

Load Rating Atypical Concrete Bridges with BrR

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Boise, Idaho



Mike Briggs, PE, SE
Allie Wagner, PE

HNTB Corporation - Kansas City, MO



Overview

- **Complex Slab Systems using Simplified Line Analyses**
 - Edge-Supported Skewed Slab
 - Illinois Bulletin Slab (IBS) Bridges
- **Unsupported Structures using “Static Rating Factor” Models**
 - Filled-Spandrel Arches
- **Conclusions**

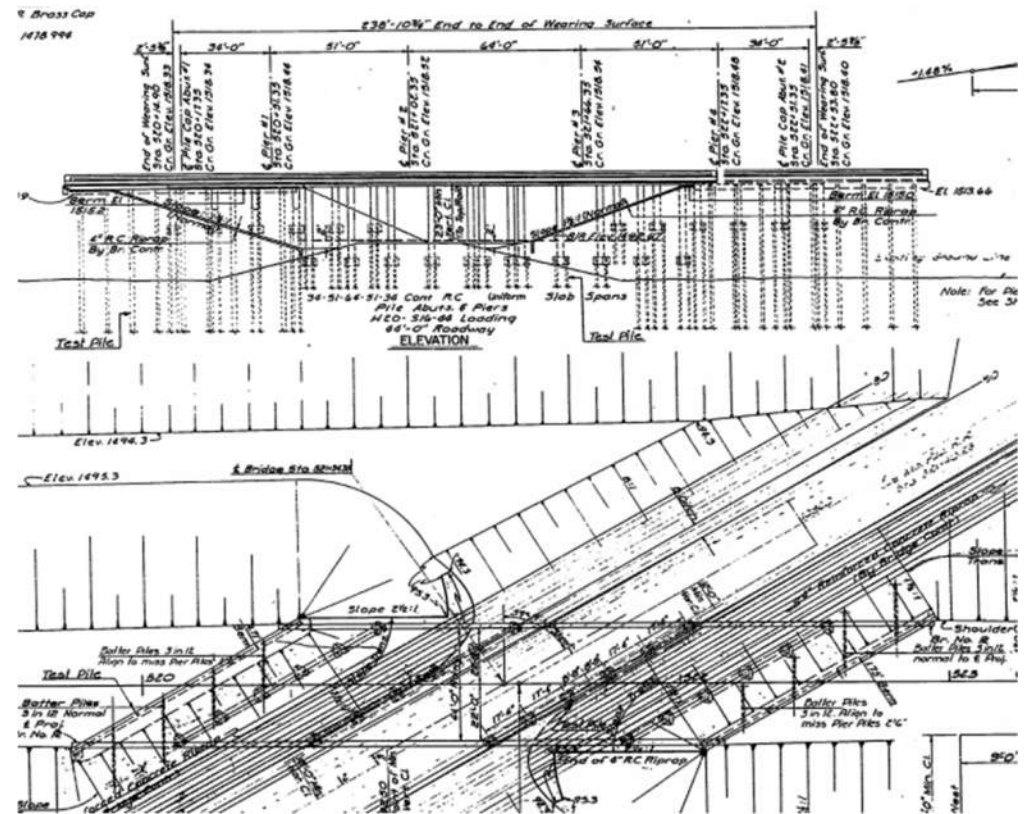


Edge-Supported Skewed Slab

Edge-Supported Skewed Slab

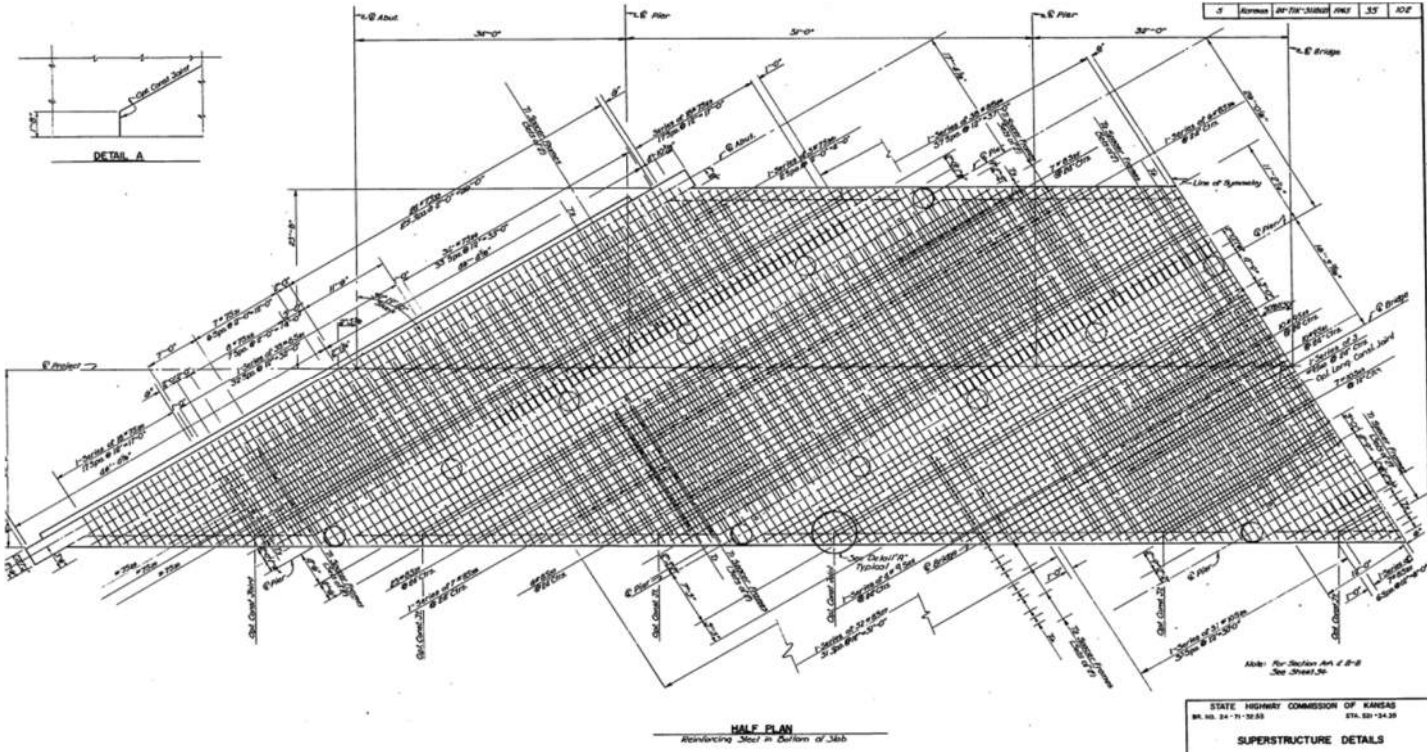
General Description:

- 5-Span Slab
 - 34'-51'-64'-51'-34'
- 59°19'10" Skew
- 44' Roadway Width



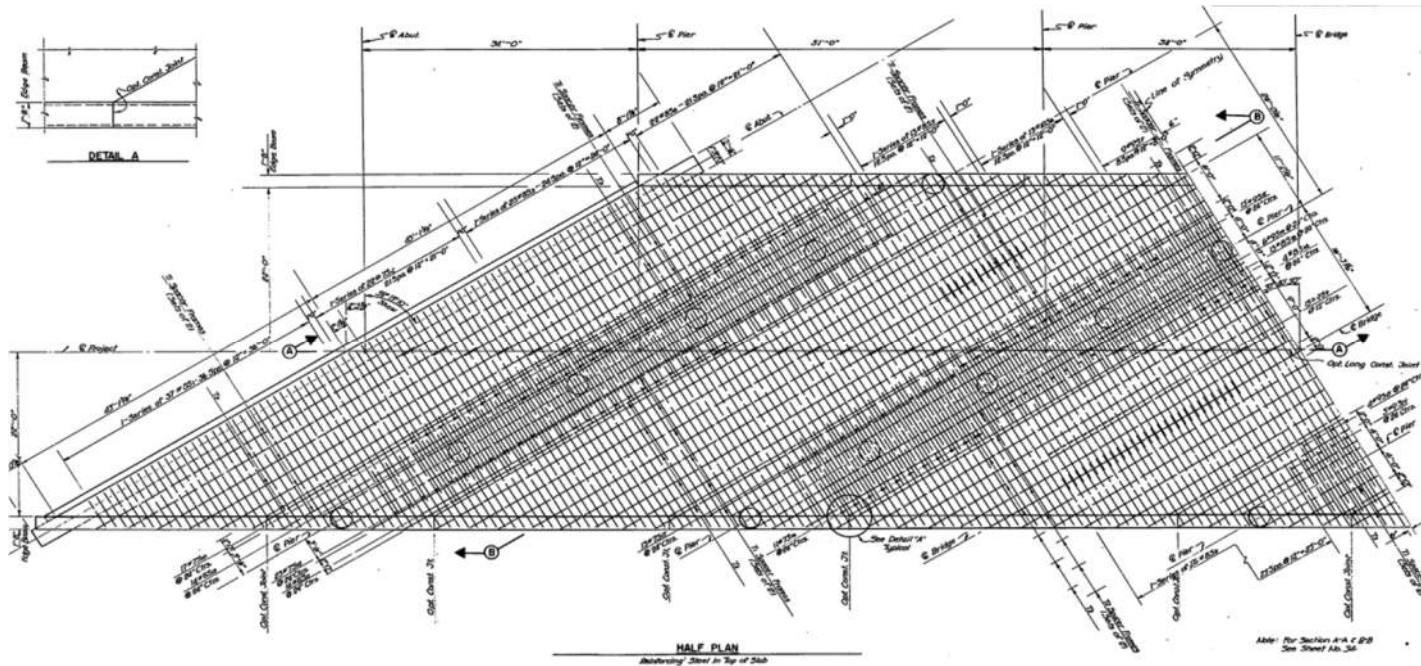
CONSTRUCTION LAYOUT

Edge-Supported Skewed Slab



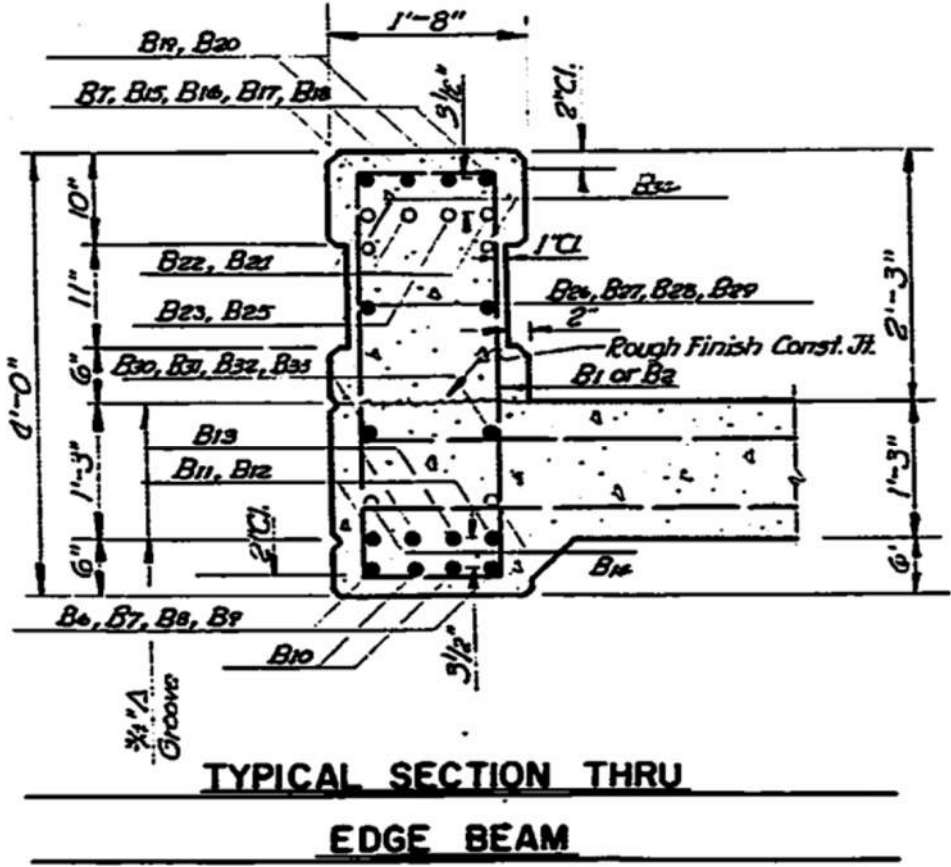
Bottom Slab Reinforcement

Edge-Supported Skewed Slab



Top Slab Reinforcement

Edge-Supported Skewed Slab



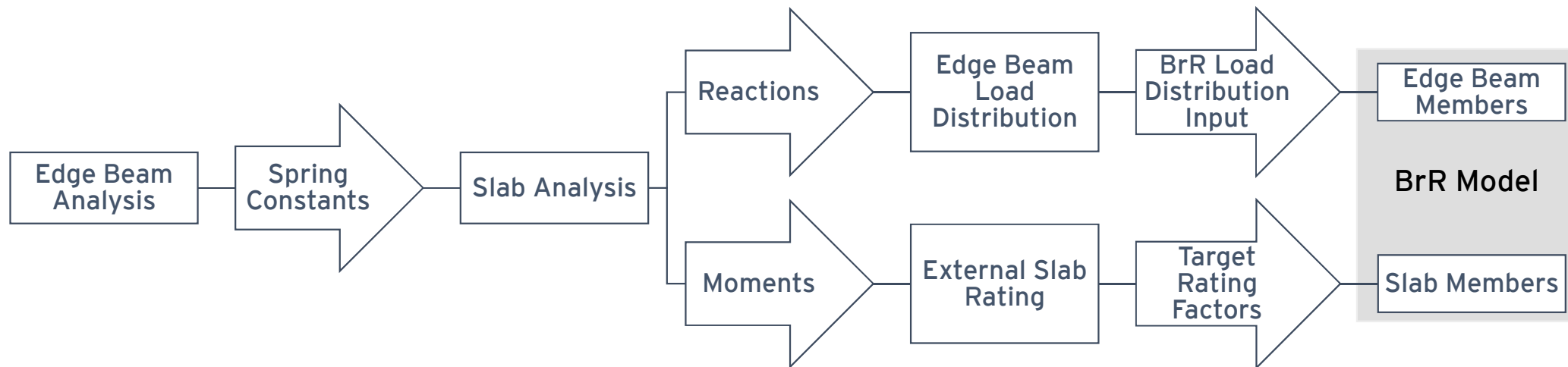
Edge-Supported Skewed Slab



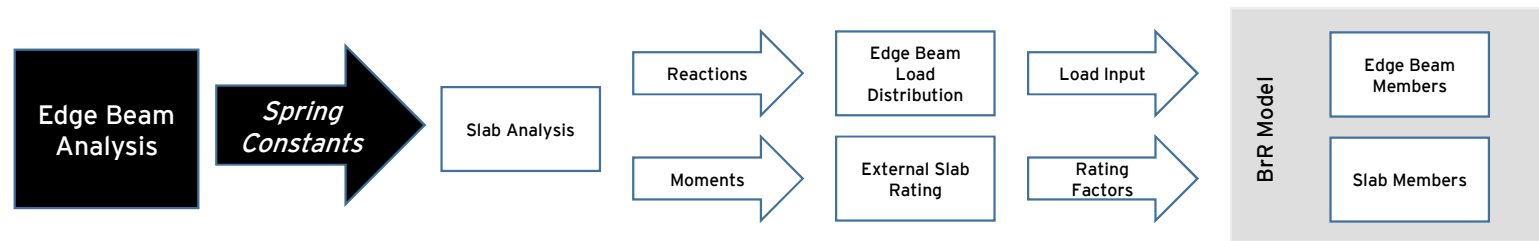
Top Slab Reinforcement

Edge-Supported Skewed Slab

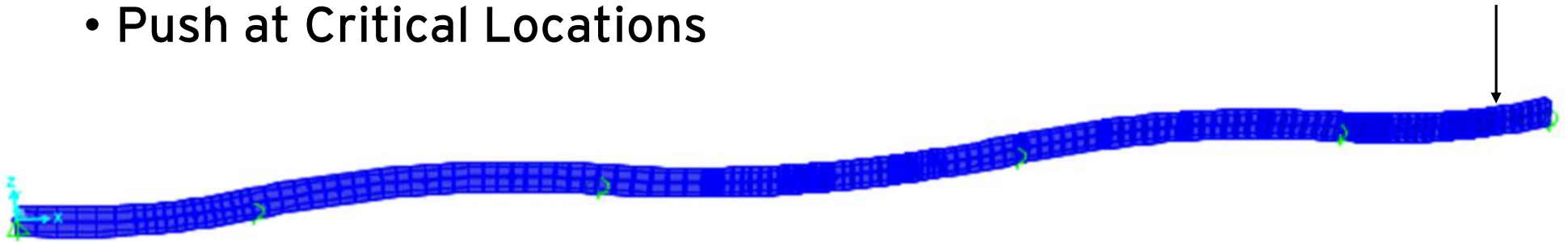
Rating Procedure:



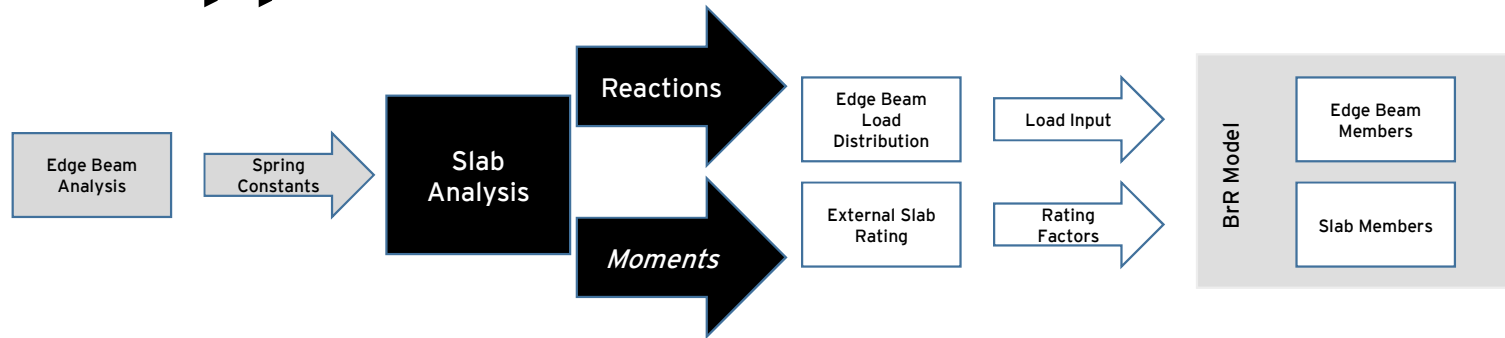
Edge-Supported Skewed Slab



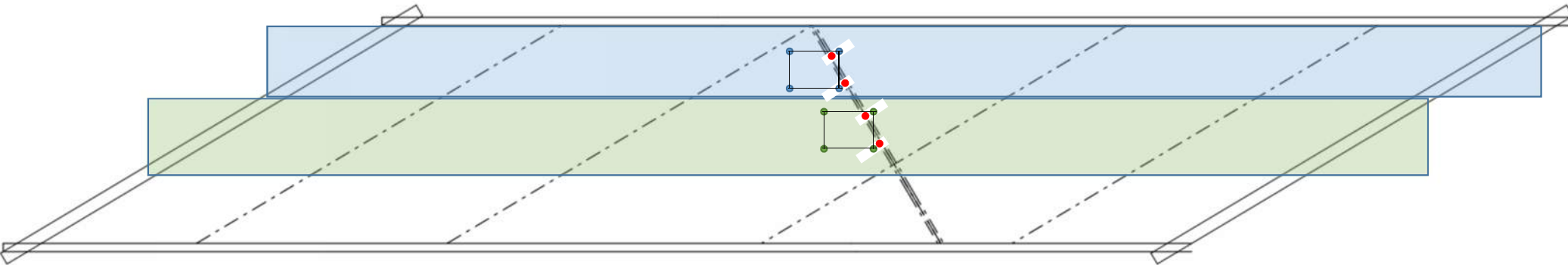
- Simple Line Model
- Rectangular Cross Section
- Pin/Roller Supports
- Push at Critical Locations



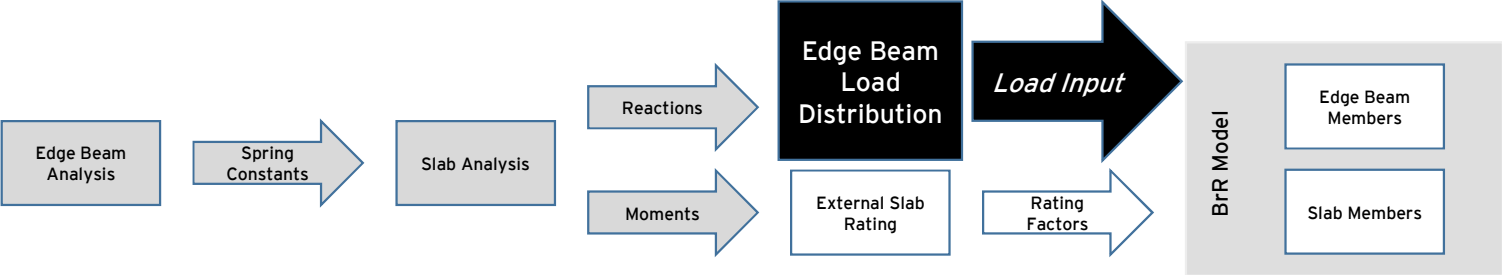
Edge-Supported Skewed Slab



- Used Spring Constants
- Manual Truck Placement
- Effective Strip Width per AASHTO



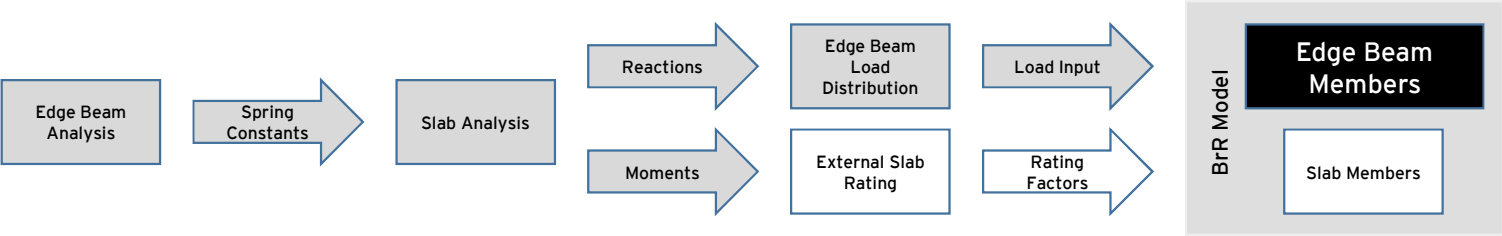
Edge-Supported Skewed Slab



- Calculate from Slab Strip Reactions at Spring Supports



Edge-Supported Skewed Slab



- Girder Line Superstructure
- Omit Support Point POI
 - Analyze at Face of Pier
- Input for Load Distribution

Self Load

Load case: Engine Assigned

Additional self load = kip/ft

Additional self load = %

“Turn Off” Self Weight

LFD

Points of Interest

- Generate at tenth points except supports
- Generate at support points
- Generate at support face & critical shear points
- Generate at section change points
- Generate at user-defined points
- Ignore shear

