Load Rating of 108B00033N Based on Field Testing

(KY-248 over Little Beech Creek. Spencer County, D05, KY)

Figure E1 – 108B00033N in Spencer County, KY

Executive Summary

108B00033N is a prestressed concrete bridge constructed in 1981 and located in Spencer County, KY. This bridge has two lanes of traffic and carries KY-248 over Little Beech Creek. Structural plans are unavailable, and bridge dimensions were determined from field measurements. Material properties and prestressing information are conservatively estimated based on the PCI Bridge Design Manual (2014). Load Factor Ratings (LFR) and Load and Resistance Factor Ratings (LRFR) are derived using two methods: (1) Finite Element (FE) analysis, and (2) field testing of the bridge using tandem rear axle dump trucks.

Recommendation: Based on field testing (4.1, Page ~~16~~17), 108B00033N Does Not Require Posting for the following legal trucks:

- AASHTO Standard HS20 Truck;
- Kentucky Truck Types 1, 2, 3, 4, 2EW, 3EW, and 4EW;
- AASHTO Special Hauling Vehicles SU4, SU5, SU6, and SU7; and
- Emergency Vehicles EV2 and EV3.

Note: *During the May 24, 2022, site visit, no structural damage was observed on the load-bearing portion of* 108B00033N. *If future inspections reveal any structural damage of the load-bearing portion of the bridge, load ratings must be reevaluated.*

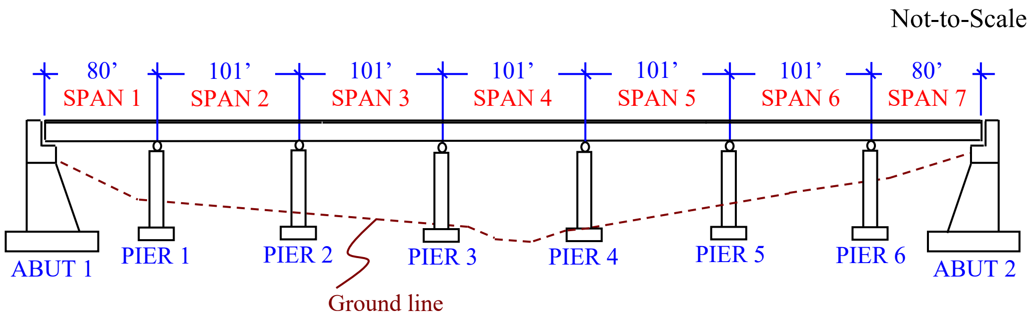
Load Rating of 108B00033N Based on Field Testing

(KY-248 over Little Beech Creek. Spencer County, D05, KY)

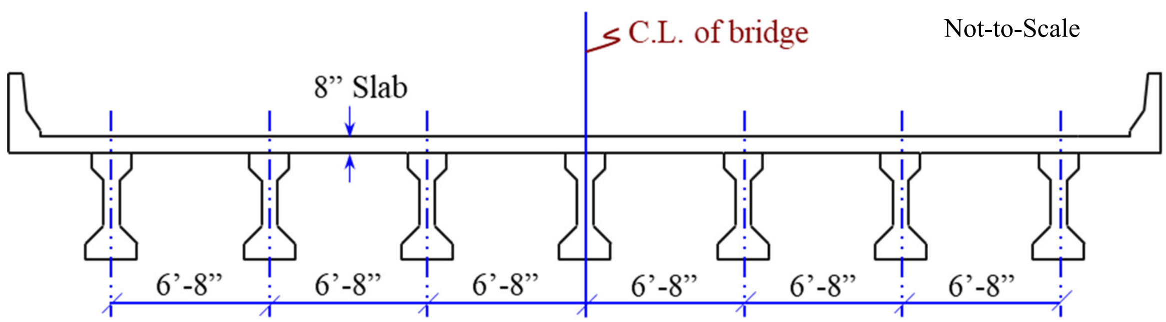
1. Introduction

The bridge 108B00033N, constructed in 1981, is in Spencer County, KY. The bridge carries KY-248 over Little Beech Creek.

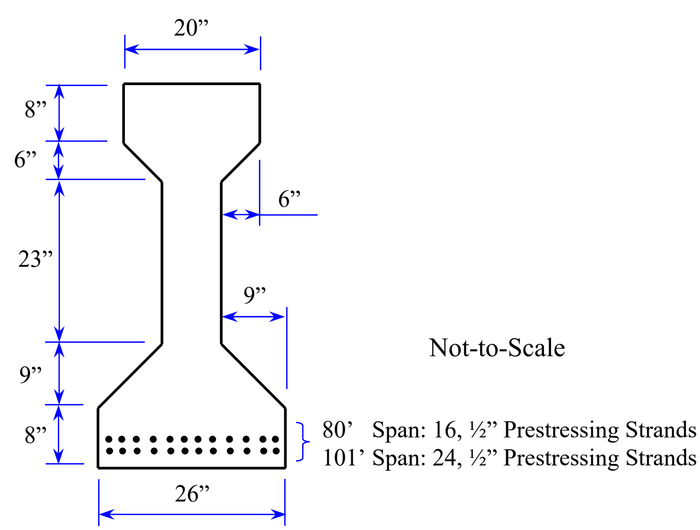
Bridge plans are unavailable, and the bridge dimensions presented in Figure 1.1 are based on field measurements. The dimensions of the I-beams' exposed portion indicated that they are Type IV AASHTO I-Beams. Based on preliminary design calculations in accordance with the PCI Bridge Design Manual (2014) and AASHTO (2020), it was conservatively assumed that beams in the 80 ft exterior spans (Spans 1 and 7) were pretensioned with sixteen (16) strands while the 101 ft interior spans were pretensioned with twenty-four (24) strands. The strands were assumed to be 0.5 in. Grade 270 strands.



(a) Elevation View of 108B00033N



(b) Cross Section of 108B00033N



(c) Type IV Beam with Prestressing Strands

Figure 1.1 – Bridge Geometry

2. Material Properties

Table 2.1 presents the material properties that are conservatively assumed based on guidance from the AASHTO LRFD Bridge Design Specifications (AASHTO LRFD 9th Edition - 2020) and PCI Bridge Design Manual (PCI 3rd Ed. - 2014).

Table 2.1 – Material Properties

Material	Parameter	Value	Assumed/ Calculated	Reference
Deck Concrete	Strength	$f_c' = 5000$ psi	Assumed	PCI 3rd Ed. Section 2.5
	Modulus of Elasticity	$E_c = 4287$ ksi	Calculated	AASHTO LRFD 9th Ed. Eq. 5.4.2.4-1
	Unit Weight	$\gamma_c = 150$ pcf	Assumed	AASHTO LRFD 9th Ed. Table 3.5.1.1
Beam Concrete	Strength	$f_c' = 7000$ psi	Assumed	PCI 3rd Ed. Section 2.5
	Modulus of Elasticity	$E_c = 5072$ ksi	Calculated	AASHTO LRFD 9th Ed. Eq. 5.4.2.4-1
	Unit Weight	$\gamma_c = 150$ pcf	Assumed	AASHTO LRFD 9th Ed. Table 3.5.1.1
Prestressing Strands	Ultimate Strength	$f_{pu} = 270$ ksi	Assumed	PCI 3rd Ed. Section 2.11
	Yield Strength	$f_{py} = 243$ ksi	Assumed	PCI 3rd Ed. Section 2.11
	Modulus of Elasticity	$E_{ps} = 28500$ ksi	Assumed	PCI 3rd Ed. Section 3.3

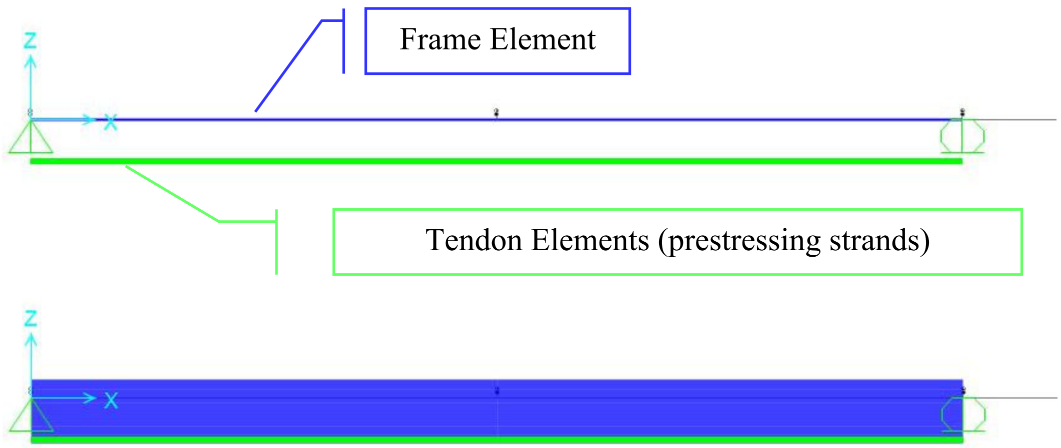
3. Finite Element Modeling

The Finite Element (FE) models were generated in SAP2000 for a single AASTHO Type IV beam with a fully composite 80 in. wide and 8 in. thick deck. The prestressing strands were conservatively assumed to be straight. Material properties used for the elements are listed in Table 2.1. The FE model's primary function is to determine the analytical load ratings for the legal trucks being load rated. The model is also used to determine the theoretical effect of the trucks used in field testing to generate the adjustment factors for load rating (refer to Section 4).

