CHAPTER 3
TESTING MATERIALS AND PROCEDURES

3.1 Introduction

The purpose of this chapter is to describe the materials used during the load tests and the procedure for carrying out the tests. Descriptions of the bridge, test trucks, data acquisition system and gauges, and load cases are included.

3.2 Bridge Description

The bridge is located in Mecklenburg County, VA on US Route 58 over Little Buffalo Creek, hence the title Little Buffalo Creek Bridge. Construction ended in June 1996. The aluminum bridge deck is a replacement of a reinforced concrete bridge deck that spanned 54 ft and was 22 ft wide. The original bridge was 67 years old and was deemed "functionally obsolete" because of its narrow width. The new bridge deck is wider and weighs approximately 40,000 pounds, which is over 120,000 pounds less than the narrower reinforced concrete deck. The new bridge is a simply supported span of 54'-7 1/4 " (53'-3 3/4" center-to-center of bearing) and is 32 ft wide (28 ft face-to-face of curbs). Figures 3.1 and 3.2 show an elevation and plan view of the Little Buffalo Creek Bridge, respectively. The significant decrease in weight of the new bridge allowed the existing foundations to be used. This research dealt with the behavior of the superstructure of the bridge and not the substructure; therefore, only a brief description of the substructure will be included.

3.2.1 Superstructure

3.2.1.1 Aluminum Deck Description

The aluminum deck is a system of longitudinally welded extrusions that combine to form cellular deck panels. Typical extrusion shapes are shown in Figure 3.3. The shape in Figure 3.3a is the three-void shape and the two-void shape is shown in Figure 3.3b. The Little Buffalo Creek Bridge employs the two-void shape, which is shown in

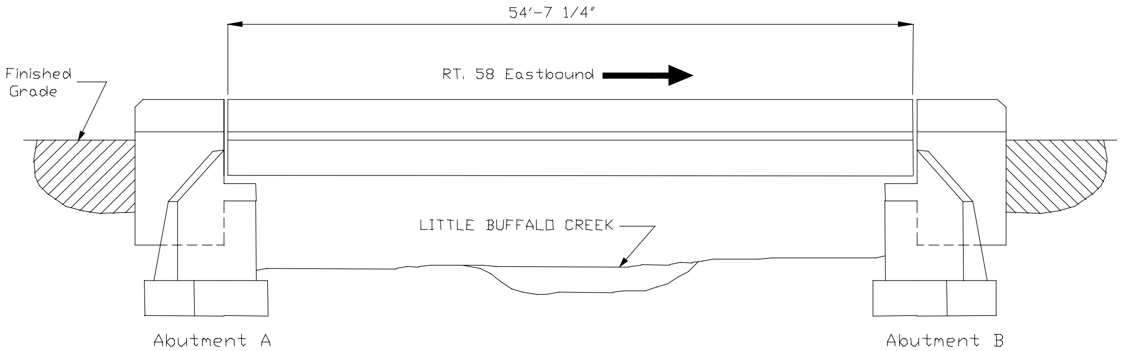


Figure 3.1 Elevation of Little Buffalo Creek Bridge (Adapted from VDOT bridge plans)

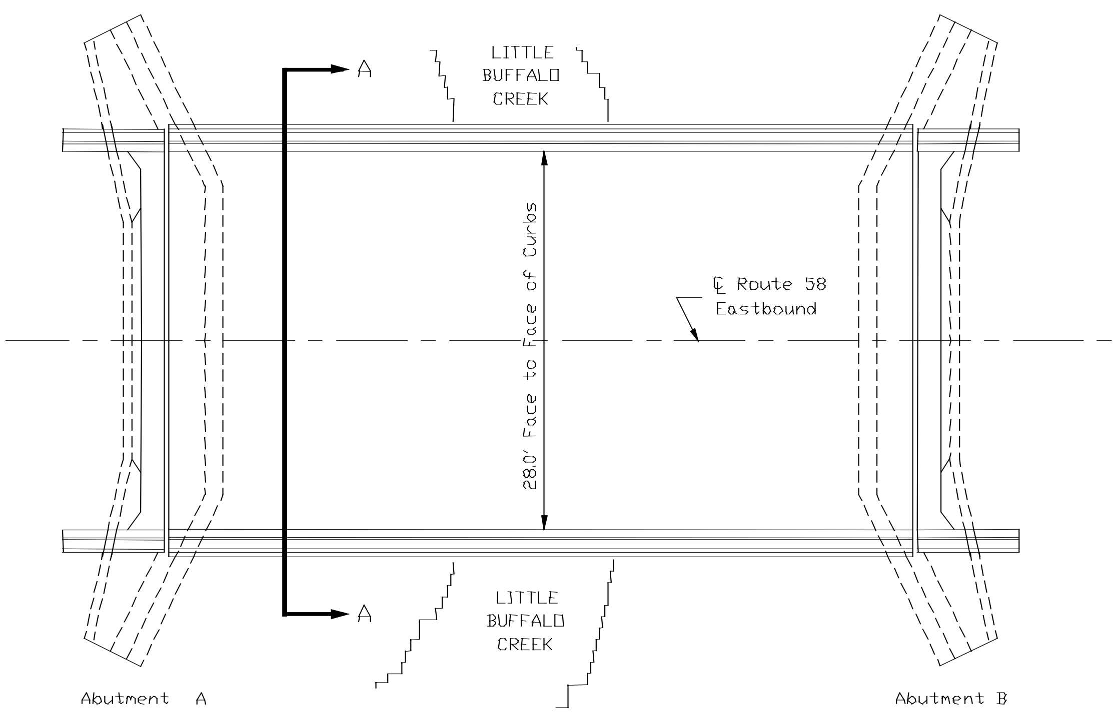
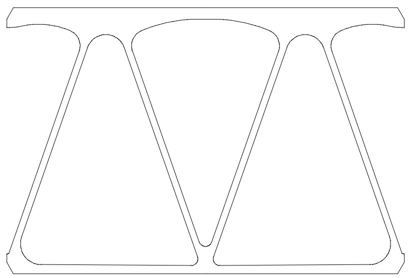
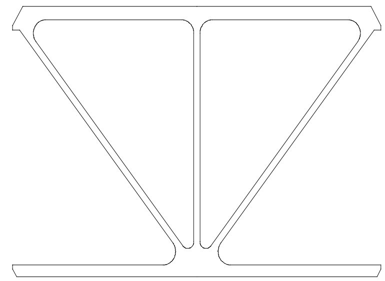


