Load Rating Analysis
Structural Load Rating Criteria

CLINE AVENUE BRIDGE
S.R. 912 OVER THE INDIANA HARBOR CANAL
AT EAST CHICAGO, INDIANA
LAKE COUNTY

Prepared by:

URS

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Revision 3

REVISIONS

Project: Cline Avenue Bridge – Load Rating Analysis
SR 912 over Indiana Harbor Canal
East Chicago, Indiana

Document: Structural Load Rating Criteria

Revision	Date of Issue	Description
-	15 January 07	Draft Issue
-	20 February 07	Initial Issue
1	10 December 07	Added Legal Load and Permit Vehicles
2	04 March 09	Updated Criteria to Conform with Final Analysis of Pristine Structure
3	30 October 09	Updated for Independent Technical Review Incorporation of HL-93 Design and Striped Lanes

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CONTENTS

1. GENERAL REQUIREMENTS

1.1 Introduction

This Load Rating Criteria defines how the structural integrity of the bridge shall be evaluated for the effects of design vehicles. The live load effect is compared to the structural capacity available beyond dead load effects for the three following criteria:

1. Longitudinal Moment
2. Longitudinal Shear and Torsion
3. Transverse Moment

1.2 Codes, Standards and Specifications

1.2.1 AASHTO LRFD Bridge Design Specifications - Customary Metric Units, Fourth Edition, 2007.

1.2.2 AASHTO Guide Manual for the Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges Specifications - Customary Metric Units, First Edition, 2004, with Interim Specifications through 2005.

1.2.3 AASHTO Guide Specifications for Design and Construction of Segmental Concrete Bridges, Second Edition, 1999.

1.2.4 AASHTO Guide Specifications - Thermal Effects in Concrete Bridge Superstructures, 1989.

1.2.5 CEB/FIP Model Code for Concrete Structures, 1978 (for time dependent behavior of concrete - creep and shrinkage).

1.2.6 AASHTO/AWS Bridge Welding Code D1.5M/D1.5.

1.2.7 Indiana DOT Design Manual, updated September 7, 2005, including all design memorandums.

1.3 Units and Dimensions:

1.3.1 All dimensions shall be denoted in US Customary units

1.3.2 Structural proportions shall be considered from those dimensions shown on the as-built structural plans, except as noted otherwise. As-built plan dimensions are assumed horizontal and are for the structure at 60 degree F.

2. RATING SUMMARY

2.1 Introduction

The load rating analysis shall be performed to meet Indiana Department of Transportation requirements and shall also to serve as reference for the bridge load carrying capacities. The rating factors will be derived for the effects of design vehicles and also for the actual condition of the bridge including compensations for redundancy and section loss. The initial load rating report summarizes the load rating analysis assuming the bridge is in pristine condition. Section losses related to the loss of reinforcement area or post-tensioning tendon area due to corrosion will be input based upon corrosion studies and recommendations will be the subject of further study.

Evaluations will be made at section changes, where tendons are dropped or added, at locations of peak stresses and forces, and at regular intervals along the length of the bridge to define trends in the load rating factors.

The "Guide Manual for Condition Evaluation for Load and Resistance Factor Rating (LRFR) of Highway Bridges" specification from 2003, with 2005 Interim Revisions, shall be used. The intent of LRFR is to provide the same methodology consistent with LRFD, but based on target reliabilities that are different from those used in the design. This document provides further guidance to the LRFR manual for segmental bridge types.

Comparisons of the structure deflected shape versus survey data are made in the inspection reports.

2.2 Inventory and Operating Rating Levels

The Inventory rating represents the load level at which a structure can be utilized for an indefinite period of time. This is also the design level. The Operating rating represents the absolute maximum permissible load level allowed on a bridge. Legal load trucks and permit load trucks are analyzed using this level. The Inventory and Operating ratings differ primarily by the use of different load factors at ultimate limits or different allowable stresses at service load limits. For service limit states in the longitudinal direction, the Operating rating is based on the number of loaded lanes per AASHTO LRFD.

To extend bridge durability, Inventory and Operating rating levels shall be checked for both Service and Strength Limit States. Table 2.2.1 and Table 2.2.2, respectively, show the allowable stresses and the load factors.

Five features of concrete segmental bridges are to be rated at both Inventory and Operating, as follows:

At Service Limit State

- Longitudinal Box Girder Flexure
- Principal Web Tension

At Strength Limit State

- Longitudinal Box Girder Flexure
- Transverse Top Slab and Web Flexure
- Web Shear
- Transverse Web Bending with Web Shear

Table 2.2.1 Allowable Service Stresses for Rating of Concrete Segmental Bridges

At the Service Limit State after Losses	Stress Limit Inventory	Stress Limit Operating
Compression (longitudinal or transverse)	$0.60 \cdot f'c$	$0.60 \cdot f'c$
Longitudinal Tensile Stress in Precompressed Tensile Zone with minimum bonded prestressing tendons or auxiliary reinforcement.	$0.0948 \cdot \sqrt{f'c}$ (ksi) $3 \cdot \sqrt{f'c}$ (psi)	$0.240 \cdot \sqrt{f'c}$ (ksi) $7.5 \cdot \sqrt{f'c}$ (psi)
Transverse distribution of reinforcement.	Not checked (Paragraph 6.5.4.1 - LRFR.)	
Principal Tensile Stresses at Neutral Axis in Webs (Service III)	$0.110 \cdot \sqrt{f'c}$ (ksi) $3.5 \cdot \sqrt{f'c}$ (psi)	$0.126 \cdot \sqrt{f'c}$ (ksi) $4 \cdot \sqrt{f'c}$ (psi)

Table 2.2.2 - LRFR Load Factors for Segmental Bridges for Cline Avenue Project

			LRFD Dead and Permanent Loads			LRFD Transient Loads					Inventory			Operating									
											LRFD Design Loads		No. of Ld. Lanes = No. of Design Lanes per LRFD	LRFD Design Loads	InDOT Legal Loads			InDOT Permit Loads					
			DC	DW	EL including PT Sec.	FR	TU [1], CR, SH	TG Inventory	TG Operating		HL-93 or Tandem	No. of Ld. Lanes = No. of Design Lanes per LRFD		HL-93 or Tandem	R1	R2	R3	R4	R5	S1	S2	S3	S4	S5
Longitudinal	Strength I	γL =	1.25	1.50	1.00	1.00	0.50	0.00	0.00	γL =	1.75	X	X	1.35										
Longitudinal	Strength II	γL =	1.25	1.50	1.00	1.00	0.50	0.00	0.00	γL =		X	X		1.65 [3]			1.40 [4]						
Longitudinal	Service I	γL =	1.00	1.00	1.00	1.00	1.00	0.50	0.00	γL =	1.00	X	X	1.00	1.00			1.00						
Longitudinal	Service III	γL =	1.00	1.00	1.00	1.00	1.00	0.50	0.00	γL =	0.80	X	X	0.80 [2]	0.80 [2]			0.80 [2]						
Transverse	Strength I	γL =	1.25	1.50	1.00	n/a	n/a	n/a		γL =	1.75	X	X	1.35	1.65 [3]			1.40 [4]						

The appropriate summary rating factors shall be the lowest rating factor of load case (1)-(2) for Inventory and load case (3)-(4), (5), (8)-(10) for Operating per Table 2.2.3 as follows.