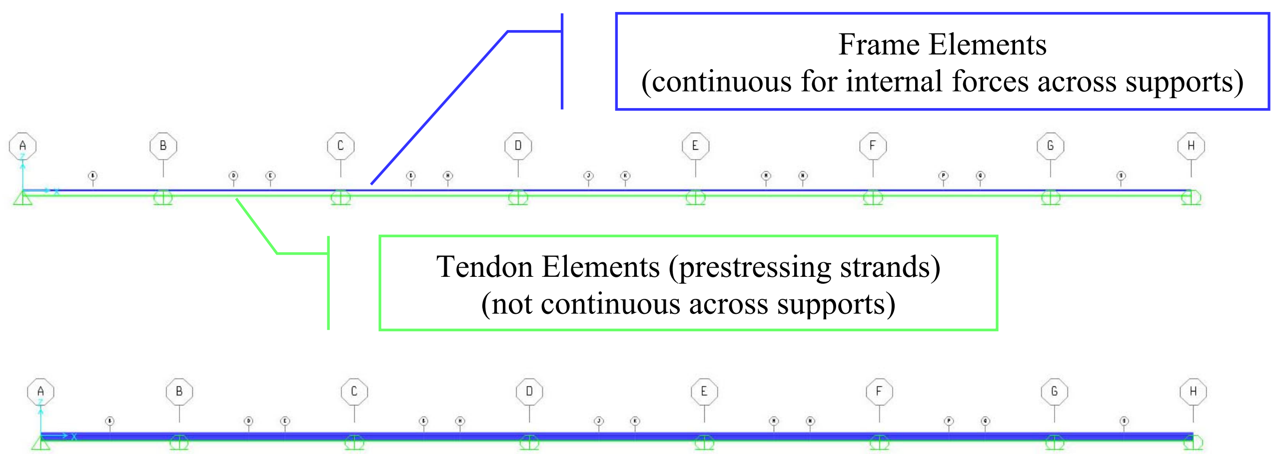
The dead load analysis was carried out using prestressed simply supported frame elements with a length of either 80 ft (spans 1 and 7) or 101 ft (spans 2 through 6). The beams were subjected to self-weight, deck weight, and any other attributed dead loads (e.g., barrier weight) and modeled as simply supported (Figure 3.1a). The prestressing strands were modeled as individual tendon elements symmetrically filling the lowest 16 or 24 strand positions as shown in Figure 1.1 above (PCI Bridge Design Manual 3rd Ed. – 2014).

The live load analysis is carried out using individual frame elements and tendon elements (unstressed) for each span with complete continuity of internal forces across joints (supports) for the frame elements in Spans 1 to 7 (Figure 3.1b). Since a single beam is modeled in the finite element analysis, the live load effects were reduced in accordance with the AASHTO LRFD (2020) live load moment reduction factor or the AASHTO Standard Specifications (2002) live load distribution factor as required by the rating method.

The rating factors (*RF*), derived in accordance with the AASHTO Load Factor Rating (LFR) and Load and Resistance Factor Rating (LRFR), are presented in Table 3.1. The factors were determined at 1 in. increments along the bridge with the reported ratings being the minimum ratings. This analysis concluded that Span 4 contains the critical section for flexure for all rated trucks. For LRFR, the Inventory *RF* < 1.0 for Kentucky Truck Type 4EW.



(a) Simple span for Dead/Prestressing Load Model (Span 1 shown)



(b) Continuous for Live Load Model

Figure 3.1 – SAP2000 Finite Element Models (wireframe and extruded views)

Table 3.1 – Load Rating Factors (*RF*) for 073B00161L&R Based on Finite Element Analysis.

Truck Type [a]		AASHTO LFR [b]		AASHTO LRFR [b]	
Type	Weight (Tons)	Inventory *RF*	Operating *RF*	Inventory *RF*	Operating *RF*
HS20	36.00	1.74	2.90	1.51	1.96
Type 1	20.00	2.65	4.42	2.31	2.99
Type 2	28.35	1.92	3.20	1.67	2.16
Type 2EW	45.00	1.21	2.01	1.05	1.36
Type 3	36.75	1.56	2.61	1.36	1.76
Type 3EW	50.00	1.15	1.92	1.00	1.29
Type 4	40.00	1.69	2.82	1.47	1.90
Type 4EW	60.00	1.13	1.88	0.98 [b]	1.27
Type SU4	27.00	2.11	3.52	1.84	2.38
Type SU5	31.00	1.91	3.18	1.66	2.15
Type SU6	34.75	1.71	2.86	1.49	1.93
Type SU7	38.75	1.57	2.62	1.37	1.77
EV2	28.75	1.97	3.29	1.71	2.22
EV3	43.00	1.35	2.26	1.18	1.53

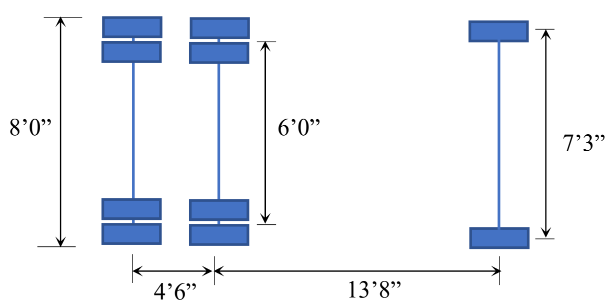
[a] Refer to Appendix A for Truck Type details regarding number of axles, axle weight, total weight, and spacing between axles.
[b] The *RF*s presented in this table are conservative. Strand draping is neglected, and the number of strands and material properties are conservatively estimated.

Notes:
1. An Impact factor, based on the MBE (2018), is included in the load rating analysis.
2. Flexural capacity of the bridge is determined in accordance with the PCI Bridge Design Manual, 3rd Edition (2014).
3. Load ratings in Table 3.1 are controlled by Span 4.
4. As no visible signs of shear distress were observed, the shear rating was not evaluated (MBE, 2018).

4. Load Rating Based on Field Testing

Load rating was carried out using three loaded tandem axle dump trucks like the one shown in Figure 4.1a. All trucks had the same dimension (Figure 4.1b) and had gross weights of 66,800 lbs, 65,000 lbs, and 64,000 lbs.

(a) Tandem Axle Dump Truck used for Testing



(b) Test Truck Axle Spacing

Figure 4.1 – Trucks used for Field Testing

Four spans of the bridge were selected for testing: two 80 ft spans (Spans 1 and 7) and two 101 ft spans (Spans 3 and 5). These spans were chosen as they provided data for both span lengths, allowed for a greater length of the bridge to be tested, and allowed for direct comparison of data between the matching pairs. It can also be noted that although Span 4 contained the critical section for load rating, the ratings for spans 3 and 5 were within 2% and thus not significantly different. The chosen spans were instrumented and tested as outlined in the following subsections.

4.1 Instrumentation

Figure 4.2 presents the typical strain gage layout for all tested spans. Gages were placed on the bottom of each beam with the central beam and one of the adjacent interior beams having additional gages on the web. As seen in Figure 4.2a, the gages were placed at midspan and the quarter span points.

Reusable strain gages, manufactured by Bridge Diagnostics Inc. (https://bditest.com/), were attached to the bridge using tabs adhered to the beams as shown in Figure 4.3. The gages were connected to nodes that wirelessly link to a base station and laptop used for data acquisition (Figure 4.4). Data was reviewed in real-time for anomalies with adjustments made to gages and load cases as needed.

4.2 Field Testing

Single loaded lane load cases were selected to maximize the test truck effect at midspan of each span tested. Four load cases (LC 1-4) were identified with each case having three loading steps (a, b, and c) performed in sequence with continuous data acquisition. Detailed load case diagrams are provided in Appendix B.

In loading step “a” (i.e., LC 1a, LC 2a, LC 3a, and LC 4a), Test Truck 1 (the heaviest of the three test trucks) slowly made its way onto the bridge and stopped at midspan (Figures B1, B4, B7, and B10). Then in step “b”, Test Truck 1 pulled forward and Test Truck 2 backed against Test Truck 1 such that the axle spacing was symmetric about midspan (Figures B2, B5, B8, and B11). Finally, loading step “c” has Test Truck 3 back against Test Truck 2 (Figures B3, B6, B9, and B12).

This loading sequence was performed with the trucks straddling the middle beam (LC 1), with one wheel line over the middle beam (LC 2), with the trucks straddling the adjacent interior beam (LC 3), and with one wheel line over the beam adjacent to the middle beam (LC 4) as shown in Figure 4.5a. The 80 ft exterior spans (Spans 1 and 7) could only accommodate two of the three test trucks, consequently, they were only subjected to loading steps “a” and “b” (i.e., LC 1a, LC 1b, LC 2a, LC 2b, etc.).

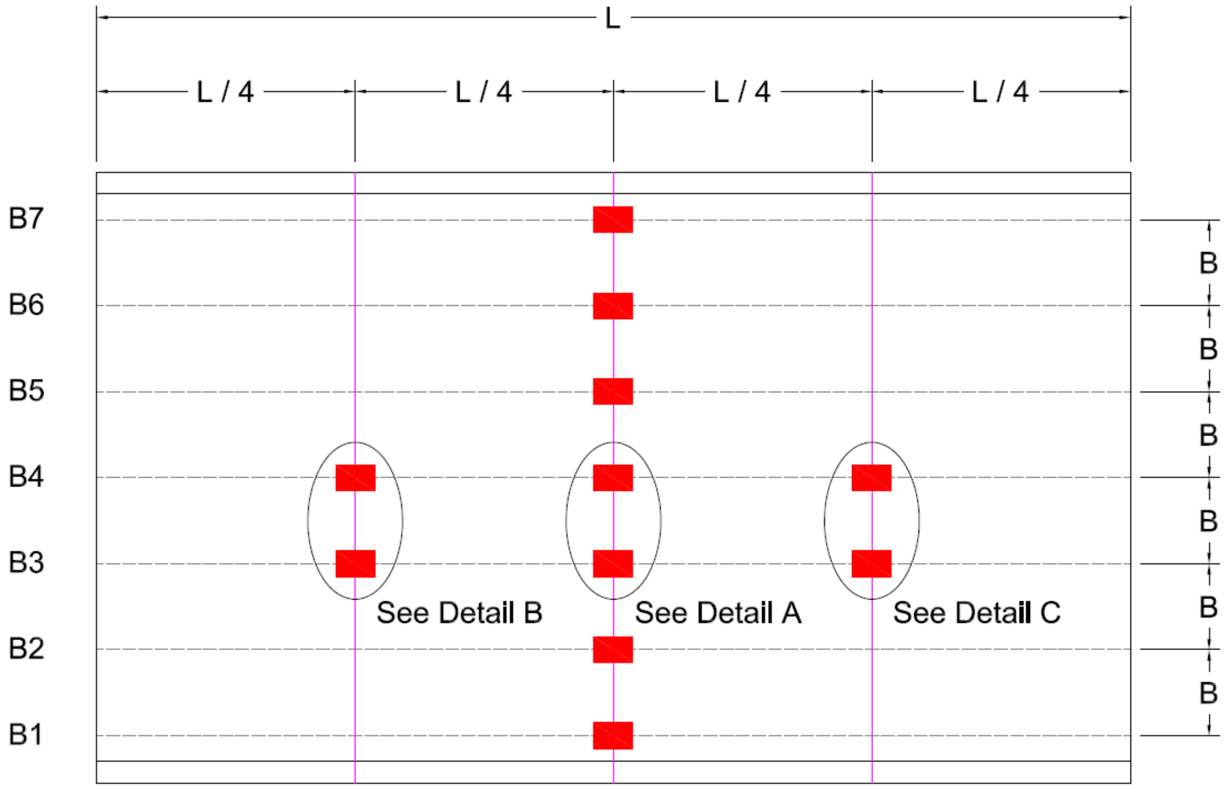
Two "multiple presence" load cases (Figure 4.5b) were also taken. LC 5 and LC 6 placed two test trucks side-by-side with the middle beam between them (LC 5) or with the beam adjacent to the middle beam between them (LC6).