Figure 3.2 Plan View of Little Buffalo Creek Bridge (Adapted from VDOT bridge plans)



(a)



(b)

Figure 3.3 Deck Extrusion Shapes

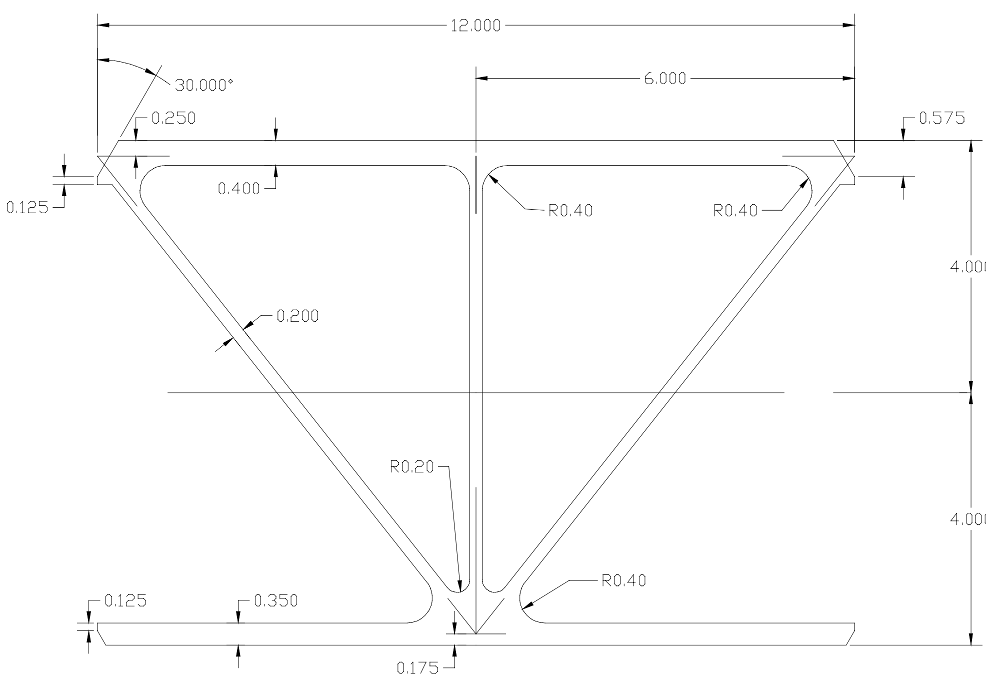


Figure 3.4 Two-Void Extrusion Detail

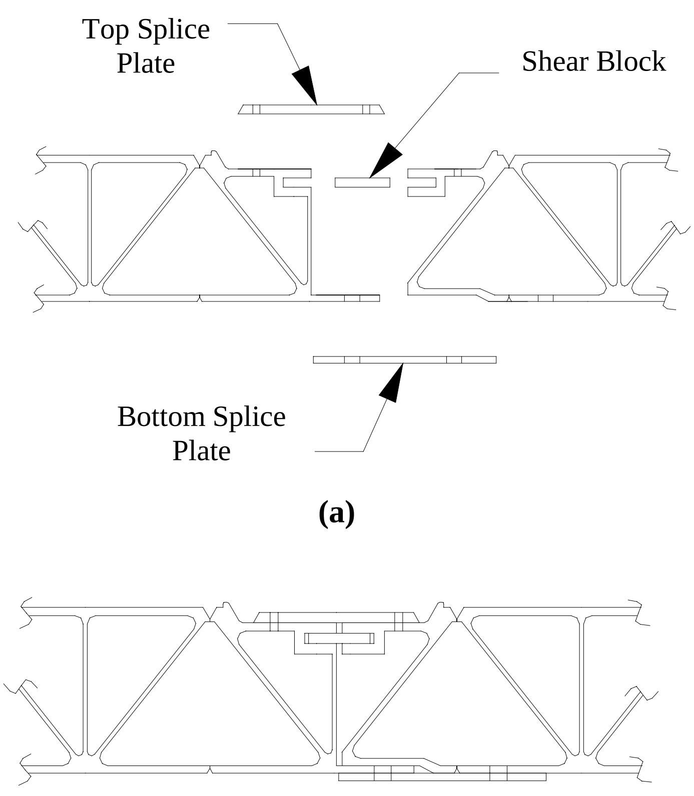
better detail in Figure 3.4. The extrusions are manufactured in one-foot widths and various lengths, and are made of ASTM B221 Grade 6063-T6 aluminum. The bending stiffness in the longitudinal direction is nearly four-percent larger than in the transverse direction for the two-void shape used in the Little Buffalo Creek Bridge. Table 3.1 lists the material properties of 6063-T6 aluminum and the cross-sectional properties of the two-void shape.