(1) TU considered for Service I and Service III Design Inventory Only (per Recommendations from FDOT Modifications to LRFR Table 6-1)
(2) Factor Based on Recommendations per FDOT Modifications to LRFR Table 6-1
(3) Based on AASHTO LRFR Table 6-5 with ADTT = 1000
(4) Based on AASHTO LRFR Table 6-5 with ADTT = 100

Table 2.2.3 – Load Combinations for LRFR

				Inventory		Operating					
				LRFD Design Loads		LRFD Design Loads		InDOT Legal Loads	InDOT Permit Loads		
				HL-93 or Tandem		HL-93 or Tandem		R1, R2 or R3	R4, R5, S1 thru S5		
		Load Combination (LC) No.:		**#1**	**#2**	**#3**	**#4**	**#5**	**#8**	**#9**	**#10**
Longitudinal	All regions, all Spans.	HL 93 Design Truck or Tandem plus 0.64 k/lf uniform lane load in All Load Lanes (except Permit Lane for LC #9)	LRFD 3.6.1.2 LRFR 6.4.3	X		X				X	
		InDOT Legal Loads - one R1, R2 or R3 in each load lane plus 0.64 k/lf uniform lane load simultaneously and not interrupted by space occupied by the trucks..	InDOT – Cline Ave.					X			
		One InDOT Permit Vehicle (R4, R5, S1 thru S5) in one load lane plus 0.64 k/lf uniform lane load simultaneously and not interrupted by the space occupied by the trucks. The remainder of loaded lanes contains the force extreme effect from HL-93, with the position of the permit load varying across the roadway width.	InDOT - Cline Ave. LRFR 6.4.5.4						X		
	Negative moment regions, all spans.	90% of Two HL 93 Design Trucks in same lane spaced at 50 ft minimum plus 90% of 0.64 k/lf uniform lane load	LRFD 3.6.1.3.1		X		X				X
Transverse or Local Details	All regions, all Spans.	HL 93 Design Truck or Tandem Only (one per lane) (no uniform lane load) in All Load Lanes (except Permit Lane for LC #9)	LRFD 3.6.1.2 LRFR 6.4.3	X		X				X	
		InDOT Legal Loads - one R1, R2 or R3 in each load	InDOT – Cline Ave.					X			
		One InDOT R4, R5, or S1 thru S5 Permit Vehicle in one load lane. The remainder of loaded lanes contains the force extreme effect from HL-93 (no uniform lane load), with the position of the permit load varying across the roadway width.	InDOT LRFR 6.4.5.4						X		

Notes:

Apply Dynamic Load Allowance, IM, of 33% to Vehicle and Axle Loads only

Permit Load Rating for mixed traffic is (#8 + #9) or (#8 + #10).

2.3 GENERAL LOAD RATING EQUATION

In accordance with AASHTO LRFR Equation 6-1, the general Load Rating Factor, RF, should be determined according to the formula:

$$RF = \frac{C - \gamma_{DC}DC - \gamma_{DW}\,DW \pm \gamma_{EL}(P + EL) - \gamma_{FR}\,FR - \gamma_{CR}\,(TU + CR + SH) - \gamma_{TG}\,TG}{\gamma_{L}(LL+IM)}$$

Where:

For Strength Limit States:

C = Capacity = $(\phi_c \times \phi_s \times \phi)\,Rn$
ϕ_c = Condition Factor
ϕ_s = System Factor
ϕ = Strength Reduction Factor per LRFD
Rn = Nominal member resistance as inspected, measured and calculated according to formulae in LRFD

For Service Limit States:

$C = f_R$ = Allowable stress at the Service Limit State (Table 2.2.1).

Allowable stress levels have been established in order to limit cracking and protect the integrity of corrosion protection afforded post-tensioning tendons.

Load Effects and Nomenclature per LRFD / LRFR:

DC = Dead load of structural components (includes barriers if accurately known).
DW = Dead load of permanent superimposed loads such as wearing surface and utilities (applies to barriers when weight is not accurately known).
P = Permanent effects other than dead load (LRFR), including prestress.
EL = Permanent effects of erection forces (e.g. from erection equipment, changes in statical scheme) and includes secondary effects of post-tensioning.
FR = Forces from fixed bearings, bearing friction or frame action, otherwise zero.
TU = Uniform temperature effects from fixed bearings or frame action, otherwise zero.
CR = Creep.
SH = Shrinkage.
TG = Thermal gradient.
LL = Live load.
IM = Dynamic Load Allowance (Impact).
γ_{DC} = Load factor for structural components.
γ_{DW} = Load factor for permanent superimposed dead loads.
γ_{EL} = Load factor for secondary PT effects and locked-in erection loads.
γ_{FR} = Load factor for bearing friction or frame action.
γ_{CR} = Load factor for uniform temperature, creep and shrinkage.
γ_{TG} = Load factor for thermal gradient.
γ_{L} = Live load factor.

Capacity factors (Condition, System) will not be used for Service Limit States.

2.4 Condition Factors (To be determined - Subject of further study):

The condition factor will be estimated from Table 2.4.1. These are the same condition factors indicated in LRFR Table 6.4.2.3-1. Condition factors used in the load rating analysis will be derived from the inspection report.

Table 2.4.1 - LRFR Condition Factors Related to NBI Rating

Structural Condition of Member	NBI Rating	Condition Factor (ϕ_c)
Good or Satisfactory	> 6	1.00
Fair	5	0.95
Poor	< 4	0.85

Section losses of reinforcing bars and post-tensioning shall be accounted for in the load rating analysis. Section losses used will be derived from the inspection report.

2.5 System Factors:

The System Factor *(ϕ_s)* is related to the degree of redundancy in the total structural system. In LRFR, bridge redundancy is defined as the capability of a structural system to carry loads after damage or failure of one or more of its members. LRFR recognizes that structural members of a bridge do not behave independently, but interact with one another to form one structural system.

The System Factor *(ϕ_s)* will be derived following the data presented in Table 2.5.1.

Table 2.5.1 - LRFR System Factors for Longitudinal Flexure (Strength Limits Only)

			System Factors			
Bridge Type	Span Type	# of Hinges to Failure	No. of Tendons per Web			
			1/web	2/web	3/web	4/web
Cast-In-Place	Interior Span	3	0.90	1.05	1.15	1.20
	End or Hinge Span	2	0.85	1.00	1.10	1.15
	Statically Determinate	1	n/a	0.90	1.00	1.10

The System Factor (ϕ_s) for transverse flexure shall be $\phi_s = 1.00$.