4.3 Load Rating

The field test load rating factors (*RF*) are derived from the finite element load rating factors using an adjustment factor, *K*. The field test adjustment factor is dependent on two sub factors, K_a and K_b (MBE, 2018). The K_a factor accounts for both the benefits derived from the load test, if any, and consideration for the section factor resisting the applied test load. The K_b factor depends on (1) the ratio of the test truck weight to the standard truck weight which is being considered for load rating; and (2) the confidence with which the live load effects may safely be extrapolated to 1.33 times the standard truck weight, *W*.

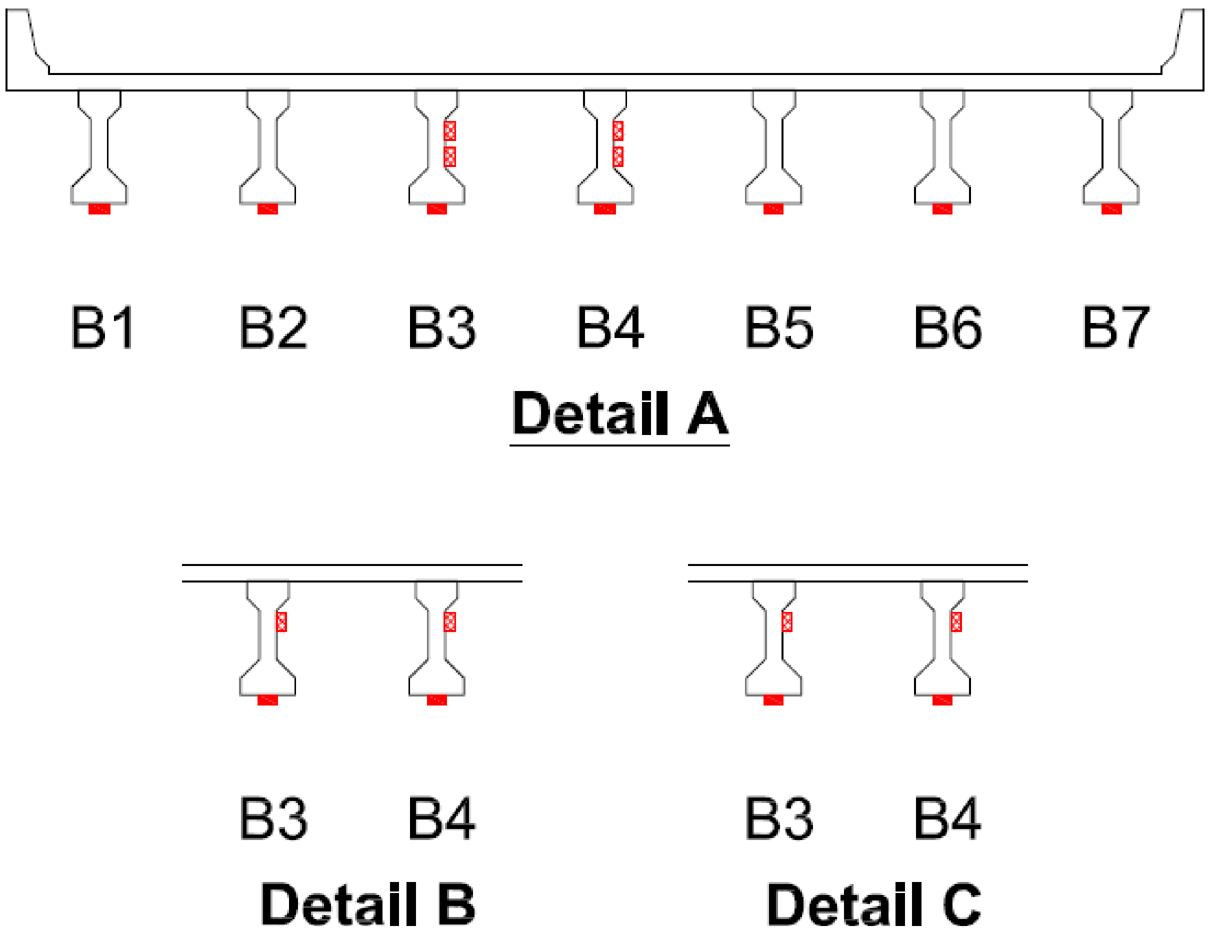
For the heaviest standard trucks (Type III EW and Type IV EW), a single test truck can weigh less than 70% of the standard truck which would significantly reduce the field test adjustment factor, *K*, and lead to unrealistically low field test adjusted load ratings. For this reason, field test adjustments are based on a load case in which a single lane of the bridge was loaded using either two trucks (80 ft spans) or three trucks (101 ft spans). The ability to extrapolate to 1.33*W* was based on if 1.33 times the total stress in the prestressing strands (including initial prestress, dead load effects, and live load effects) being less than 80% of the yield stress.

Table 4.1 provides a summary of the field adjusted load ratings. These ratings were determined by applying the field test adjustment factor, *K*, to the finite element analysis load ratings provided in Table 3.1. Consequently, the ratings provided in Table 4.1 are at the same critical section within the 101 ft interior span.



(a) Plan View of Gage Layout for Bridge 108B00033N (typical for all spans)

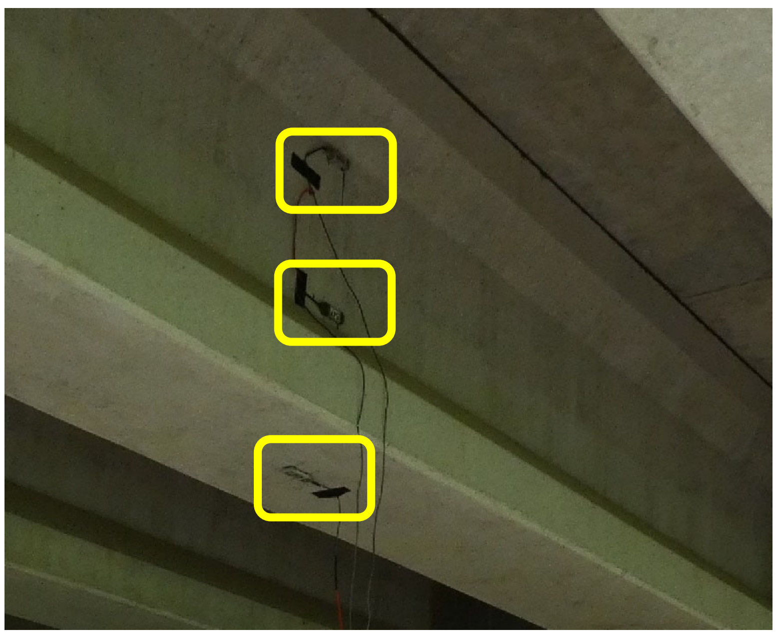
Figure 4.2 – Strain Gage Layout



(b) Typical Gage Layout Details

Figure 4.2 (Continued) – Strain Gage Layout

(a) Attaching BDI Reusable Strain Gages



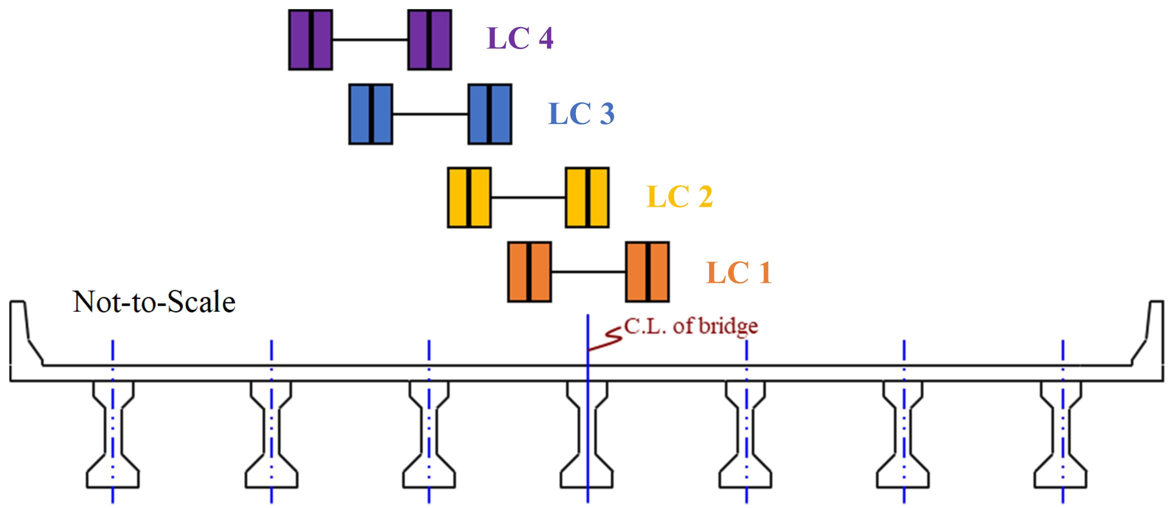
(b) Typical Gage Applications on the Side and Bottom of Beam