Table 3.1 Mechanical and Cross-sectional Properties of Two-Void Extrusion

	Minimum Mechanical Properties*				
	Tension		Compression	Mod. of Elasticity	Coeff. Thermal Expansion
Alloy	$F_{ultimate}$	F_{yield}	F_{yield}	E	α_{Al}
6063-T6	30 ksi	25 ksi	25 ksi	10100ksi	12.8×10^{-6} in/in-^oF
*Aluminum Design Manual (1994)					
	Cross-section Properties**				
Extrusion Shape	Area	Principal Mom. Of Inertia		Depth to Neutral Axis	
	A	Ixx	Iyy	y top	y bottom
2-void	15.05 in^2/ft	163.24 in^4/ft	156.93 in^4/ft	4 in.	4 in.
**Reynolds Metals Company					

The one-foot wide extrusions are welded on their sides with a continuous, longitudinal groove weld to form a cellular deck panel. The diagonal web members shown in Figure 3.4 form triangular cells that resemble a truss. The one-foot wide extrusions are staggered in length and welded transversely at their ends to allow for greater panel lengths and a near joint free deck system. Because the aluminum deck is essentially isotropic, the deck could be oriented with the extrusions parallel or perpendicular to the longitudinal steel girders. The preferred orientation, as in the Little Buffalo Creek Bridge, is with the extrusions parallel to the girders. Parallel orientation allows for easier connection to the girders and higher allowable stresses for System I bending (Matteo 1997).

The aluminum deck system for the Little Buffalo Creek Bridge is comprised of three separate deck panels. The deck panels were shop constructed to be the entire length of the bridge using the one-foot wide extrusions and the welding process previously mentioned. The middle panel is 14 ft. wide, and the two exterior panels are 9 ft. wide. As shown in Figure 3.5a, the panels are shop-fitted with mechanical splice connection pieces on each side to allow for connection between adjacent panels. The sides of the mechanical splice are field connected using top and bottom flange splice plates, a shear block, and appropriately spaced fasteners, and are shown in the connected position in Figure 3.5b. The welds are not shown for clarity. Figure 3.6 shows the deck panel plan, including longitudinal weld locations and mechanical splice locations.



(a)

(b)

Figure 3.5 Mechanical Deck Splice Cross-section

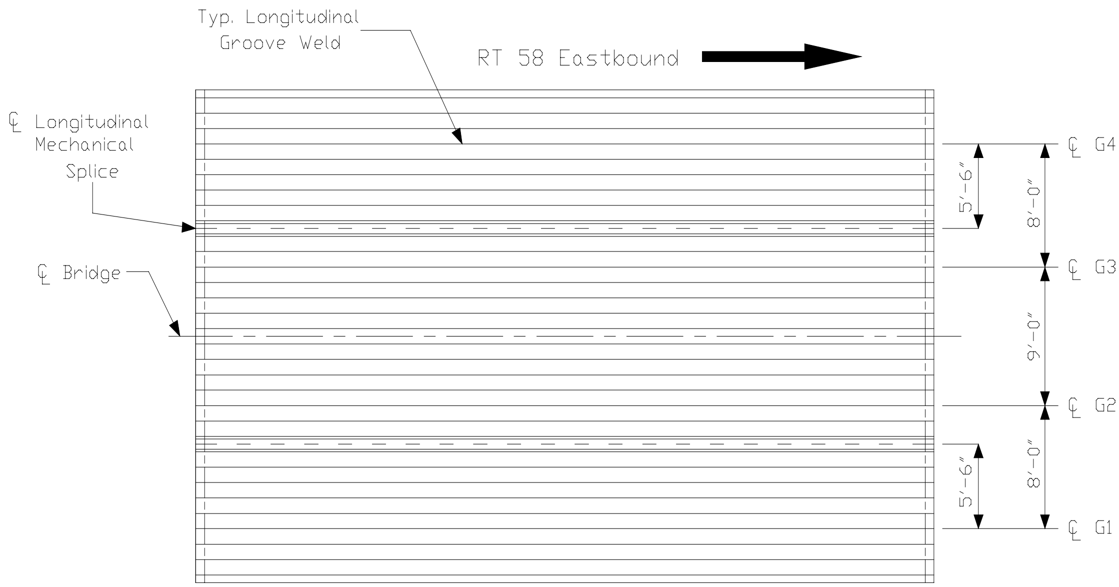


Figure 3.6 Plan View of Entire Aluminum Deck
(Adapted from VDOT Bridge Plans)

3.2.1.2 Aluminum Deck to Steel Girder Connection

Proper connection between the aluminum deck panels and the supporting steel plate girders was required to provide for composite action. The aluminum deck acting composite with the steel plate girders allows for a greater effective width of deck panel to resist bending (Matteo et al 1996). In addition, the section modulus and moment of inertia of the composite aluminum deck/steel girder section is increased. In this particular bridge, shear studs were placed on the top flanges of the steel girders as would be done with a composite reinforced concrete deck. The design of the shear studs took into account the interface shear from dead load, live load, and thermal expansion differences. The thermal interface shear had to be included because the coefficient of thermal expansion of aluminum (α_{Al}=12.8x10^{-6} in/in-^{o}F) is roughly twice that of steel (α_{ST}=6.5x10^{-6} in/in-^{o}F). The aluminum deck panels were shop-drilled in the appropriate locations above the steel girders to provide holes for the shear studs. The panels were set into place above the girders using shim plates to provide for the appropriate haunch depth. The aluminum deck was made to act composite with the steel plate girders by injecting high strength grout slurry into the deck voids and encasing the shear studs. The grout used was a magnesium phosphate grout with a modulus of elasticity of 5,250 ksi at 28 days and a minimum strength of 6 ksi. The grout extends the entire length of the bridge within the voids and also forms the nominal 2 in. haunch at each girder location. Figure 3.7 shows a cross section of the entire aluminum deck and steel plate girder system, and Figure 3.8 shows an enlarged view of the grouted connection.