Distribution Factor Application Method

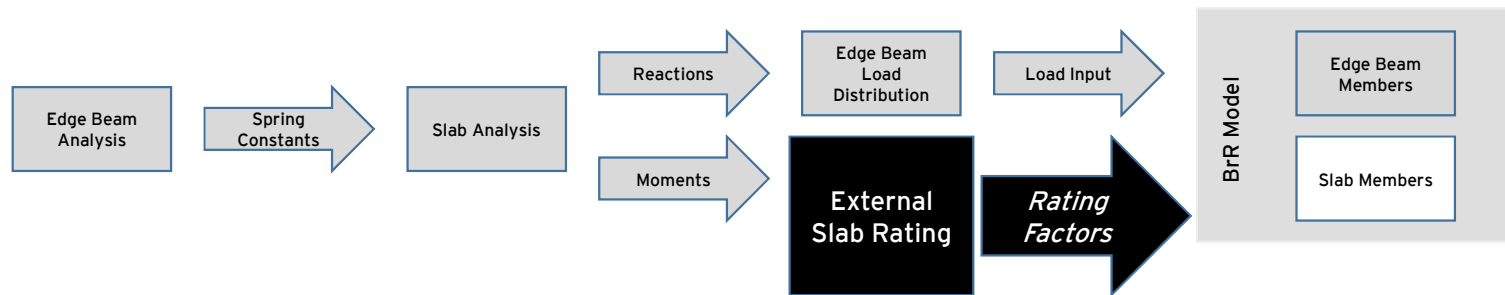
- By axle
- By POI

Control Options

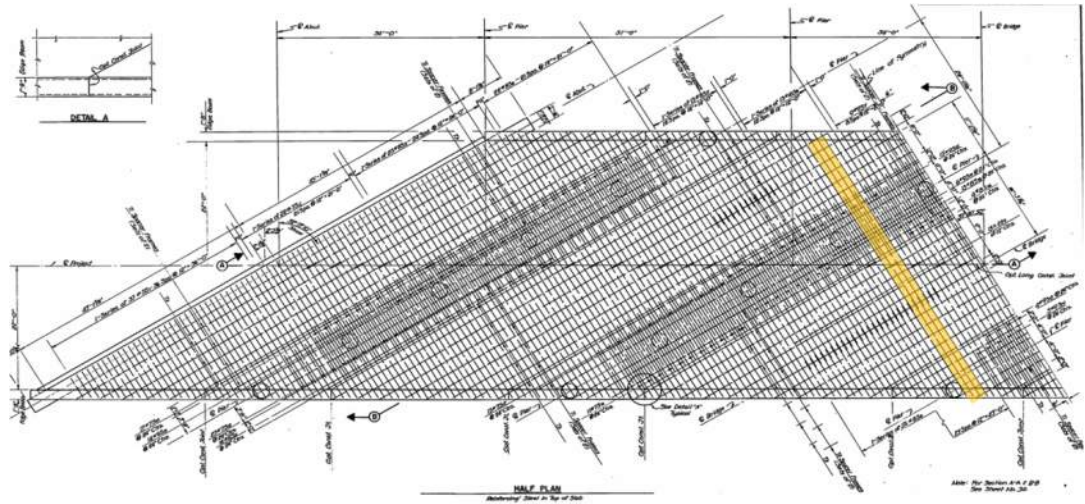
Span	From Start (in)	From End (in)
1	29.397	33.317
2	33.317	33.317
3	33.317	33.317
4	33.317	33.317
5	33.317	29.397

Effective Supports

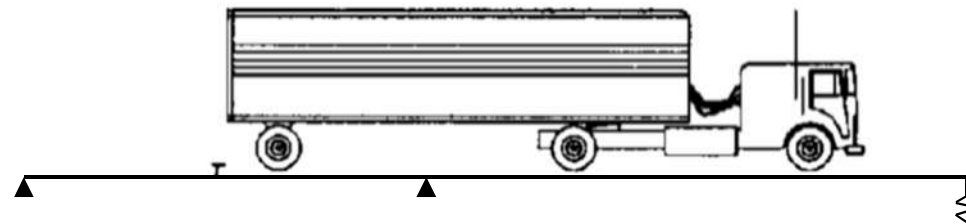
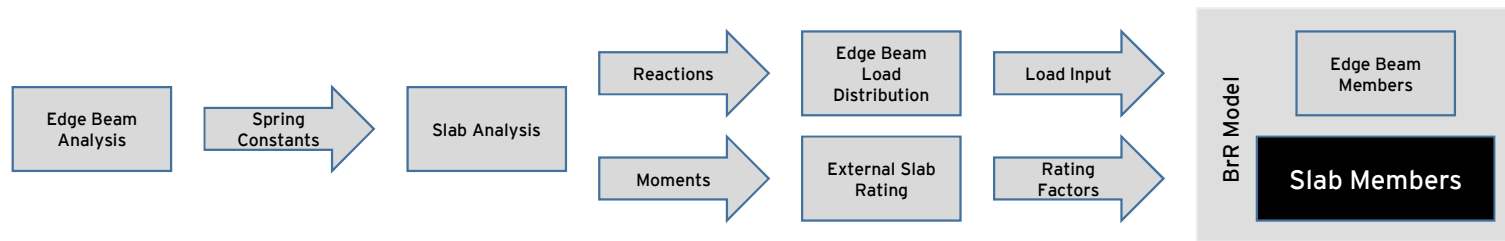
Edge-Supported Skewed Slab



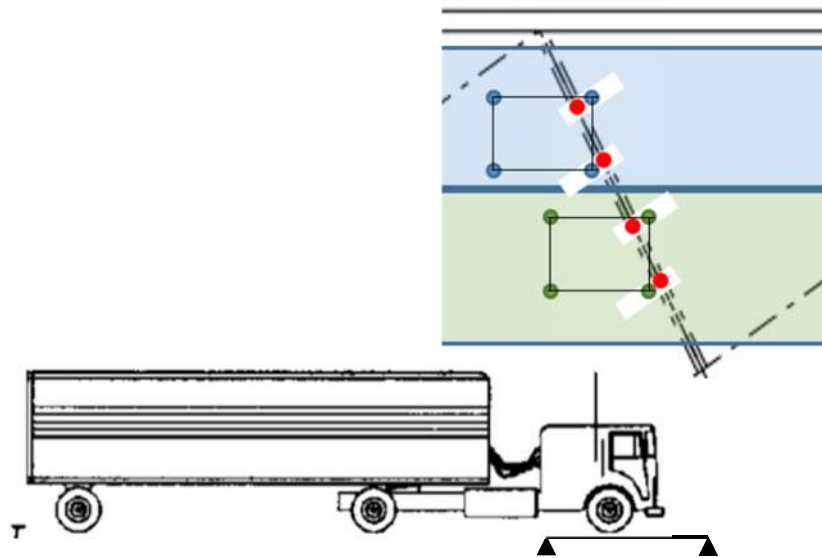
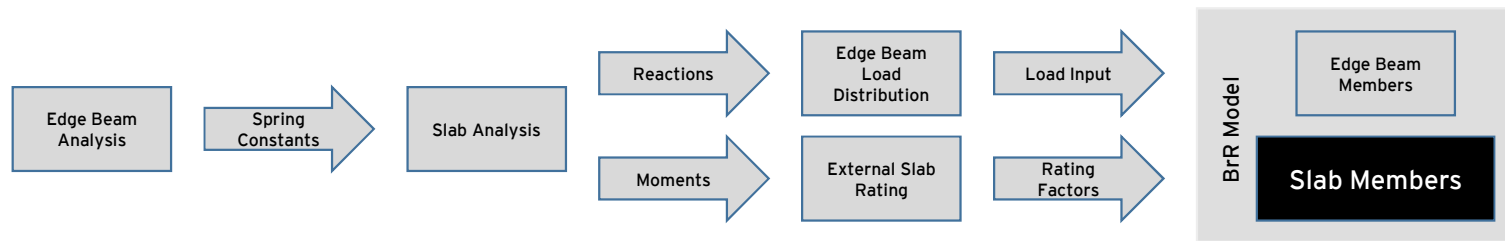
- Moments pulled from slab analysis
- Capacity from BrR
- External Calculation for Rating Factors



Edge-Supported Skewed Slab



Edge-Supported Skewed Slab



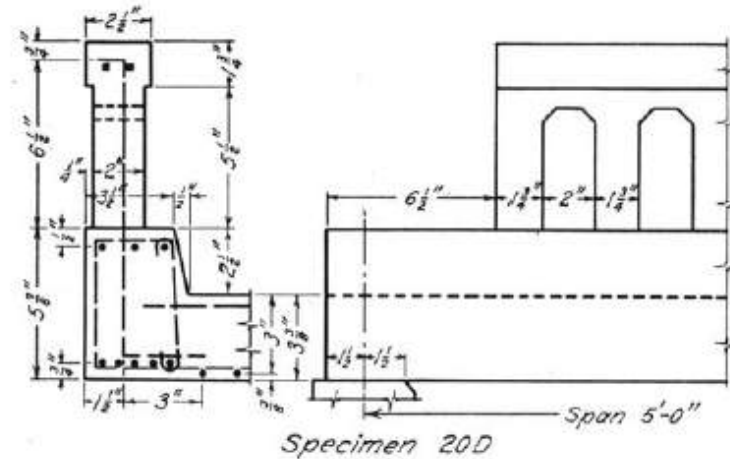
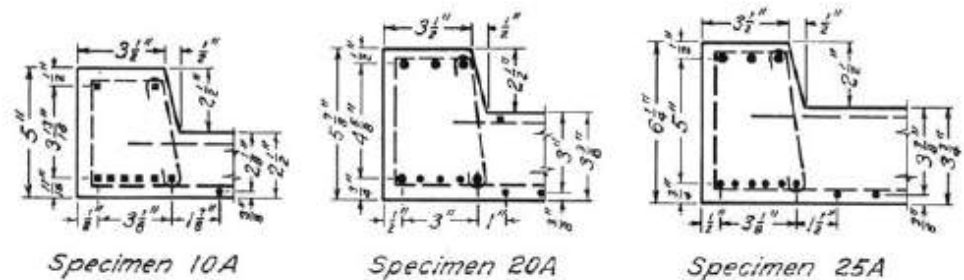