Figure 4.3 – Reusable Strain Gages used in Data Acquisition

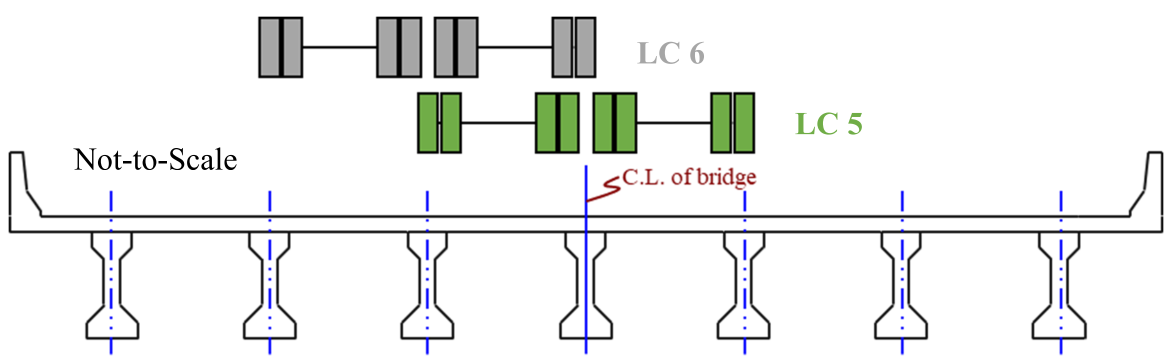
(a) BDI Wireless Node

(b) Data Acquisition

Figure 4.4 – Instrumentation and Data Acquisition Setup



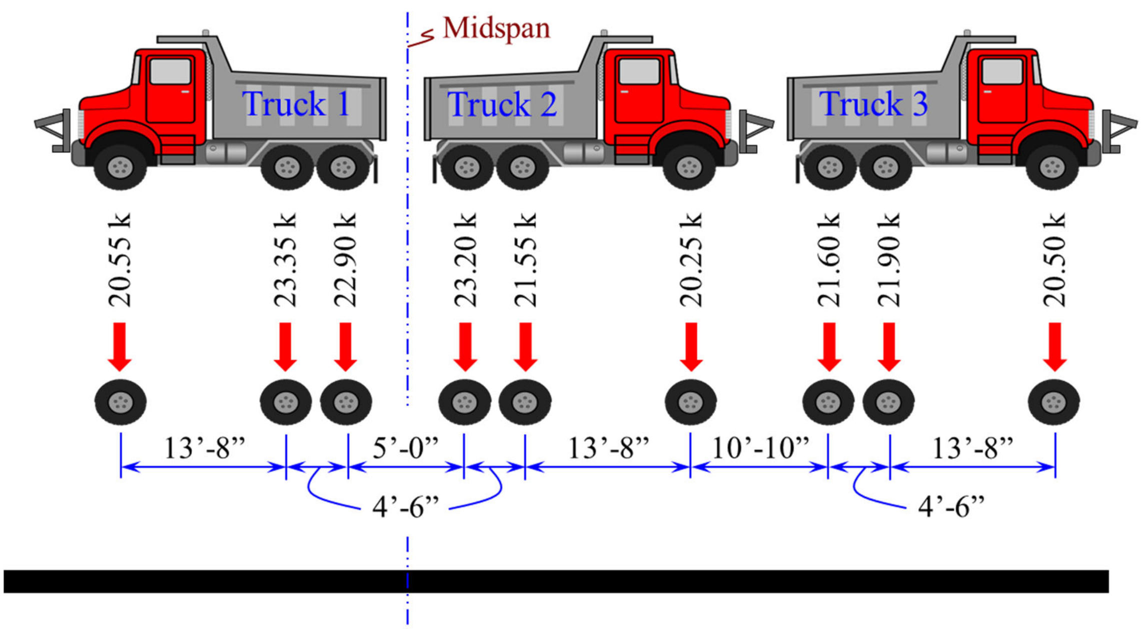
(a) Section Showing Single Loaded Lane Load Cases



(b) Section Showing Double Loaded Lane Load Cases

Figure 4.5 – Load Cases

(a) Test Trucks



Not-to-Scale

(b) Axle loads (shown in loading step "c" configuration)

Figure 4.6 – Load Case 2c Showing the Test Trucks in Span 1

Table 4.1 – Load Rating Factors (*RF*) for 073B00161L&R Based on Field Testing

Truck Type [a]		AASHTO LFR [b]		AASHTO LRFR [b]	
Type	Weight (Tons)	Inventory *RF*	Operating *RF*	Inventory *RF*	Operating *RF*
HS20	36.00	10.47	17.47	9.38	12.16
Type 1	20.00	16.14	26.94	14.46	18.75
Type 2	28.35	11.65	19.45	10.44	13.53
Type 2EW	45.00	7.34	12.25	6.58	8.52
Type 3	36.75	9.48	15.82	8.49	11.01
Type 3EW	50.00	6.97	11.63	6.24	8.09
Type 4	40.00	10.10	16.85	9.05	11.73
Type 4EW	60.00	6.73	11.24	6.03	7.82
Type SU4	27.00	12.82	21.39	11.48	14.89
Type SU5	31.00	11.55	19.28	10.35	13.41
Type SU6	34.75	10.36	17.30	9.28	12.04
Type SU7	38.75	9.48	15.82	8.49	11.01
EV2	28.75	11.95	19.94	10.70	13.88
EV3	43.00	8.20	13.68	7.35	9.52

[a] Refer to Appendix A for Truck Type details regarding number of axles, axle weight, total weight, and spacing between axles.
[b] The *RF* equation in MBE (2018) does not provide an upper limit and can lead to large *RF* values.

Notes:
1. Field load testing took place on May 24 and 25, 2022.
2. An Impact factor, based on the MBE (2018), is included in the load rating analysis.
3. Flexural capacity of the bridge is determined in accordance with the PCI Bridge Design Manual, 3rd Edition (2014).
4. Load ratings in Table 4.1 are controlled by Span 4.
5. As no visible signs of shear distress were observed, the shear rating was not evaluated (MBE, 2018).

5. Conclusions

The rating factors for 108B00033N are derived using two methods: (1) finite element analysis, and (2) field testing using tandem rear axle dump trucks.

Preliminary analysis of the bridges using the finite element (FE) model determined that Span 4 governs the load rating. The LRFR rating factor at the inventory level for Kentucky Truck Type 4EW was 0.98, and the only *RF* < 1.0.

The rating factors derived from load testing resulted in rating factors *RF* >1.0 for the legal trucks listed in Table 4.1 and in Appendix A.

Based on field testing of Bridges 108B00033N, load posting is not required for the AASHTO Standard HS20 Truck, Kentucky Truck Types 1, 2, 3, 4, 2EW, 3EW, or 4EW, AASHTO Special Hauling Vehicles SU4, SU5, SU6, or SU7, or Emergency Vehicles EV2 and EV3. This recommendation is based on the evaluation of the bridge as of May 24, 2022. If there is any change in the condition of the load-bearing portion of the bridges, then this recommendation must be re-evaluated.

6. References

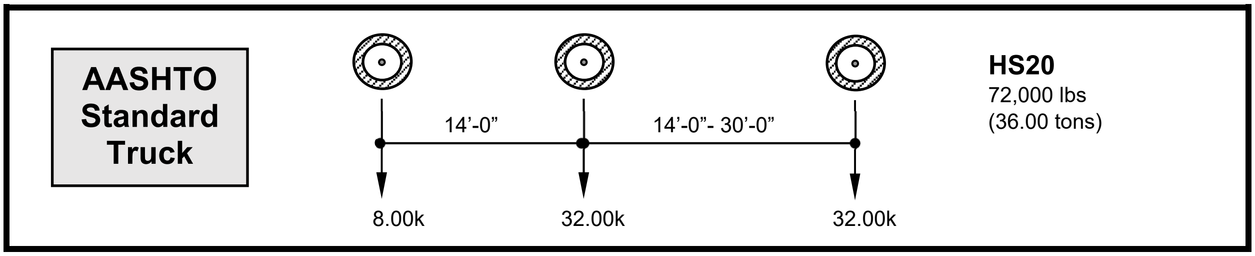
AASHTO. 2020. *AASHTO LRFD Bridge Design Specifications*, Ninth Edition. American Association of State Highway and Transportation Officials, Washington, DC.

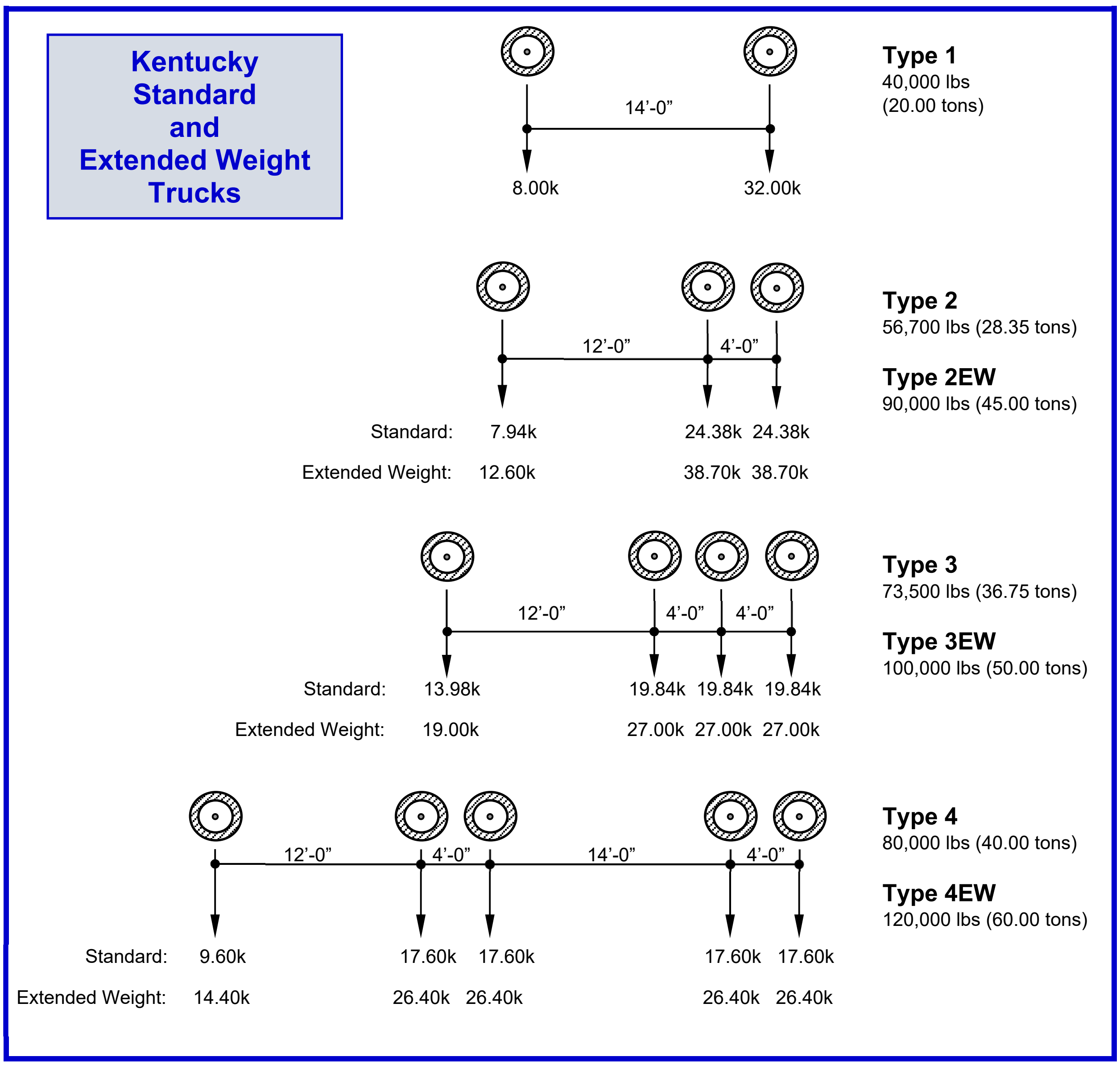
AASHTO. 2018. *Manual for Bridge Evaluation*, Third Edition. American Association of State Highway and Transportation Officials, Washington, DC.