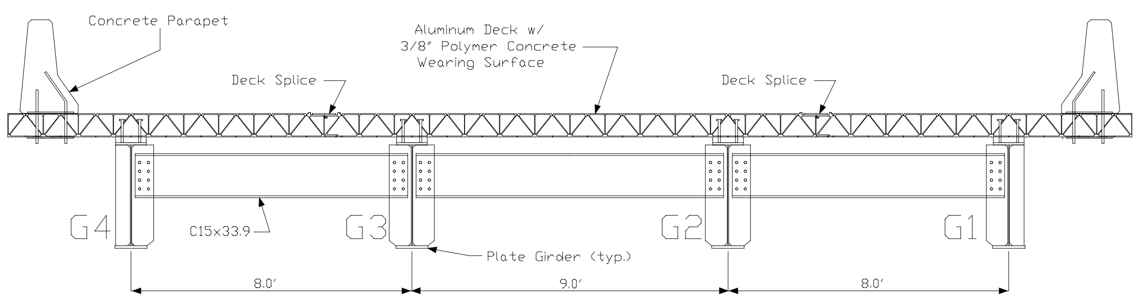


Figure 3.7 Transverse Section of the Little Buffalo Creek Bridge Superstructure (Section A-A of Figure 3.2)

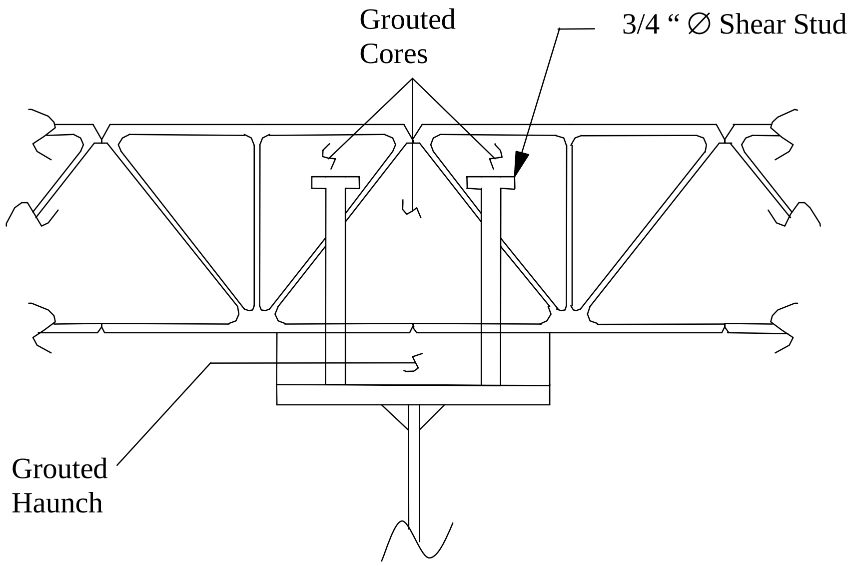


Figure 3.8 Grouted Connection between Deck and Girders (Adapted from VDOT Bridge Plans)

3.2.1.3 Steel Girders

Four steel plate girders spanning 55 ft. provide the longitudinal support for the bridge deck. The steel plate girders were constructed using ASTM A709, Grade 50 steel. A transverse section of the Little Buffalo Creek Bridge in Figure 3.7 shows the girder spacing. The girders are numbered one to four, with Girder 1 being the far right girder looking east. All four-plate girders have the same cross section. The plate girders are comprised of a 3/4 in. x 10-1/2 in. top flange plate, a 7/8 in. x 11 in. bottom flange plate, and a 7/16 in. x 34-3/8 in. web plate. The steel plate girders are braced at the ends and at the one-third points by transverse diaphragms. The diaphragms, shown in Figure 3.7, are C15x33.9 structural steel C-shapes fabricated of ASTM A709, Grade 36 steel. Additional diaphragm deck support plates are provided at the abutments, but are not shown in Figure 3.7 for clarity. The diaphragm to girder connection shown in Figure 3.7 is provided by 7/8 in. diameter A325 high strength bolts, bolted to the stiffeners within the plate girders' depth. The stiffeners are 1/2 in. x 7-1/2 in. full depth plates at all locations except for the exterior bearing stiffeners on Girders 1 and 4. The exterior bearing stiffeners at these locations are 1/2 in. x 5 in. full depth plates. The stiffeners are ASTM A709, Grade 36 steel.

3.2.2 Substructure

The substructure of the Little Buffalo Creek Bridge consists of the abutments and the bearings. The abutments were partially reconstructed during the construction process. The abutments are typical gravity abutments with wingwalls. A typical gravity abutment has a bridge seat, backwall, wingwalls, and an integral footing (Barker and Puckett 1997). Figures 3.1 and 3.2 contain a side elevation and plan view of the abutments, respectively.

