# CHAPTER 8
# EVALUATION OF DECK STRESSES RESULTS

## 8.1 Introduction

This purpose of this chapter is to present the results of the evaluations of the deck stresses that were developed during testing of the Little Buffalo Creek Bridge. The evaluations consist of a comparison of the developed stress ranges in the deck to the allowable fatigue stress ranges from SAS-ASD (1994) and AASHTO LRFD (1994), and an evaluation of the longitudinal, mechanical deck splice that joins adjacent aluminum deck panels. The methods used during the evaluations are presented in Section 4.6.

## 8.2 Deck Stress Ranges from Available Field Data

The results of the stress ranges determined from the field data are shown in Tables 8.1 and 8.2, following this section. The tables were divided into stress ranges from transverse (TS) gauges and longitudinal (LS) gauges. The detail category determined in Section 4.6.3.1 is listed for each deck gauge. The highlighted value in each column represents the maximum stress range that was measured at each gauge location. As discussed in Section 4.2, gauge TS 2 in Test Set 2 contained a significant amount of signal noise, thus the stress ranges for TS 2 in Table 8.1 may be larger than what actually occurred.

Three of the six TS gauges and one of the LS gauges have maximums that resulted from load cases in Test Set 1, stationary static load cases without impact effects. As mentioned in Section 4.6.3.3, the stress ranges determined for load cases in Test Set 1 may not be the true stress range developed at the particular deck location. Larger stress ranges may result for side-by-side truck crossings if the maximum or minimum strains occur with the trucks in different longitudinal locations than those of Test Set 1.

Considering the longitudinal groove welds, Tables 8.1 and 8.2 indicate that for the load tests performed, the orthogonal loading of the groove welds was the more critical stress direction. All of the stress ranges for the parallel loading of the groove welds are below 0.5 ksi. The largest Category A stress range ($\sigma$ = 1.24 ksi) was developed at gauge

TS 6, which is just to the right of the mechanical deck splice between Girders 1 and 2. The largest Category B stress range (σ = 0.48 ksi) was developed at gauge LS 3, which is centered near the longitudinal weld between Girders 1 and 2. The largest Category C stress range (σ = 1.68 ksi) was developed at gauge TS 3, which is in the same location as gauge LS 3 just mentioned.

**Table 8.1 Stress Ranges from Field Data of TS Gauges**

| Test Set | Load Case | Stress Ranges (ksi) from Deck Gauges Deck Gauge/ (Detail Category) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | TS 1/ (C) | TS 2/ (A) | TS 3/ (C) | TS 4/ (C) | TS 5/ (A) | TS 6/ (A) | TS 7/ (C) |
| 1* | 1 | 1.04 | 1.22 | 0.82 | --- | 1.02 | 1.13 | 0.48 |
| | 2 | 0.40 | 0.21 | 0.54 | --- | 0.57 | 0.46 | 0.36 |
| 2** | 6 | 0.20 | 0.55 | 1.67 | --- | 0.97 | 1.24 | 1.16 |
| | 7 | 0.21 | 0.64 | 1.68 | --- | 0.93 | 1.21 | 1.16 |
| | 8 | 0.23 | 0.96 | 0.37 | --- | 0.56 | 0.43 | 0.24 |
| | 9 | 0.16 | 1.01 | 0.26 | --- | 0.50 | 0.35 | 0.16 |
| 3 | PS-1 | --- | --- | --- | 1.18 | --- | --- | --- |
| | PS-2 | --- | --- | --- | 1.25 | --- | --- | --- |
| | DYN-3 | --- | --- | --- | 1.32 | --- | --- | --- |
| | DYN-4 | --- | --- | --- | 1.23 | --- | --- | --- |
| | DYN-5 | --- | --- | --- | 1.34 | --- | --- | --- |
| | DYN-6 | --- | --- | --- | 1.50 | --- | --- | --- |
| | DYN-7 | --- | --- | --- | 1.44 | --- | --- | --- |
| | DYN-8 | --- | --- | --- | 1.16 | --- | --- | --- |

* Stress ranges obtained from stationary static tests at pre-selected locations
** Considerable signal noise present in TS 2

**Table 8.2 Stress Ranges from Field Data of LS Gauges**

| Test Set | Load Case | Deck Stress (ksi) Deck Gauge/ (Detail Category) | | | | |
|---|---|---|---|---|---|---|
| | | LS 1/ (B) | LS 2/ (A) | LS 3/ (B) | LS 4/ (A) | LS 5/ (A) |
| 1* | 1 | 0.32 | 0.33 | 0.17 | 0.18 | 0.42 |
| | 2 | 0.28 | 0.43 | 0.24 | 0.21 | 0.32 |
| 2 | 6 | --- | 0.28 | 0.48 | 0.21 | 0.71 |
| | 7 | --- | 0.28 | 0.44 | 0.22 | 0.70 |
| | 8 | --- | 0.40 | 0.14 | 0.19 | 0.21 |
| | 9 | --- | 0.42 | 0.15 | 0.20 | 0.21 |
| 3 | PS-1 | --- | --- | --- | 0.19 | --- |
| | PS-2 | --- | --- | --- | 0.18 | --- |
| | DYN-3 | --- | --- | --- | 0.18 | --- |
| | DYN-4 | --- | --- | --- | 0.21 | --- |
| | DYN-5 | --- | --- | --- | 0.17 | --- |
| | DYN-6 | --- | --- | --- | 0.21 | --- |
| | DYN-7 | --- | --- | --- | 0.18 | --- |
| | DYN-8 | --- | --- | --- | 0.18 | --- |