Precast/Prestressed Concrete Institute (PCI). 2014. *Bridge Design Manua*l, 3rd Edition, Second Release, Chicago, IL.

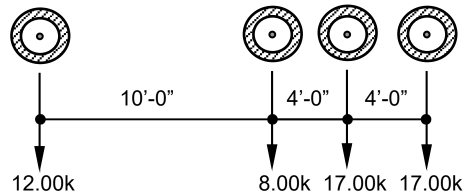
Appendix A

Truck Types for Load Rating

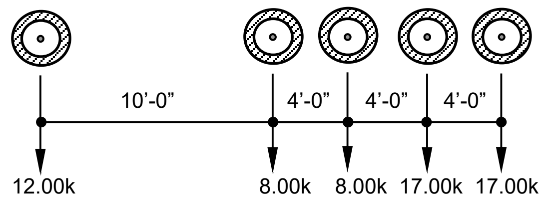

AASHTO Standard Truck
14'-0"
14'-0"- 30'-0"
8.00k
32.00k
32.00k
HS20
72,000 lbs
(36.00 tons)


Kentucky Standard and Extended Weight Trucks
14'-0"
8.00k
32.00k
Type 1
40,000 lbs
(20.00 tons)
12'-0"
4'-0"
Standard: 7.94k 24.38k 24.38k
Extended Weight: 12.60k 38.70k 38.70k
Type 2
56,700 lbs (28.35 tons)
Type 2EW
90,000 lbs (45.00 tons)
12'-0"
4'-0"
4'-0"
Standard: 13.98k 19.84k 19.84k 19.84k
Extended Weight: 19.00k 27.00k 27.00k 27.00k
Type 3
73,500 lbs (36.75 tons)
Type 3EW
100,000 lbs (50.00 tons)
12'-0"
4'-0"
14'-0"
4'-0"
Standard: 9.60k 17.60k 17.60k 17.60k 17.60k
Extended Weight: 14.40k 26.40k 26.40k 26.40k 26.40k
Type 4
80,000 lbs (40.00 tons)
Type 4EW
120,000 lbs (60.00 tons)

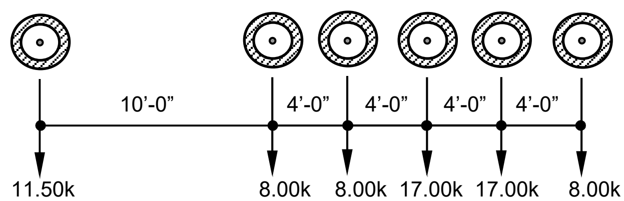
AASHTO Special Hauling Vehicles



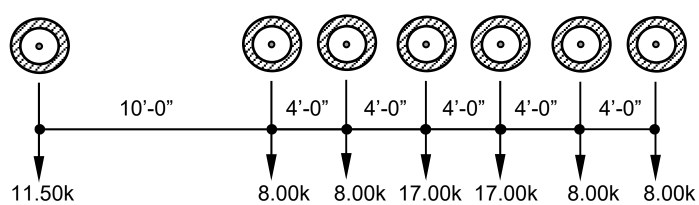
SU4
54,000 lbs
(27.00 tons)



SU5
62,000 lbs
(31.00 tons)

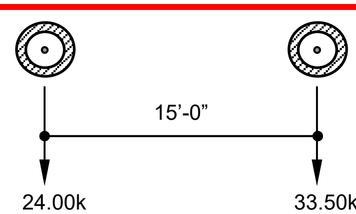


SU6
69,500lbs
(34.75 tons)

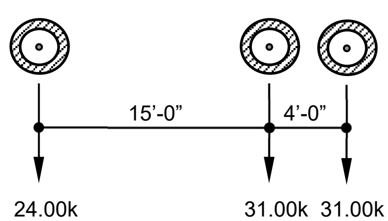


SU7
Standard: 77,500 lbs
(38.75 tons)

Emergency Vehicles



EV2
57,500 lbs
(28.75 tons)



EV3
86,000 lbs
(43.00 tons)