Sole plates in combination with steel-laminated elastomeric bearing pads provide the bearings at Abutments A and B.

3.2.3 Secondary Elements

The three aluminum deck panels were shop-coated with a 3/8 in. polymer concrete wearing surface. After adjacent panels were connected in the field with the mechanical deck splice previously described, the remaining surface of the aluminum deck assemblage was field coated with the polymer concrete wearing surface. In addition, reinforced concrete parapets were installed on each side of the bridge as shown in Figure 3.7. The parapets were constructed with Class A4 concrete with a minimum compressive strength of 4000 psi at 28 days. The parapets were connected to the aluminum deck by threaded 3/4 in. diameter, galvanized steel rods connected through the deck and embedded into the concrete parapet. The threaded rods were connected through the deck using galvanized steel plates on the top and bottom surfaces of the deck beneath the parapet.

3.3 Test Truck Descriptions

Three different test trucks were used during the load tests. The test trucks had three-axle configurations, with only minor differences in axle dimensions amongst them. Figure 3.9, accompanied by Table 3.2, gives the plan dimensions of each test truck, total weight, and front axle weight for each truck. Truck 1 was the only truck that had actual front axle weights recorded; however, the trucks had nearly identical plan dimensions and the total weight differences between the trucks were less than 4-1/2 percent. Therefore, it was estimated that the percentage of weight distributed between the front and rear axles for Truck 1 was the same for Trucks 2 and 3. In addition, the rear tandem-axle weight for each truck was assumed to be carried equally by each rear axle. Truck 3 is the same type of truck as Truck 1, but with different total weight.

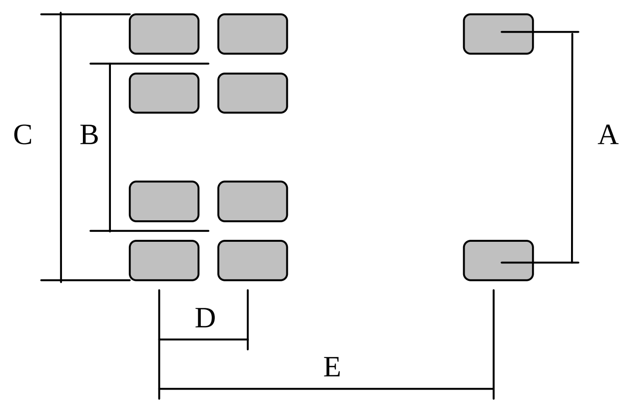


Figure 3.9 Plan View of Test Trucks

Table 3.2 Test Truck Plan Dimensions and Axle Weights

Truck/ Type	Dimension A	Dimension B	Dimension C	Dimension D	Dimension E	Total Wt (lb)	Front Axle Wt. (lb)
Truck 1/ International	6’-9.0”	6’-0.0”	7’-9.0”	4’-5.5”	18’-9.5”	57860	14280
Truck 2/ Ford	6’-9.0”	6’-0.0”	7’-9.0”	4’-5.0”	19’-3.0”	55600	13720*
Truck 3/ International	6’-9.0”	6’-0.0”	7’-9.0”	4’-5.5”	18’-9.5”	58020	14320*

*Estimated

The Little Buffalo Creek Bridge was designed for HS20-44 Loading and Alternate Military Loading as required by AASHTO SSHB (1989). The HS20-44 Loading for moment corresponds to either an HS20-44 design truck with variable rear axle spacing (14 ft to 30 ft, inclusive) or a uniform lane load (0.64 kip/ft) combined with a single concentrated load (18 kip). The Alternate Military Loading corresponds to two axles (24 kip each) spaced 4 ft apart. For the simply supported span of 53’-3 3/4” of the Little Buffalo Creek Bridge, the HS20-44 design truck governs the live load bending moment and will be the loading used for comparison to the test trucks. The HS20-44 design truck has the same axle configuration and weight as the design truck part of the HL-93 live load model (Barker and Puckett 1997). The HL-93 live load model specifies the uniform lane load (0.64 kip/ft) to be applied simultaneously with the design truck; however, for comparison to the tests performed with the previously described test trucks, only the design truck portion is considered. Figure 3.10 shows the axle weights and axle spacing of the HS20-44 truck. The actual location of maximum bending moment resulting from a set of concentrated axle loads traversing a simple span occurs under one of the concentrated loads when the particular load is as far from one end as the center of gravity of the concentrated loads is from the other end. However, for simplicity and to match gauge locations, the point of reference is at mid-span.

The maximum live load bending moments at mid-span created by the test trucks and the HS20-44 design truck were calculated for comparison. The influence line for mid-span moment of the Little Buffalo Creek Bridge was analyzed with each truck’s axle configuration and weight. The ratio of the live load moment from each truck to the HS20-44 live load moment is shown in Table 3.3. The ratios are all around 90 percent which signifies that the test trucks are representative of the design truck for bending effects. Bakht and Pinjarkar (1989) express the importance of using test trucks that have similar effects on the structure as the design truck. Bakht and Pinjarkar (1989) suggested that the data used in evaluating the statistics of the dynamic amplification factor agree with the weight class of the design or evaluation vehicle. This requirement prevents the use of dynamic amplification factors from lighter vehicles, which are higher, that tend to sway the results.