* Stress ranges obtained from stationary static tests at pre-selected locations

**8.3 Deck Stress Ranges Compared to Allowable Fatigue Stress Ranges**

The design allowable stress ranges for comparison to the stress ranges from the field data were calculated from the methods discussed in Section 4.6.3. Three different values of N were used to allow for comparisons between possible calculated, allowable fatigue stress ranges. Table 8.3 represents the allowable fatigue stress ranges from SAS-ASD (1994) and AASHTO LRFD (1994) for the three values of N considered.

Two million-cycles was the N value used during the design calculations, and represents the number of cycles determined from AASHTO SSHB (1996). The cycle value of N equal to $1.26 \times 10^6$ cycles corresponds to an $(AADT)_{SL}$ of 46 trucks determined from the actual AADT of 54 trucks (as listed in the design calculations) using Equations 4.15 and 4.16. The same equations were used to determine the value of N equal to $2.32 \times 10^6$ cycles, which corresponds to an $(AADT)_{SL}$ of 85 trucks and an AADT of 100 trucks (as listed in the design calculations).

**Table 8.3 Allowable Fatigue Stress Ranges**

| Specification | Detail Category | Allowable Fatigue Stress Ranges (ksi) for N cycles | | |
|---|---|---|---|---|
| | | $N=1.26x10^6$ | $N=2.00x10^6$ | $N=2.33x10^6$ |
| SAS-ASD (1994) | A | 12.4 ksi | 11.6 ksi | 11.3 ksi |
| | B | 7.1 ksi | 6.5 ksi | 6.3 ksi |
| | C | 5.9 ksi | 5.2 ksi | 5.0 ksi |
| AASHTO LRFD (1994) | A | 11.7 ksi | 10.9 ksi | 10.7 ksi |
| | B | 9.42 ksi | 8.5 ksi | 8.3 ksi |
| | C | 6.6 ksi | 5.9 ksi | 5.7 ksi |

Table 8.3 shows that the allowable fatigue stress ranges from SAS-ASD (1994) for Categories B and C are less than those from AASHTO LRFD (1994); approximately 30 percent for Category B and 13 percent for Category C. The previously mentioned maximum stress ranges determined from the field data for each detail category are considerable lower than the allowable fatigue stress ranges of Table 8.3.

The maximum stress ranges from the field data were compared to the fatigue limit specified by SAS-ASD (1994). As discussed in Section 4.6.3.2.1, SAS-ASD (1994) states that fatigue need not be considered for variable-amplitude loading if the maximum stress range in a spectrum of loads is beneath the constant-amplitude fatigue limit. The constant amplitude fatigue limits for Categories A, B, and C are 10.2 ksi, 5.4 ksi, and 4.0 ksi, respectively. These values can be calculated from Equation 4.12 or read from Figure 4.7. The constant-amplitude fatigue limits from SAS-ASD (1994) are 8.2, 11.2, and 2.3 times the maximum field measured stress ranges for Categories A, B, and C, respectively. Noting the limitations of the stress ranges determined from Test Set 1, the spectrum of loads covered in the testing of the Little Buffalo Creek Bridge would not even need to be considered for possible fatigue damage.

Comparisons between the fatigue limits from AASHTO LRFD (1994) and the maximum stress ranges from the field data again show that for the spectrum of loads applied fatigue would not be of concern. The AASHTO LRFD (1994) fatigue limits of

4.75 ksi, 3.0 ksi ,and 2.0 ksi as calculated from the infinite life portion of Equation 4.14 are 3.8, 6.25, and 1.2 times the maximum stress ranges determined from the field data for Categories A, B, and C, respectively.

**8.4 Evaluation of the Mechanical Deck Splice**

The available data allows for only a crude evaluation of the longitudinal, mechanical deck splice connecting adjacent aluminum deck panels between Girders 1 and 2. The purpose of the evaluation was to determine if any significant stress discontinuities appeared across the deck splice during the load tests. The deck gauges used in the evaluation were TS 4, TS 5, TS 6, and TS 7. Refer to Figure 4.9 for an illustration representing the deck gauge locations with respect to the mechanical deck splice between Girders 1 and 2.

