the overall average. The results from this factor also show that, for certain tasks, a higher level of mental focus could lead to better inspection results.

INSPECTOR-REPORTED THOROUGHNESS AND EFFORT LEVEL: Inspectors did not necessarily perform the inspection in Task H in the same way that they would typically perform a similar inspection during their regular duties as a bridge inspector. For this reason, the inspector was asked to rate his thoroughness and effort compared to normal. The majority of the inspectors (65 percent) reported that they performed this task with the same thoroughness as they would perform a similar task during their normal duties as a bridge inspector. Only 15 percent of the inspectors reported a thoroughness above 6, with the remainder falling between 4 and 6. Seventy-five percent of the inspectors rated their effort level identical to their normal effort level, with 90 percent responding with an answer between 4 and 6. The overall average inspector-reported thoroughness was 5.5 and the overall average effort level was 5.2.

The Reported Thoroughness Level for the various subsets of inspectors who correctly identified defects ranged from 5.0 to 5.5. The Reported Effort Level ranged from 4.6 to 5.3. The average Reported Effort Level for the inspectors who identified no deficiencies was a 5.0, while their average Reported Thoroughness Level was a 6.0, the highest among all the inspector subsets. Only one subset of inspectors — the inspectors who noted the distortion defect — were shown by the t-test to provide a different rating at the 5 percent significance level. Their rating, a 4.6, indicates that they may have provided slightly less effort than they would normally provide. Overall, these results indicate that inspectors performed the inspections in a manner similar to their normal routine.

EXPECTED BRIDGE DEFECTS: Prior to the initiation of this task, inspectors were asked to identify any defects that they felt might occur within the bridge. It seems that inspector expectations may have an effect on the defects that the inspector ultimately finds. Specifically, only 57 percent of the inspector sample indicated that fatigue-related defects were likely; however, 86 percent of the inspectors who found a weld crack indication had previously indicated that they were likely. The same holds true for the location of the bolt defects. Here, 35 percent of the inspectors who found a bolt defect had indicated that there might be this type of deficiency, while only 23 percent of the general inspector sample mentioned this problem. These results indicate that the type of defects an inspector expects to find may increase the likelihood that the inspector will find that type of defect.

REPORTED BRIDGE DESCRIPTION: Prior to the beginning of the task, inspectors were asked to describe the type of construction used on the bridge. Of particular interest here is the number of inspectors who specifically mentioned that the bridge is continuous. These results are presented in table 197. While 52 percent of the inspectors who completed the task noted this fact, 71 percent of the inspectors who identified a weld crack indication and 80 percent of the inspectors who noted the distortion deficiency provided this information. Although mentioning specific items regarding the bridge structure does not necessarily directly result in a better inspection, there does seem to be a tendency for inspectors who more accurately describe critical parts of the bridge to perform inspections that locate more defects.

Table 197. Task H – Reported Bridge Description: Continuous.

Inspector Subset	Average
Overall Sample	52%
Weld Crack Indication	71%
Multiple Crack Indications	67%
Bolt Defect	47%
Multiple Bolt Defects	50%
Coating Defect	48%
Distortion Defect	80%
No Deficiencies	50%

REPORTED STRUCTURE COMPLEXITY LEVEL: The complexity of the bridge, as reported by the inspector, may have an effect on the way the inspector performs the inspection and also on the results of the inspection. Table 198 provides the results of the various inspector subsets with regard to their rating of bridge complexity. Overall, the average bridge complexity rating was 6.0. More than 50 percent of the inspectors rated the bridge a 6 or below. All weld crack indications were identified by inspectors who rated the bridge complexity at 7 or higher, with an average of 7.1. The inspectors who identified the flange distortion provided an average rating of 4.8. These results seem to show that differing levels of perceived complexity may lead to an inspector looking for a different type of defect.

Table 198. Task H – Reported Structure Complexity Level.

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	6.0	1.49	N/A*	N/A
Weld Crack Indication	7.1	0.38	Yes	Yes
Multiple Crack Indications	7.0	0.00	No	No
Bolt Defect	6.3	1.16	No	No
Multiple Bolt Defects	6.9	0.88	Yes	Yes
Coating Defect	5.8	1.61	No	No
Distortion Defect	4.8	1.92	Yes	Yes
No Deficiencies	6.0	1.00	No	No

* N/A = Not applicable.