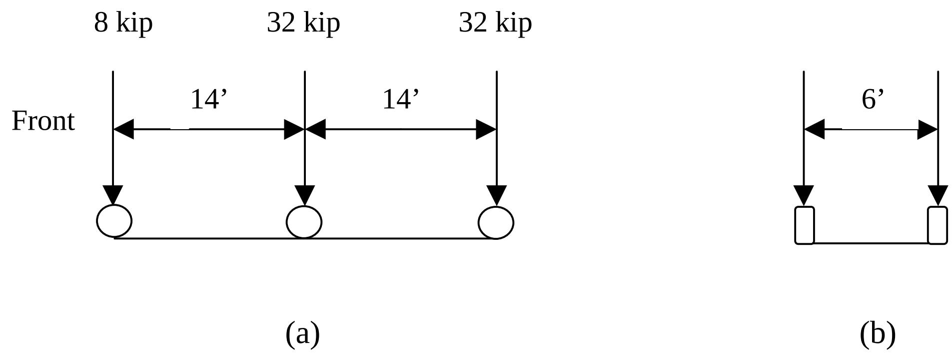


Figure 3.10 Axle Weights and Spacing for HS20-44 Truck

Table 3.3 Truck Live Load Moments at Mid-span

Truck/ Type	Live Load Moment	% HS20-44
HS20-44	680 kip-ft	-----
Truck 1/ International	620 kip-ft	91%
Truck 2/ Ford	593 kip-ft	87%
Truck 3/ International	622 kip-ft	91%

3.4 Data Acquisition Procedures

3.4.1 Data Acquisition System and Instruments

The data acquisition system used by VTRC was a MEGADEC 3108 DC with AD 684SH-1 Analog Input Modules. The WIM gauges were Bridge Weighing Systems Transducers No. ZM 54AA. The deflectometers were made at the FHWA Turner-

Fairbanks Research Center's Structures Laboratory, and were essentially full-bridge strain gauges attached to a cantilever beam. The strain gauges used on the deck were Micro Measurement CEA-13-250UW-350 gauges (1/4 in. gauge length and a resistance of 350 ohms) with pre-attached lead wires. Data was recorded every 1/200 of a second for all data acquisition instruments in the dynamic and pseudo-static load cases.

3.4.2 Gauge Layout

All data acquisition instruments were located and placed by personnel from VTRC. There were eight WIM gauges, four deflectometers, and 12 deck strain gauges used in this research. All instruments used in this research are located at the mid-span of the Little Buffalo Creek Bridge.

The WIM gauges were located on the top and bottom flanges of each girder. The top flange WIM gauges were on the underside of the top flanges and the bottom flange WIM gauges were on the upper-side of each bottom flanges. Figure 3.11 shows the WIM gauge locations four all girders. In addition, the deflectometers were clamped to the bottom flange of each girder at mid-span.

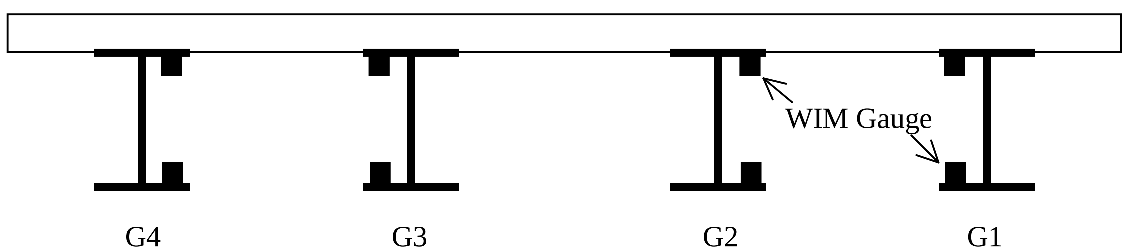
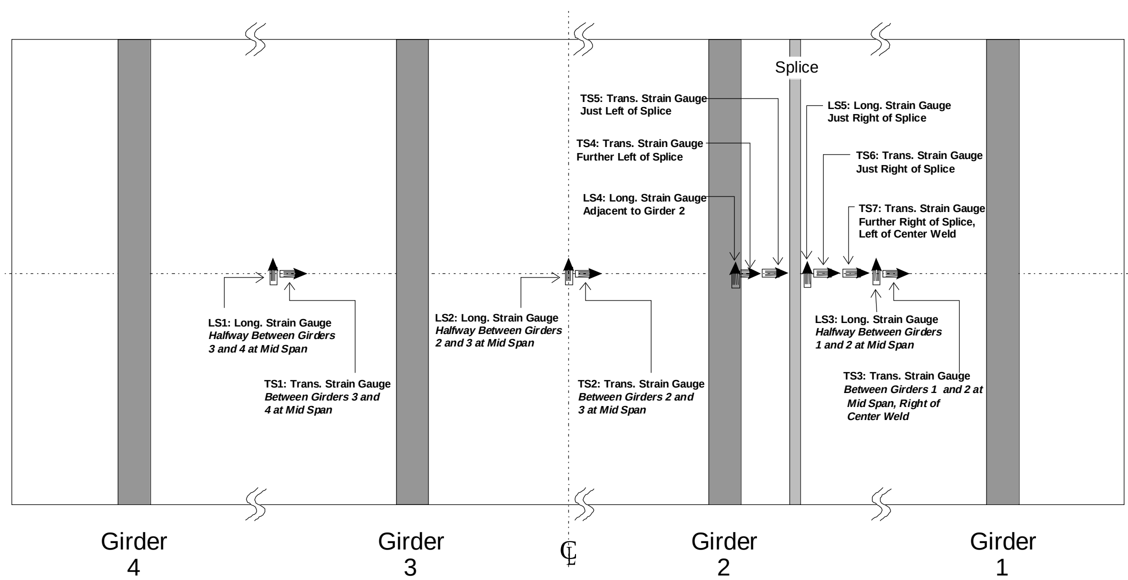