Appendix B

Load Case Diagrams

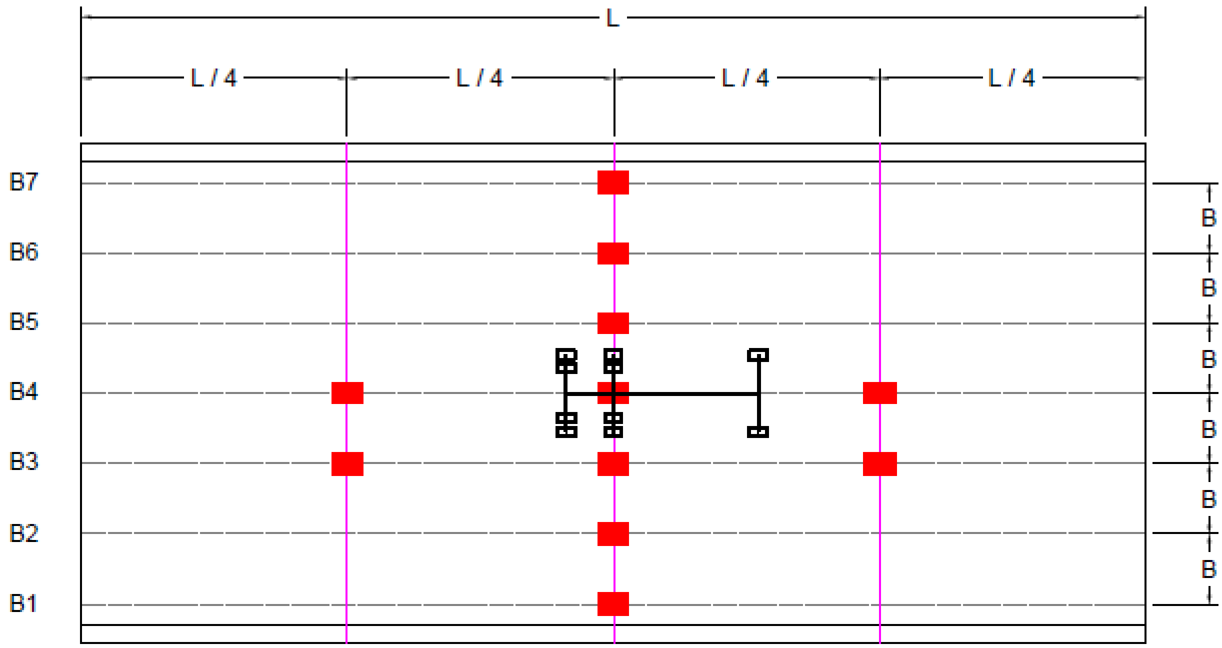


Figure B1 – Load Case 1a

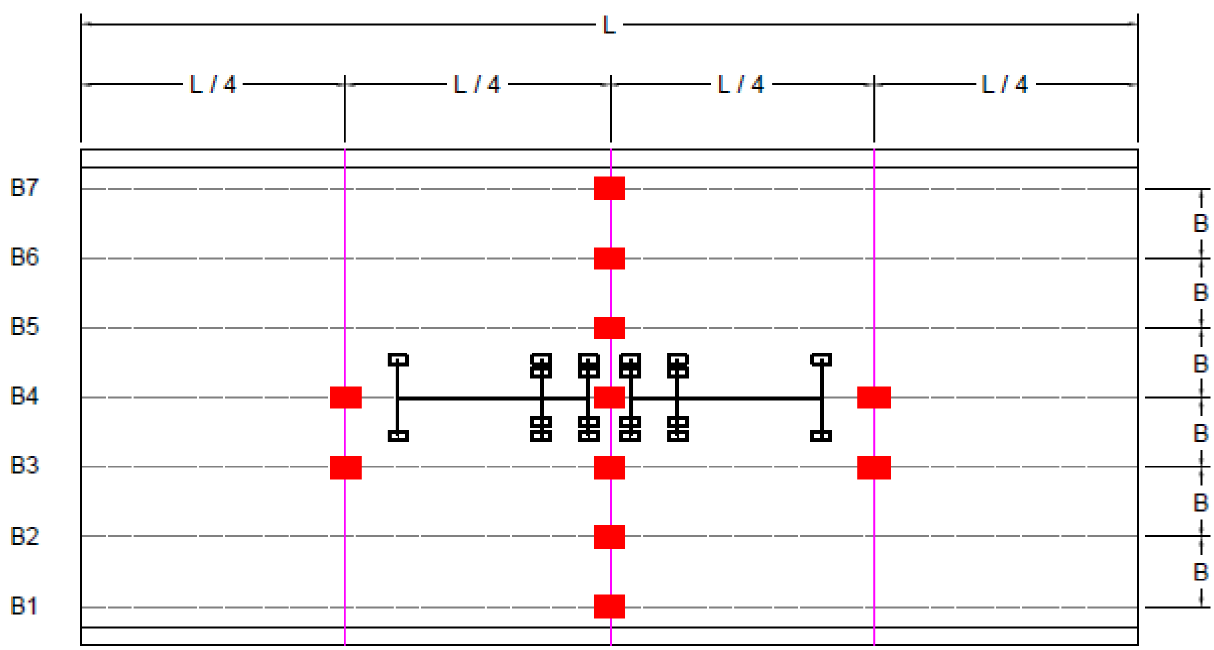


Figure B2 – Load Case 1b

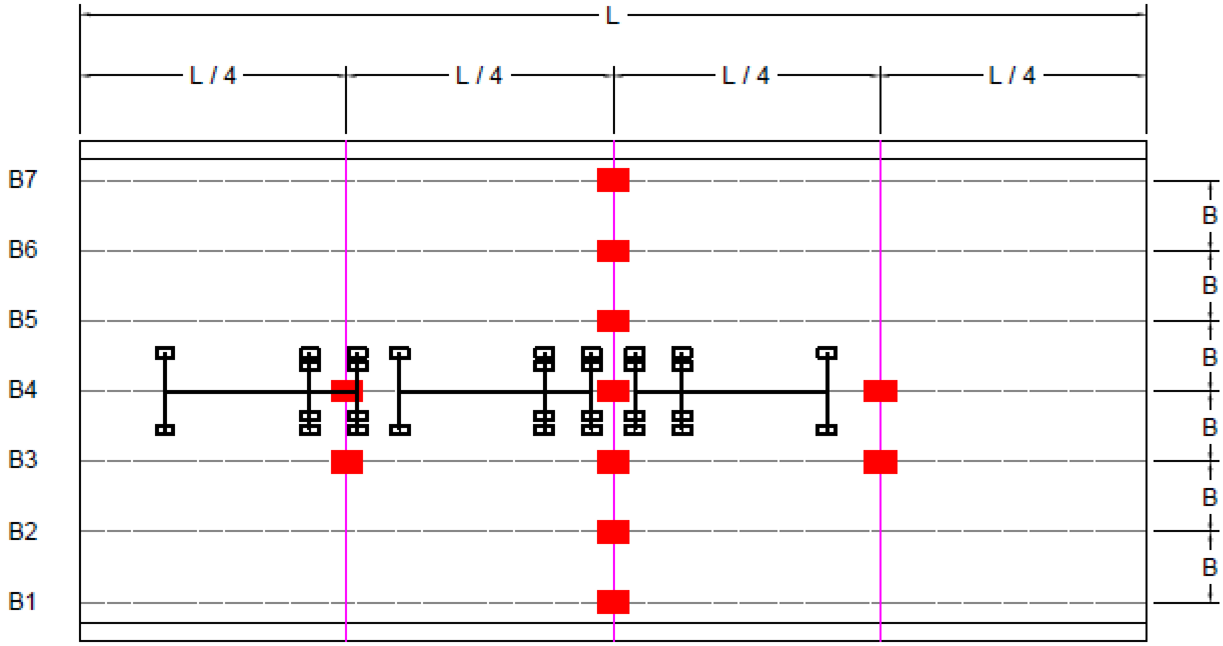


Figure B3 – Load Case 1c

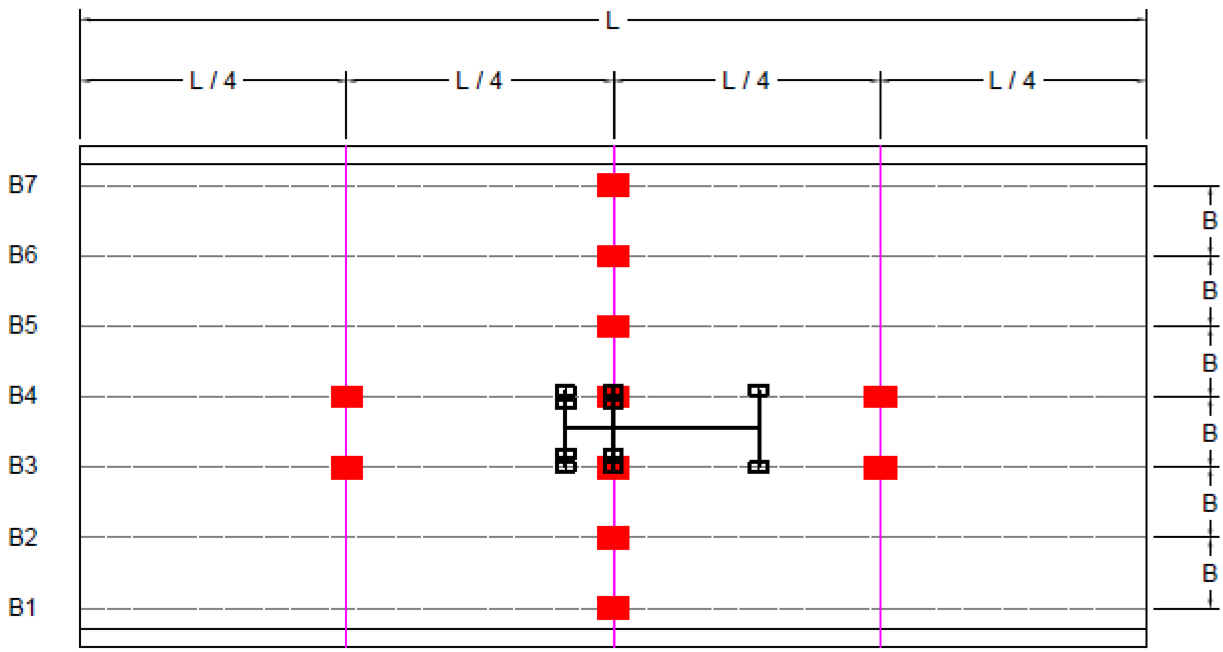


Figure B4 – Load Case 2a

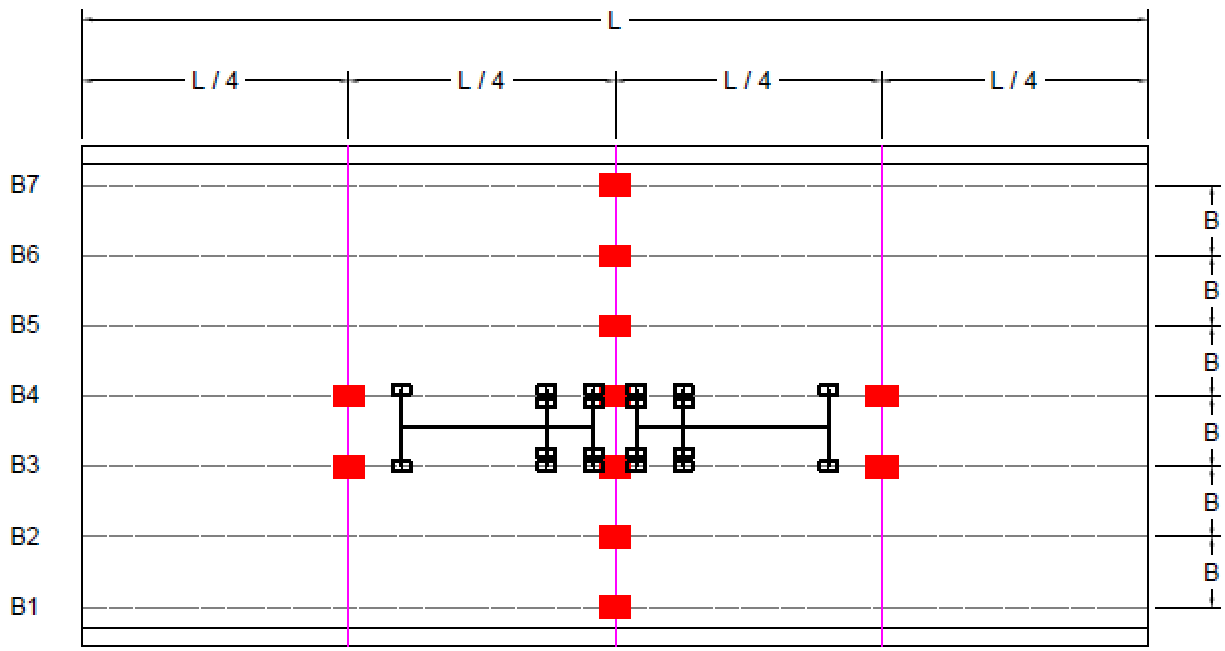