REPORTED STRUCTURE ACCESSIBILITY LEVEL: Perceived bridge accessibility is a factor quite similar to perceived bridge complexity. It is likely that the ease of access to the areas of the bridge to be inspected may affect the methods an inspector uses to perform the inspection. The results of the various inspector subsets with regard to their rating of bridge accessibility are presented in table 199. Overall, the average perceived bridge accessibility rating was 7.8. For inspectors who located a weld crack indication, the average rating was 6.6, while for inspectors who identified the flange distortion, the average rating was 8.6. As with the complexity findings, these results also indicate that an inspector's perception of the bridge may affect the defects located. Here, inspectors who found large-scale defects were the same inspectors who felt that the bridge was very accessible. The inspectors who correctly identified a weld crack indication are the ones who felt the bridge was far less accessible.

VIEWING OF WELDS: A specific set of the factors studied in this research focused on the methods used by inspectors to perform In-Depth Inspections of welded connections. Specifically, after completion of this task, inspectors were asked whether they were able to achieve the proper viewing angle for the welds they were inspecting, whether the light level was sufficient, and at what distance they were usually inspecting the welds. In addition, observers were asked to provide an estimation of the distance between the inspector and the welds being inspected, as well as noting whether the inspector varied the inspection viewpoint while inspecting the welds. The light level question did not provide any useful information and will not be discussed here.

Table 199. Task H – Reported Structure Accessibility Level.

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	7.8	1.40	N/A*	N/A
Weld Crack Indication	6.6	2.23	Yes	Yes
Multiple Crack Indications	5.7	2.08	Yes	Yes
Bolt Defect	7.9	1.11	No	No
Multiple Bolt Defects	7.7	1.34	No	No
Coating Defect	7.8	1.31	No	No
Distortion Defect	8.6	.55	No	Yes
No Deficiencies	7.7	1.70	No	No

* N/A = Not applicable.

With regard to Observed Variation in Viewing Angle, inspectors who identified a weld crack indication were significantly more likely to be reported as having frequently varied their viewing angle. The results of the inspector subsets with regard to this factor are presented in table 200. Overall, inspectors had an average rating of 5.5, while inspectors who found a weld crack indication had an average rating of 7.3. Although not significantly different from the overall average, inspectors who noted no deficiencies received an average rating of 4.8. Alternatively, the Reported Ability to Achieve Required Viewing Angle factor provided a narrow band of results, clustered around 7. This indicates that nearly all inspectors felt that they were able to get the viewing angle they were striving for during the inspection.

The weld inspection distance findings also correlated well with the inspectors who found a weld crack indication. The results of the inspector subsets with regard to this factor are presented in table 201. The inspectors who correctly identified a weld crack indication were reported to have conducted the inspection from an average distance of 330 mm, while all other subsets of inspectors averaged inspection distances of greater than 500 mm. This subset of inspector results does not pass the t-test, which is probably due to the highly skewed, and thus not Gaussian, distribution of the data. However, it is clear that proximity to the weld has a large impact on the detection of weld defect indications. Also note that the inspectors who noted no deficiencies were reported to be an average of 2.79 m from the welds that they were inspecting, a rather large distance from which to note any deficiencies.

Table 200. Task H – Observed Variation in Viewing Angle.

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	5.5	2.22	N/A*	N/A
Weld Crack Indication	7.3	0.76	Yes	Yes
Multiple Crack Indications	7.7	0.58	Yes	Yes
Bolt Defect	5.7	2.31	No	No
Multiple Bolt Defects	6.9	1.60	Yes	Yes
Coating Defect	5.4	2.26	No	No
Distortion Defect	6.6	2.70	No	No
No Deficiencies	4.8	2.64	No	No

* N/A = Not applicable.

Inspectors were also asked to personally rate their distance from the welds that they were inspecting. Aside from the subset of inspectors who located a weld crack indication, nearly all inspectors estimated themselves to be much closer to the welds that they were inspecting than the observers reported them being. The overall average value was 0.63 m, with a standard deviation of 0.38 m. Clearly, most inspectors felt that they were performing an “arm’s-length” inspection.

TOOL USE: The tools that an inspector uses to perform an inspection are indicative of the types of deficiencies that the inspector is looking for and, possibly, the types of deficiencies that the inspector will find. Of the tools provided to the inspector, the flashlight and the masonry hammer stand out as two tools that would aid in the identification of weld crack indications and bolt defects, respectively. Inspector subset usage results for these two tools are presented in table 202.