Figure 3.11 WIM Gauge Locations

The deck strain gauges were divided into two distinct groups. There were five longitudinal strain gauges, which are denoted as LS gauges. The LS gauges were oriented to measure strain parallel to the flow of traffic. The remaining seven deck gages were placed in a manner to measure strains perpendicular to the flow of traffic. These gauges had a transverse orientation and will be denoted as TS gauges. Figure 3.12 shows the strain gauge instrumentation plan with relative locations. The deck gauges were used to observe the deck stresses at locations that were entirely base metal and at locations adjacent to longitudinal groove welds. The TS gauges located on opposite sides of the mechanical deck splice between G1 and G2 were used to identify any stress discontinuities that may have appeared across the splice. The author determined more accurate lateral locations to the deck gauges after VTRC personnel had placed the gauges. Prior to taking the measurements, VTRC had covered the deck gauges with protective padding; therefore, the measurements were approximate. Table 3.4 lists each deck gauge with its approximate location from a particular reference point, as well as if the gauge was adjacent to a weld location. Reference Figure 3.6 for a plan view of the longitudinal groove weld and mechanical deck splice locations.

Not all data channels were connected or used during the recording or evaluation of the field data. The testing was performed in three different test sets. The three test sets used during the testing of the bridge contained different combinations of the available data channels.



* From the point of view of someone underneath the bridge, looking up.

Figure 3.12 Deck Strain Gauge Plan
(Adapted from VTRC drawing)

Table 3.4 Location of Deck Gauges

Deck Gauge	Location	Near Weld? *
LS 1	Approx. 1/2" to the left of center weld between G3 and G4	Y
LS 2	4.5' to left of centerline G2;centered between G2 and G3	
LS 3	Approx. 1/2" to the right of center weld between G1 and G2	Y
LS 4	Approx. 1/2" to the right of top flange G2	
LS 5	Approx. 1/2" to the right of bottom splice plate between G1 and G2	
TS 1	Same as LS 1	Y
TS 2	Same as LS 2	
TS 3	Same as LS 3	Y
TS 4	Approx. 5-1/2" to the left of bottom splice plate between G1 and G2	Y
TS 5	Approx. 1/2" to the left of bottom splice plate between G1 and G2	
TS 6	Same as LS 5	
TS 7	Approx. 7" to right of bottom splice plate between G1 and G2	Y

*Near weld is approximately within 1 in. of the weld edge

3.5 Load Case Descriptions

The purpose of this section is to describe the load cases conducted by VTRC. The load cases were performed in three sets at different times, and the load case names follow the nomenclature utilized by VTRC. Each test set description identifies the truck(s) used, the truck(s) speeds, and the transverse location on the bridge.

It is noted that during the load cases, VTRC aligned the trucks assuming that the painted centerline of the bridge coincided with the actual centerline of cross-section. The author measured the painted lanes at mid-span of the bridge surface and found that the right lane was approximately 9 ft wide and the left lane was nearly 11 ft wide. The painted centerline is approximately one foot closer to Girder 2 than would be expected for perfectly symmetrical lanes. The figures referenced in the following section concerning the transverse location of the test trucks reflect this difference.

3.5.1 Test Set 1 Description

Test Set 1 utilized Trucks 1 and 2 (see Figure 3.9 and Table 3.2) in a static fashion for a total of two load cases. The test trucks were positioned side-by-side with the first rear axle of each truck located at the 1/4, 1/2, and 3/4 span point of the Little Buffalo Creek Bridge. The load cases were designated “Max Girder Strain” and “Max Deck Strain” by VTRC, but are also referred to as Load Case 1 and Load Case 2, respectively. Load Case 1 was meant to maximize girder strains; therefore, VTRC intended to position the trucks transversely with each truck having its interior wheel line directly over an interior girder. Load Case 2 was designed to maximize the deck strains and thus the trucks were intended to straddle the interior girders (Girders 2 and 3). Figures 3.13a and 3.13b, shown at the end of this chapter, show the actual transverse location of the trucks for Load Cases 1 and 2, respectively, and account for discrepancies in the painted lanes mentioned previously.

3.5.2 Test Set 2 Description

Test Set 2 utilized Truck 1 (see Figure 3.9 and Table 3.2), with all load cases performed dynamically. The load cases within Test Set 2 were referred to as Load Cases 6, 7, 8, and 9. Load Cases 6 and 7 were performed with Truck 1 crossing the bridge in the center of the right lane at speeds of 47 mph and 20 mph, respectively. Figure 3.13c shows the transverse location of Truck 1 in Load Cases 6 and 7.

Load Cases 8 and 9 were intended to be performed with Truck 1 crossing the bridge directly in the center of the Little Buffalo Creek Bridge; however, because of the discrepancies previously noted the truck was actually closer to Girder 2. Truck 1 was travelling at speeds of 47 mph and 25 mph for Load Cases 8 and 9, respectively. Figure 3.13d shows the actual transverse location of Truck 1 as it crossed the bridge during Load Cases 8 and 9.