Figure B5 – Load Case 2b

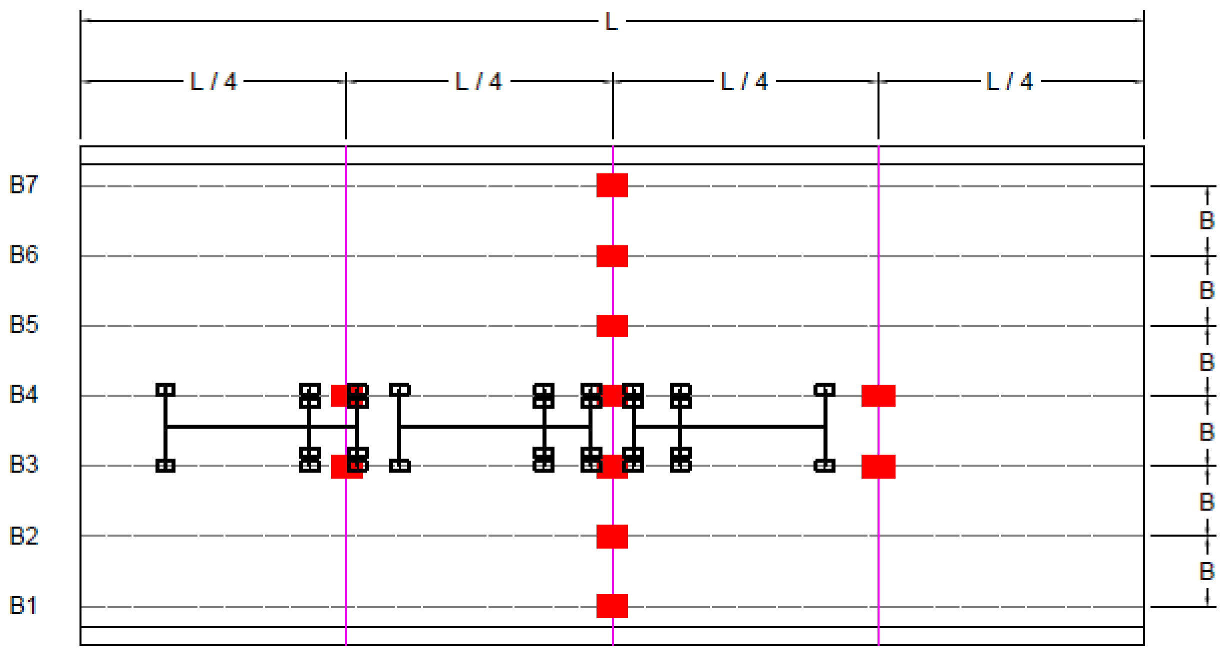


Figure B6 – Load Case 2c

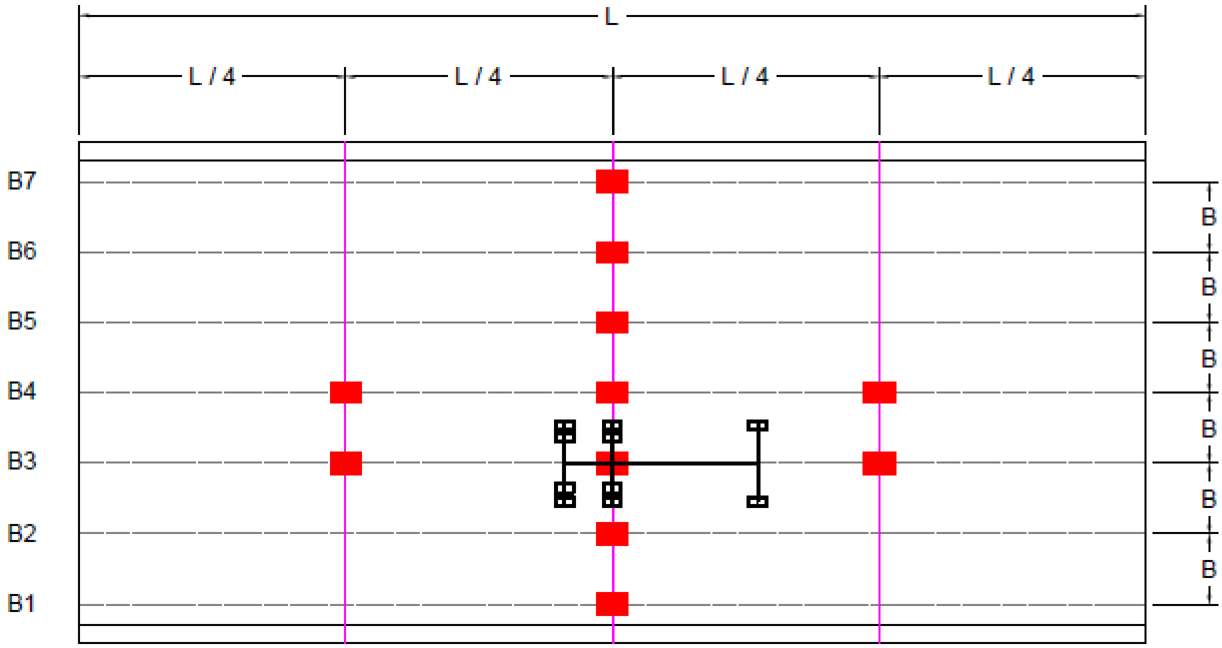


Figure B7 – Load Case 3a

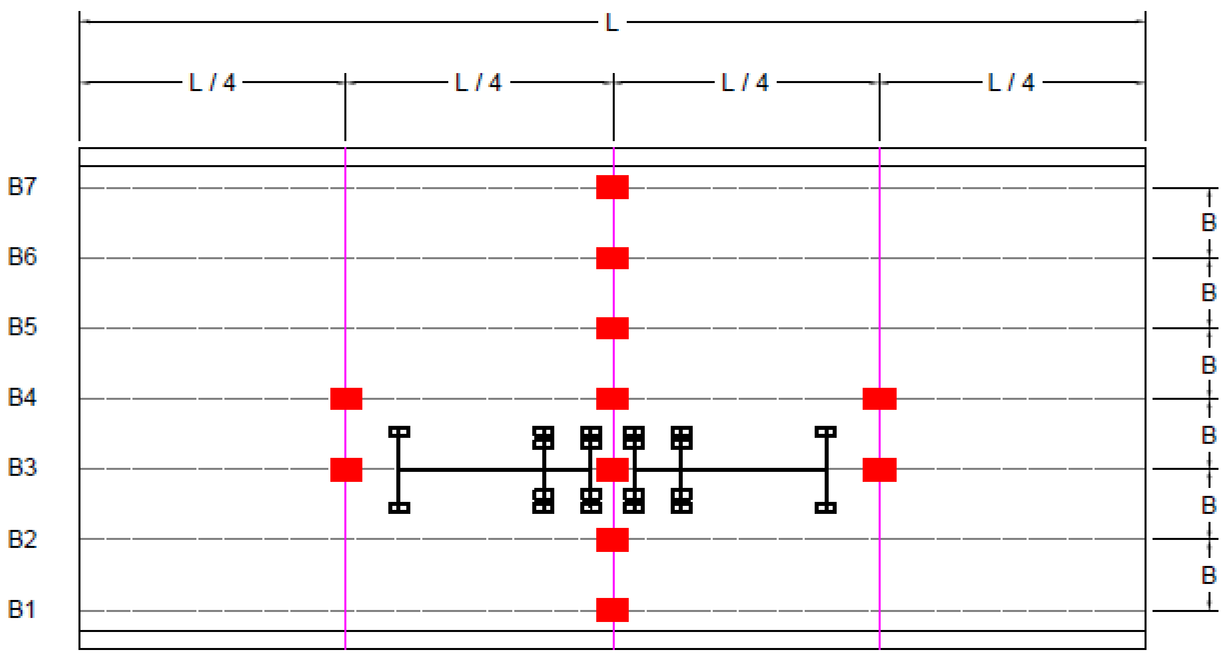


Figure B8 – Load Case 3b

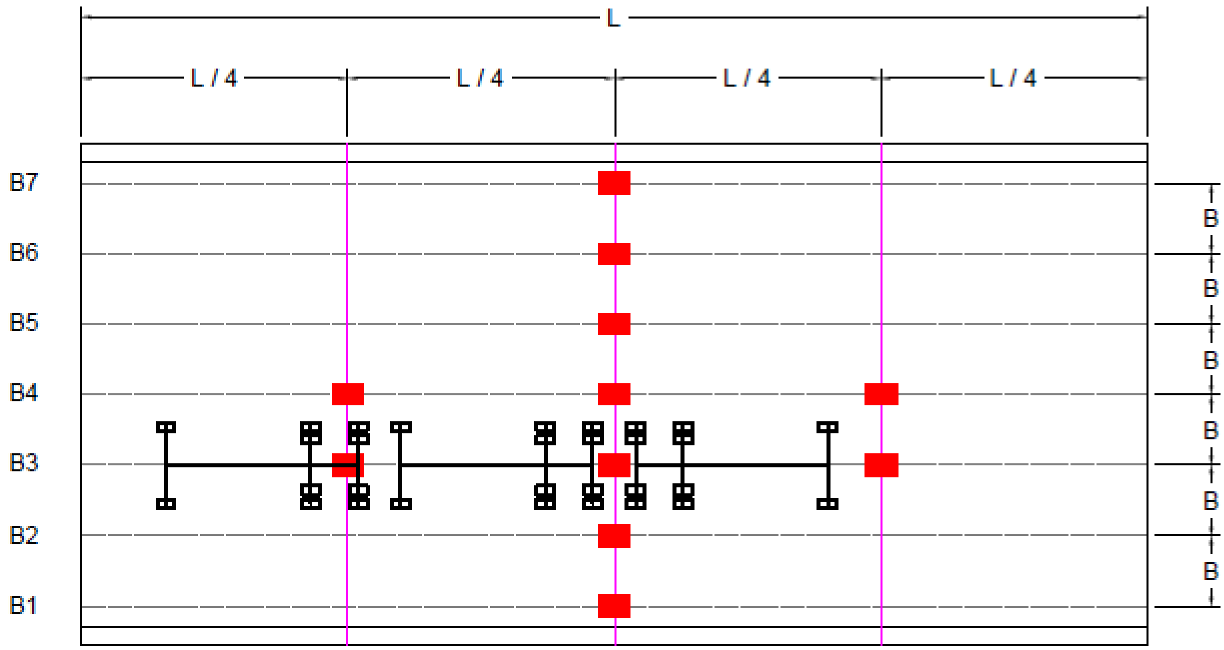


Figure B9 – Load Case 3c