Illinois Bulletin Slab (IBS) Bridges

Illinois Bulletin Slab (IBS) Bridges

General Description:

- Continuous Concrete Slabs
- 22-45 ft Spans
- Integral Edge Curbs
- 26-33 ft Widths
- Empirical Simple Span Design

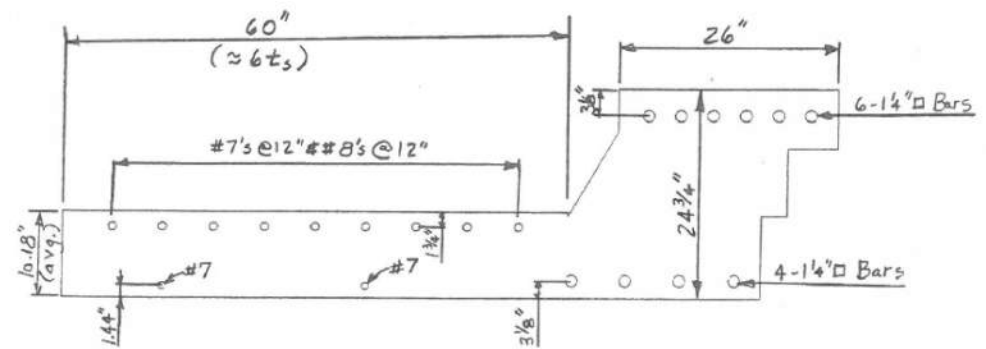


Example Edge Curbs

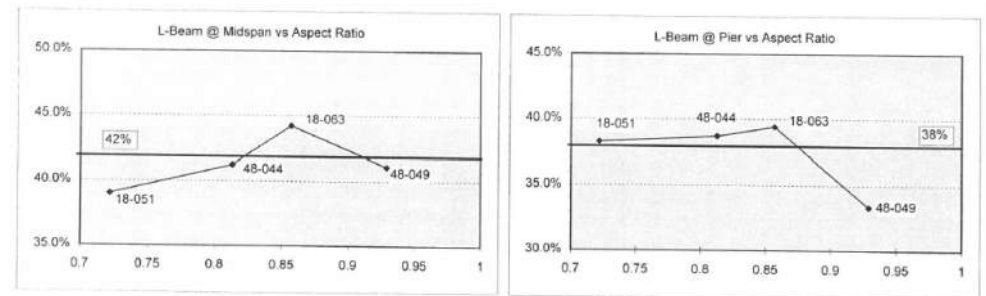
Illinois Bulletin Slab (IBS) Bridges

Methodology:

- Notional Beams
 - Edge "L" beams
 - Center slab
- Estimated Load Distribution



Edge L-Beam Section



Load Distribution Plots

Illinois Bulletin Slab (IBS) Bridges

Procedure:

1. Instrument & Field Load Test
2. Refined (Finite Element) Analysis
3. Load Distribution Behavior
4. Line Analysis Ratings



Continuous IBS Bridge

Illinois Bulletin Slab (IBS) Bridges

Field Investigations: **HNTB** **BDI**
RAW DATA. REFINED RESULTS.

- 6 In-Service IBS bridges
- Inspect, Instrument, and H/HS Load Test



Load Test Vehicles

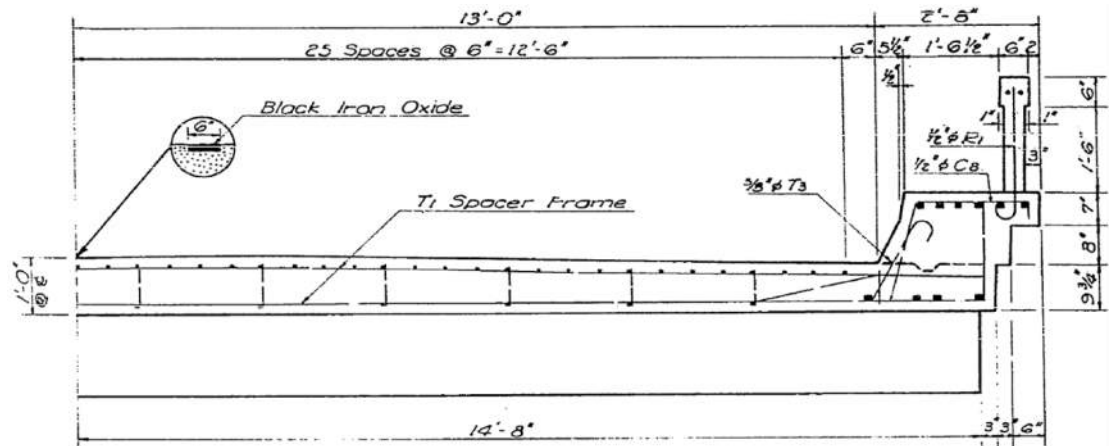


Field Inspection

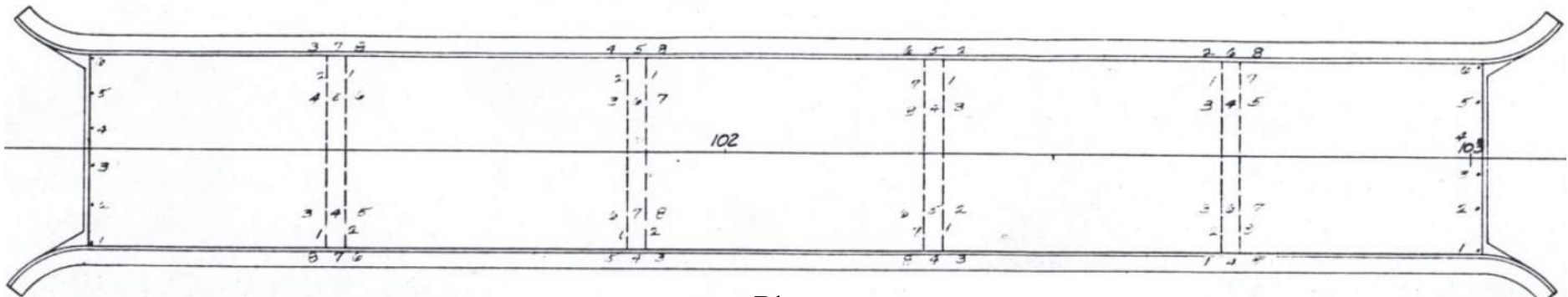
Illinois Bulletin Slab (IBS) Bridges

Refined Analysis:

- Example:
 - 32'-40'-40'-40'-32'
 - 26' Roadway; 31'-4" Wide



Half Section

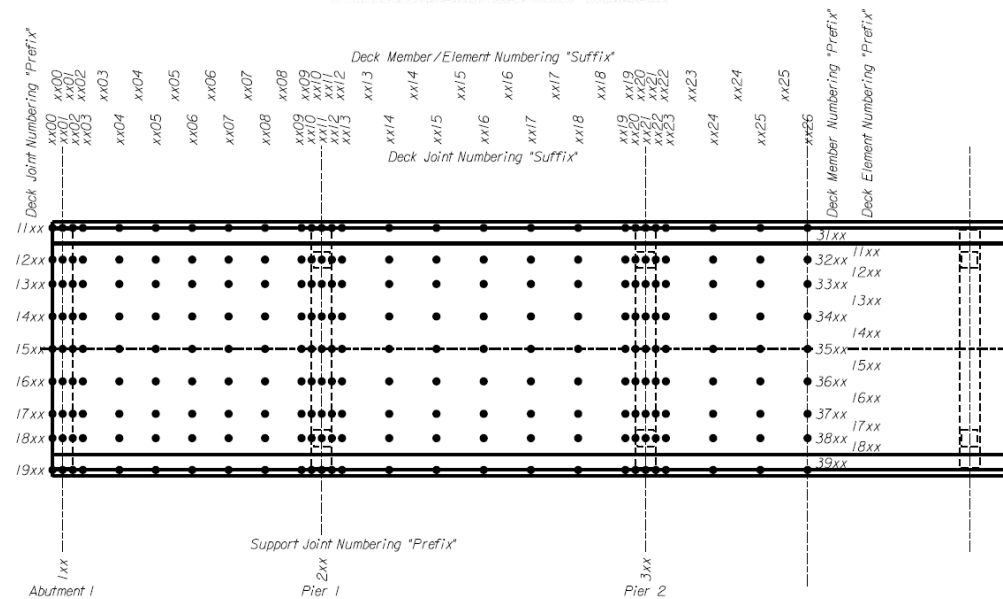
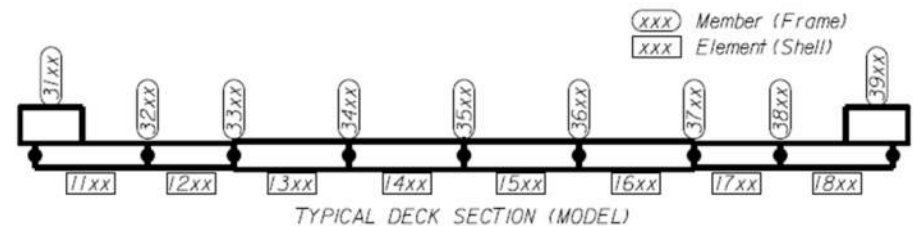