As explained in Section 4.6.4, combinations of results for similar load cases from different test sets were used when possible. In particular, Load Cases DYN-5 and DYN-6 of Test Set 3 were conducted at 45 mph with Test Truck 3. Similarly, Load Case 6 of Test Set 1 was conducted at 47 mph with Test Truck 1. As discussed in prior sections, the test trucks were nearly identical; therefore, an average of the stress ranges developed at TS 4 from Load Cases DYN-5 and DYN-6 was determined to combine with the other deck stress ranges from Load Case 6. In addition, stress ranges from gauge TS 4 for Load Cases DYN-3 and DYN-4 (25 mph) were averaged and combined with Load Case 7 (20 mph). No other combinations were considered to be possible; therefore, TS 4 is not included in the evaluations for Load Cases 1, 2, 8, and 9. Table 8.4, following this section, shows the stress ranges from the TS gauges across the mechanical deck splice between Girders 1 and 2.

The low magnitude of the deck stresses does not allow for accurate percent comparisons between stress ranges across the splice. Based on the available field data, there does not appear to be any gross discontinuities in stress ranges occurring across the mechanical deck splice. The largest difference in stress ranges directly across the splice (TS 5 and TS 6) is 0.28 ksi, which corresponds to approximately 28 $\mu\varepsilon$.

**Table 8.4 Stress Ranges for Mechanical Deck Splice Evaluation**

| Load Case | Stress Ranges (ksi) | | | |
|---|---|---|---|---|
| | TS 4 | TS 5 | TS 6 | TS 7 |
| 1 | --- | 1.02 | 1.13 | 0.48 |
| 2 | --- | 0.57 | 0.46 | 0.36 |
| 6 (combined) | 1.42* | 0.97 | 1.24 | 1.16 |
| 7 (combined) | 1.3** | 0.93 | 1.21 | 1.16 |
| 8 | --- | 0.56 | 0.43 | 0.24 |
| 9 | --- | 0.50 | 0.35 | 0.16 |

* Range from Average of Load Cases DYN-5 and DYN-6
**Range from Average of Load Cases DYN-7 and DYN-8

### 8.5 Limitations of Deck Stress Evaluations

Several factors serve to limit the previously discussed evaluations of the deck stresses. First, the location of the deck gauges on the deck may not correspond to the locations where the maximum stress ranges were occurring. On this same note, the top of the aluminum deck has longitudinal groove welds that may be experiencing considerably larger stress ranges. Although the groove welds on the top have been ground flush, which should serve to increase the fatigue resistance, the stress ranges may be considerably larger due to the affects of localized bending of the top flange beneath the truck tires.

Second, the limited number of tests only allows for general comparisons and no solid conclusions can be reached about the true fatigue behavior of the deck or the mechanical splice. The testing did not provide a representative load spectrum that the bridge would undergo while in service; therefore, calculation of an equivalent stress range to be compared to the allowable fatigue stress range was not possible. It is possible that other types of loading (i.e., simultaneous side-by-truck loading) could produce higher stresses that initiate cracks, which may propagate at stress levels as low as the values determined from the field data.

## 8.6 Summary and Need for Research

The stress ranges determined from the available field data were well below the typical allowable fatigue stress ranges for Categories A, B, and C for various numbers of cycles that could possibly be used in design. Moreover, the maximum stress ranges for each detail category were lower than the fatigue limits from both SAS-ASD (1994) and AASHTO LRFD (1994). Based on the available field data and the load test spectrum, fatigue does not seem to be a topic of concern. The evaluation of the mechanical deck splice between Girders 1 and 2 showed stress ranges that were all below 1.30 ksi with no gross discontinuities in stress range resulting from the load tests; however, the available data did not allow for a firm conclusion to be drawn.

There is a definite need for laboratory research concerning the fatigue behavior of the groove welds on the top and bottom panels of the aluminum deck. Laboratory testing should involve full-scale deck panels subjected to simulated tire patches to provide a true representation of the welded condition. The mechanical splice may be another connection that needs to be tested for fatigue resistance under laboratory loading. Also, future testing of the Little Buffalo Creek Bridge could be conducted under normal traffic, while monitoring the deck strains. Stress ranges from a sizeable sample (i.e., 300 vehicles) could be evaluated to determine the maximum and minimum stress ranges that a particular detail undergoes. Cycle counting over the sample could be conducted and an equivalent stress range could be calculated that may be more typical of the stress range needed for comparison to the allowable fatigue stresses for the different detail categories. This type of approach has been taken by Stallings et al (1996) in evaluating fatigue of steel diaphragm-girder connections.

The equivalent stress range from the normal traffic load spectrum could serve as the target stress range for constant-amplitude laboratory testing. If the load spectrum found from normal traffic contains considerable stress ranges that exceed the allowable fatigue stress ranges for the particular detail category, then variable-amplitude block loading representing the normal traffic load spectrum may be more logical for laboratory testing.