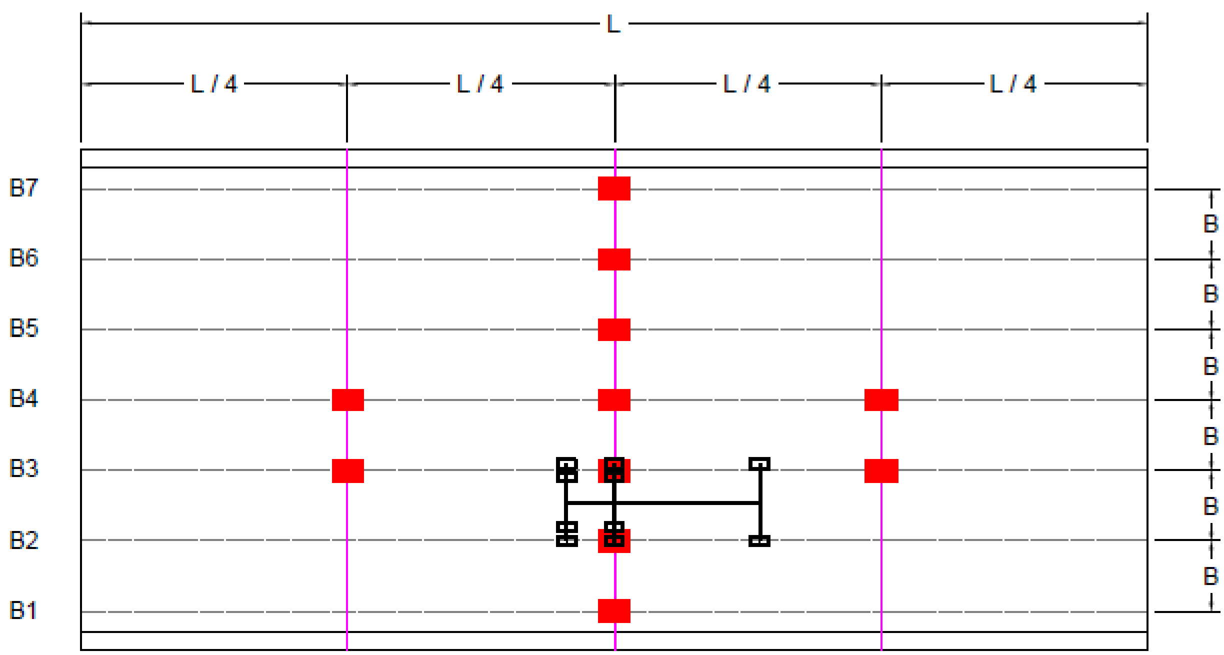


Figure B10 – Load Case 4a

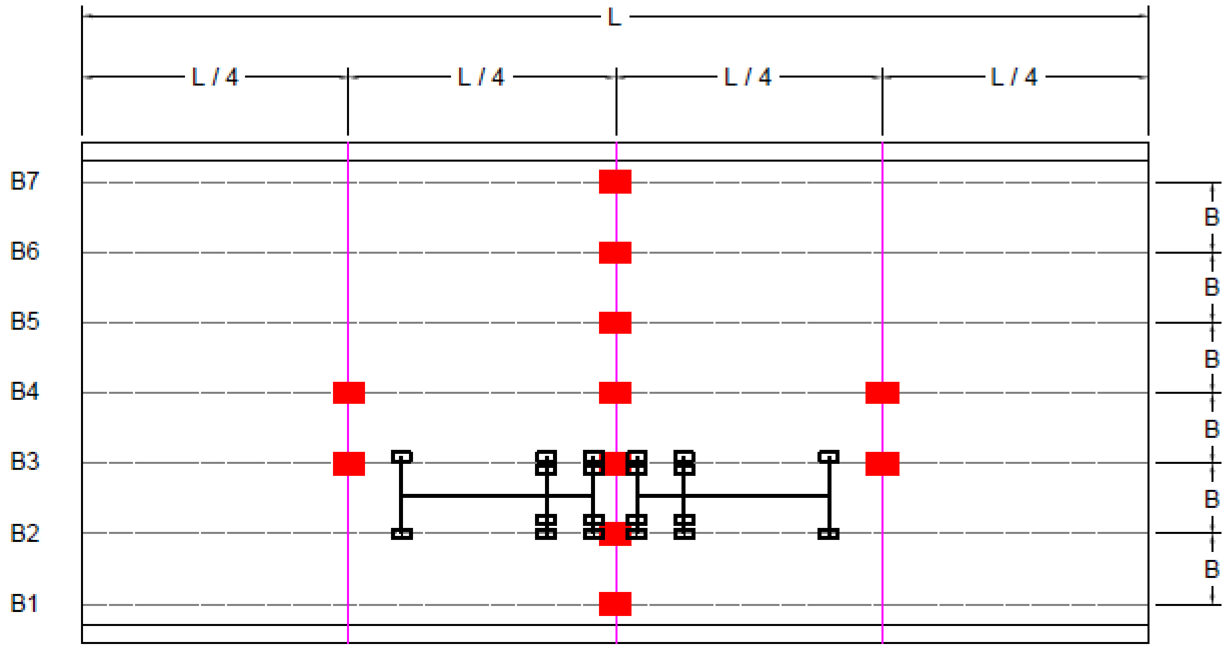


Figure B11 – Load Case 4b

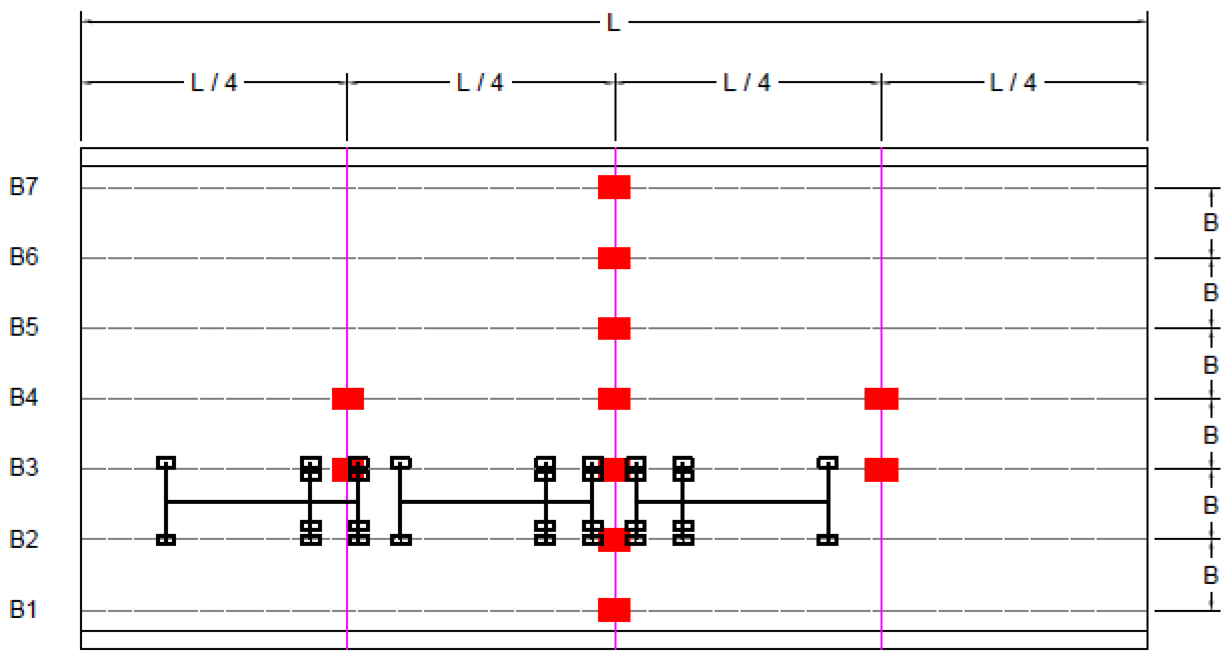


Figure B12 – Load Case 4c

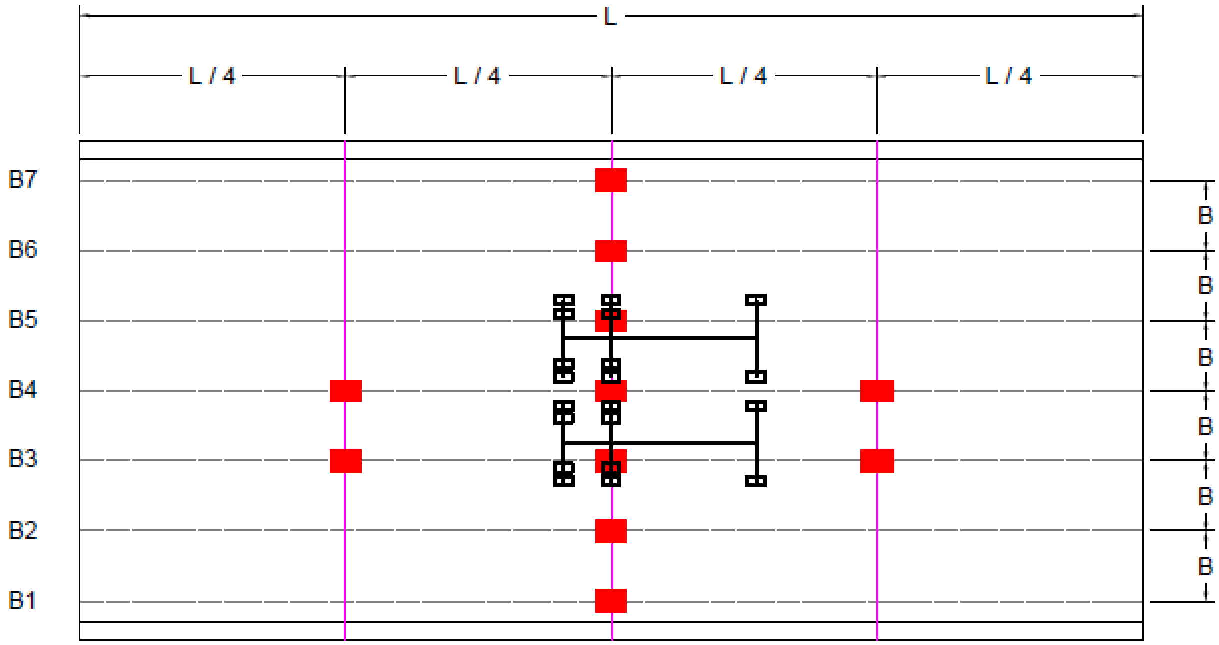


Figure B13 – Load Case 5

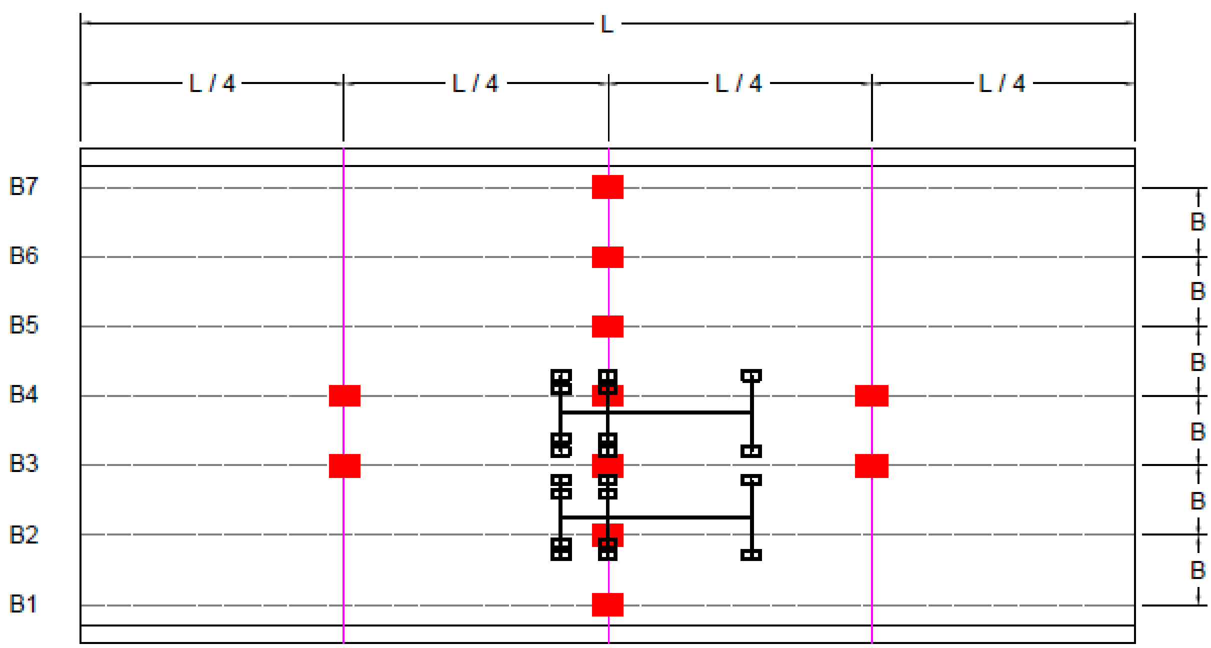


Figure B14 – Load Case 6