Plan

Illinois Bulletin Slab (IBS) Bridges

Refined Analysis:

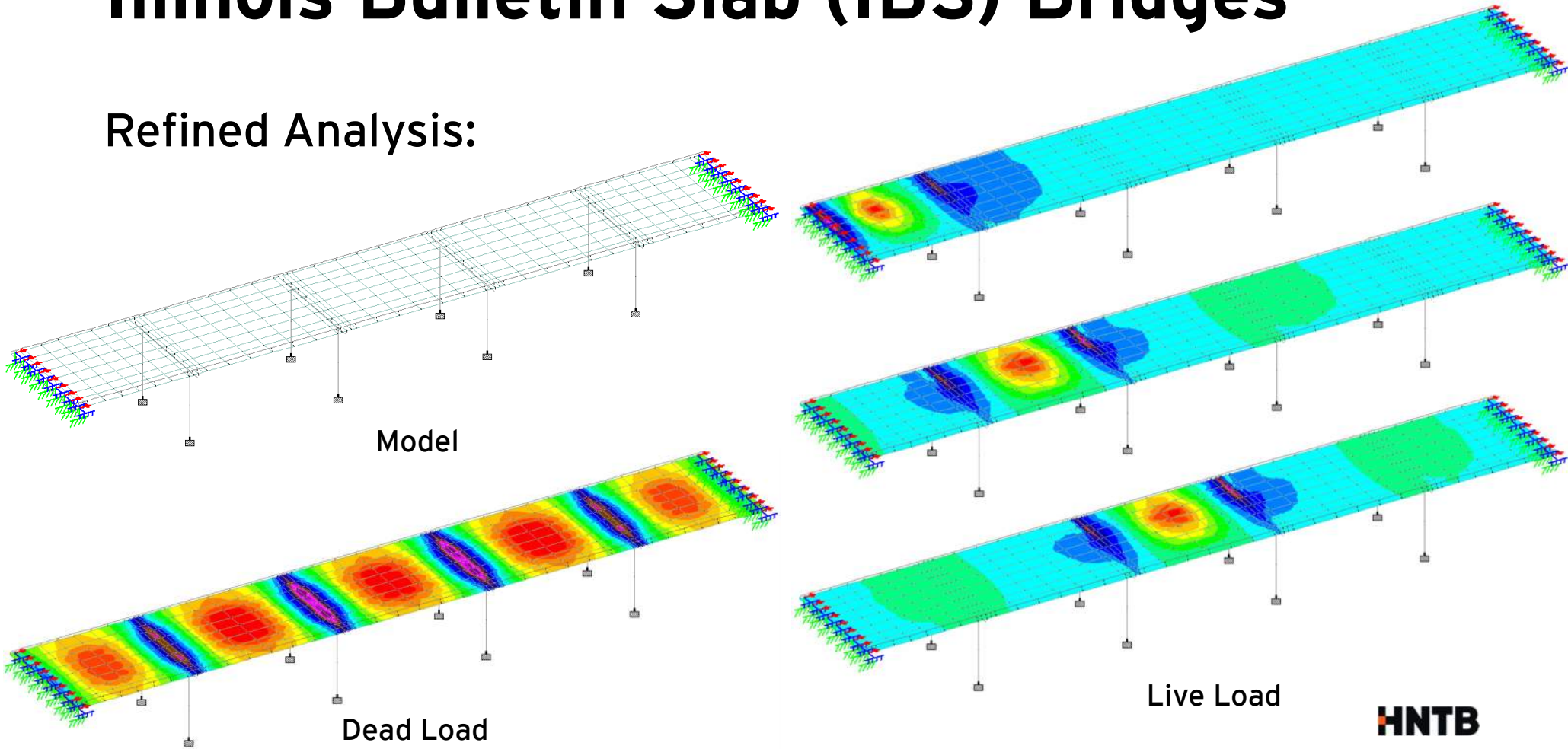
- Frames and “Thick” Shells
- Section Properties
 - Field load test calibrated
 - Uncalibrated “plan” dimensions
- Discretized at
 - Element boundaries
 - $\sim L/6$ of clear span
 - Additional near support faces



Example Node Map

Illinois Bulletin Slab (IBS) Bridges

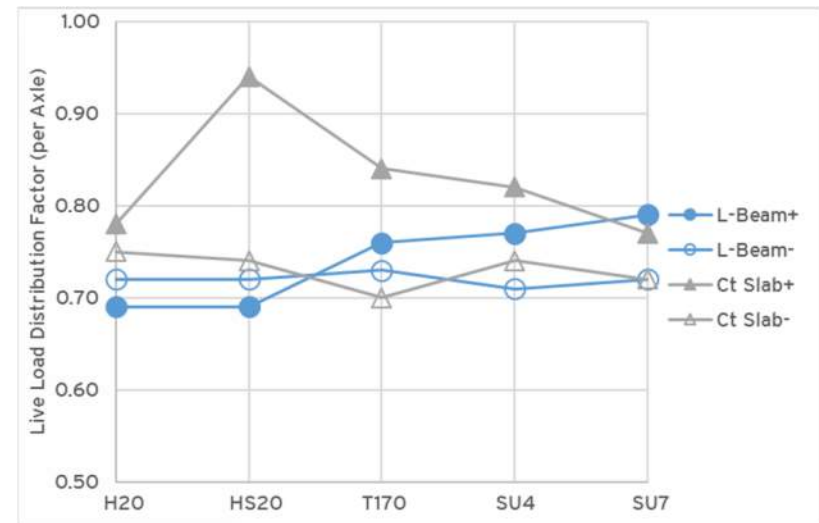
Refined Analysis:



Illinois Bulletin Slab (IBS) Bridges

Load Distribution:

- Dead load
- Live Load
 - Single- & multi-lane
 - Low sensitivity to vehicle configuration



LLDF - Vehicle Configuration

Illinois Bulletin Slab (IBS) Bridges

BrR Modeling:

- Line girder superstructure
 - Edge L-beams
 - Center slab
- T-Beam Member Type
 - Inverted L-beam
 - Wide “web” overpredicts shear capacity - not critical

The screenshot shows the 'Girder Profile' software interface. The 'Type' is set to 'Reinforced Concrete Tee'. The 'Section' tab is active, showing a diagram of a T-beam cross-section. The diagram includes dimensions for tributary width (26.0000 in), effective width (26.0000 in), and depth (83.0000 in). The diagram also shows the flange thickness (15.0000 in) and the depth of the web (83.0000 in). The diagram is labeled with 'A' and 'CJ' for the depth of the flange and the depth of the web, respectively. The input fields for 'A' and 'CJ' are currently empty.