2.6 Reinforced Concrete Members:

Reinforced concrete members shall be evaluated by the strength design method and will not be checked for distribution of reinforcement (LRFR Article 6.5.4.1).

2.7 Local Details (To be determined - Subject of further study):

2.4.1 If local details such as diaphragms, anchorage zones, blisters, deviation saddles are showing signs of distress, they will be evaluated at the Strength I Limit State and will be given a capacity versus demand ratio.

2.4.2 Strut and Tie modeling shall comply with AASHTO LRFD Specifications Article 5.6.3 and will be used to evaluate local details.

2.8 Principal Tensile Stress – Service Limit State:

A check of the principal tensile stress verifies the adequacy of webs for longitudinal shear at service. The verification, made at the neutral axis, is the recommended minimum prescribed procedure, as follows:

Sections shall be considered only at locations greater than "H/2" from the edge of the bearing surface or face of diaphragm, where classical beam theory applies: i.e. away from discontinuity regions. In general, verification at the elevation of the neutral axis may be made without regard to any local transverse flexural stress in the web itself given that in most large, well proportioned boxes the maximum web shear force and local web flexure are mutually exclusive load cases. This is a convenient simplification. However, should the neutral axis lie in a part of the web locally thickened by fillets, then the check should be made at the most critical elevation, taking into account any coexistent longitudinal flexural stress. Also, if the neutral axis (or critical elevation) lies within 1 duct diameter of the top or bottom of an internal, grouted duct, the web width for calculating stresses should be reduced by half the duct diameter.

All stresses at the elevation of the neutral axis due to thermal gradient at Inventory conditions may be disregarded for principal tension checks.

Classical beam theory and Mohr's circle for stress shall be used to determine shear and principal tensile stresses. At the Service Limit State, the shear stress and Principal Tensile Stress shall be determined at the neutral axis (or critical elevation) under the long-term residual axial force, maximum shear and/or maximum shear force combined with shear from torsion in the highest loaded web, using a live load factor, $\gamma_L = 1.00$. The live load shall then be increased in magnitude so that the shear stress in the highest loaded web increases until the Principal Tensile Stress reaches its allowable maximum value (Table 2.2.1).

The Rating Factor at the Service Limit State is the ratio between the live load shear stress required to induce the maximum Principal Tensile Stress to that induced by a live load factor of 1.00.

2.9 Shear, Torsion, and Flexure for Negative Moment Regions – Ultimate Limit State:

Shear capacity shall be determined in accordance with the General Procedure outlined in the AASHTO LRFD Specifications Article 5.8.3.4.2.

2.10 Structural Steel Members: (Not Applicable)

2.11 Substructure Elements: (Will not be Load Rated)

2.11 Bearings: (Will not be Load Rated)

2.12 Expansion Joints: (Will not be Load Rated)

3. DESIGN LOADINGS

3.1 Dead Loads:

3.1.1	Post-tensioned Concrete	156 lbs/ft^3
3.1.2	Normal Weight Reinforced Concrete	150 lbs/ft^3
3.1.3	Structural Steel	490 lbs/ft^3
3.1.3	Overlay Wearing Surface	25 lbs/ft^2
3.1.4	Barrier, Traffic Railing	450 lbs/ft
3.1.5	Barrier, Median	530 lbs/ft
3.1.6	Soil, Compacted	125 lbs/ft^3
3.1.7	Bridge Supported Drainage Pipes	65 lbs/ft

3.2 Live Loads:

Apply LRFD live load HL 93 Design Truck or Tandem plus 0.64 kip/ ft. uniform lane load. In addition, the following Legal Loads and Permit Loads shall be rated:

Per Figure 3.2.1 and 3.2.2, respectively:

R1 - Legal Load - Toll Road Loading No. 1 (W = 90 k)
R2 - Legal Load - Toll Road Loading No. 2 (W = 90 k)
R3 - Legal Load - Special Toll Road Truck (W = 126 k)
R4 - Permit Load - Michigan Truck Train No. 5 (W = 134 k)
R5 - Permit Load - Michigan Truck Train No. 8 (W = 134.2 k)

S1 - Permit Load - Special Truck 11 Axle Loading (W = 258 k)
S2 - Permit Load - Special Truck 13 Axle Loading (W = 267 k)
S3 - Permit Load - Special Truck 14 Axle Loading (W = 350 k)
S4 - Permit Load - Superload 19 Axle Loading (1) (W = 305 k)
S5 - Permit Load - Superload 19 Axle Loading (2) (W = 480 k)

For all legal and permit trucks include a 0.64 k/lf uniform lane load simultaneously and not interrupted by space occupied by the trucks. The transverse wheel spacing and tire contact area used in the load rating evaluation are shown in Figure 3.2.3.

The application and spacing of longitudinal lanes for the HL 93 Design Load (Inventory and Operating), the Legal Loads (Operating), and the Permit Loads (Operating) are shown in

Figure 3.2.4. Further discussion of this topic is continued in Section 3.10 – Load Combinations.

Due to the low rating factors for the Cline Avenue Bridge for AASHTO design loadings, further analysis was undertaken to show the effect of restricting traffic from the bridge shoulders and thus keeping traffic confined to the striped lanes. The summary tables (e.g., Table 5.1) in the Cline Avenue Bridge – Load Rating Report include the tabulation of AASHTO HL 93 loading for both AASHTO design and striped lanes.

3.3 Thermal Loads:

3.3.1 Mean Temperature: +60 degree F
Temperature Rise +45 degree F
Temperature Fall -40 degree F

3.3.2 Coefficient of Thermal Expansion: 6.0×10^{-6} per degree F

3.3.3 Temperature Gradient (TG):

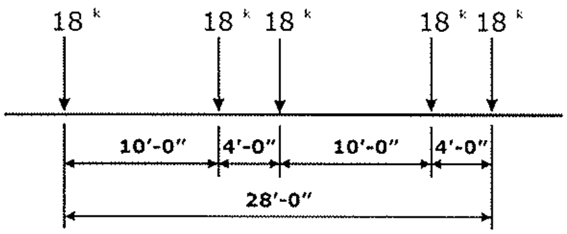
Thermal Forces (Longitudinal):

Non-Linear temperature gradient is based on LRFD Article 3.12.3, using a plain concrete surface for solar radiation Zone 3.

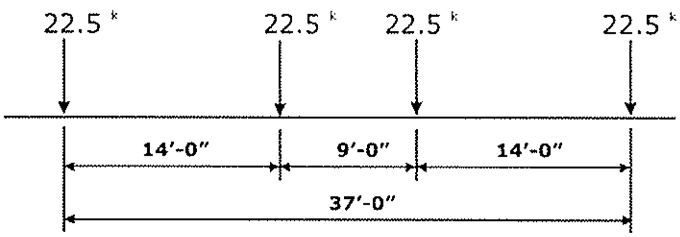
T1 = 41 Degree F and T2 = 11 Degree F
T3 is taken as 0 degree F

Thermal Forces (Transverse)- Not Considered:

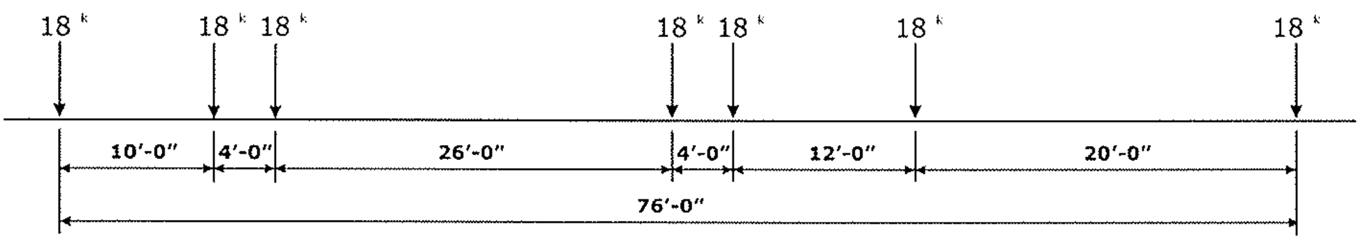
Figure 3.2.1 - InDOT Overload Legal Load and Permit Trucks (R1 thru R5) (Longitudinal Axle Loads and Spacing)



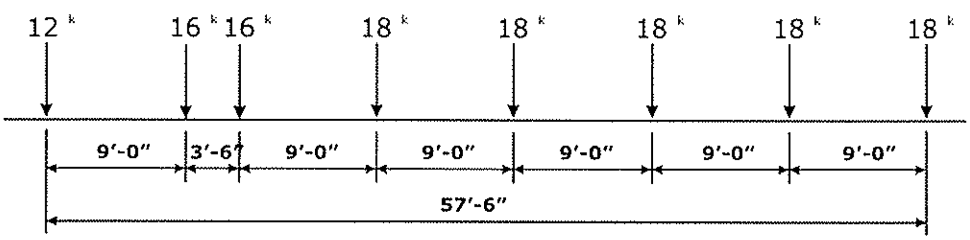
R1 - TOLL ROAD LOADING NO. 1 (W = 90 k)



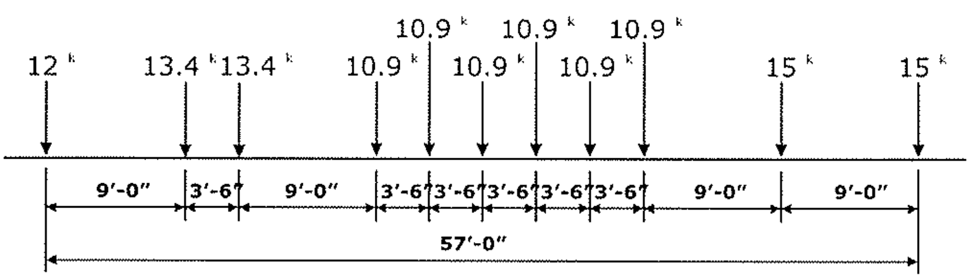
R2 - TOLL ROAD LOADING NO. 2 (W = 90 k)



R3 - SPECIAL TOLL ROAD TRUCK (W = 126 k)

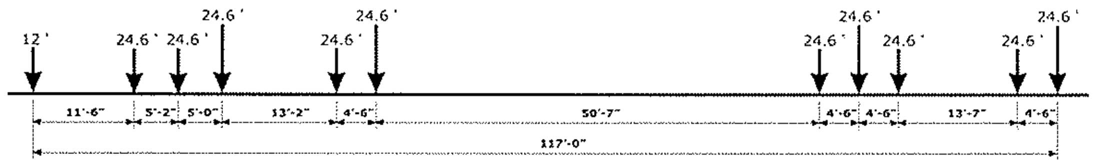


R4 - MICHIGAN TRUCK TRAIN NO. 5 (W = 134 k)

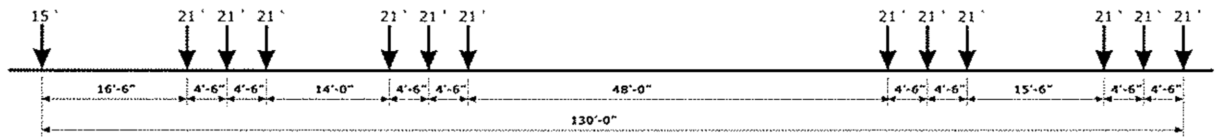


R5 - MICHIGAN TRUCK TRAIN NO. 8 (W = 134.2 k)

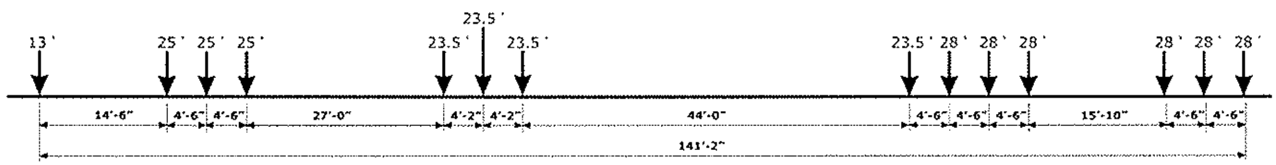
Figure 3.2.2 Special InDOT Permit Trucks (S1 thru S5) (Longitudinal Axle Loads and Spacing)



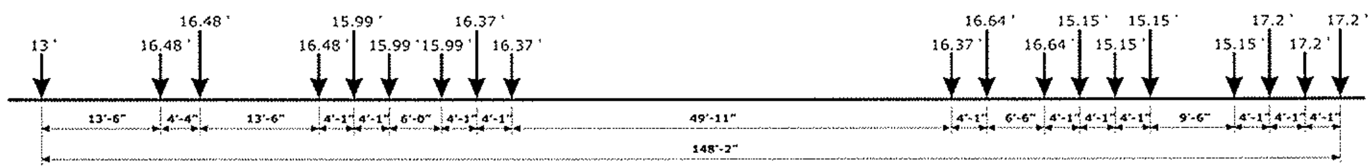
S1 - SPECIAL TRUCK 11 AXLE (W = 258 k)



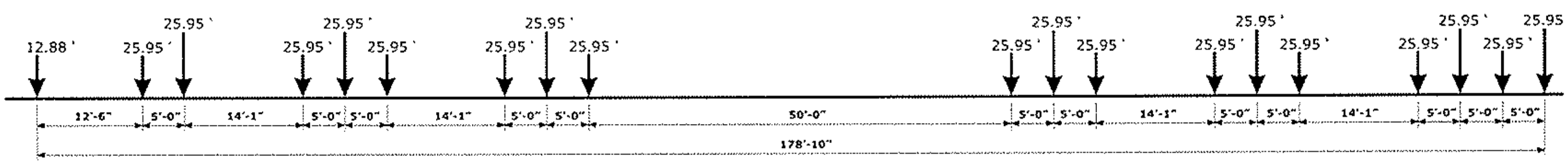
S2 - SPECIAL TRUCK 13 AXLE (W = 267 k)



S3 - SPECIAL TRUCK 14 AXLE (W = 350 k)



S4 - SUPERLOAD 19 AXLE (W = 305 k)



S5 - SUPERLOAD 19 AXLE (W =480 k)

Figure 3.2.3 Wheel Spacing and Contact Tire Area (LRFD Section 3.6.1.2)

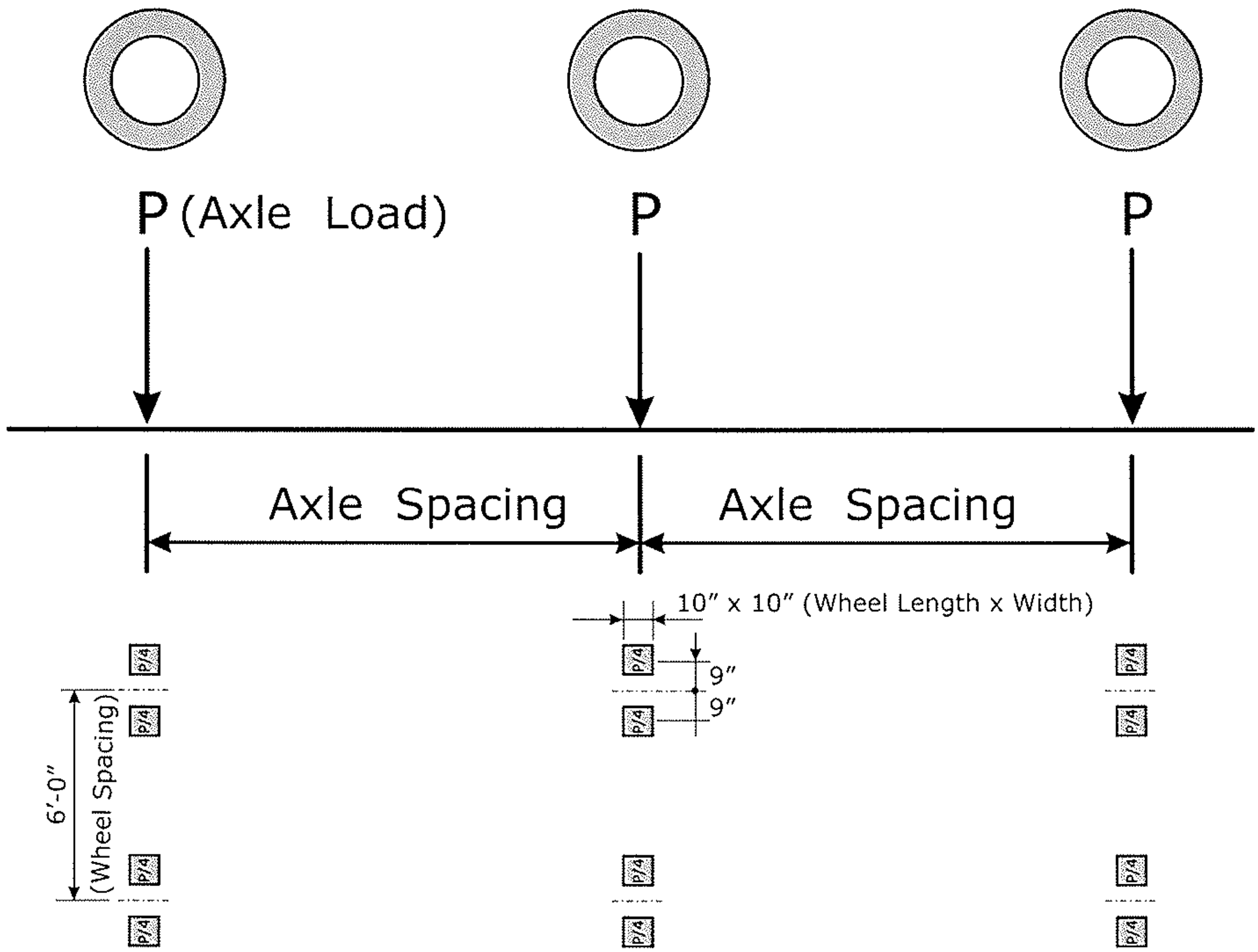
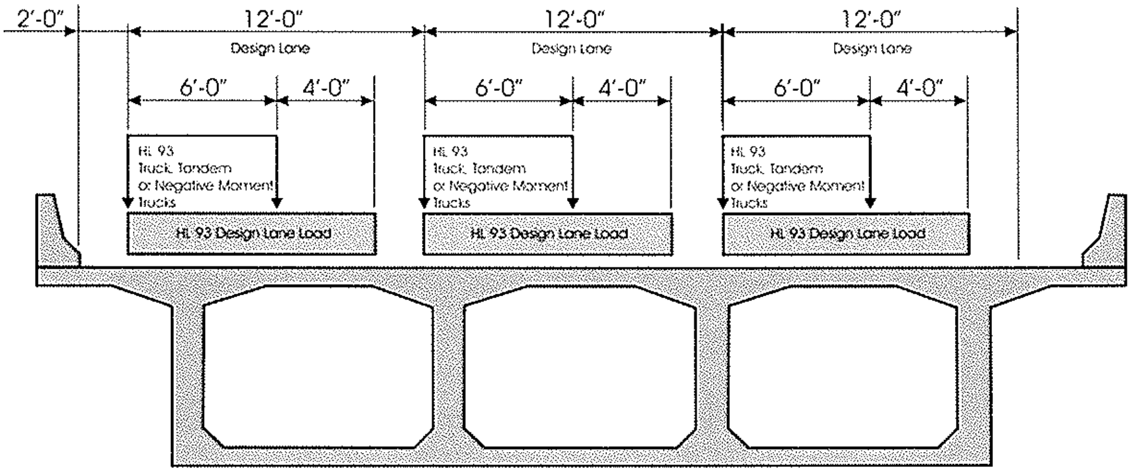
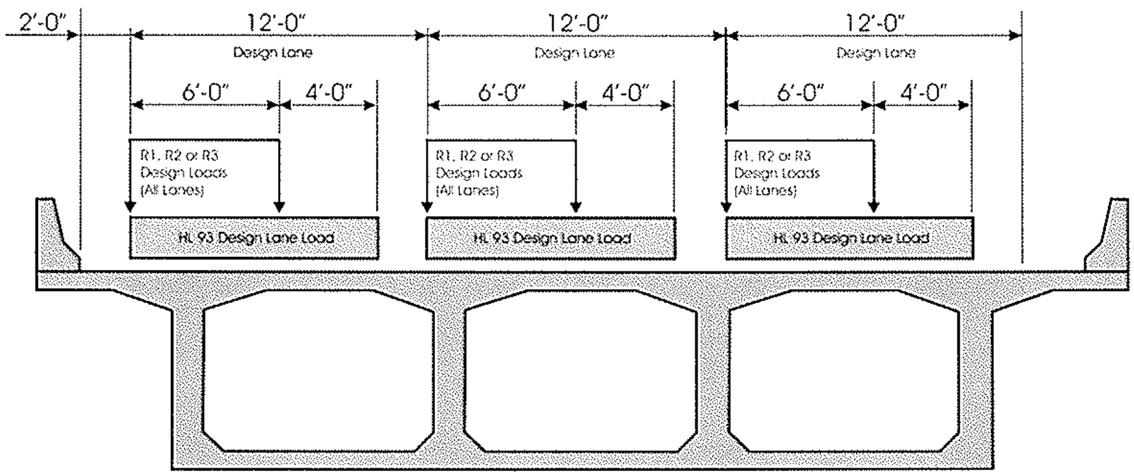


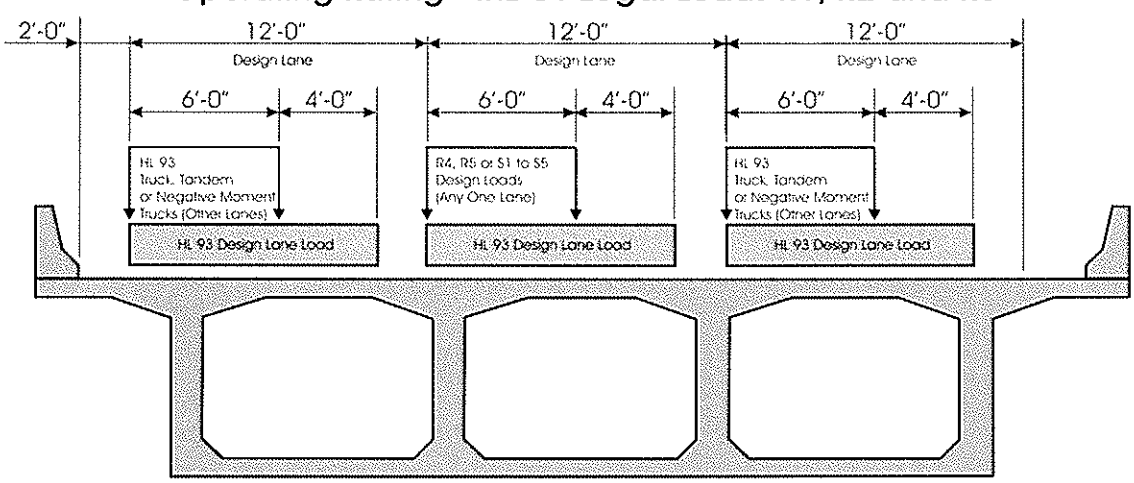
Figure 3.2.4 Application and Spacing for Design, Legal and Permit Loads



Operating and Inventory Ratings - Design Load (HL 93)



Operating Rating - InDOT Legal Loads R1, R2 and R3



Operating Rating - InDOT Permit Loads R4, R5 and S1 thru S5

3.4 Creep and Shrinkage:

3.4.1 Strains are calculated in accordance with CEB/FIP Model Code for Concrete Structures, 1978.

3.4.2 Relative Humidity: 74%

3.4.3 Permanent effects of creep and shrinkage shall be added to all AASHTO loading combinations with a load factor of 1.0.

3.5 Construction Equipment Loads and Locked-In Stresses:

Construction method and sequence shall be based on those shown on the design plans.

3.6 Wind Loads: (Not Considered in Load Rating)

3.7 Vessel Impact Loads: (Not Considered in Load Rating)

3.8 Seismic Loads: (Not Considered in Load Rating)

3.9 Differential Support Settlement: (Not Considered in Load Rating)

3.10 Load Combinations:

Load factors and load combinations for the Strength and Service Limit States should be made in accordance with Table 2.2.2, "Load Factors for Segmental Bridges". Table 2.2.2 is separated horizontally into longitudinal and transverse requirements and vertically into Inventory or Operating conditions. Load factors for permanent (e.g. dead) loads and transient (e.g. temperature) loads are provided. Note: Half thermal gradient (0.5TG) is used only for longitudinal Service Inventory conditions.

Altogether, load combinations (Table 2.2.3) are given for ten basic cases, labeled "#1" through "#10" (cases #6 and #7 omitted), which are necessary to satisfy InDOT and AASHTO LRFR. The first two (#1 through #2) are for Inventory (HL 93 Design) conditions. Load cases#3 through #4 are for Operating conditions using HL 93 Design loads. Load case #5 addresses InDOT Legal Load and load cases #8 through #10 Permit Load Vehicles which are combined with HL 93.

STRENGTH I and II and SERVICE I and III conditions are applied as follows:

STRENGTH I - Apply to Inventory and Operating conditions for HL 93 Design loads.

STRENGTH II – Applied only to InDOT Legal Loads and Permit Loads.

SERVICE I - Applies to longitudinal compression checks in prestressed components. Also applies to the concrete tensile checks in the transverse direction of post-tensioned decks. Since the Cline Avenue bridge decks are reinforced only with mild steel and do not utilize post-tensioning, Service I is not checked for the deck slabs.

SERVICE III- Applies to concrete longitudinal tension and concrete principal tension.

The following is a detailed checklist of the load applications, combinations and circumstances that will be necessary to satisfy the ratings performed for this project.

Inventory Rating - Design Load (HL 93)

Transverse:

- Apply HL 93 Design Truck or Tandem. *(Table 2.2.3, Load Combination #1)*
- Do not apply uniform lane load.
- Apply same axle loads in each lane.
- Apply Dynamic Load Allowance, IM = 1.33 on Design Truck or Tandem.
- For both Strength and Service Limit States, used number of load lanes per LRFD.
- Apply multi-presence factor: one lane, m =1.20; two lanes, m = 1.00; three, m = 0.85; four or more, m = 0.65. (Maximum value of m = 1.20 is the appropriate AASHTO LRFD/LRFR current criteria to allow for rogue vehicles).
- Place loads in full available width as necessary to create maximum effects (design lanes and striped lanes were evaluated).
- Apply no Thermal Gradient transversely.
- For STRENGTH I Limit State use AASHTO design trucks with live load factor, γ_L = 1.75.

Longitudinal (see Figure 3.10.1):

- Apply HL 93 Design Truck or Tandem, including 0.64 kip/ft uniform lane load. *(Table 2.2.3, Load Combination #1)*
- Apply same load in each lane.
- Apply Dynamic Load Allowance, IM = 1.33 on Design Truck or Tandem only.
- For both Strength and Service Limit States, use number of load lanes per LRFD.
- Apply multi-presence factor: one lane, m =1.2; two lanes, m = 1.00; three, m = 0.85; four or more, m = 0.65. (Maximum value of m = 1.20 is the appropriate AASHTO LRFD/LRFR current criteria for notional loads and rogue vehicles).
- For negative moment regions: Apply 90% of the effect of two HL 93 Design Trucks spaced a minimum of 50 feet apart between the leading axle of one and the trailing axle of the other, plus 90% of uniform lane load.
- Place loads in full available width as necessary to create maximum effects (design lanes and striped lanes were evaluated).
- For Thermal Gradient, apply 0.50TG with live load for Service but zero TG for Strength.
- Use SERVICE III Limit State with live load factor, γ_L = 0.80, used for Principal Tensile Stress check.
- For SERVICE III Limit State, limit concrete Longitudinal Flexure Tensile Stress to values in Table 2.2.1 as appropriate.
- For SERVICE III Limit State, limit Principal Tensile Stress at the neutral axis to $0.110\sqrt{fc}$ (psi).
- Use SERVICE I Limit State with live load factor, γ_L = 1.00 and limited concrete longitudinal flexural compressive stresses to values in Table 2.2.1.
- For STRENGTH I Limit State use AASHTO design trucks with live load factor. γ_L = 1.75.

Operating Rating - Design Load (HL 93)

Transverse:

- Apply one HL 93 Design Truck or Tandem per lane. *(Table 2.2.3, Load Combination #3)*

- Do not apply uniform lane load.
- Apply same axle loads in each lane.
- Apply Dynamic Load Allowance, IM = 1.33 on Design Truck or Tandem.
- For both Strength Limit States, use number of load lanes per LRFD.
- Apply multi-presence factor: one lane, m =1.20; two lanes, m = 1.00; three, m = 0.85; four or more, m = 0.65. (Maximum value of m = 1.20 is the appropriate AASHTO LRFD/LRFR current criteria to allow for rogue vehicles).
- Place loads in full available width as necessary to create maximum effects
- Do not apply Thermal Gradient transversely.
- For STRENGTH I Limit State use live load factor, γ_L = 1.35.

Longitudinal (see Figure 3.10.1):

- Apply HL 93 Design Truck or Tandem, including 0.64 kip/ft uniform lane load. *(Table 2.2.3, Load Combination #3)*
- Apply same load in each lane.
- Apply Dynamic Load Allowance, IM = 1.33 on Design Truck or Tandem only.
- For the Strength Limit State, use number of load lanes per LRFD.
- For the Service Limit State , use number of load lanes per LRFD.
- Place loads in full available width as necessary to create maximum effects (for example, in shoulders).
- Multi-presence factor: HL 93 Design Load (including uniform lane load) one lane, m=1.20; two lanes, m = 1.00; three, m = 0.85; four or more, m = 0.65. (The maximum value of 1.20 for one lane is necessary because the load is a notional load with a uniform lane load component).
- For negative moment regions, Apply 90% of the effect of two HL 93 Design Trucks each spaced a minimum of 50 feet apart between the leading axle of one and the trailing axle of the other, plus 90% of 0.64 kip/LF uniform lane.
- Do not apply Thermal Gradient.
- Use SERVICE III Limit State with live load factor, γ_L = 0.80 and limit concrete principal tensile stresses to values in Table 2.2.1.
- Use SERVICE III Limit State with live load factor, γ_L = 0.80 and limit concrete longitudinal flexural tensile stress to values in Table 2.2.1.
- For STRENGTH I Limit State use live load factor, γ_L = 1.35.

Operating Rating – InDOT Legal Loads

Transverse:

- Apply InDOT Legal Load Trucks *R1, R2 and R3 (Table 2.2.3, Load Combination #5).*
- Do not apply any uniform lane load.
- Apply same axle loads in each lane using only one truck per lane (i.e. do not mix Trucks).
- Apply Dynamic Load Allowance, IM = 1.33 on Legal Load trucks only.
- For both Strength and Service Limit States, use number of load lanes per LRFD.

- Apply multi-presence factor: one lane, m =1.2; two lanes, m =1.0; three lanes, m = 0.85; four or more lanes, m= 0.65.
- Place loads in full available width as necessary to create maximum effects.
- Do not apply Thermal Gradient transversely.
- For STRENGTH II Limit State use InDOT R1, R2, or R3 Trucks with live load factor, γ_L =1.65.

Longitudinal:

- Apply InDOT Legal Load Trucks (Trucks R1, R2, or R3) *(Table 2.2.3, Load Combination #5).*
- Apply same Truck load in each lane using only one truck per lane (i.e. do not mix Trucks).
- Apply 0.64 k/ft uniform lane load simultaneously with legal load trucks and not interrupted by space occupied by the trucks.
- Apply Dynamic Load Allowance, IM = 1.33 on Legal Load trucks only.
- For the Strength Limit States, use number of load lanes per LRFD.
- For Service Limit States, use number of load lanes per LRFD.
- Place loads in full available width as necessary to create maximum effects (for example, in shoulders).
- Use multi-presence factor: one lane, m = 1.20, two lanes, m = 1.00; three lanes, m = 0.85; four or more lanes, m= 0.65. (Maximum limit of 1.0 applies because loads are specific (defined) truck loads, not notional loads or rogue vehicles).
- Do not apply Thermal Gradient.
- Use SERVICE III Limit State with live load factor, γ_L = 0.80 and limit concrete longitudinal flexural tensile and principal tensile stresses to values in Table 2.2.1 as appropriate. (Note: use of γ_L = 0.80 is appropriate because reduced reliability for large boxes is attained through the use of the number of LRFD lanes. At Operating, although no increase in allowable tensile stress (i.e. zero) can be allowed in precast joints, an increase is allowed from 3 to $7.5\sqrt{f'c}$ (psi) in reinforced joints and the Principal Tensile Stress at the neutral axis is raised to $4\sqrt{f'c}$ (psi) to attain the benefit of reduced reliability per Table2.2.1)
- Use SERVICE I Limit State with live load factor, γL = 1.00 and limit concrete longitudinal flexural compressive stress to values in Table 2.2.1. (Note: γL = 1.00 AASHTO LRFR).

Operating Rating - InDOT Permit Loads

Transverse:

- Apply one InDOT Permit Vehicle (Trucks *R4, R5, or S1 thru S5*) in one load lane *(Table 2.2.3, load combination #8 or #9).*
- Apply HL 93 Design Truck or Tandem axles only in each of the other load lanes as necessary to create maximum effects *(Table 2.2.3, load combination #8 or #9).*
- Do not apply any uniform lane load.
- Apply Dynamic Load Allowance, IM = 1.33 on Permit Vehicle, HL 93 Design Truck or Tandem only.
- Do not mix Permit Loads with Legal Loads.
- For both Strength and Service Limit States, used number of load lanes per LRFD.
- Apply multi-presence factor: one and two lanes, m =1.0; three, m = 0.85; four or more, m = 0.65. (Maximum limit of 1.0 applies because this is a rating for specific (defined) axle loads, not notional loads or rogue vehicles).
- Place loads in full available width as necessary to create maximum effects.
- Do not apply Thermal Gradient transversely.
- A reduced Dynamic Load Allowance (IM) or live load factor (γL) may be considered only to avoid restrictions.
- For STRENGTH II Limit State use InDOT permit trucks with live load factor, γ_L = 1.40.

Longitudinal (see Figure 3.10.1):

- Apply one InDOT Permit Vehicle (Trucks *R4, R5, or S1 thru S5*) in one load lane *(Table 2.2.3 Load Combinations #8)*.
- Apply 0.64 k/ft uniform lane load simultaneously with Permit Vehicles and not interrupted by space occupied by the trucks.
- Apply HL 93 Design Truck or Tandem, including 0.64 k/ft uniform lane in each of the other load lanes as necessary to create maximum effects. *(Table 2.2.3, Load Combination #9, combine #8 with #9)*.
- Alternatively, for negative moment regions: in conjunction with the Permit Vehicle in its lane, apply to the other lanes 90% of the effect of two HL 93 Design Trucks each spaced a minimum of 50 feet apart between the leading axle of one and the trailing axle of the other, plus 90% of 0.64 kip/LF uniform lane load. *(Table 2.2.3, Load Combination #10, combine #8 with #10)*.
- For the Strength Limit State for Permit Vehicles R4 and R5, use number of load lanes per LRFD.
- For the Strength Limit State for Permit Vehicles S1 thru S5, use number of load lanes per LRFD.
- For Service Limit States for all Permit Vehicles, use number of load lanes per LRFD.
- Place loads in full available width as necessary to create maximum effects (for example, in shoulders).
- Use multi-presence factor: one and two lanes, m = 1.00; three, m = 0.85; four or more, m = 0.65. (Maximum limit of 1.0 applies because loads are specific (defined) Permit loads, not notional loads or rogue vehicles).
- Dynamic Load Allowance, IM = 1.33 on Permit Vehicles, HL 93 Design Truck or Tandem only.
- Do not apply Thermal Gradient for Strength Limit State.
- Use SERVICE III Limit State with live load factor, γ_L = 0.80 and limit concrete principal tensile stresses to values in Table 2.2.1.
- Use SERVICE III Limit State with live load factor, γL = 0.80 and limited concrete longitudinal flexural tensile stress to values in Table 2.2.1.
- For STRENGTH II Limit State, used live load factor, γL = 1.40.

4. MATERIALS

4.1 Concrete:

4.1.1 All concrete properties shall be in accordance with specified 28 day compressive strength (f'_c) as follows:

Element	f'_c
C.I.P. Box Girder Elements (Mainline)	5.0 ksi
C.I.P. Box Girder Elements (Ramps)	5.5 ksi

4.2 Reinforcing Steel:

4.2.1 Reinforcing steel is assumed to conform to ASTM A615, Grade 60 unless otherwise required.

4.2.2 Minimum concrete cover for reinforcing steel:

a. Superstructure

Box Girders:	1-1/2 inch top of slab 1 inch all other surfaces

b. Substructure

Columns and Pier Caps:	2 inch clear to spiral, ties or stirrups
Foundation Elements:	3 inch clear

4.3 Prestressing Steel

4.3.1 Prestressing Parameters for Strand:

All strands are assumed to conform to the requirements of ASTM A416 Grade 270 for low relaxation strands.

Post-Tensioning:
Material Properties / Parameters:

Tensile Strength of Prestressing Strand: *(f_{pu})*	270 ksi
Yield Strength of Prestressing Strand: *(f_{py})*	243 ksi
Apparent modulus of elasticity:	28,500 ksi
Anchor Set:	3/8 in.
Friction Coefficient (μ):	
Internal tendons in metal ducts	0.25
Wobble Coefficient (k) (Internal Tendons):	0.0002/ft.

Allowable Stresses:

Maximum jacking stress at anchorage:	0.80 f_{pu}
Maximum anchorage stress at anchorage immediately after anchorage:	0.70 f_{pu}
Max. anchorage stress at internal locations immediately after anchorage:	0.70 f_{pu}
Maximum jacking stress at anchorage:	0.80 f_{pu}

4.3.2 Prestressing Parameters for Bars:

Material Properties / Parameters:

Tensile Strength of Prestressing Bars: *(f_{pu})*	150 ksi
Yield Strength of Prestressing Bars: *(f_{py})*	120 ksi
Modulus of Elasticity:	29,000 ksi
Maximum jacking stress:	0.80 f_{pu}
Maximum anchorage stress:	0.70 f_{pu}
Anchor Set:	1/16 in.
Friction Coefficient (μ):	0.30
Wobble Coefficient (k):	0.0002 / ft.
Allowable Stresses:	
Maximum jacking stress at anchorage:	0.80 f_{pu}
Maximum anchorage stress at anchorage immediately after anchorage:	0.70 f_{pu}

Max. anchorage stress at internal locations immediately after anchorage:	0.70 f_{pu}
Maximum jacking stress at anchorage:	0.80 f_{pu}

5. SUMMARY

Summary rating factors will be tabulated in the following table.

Table 5.1 - LRFR Rating Factors Summary Table

			Inventory			Operating										
			LRFD Design Loads		No. of Ld. Lanes = No. of Design Lanes per LRFD	LRFD Design Loads	InDOT Legal Loads			InDOT Permit Loads						
			HL 93 or Tandem	No. of Ld. Lanes = No. of Design Lanes per LRFD		HL 93 or Tandem	R1	R2	R3	R4	R5	S1	S2	S3	S4	S5
Longitudinal	Strength	Flexure	?	X	X	?	?	?	?	?	?	?	?	?	?	?
		Shear	?	X	X	?	?	?	?	?	?	?	?	?	?	?
	Service	Flexure	?	X	X	?	?	?	?	?	?	?	?	?	?	?
		Principle Stress	?	X	X	?	?	?	?	?	?	?	?	?	?	?
Transverse	Strength	Top Slab Centerline	?	X	X	?	?	?	?	?	?	?	?	?	?	?
		Top Slab Thickness Change	?			?	?	?	?	?	?	?	?	?	?	?
		Top Slab Webs & Cantilever	?			?	?	?	?	?	?	?	?	?	?	?
		Web Bending	?			?	?	?	?	?	?	?	?	?	?	?
Overall Minimum Rating Factor			?			?	?			?						