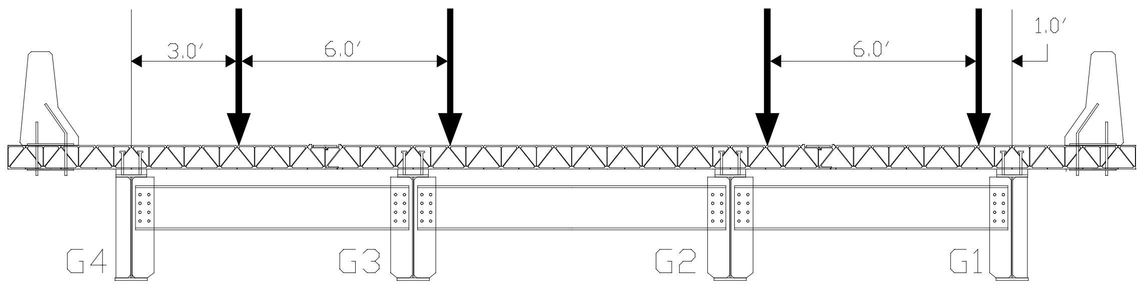
3.5.3 Test Set 3 Description

Test Set 3 was performed using Truck 3 (see Figure 3.9 and Table 3.2). All load cases were performed with Truck 3 centered in the right lane. Figure 3.13c shows the transverse location of Truck 3 during the test set. There were eight load cases in this particular test set. Two load cases were performed pseudo-statically and six were dynamic. Table 3.5 lists the load case name and speed of Truck 3 during the load cases of Test Set 3.

Table 3.5 Load Cases in Test Set 3

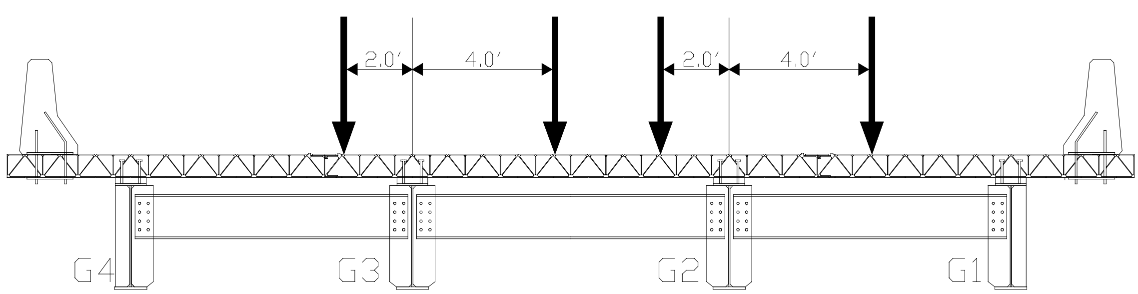
Test Set 3	
Load Case Name	**Speed of Truck 3**
Pseudo-Static 1 (PS-1)	<3 mph
Pseudo-Static 2 (PS-2)	<3mph
Dynamic 3 (DYN-3)	25 mph
Dynamic 4 (DYN-4)	25 mph
Dynamic 5 (DYN-5)	45 mph
Dynamic 6 (DYN-6)	45 mph
Dynamic 7 (DYN-7)	10 mph
Dynamic 8 (DYN-8)	10 mph

Test Set 1: Load Case 1 "Max Girder Strain"



(a)

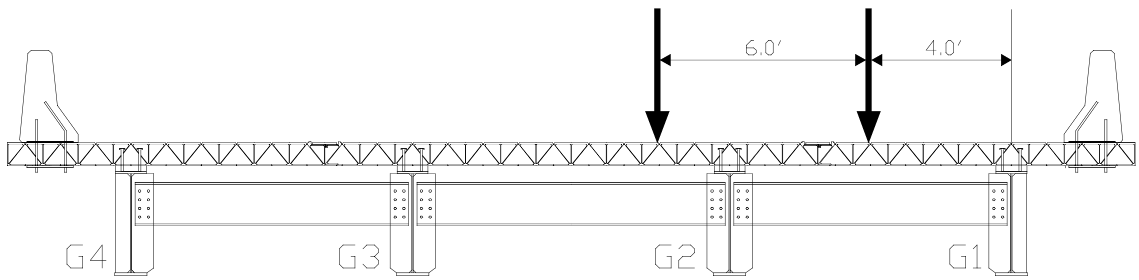
Test Set 1: Load Case 2 "Max Deck Strain"



(b)

Figure 3.13 Transverse Truck Locations

Test Set 2: Load Cases 6 and 7 & Test Set 3: All Load Cases



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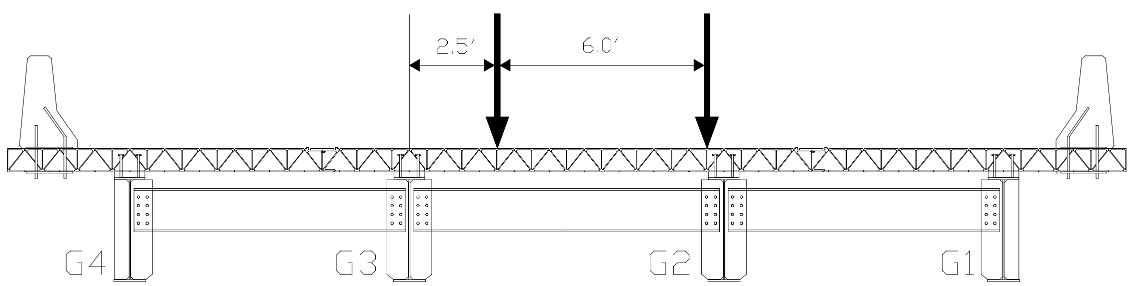
Test Set 2: Load Cases 8 and 9



(d)

Figure 3.13 (cont.)