Parameter	Value	Unit
Type	Reinforced Concrete Tee	
Tributary width	26.0000	in
Eff. width (Std)	26.0000	in
Flange thickness	15.0000	in
Web depth	83.0000	in
A		in
CJ		in

T-Beam Input

Illinois Bulletin Slab (IBS) Bridges

BrR Modeling:

- Re-Define Self-Weight
 - Member Alternative definition
 - Remove tributary self-weight
 - Apply as line load
- Live Load Distribution
 - Single- & multi-lane values

The screenshot shows the 'Member Alternative Description' window with the following details:

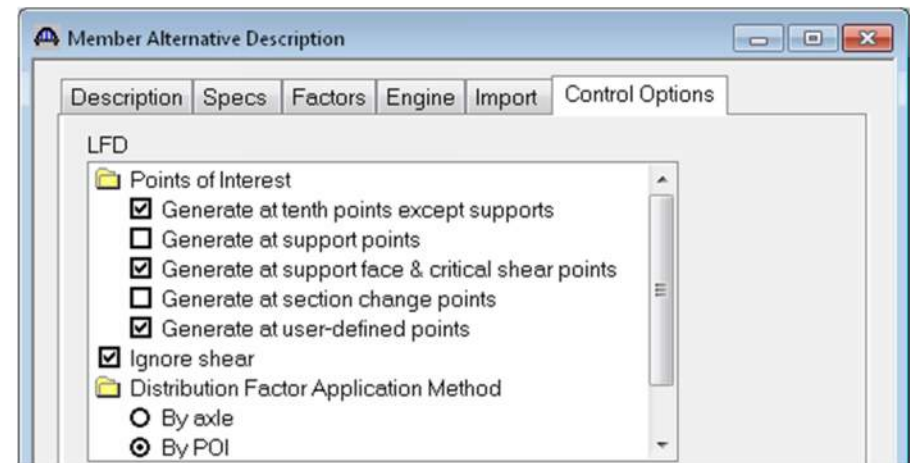
- Member Alternative: Edge L-Beam
- Tabbed interface: Description, Specs, Factors, Engine, Import, Control Options
- Description: (Empty text area)
- Girder property input method: Schedule based, Cross-section based
- End bearing locations: Left: 15.0000 in, Right: 15.0000 in
- Sustained modular ratio factor: 2.000
- Default rating method: LFD
- Self Load: Load case: Engine Assigned
- Additional self load = 1.951 kip/ft
- Additional self load = -100.0 %

Self-Weight Input

Illinois Bulletin Slab (IBS) Bridges

BrR Modeling:

- Substructure Restraint
 - Define rotational and translational springs
- Control Options
 - Omit support point POIs



Control Options

A photograph of a concrete bridge with a filled-spandrel arch. The bridge is made of grey concrete and has a decorative railing with vertical balusters. The arch is filled with a dark material, likely soil or gravel. The bridge is surrounded by tall, dry grass in the foreground. The background shows a clear sky and some distant structures.

Filled-Spandrel Arches

Filled-Spandrel Arches

Scope & Methodology:

- Buried Arch Structures
 - Reinforced Concrete
 - Unreinforced
 - Structural Plate (Corrugated)
- “Static Rating Factor” Models
 - Same RF for any vehicle
 - Useful For Any Non-Conforming Bridge

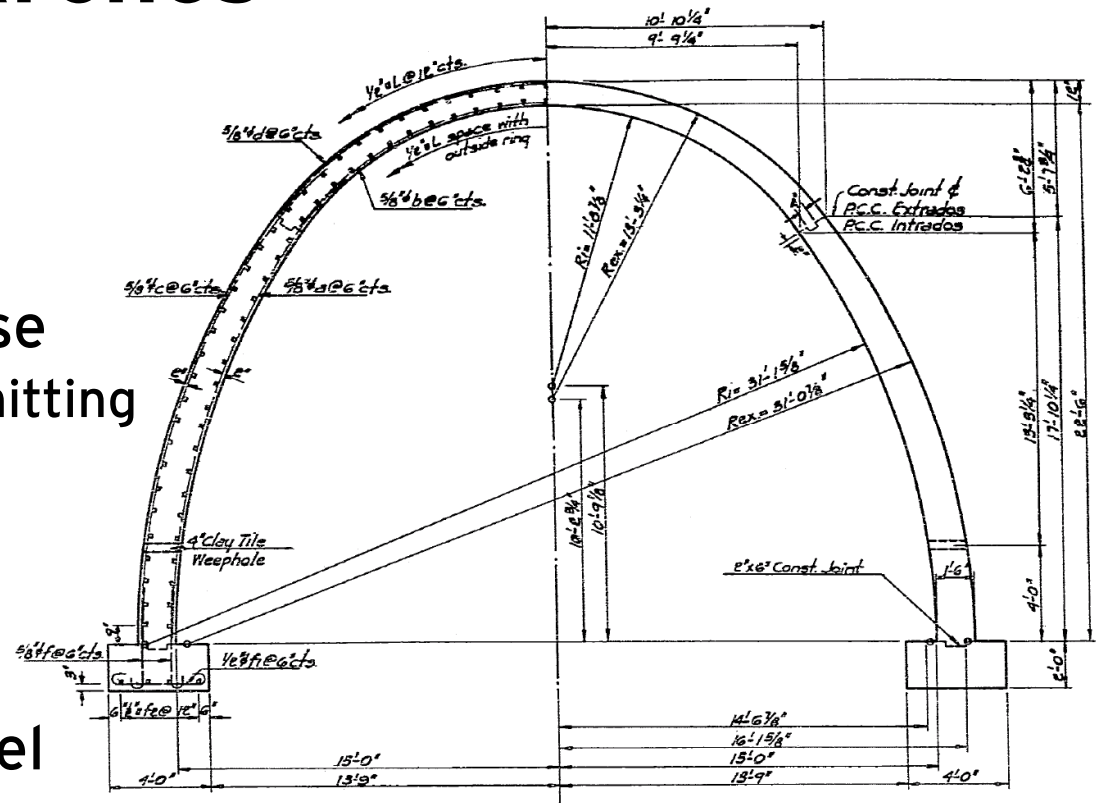


Reinforced Concrete Filled-Spandrel Arch

Filled-Spandrel Arches

Procedure:

- Identify BrR Model Purpose
 - Automated superload permitting
- Load Rate Externally
- Create/Calibrate BrR Model

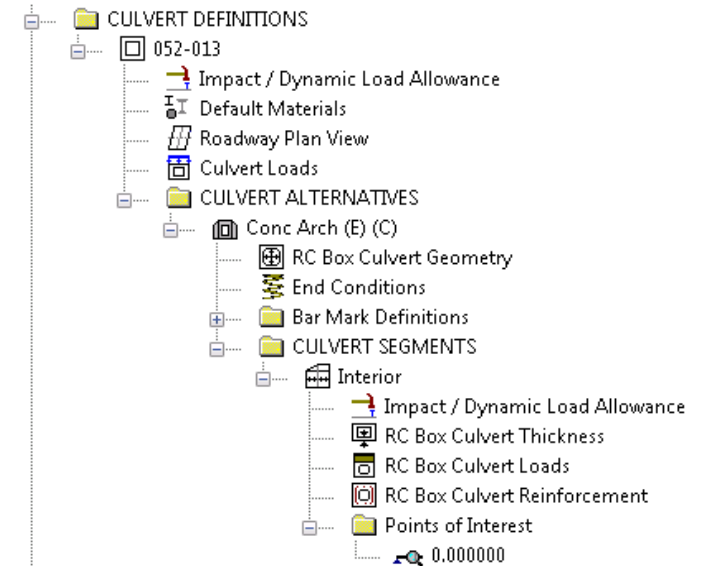


Reinforced Concrete Arch Typical Section

Filled-Spandrel Arches

BrR Modeling:

- Culvert Model
- Single Point of Inspection
 - Base of exterior wall
- Notional Properties
 - Geometry
 - Materials and reinforcing