Table 201. Task H – Observed Distance to Weld Inspected (in meters).

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	1.17	2.30	N/A*	N/A
Weld Crack Indication	0.33	0.15	No	No
Multiple Crack Indications	0.33	0.23	No	No
Bolt Defect	0.69	0.46	No	No
Multiple Bolt Defects	0.56	0.38	No	No
Coating Defect	0.86	0.79	No	No
Distortion Defect	0.51	0.41	No	No
No Deficiencies	2.79	5.11	Yes	Yes

* N/A = Not applicable.

Table 202. Task H – Tool Use.

Inspector Subset	Flashlight	Masonry Hammer
Overall Sample	59%	30%
Weld Crack Indication	86%	43%
Multiple Crack Indications	67%	33%
Bolt Defect	53%	41%
Multiple Bolt Defects	60%	50%
Coating Defect	66%	28%
Distortion Defect	60%	60%
No Deficiencies	38%	13%

Overall, 59 percent of the inspectors used a flashlight during this task, while 86 percent of the inspectors who identified a weld crack indication used supplemental lighting. With regard to the bolt defects, overall, 30 percent of the inspectors used the masonry hammer, while 41 percent of those identifying a bolt defect used it. In addition, note that most of the inspectors who identified no deficiencies tended to use very few or no tools during this inspection. Although this does not necessarily indicate that the use of tools aids in the identification of defects, this does show that the methods used by some inspectors may have an effect on the results of the inspection.

NORMAL BRIDGE INSPECTION: The types of bridges an inspector normally inspects may play an important role in the quality of the inspection that was provided for this study. It is possible that an inspector who is not used to performing a certain type of inspection will perform a poorer inspection. The number of bridges an inspector inspects each year can provide some insight into the types of inspections that are usually performed. Also, the inspector responses to the SRQ question regarding percentage of time spent performing In-Depth Inspections and to the post-task question regarding the similarity of this task to his normal work can also be good indicators. Information concerning the number of bridges each subset of inspectors inspects per year is presented in table 203.

Table 203. Task H – Number of Annual Bridge Inspections.

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	388	246	N/A*	N/A
Weld Crack Indication	254	100	No	Yes
Multiple Crack Indications	317	76	No	No
Bolt Defect	413	250	No	No
Multiple Bolt Defects	463	249	No	No
Coating Defect	353	276	No	Yes
Distortion Defect	465	129	No	No
No Deficiencies	500	158	No	Yes

* N/A = Not applicable.

In general, In-Depth Inspections are more thorough inspections that may be performed on relatively large bridges. Given this fact, an inspector who performs a large number of inspections per year would probably be performing fewer In-Depth Inspections. Overall, the inspectors who completed this task inspected an average of 388 bridges per year. However, the inspectors who correctly identified a weld crack indication averaged 254 bridge inspections per year, with none inspecting more than 400 bridges per year. The inspectors who reported no deficiencies averaged 500 bridge inspections per year.

The results with regard to the similarity of this task to an inspector's normal In-Depth Inspection, as well as to the percentage of an inspector's inspections that are In-Depth Inspections, are less clear. Inspectors who correctly identified a weld crack indication or the flange distortion reported that they tended to spend more than 40 percent of their time performing In-Depth Inspections, while the overall average and the remainder of the other deficiency identification subsets tended to average between 32 and 36 percent. Also, overall, inspectors rated the similarity of this task to their normal In-Depth Inspections as a 7.5, while inspectors who correctly identified a weld crack indication or bolt defects rated it as a 7.7, and inspectors who noted the distortion rated it as an 8.2. However, with regard to these inspector responses, none of the subsets of the inspectors passed the t-test at the 10 percent significance level; therefore, these results are only presented for the general trends that they may exhibit.

INSPECTOR AGE AND BRIDGE INSPECTION EXPERIENCE: Inspector age and bridge inspection experience provide some noteworthy results. The results of the number of years of experience that the inspectors have in bridge inspection are presented in table 204. The overall average inspector age was 40. The inspectors who noted a weld crack indication, bolt defect, or coating defect had average ages of 39, 38, and 39, respectively. The inspectors who reported the flange distortion defect were, on average, 36 years old, while the inspectors who reported no deficiencies had an average age of 43. As none of these subsets of inspectors passed the t-test with 5 percent significance, these results are presented for general trends only. With regard to inspection experience, the overall average was 9.8 years. Inspectors who noted a weld crack indication, or bolt, coating, or distortion defect all averaged within 1.2 years of experience of the overall average. However, the inspectors who reported no deficiencies averaged 14.3 years of experience. These results indicate that more experienced inspectors may tend to report fewer defects.

EDUCATION AND FORMAL TRAINING: The education level and formal training of inspectors are both factors that may affect the work that an inspector performs. Table 205 shows the education level of the inspectors who completed this task. The inspectors are shown grouped into six categories, including all inspectors, inspectors who identified the four subsets of deficiencies, and inspectors who did not identify any deficiencies. Two conclusions can be

Table 204. Task H – Experience in Bridge Inspection (in years).

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	9.8	6.1	N/A*	N/A
Weld Crack Indication	8.6	4.9	No	No
Multiple Crack Indications	8.5	3.5	No	No
Bolt Defect	8.6	5.7	No	No
Multiple Bolt Defects	7.9	4.4	No	No
Coating Defect	8.8	5.8	No	Yes
Distortion Defect	10.3	7.2	No	No
No Deficiencies	14.6	7.3	Yes	Yes

* N/A = Not applicable.

drawn from this table. First, inspectors who identified a weld crack indication tended to have completed more formal education, with 71 percent of them having obtained a Bachelor's degree. Second, inspectors who did not identify any deficiencies tended to have an Associate's degree. Overall, 63 percent of them had obtained this degree. Combined, these findings indicate that the level of education may have an impact on inspection performance.

The number and type of formal training classes did not seem to have any effect on the results of this task. The results from each subset of inspectors were relatively similar to the overall averages for the courses studied. The overall results were provided within the presentation of the SRQ results.

Table 205. Task H – General Education Level.

Inspector Subset	Some High School	High School or Equivalent	Some Trade School	Trade School Degree	Some College	Associate's Degree	Bachelor's Degree	Some Graduate School	Master's Degree	Terminal Degree
All Inspectors	0%	18%	5%	0%	18%	20%	34%	2%	2%	0%
Weld Crack Indication	0%	14%	0%	0%	14%	0%	71%	0%	0%	0%
Bolt Defect	0%	24%	6%	0%	6%	18%	47%	0%	0%	0%
Coating Defect	0%	14%	3%	0%	24%	10%	41%	3%	3%	0%
Distortion Defect	0%	20%	0%	0%	20%	20%	40%	0%	0%	0%
No Deficiencies	0%	13%	13%	0%	0%	63%	13%	0%	0%	0%

PROFESSIONAL ENGINEER LICENSE: Following the study, inspectors were contacted to determine if they held a Professional Engineer (PE) license. Table 206 provides the corresponding results in terms of the subsets of inspectors defined for this task. This information shows no clear correlation between this factor and the inspection results. However, the small size of the sample, along with the small size of most inspector subsets, makes interpreting these results difficult.

Table 206. Task H – Inspectors holding a PE license.

Inspector Subset	PE License
Overall Sample	14%
Weld Crack Indication	29%
Multiple Crack Indications	33%
Bolt Defect	12%
Multiple Bolt Defects	20%
Coating Defect	14%
Distortion Defect	20%
No Deficiencies	13%

MANAGEMENT INSPECTION PHILOSOPHY: There are two locations from which inferences regarding this factor can be made. First, the SRQ contained a question regarding whether the management philosophy of their State focused more on identifying all defects in the bridge or on complying with NBIS regulations. Overall, 33 percent of the inspectors reported that their State focuses on complying with the NBIS regulations, while the remainder focused on finding all defects. Similar percentages held for most subsets of inspectors, except for the inspectors who noted a weld defect indication or the flange distortion, 80 and 86 percent, respectively, reported that their State focused on finding defects.

The SRQ also asked inspectors to report the level of control that their managers typically exercised over their inspections. Overall, 27 percent of the inspectors stated that they were provided with a detailed checklist for the inspections, 34 percent were provided with loose guidelines, and 39 percent were allowed to inspect solely using their own inspection knowledge and techniques. In general, these percentages held across the various subsets of inspectors who noted certain deficiency types.

The results presented above indicate that States that focus on finding defects may, in fact, locate more of the defects that occur in their bridge population. However, there is no clear indication that management playing a greater or lesser role in how the inspection is performed will affect the inspection results.

VISION: The near and far visual acuity of each inspector was quantified, with the overall data presented previously. Recall that the use of corrective lenses was allowed during this testing. With regard to this task, inspector visual acuity did tend to correlate with some subsets of inspectors. Specifically, four of the five inspectors who noted the distortion of the flange had 20/16 or better near and far vision in both eyes. The remaining inspector had 20/32 or better near and far vision in each eye. All the inspectors who correctly identified a weld crack indication had at least 20/20 far vision in both eyes and 86 percent had 20/20 near vision. The subset of inspectors who found bolt defects, the coating defect, or no deficiencies at all tended to fall within the overall distribution of inspector visual acuity. The correlation between visual acuity and the inspectors who found the weld or distortion defects may indicate that these types of defects are more likely to be located by inspectors who possess better vision.

ATTITUDE TOWARD WORK: Whether bridge inspectors find their work interesting tends to have a slight effect on the results that the inspector produces. Overall, the SRQ results show that inspectors rated their level of interest in their work at 4.5 on a 1 to 5 scale, with 5 being very interesting. The results for the specific subsets of inspectors are presented in table 207. This table shows that inspectors who noted defects tended to provide ratings slightly above the overall average, with inspectors who found weld crack indication, bolt defects, and coating defects providing a rating of 4.6 and inspectors who found the distortion defect providing a rating of 5.0. The inspectors who did not note any deficiencies provided an average rating of 4.0. Although a one-point difference on this scale is relatively minor, the fact that many of these subsets pass the t-test indicates that this factor may correlate with inspectors who perform differing qualities of inspection.

ENVIRONMENTAL FACTORS: The environmental factors did not have any discernible impact on the findings of this inspection. This is probably due to insufficient variability in the weather conditions encountered. Granted, factors such as these could adversely affect an inspection; however, the results obtained in this study provided no concrete data to support this supposition.

Table 207. Task H – Interest in Bridge Inspection Work.

Inspector Subset	Average	Standard Deviation	Pass t-Test?	
			5% Significance Level	10% Significance Level
Overall Sample	4.5	0.59	N/A*	N/A
Weld Crack Indication	4.6	0.53	No	No
Multiple Crack Indications	4.7	0.58	No	No
Bolt Defect	4.6	0.61	Yes	Yes
Multiple Bolt Defects	4.6	0.70	No	No
Coating Defect	4.6	0.50	Yes	Yes
Distortion Defect	5.0	0.00	Yes	Yes
No Deficiencies	4.0	0.53	Yes	Yes

* N/A = Not applicable.

5.3.3.3.2. Inspection Profiling

OVERVIEW: While each inspector was performing the task, the observer noted how the task was performed and what items were inspected. This information can be used to provide a pseudo-quantitative measure of the thoroughness of each inspection. Although the data collected were not sufficient to aid in the discussion of the identification of bolt, coating, or distortion defects, it was sufficient to provide a relatively complete rating as to the thoroughness of the weld inspection.

The weld inspection portion of Task H was divided into four parts based on the locations within the test bed that were probable places for weld crack indications to occur. These locations included the stiffener-to-girder connections, the drain-to-web connections, the utility bracket-to-web connections, and the lateral bracing-to-web connections. Inspectors were assigned rating points contingent on the thoroughness of their inspection of these areas. The rating point scheme is as follows:

- Stiffener-to-girder connection:
  - 0 points if very few or none of the connections were inspected, or
  - 1 point if most significant top flange connections were inspected, and
  - 1 point if most significant bottom flange connections were inspected.
- Drain-to-web connection:
  - 0 points if none of the connections were inspected, or
  - 1 point if some connections were inspected or if inspections were cursory, or
  - 2 points if all connections were inspected thoroughly.
- Utility bracket-to-web connection:
  - 0 points if none of the connections were inspected, or
  - 1 point if some, but less than 25 percent, of the connections were inspected, or
  - 2 points if between 25 and 75 percent of the connections were inspected, or
  - 3 points if more than 75 percent of the inspections were inspected.
- Lateral bracing-to-web connection:
  - 0 points if none of the connections were inspected, or
  - 1 point if some, but less than 25 percent, of the connections were inspected, or
  - 2 points if between 25 and 75 percent of the connections were inspected, or
  - 3 points if more than 75 percent of the connections were inspected.

This rating system allows each inspector to achieve a rating from 0 to 10 based on the thoroughness of his weld inspection. Note, however, that this rating system focuses on whether the inspector seemed to inspect the general categories of welded connections. It makes no inference as to whether the inspector performed a specific, individual inspection of each weld within the components in a systematic and complete manner that would allow for correct identification of weld crack indications.

RESULTS: The inspector thoroughness ratings were used to classify the inspectors into groups. The groups are defined as those inspectors who received a score of 8 to 10, those who received a score of 5 to 7, and those who received a score of 0 to 4. The following discusses these groupings of inspectors and the factors that tend to correlate with these groupings. Note that other divisions of the inspector sample were also studied, such as inspectors who received scores from 0 to 3, 4 to 6, and 7 to 10. In all cases, slight changes to the groupings of the inspectors provided no substantial change in the results presented in this section.

Forty-five percent of the inspectors earned an inspection thoroughness rating of 8 or higher. These inspectors could be considered to have completed a comparatively thorough In-Depth Inspection of the superstructure. Six of the seven inspectors who correctly identified a weld crack indication were in this group, and 11 of the 12 correct weld crack indication calls came from this group. Also, in terms of correct crack indication calls, a t-test comparison between this group and the remainder of the inspectors not in this group shows that the groups are different at a 5 percent significance level. Even so, the overall accuracy rate for this group at correctly identifying crack indications was only 8.0 percent.

Eighteen percent of the inspectors earned a profile rating from 5 to 7; thus, they are considered to have completed a partial In-Depth Inspection. One of the seven inspectors who correctly identified a weld crack indication fell into this group, accounting for only 1 of the 12 correct weld crack indication calls. The overall accuracy rate for this group for correctly identifying crack indications was 1.9 percent.

Finally, 36 percent of the inspectors earned a rating from 0 to 4. These inspectors can be considered to have performed an incomplete In-Depth Inspection. None of the inspectors who correctly identified a weld crack indication fell into this group.

Table 208 shows the results corresponding to the profile groupings of inspectors with regard to a number of factors. Various trends are evident in this table. Specifically, the inspectors who earned the higher profile ratings tended to take longer to complete the inspection, were generally more mentally focused, and were more comfortable than average when performing the inspection. These inspectors were also more likely to use a flashlight, to expect fatigue-related deficiencies, and to be closer to the welds that they were inspecting. The converse is true for each of these factors for the inspectors who earned the lower inspection profile ratings.

These results demonstrate that the type of inspection an inspector performs will probably have an influence on the type of results obtained. Inspectors who performed a more thorough weld inspection were much more likely to correctly identify a weld crack indication. As stated above, 92 percent of the correct weld crack indication identifications came from this group. The factors that correlate better with the more highly rated group than the other groups are the same factors that intuitively would seem likely to affect this type of inspection. In general, inspectors who received high weld inspection thoroughness ratings were the inspectors who also tended to be focused, had a high tolerance for working at heights, had managers who encouraged them to locate all deficiencies, used the necessary tools, and inspected in the more critical locations.

Table 208. Task H – Inspector profiling results.

Factor	Profile Rating 8-10		Profile Rating 5-7		Profile Rating 0-4	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
Actual Time to Complete Task (in minutes)	80	24	64	32	48	21
Reported Thoroughness Level	5.6	1.1	5.7	1.2	5.2	0.7
Reported Effort Level	5.3	0.7	5.2	0.9	5.0	0.7
Observed Inspector Focus Level	6.8	0.6	6.3	0.7	4.8	1.3
General Mental Focus	4.7	1.4	4.6	0.5	3.9	0.8
Experience in Bridge Inspection (in years)	8.6	4.6	10.4	5.1	11.0	8.1
Age (in years)	40	5.3	41	4.1	40	8.5
Fear of Heights	3.1	0.6	2.9	0.8	2.8	0.9
Observed Inspector Comfort With Heights	7.6	1.2	6.9	1.7	6.5	1.8
Management Inspection Philosophy: Locate All Defects	74%	N/A*	57%	N/A	62%	N/A
Expected Bridge Deficiencies: Fatigue-Related Deficiencies	70%	N/A	38%	N/A	44%	N/A
Tool Use: Flashlight	85%	N/A	50%	N/A	31%	N/A
Observed Distance to Weld Inspected (in meters)	0.58	0.64	1.01	0.98	1.98	3.6

* N/A = Not applicable.