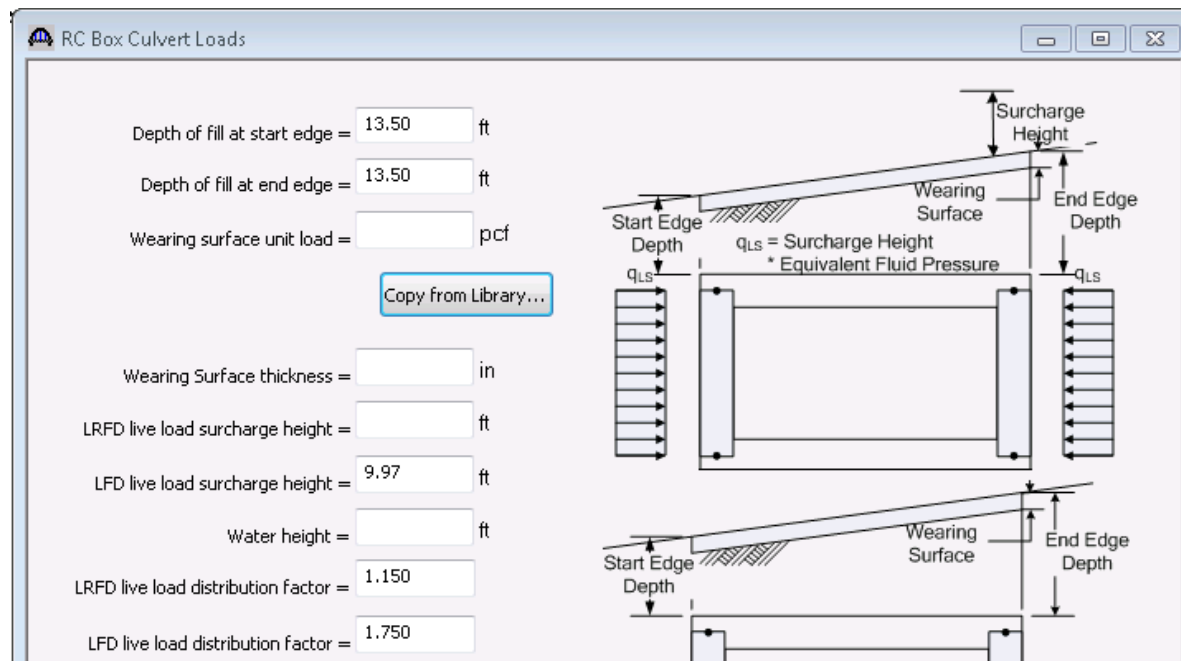
BrR Definitions

HNTB

Filled-Spandrel Arches

BrR Modeling:

- Calibrate Lateral Loads
 - Horiz. earth pressure EH overcomes vert effects
- Live load surcharge LS determines RF
 - Critical superload

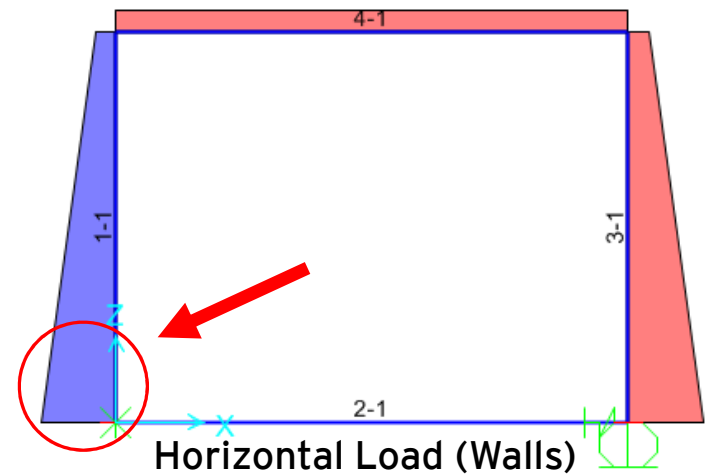
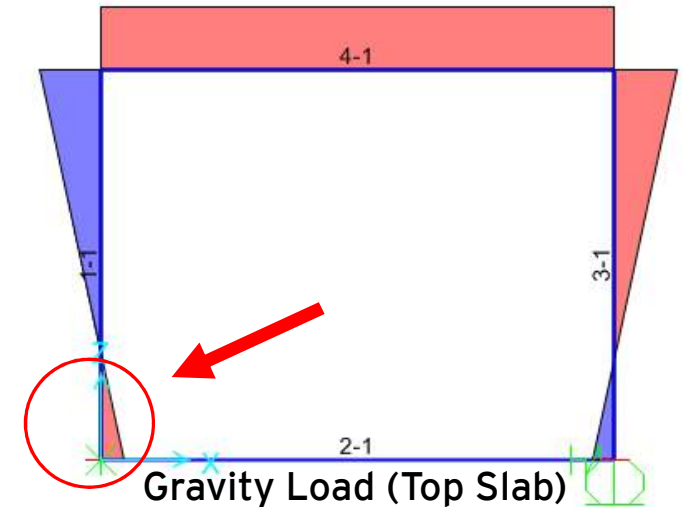


BrR Culvert Loads

Filled-Spandrel Arches

BrR Modeling:

- Moment at Wall Base POI
 - DL, EV and LL (+)
 - EH and LS (-)
- Choose: $EH > EV+DL$
- Choose: $LS > (\text{expected}) LL$
- BrR uses LS (constant), but no LL
 - Vehicle approaching culvert



Filled-Spandrel Arches

BrR Modeling:

Analysis Results - Interior

Report Type: Rating Results Summary

Lane/Impact Loading Type: As Requested Detailed

Display Format: Multiple rating levels per row

Live Load	Live Load Type	Rating Method	Inventory Load Rating (Ton)	Operating Load Rating (Ton)	Inventory Rating Factor	Operating Rating Factor	Inventory Component	Inventory Location (ft)	Inventory Location (%)
HS 20-44	Axle Load	LFD	30.24	50.51	0.840	1.403	Ext. Wall 1	0.00	0.000
NRL	Axle Load	LFD	33.60	56.12	0.840	1.403	Ext. Wall 1	0.00	0.000
SU4	Axle Load	LFD	22.68	37.88	0.840	1.403	Ext. Wall 1	0.00	0.000
SU5	Axle Load	LFD	26.04	43.49	0.840	1.403	Ext. Wall 1	0.00	0.000
SU6	Axle Load	LFD	29.19	48.75	0.840	1.403	Ext. Wall 1	0.00	0.000
SU7	Axle Load	LFD	32.55	54.37	0.840	1.403	Ext. Wall 1	0.00	0.000
1 K H 20-44	Axle Load	LFD	16.80	28.06	0.840	1.403	Ext. Wall 1	0.00	0.000
2 K Type 3	Axle Load	LFD	21.00	35.07	0.840	1.403	Ext. Wall 1	0.00	0.000
4 K Type 3S2	Axle Load	LFD	30.24	50.51	0.840	1.403	Ext. Wall 1	0.00	0.000
5 K Type 3-3	Axle Load	LFD	33.60	56.12	0.840	1.403	Ext. Wall 1	0.00	0.000
6 Type T130	Axle Load	LFD	54.61	91.19	0.840	1.403	Ext. Wall 1	0.00	0.000
7 Type T170	Axle Load	LFD	71.41	119.25	0.840	1.403	Ext. Wall 1	0.00	0.000
8 Heavy Equipment Tr	Axle Load	LFD		154.27		1.403			
Type EV2	Axle Load	LFD		40.34		1.403			
Type EV3	Axle Load	LFD		60.33		1.403			

“Static Rating Factor” Summary Table

Specification Checks for Interior - 2 of 2

- Ext. Wall 1
 - 0.00 ft.
 - Ext. Wall 2
 - Top Slab 1

Specification Reference

- ✗ 8.16.4 Compression
- ✗ APPG.6.1 P-M Interaction Diagram

Spec Check Detail for APPG.6.1 P-M Interaction Diagram

Max Pn = 489.60 (kip)
Min Pn = 0.00 (kip) Mx: 0.00, My: 0.00

DC Moment	=	10.5282 (kip-ft)
DW Moment	=	0.0000 (kip-ft)
EV Moment	=	61.2804 (kip-ft)
EH(max) Moment	=	-66.2664 (kip-ft)
EH(min) Moment	=	-66.2664 (kip-ft)
ES Moment	=	0.0000 (kip-ft)
LS Moment	=	-28.3547 (kip-ft)
DC Axial	=	9.8000 (kip)
DW Axial	=	0.0000 (kip)
EV Axial	=	28.5211 (kip)
EH(max) Axial	=	0.0000 (kip)
EH(min) Axial	=	0.0000 (kip)
ES Axial	=	0.0000 (kip)
LS Axial	=	0.0000 (kip)
Total DL(max) Moment	=	5.5422 (kip-ft)
Total DL(min) Moment	=	5.5422 (kip-ft)
Total DL(max) Axial	=	38.3210 (kip)
Total DL(min) Axial	=	38.3210 (kip)

Spec Check Moment Components

Conclusions

- **Complex Slab Systems**
 - Line analysis BrR models
 - “Inverted” T-beams for integral curbs
 - Load distribution calculated externally
 - Load testing
 - Finite element modeling
 - Vehicle paths transverse to members
 - Short simple spans for transverse members
- **“Static Rating Factor” Models**
 - Single POI culvert BrR models
 - Rating calculated externally
 - Earth pressures calibrated for desired RF

Questions?

HNTB

100+

YEARS OF
INFRASTRUCTURE
SOLUTIONS

Thanks to:

