# Load Rating Atypical Concrete Bridges with BrR

2018 RADBUG Meeting

Boise, Idaho

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# 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

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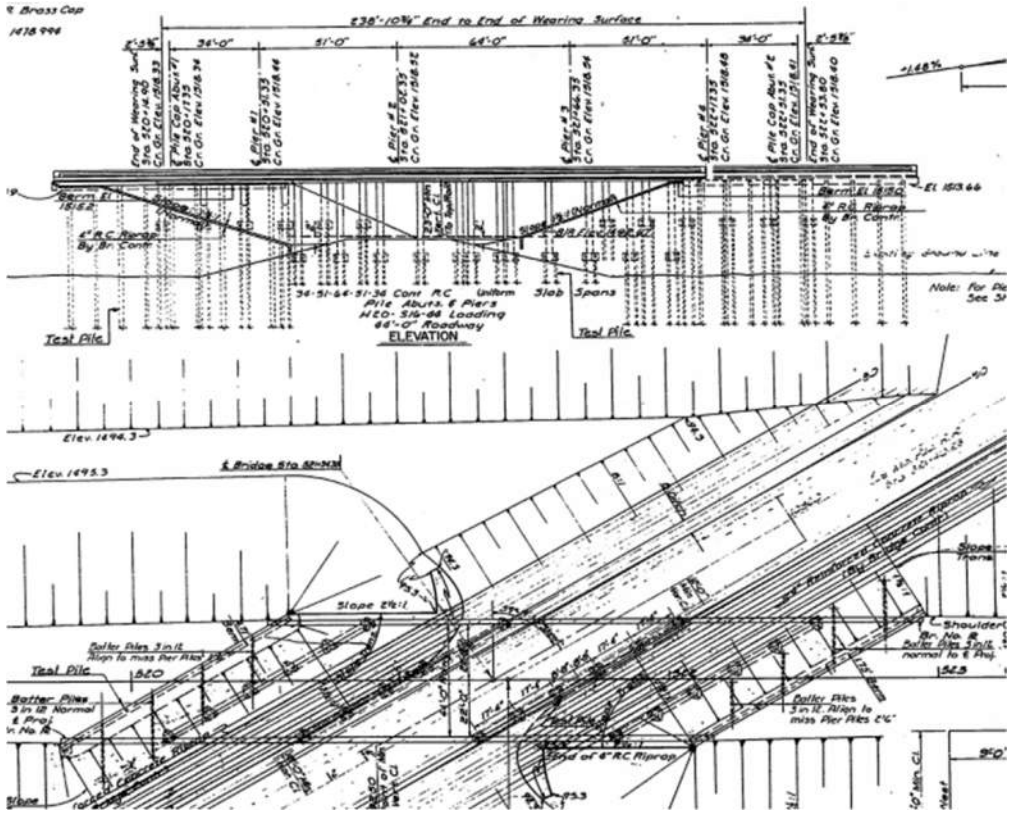
# Edge-Supported Skewed Slab

# Edge-Supported Skewed Slab

General Description:

- 5-Span Slab
  - 34′-51′-64′-51′-34′
- 59°19′10″ Skew
- 44′ Roadway Width




CONSTRUCTION LAYOUT

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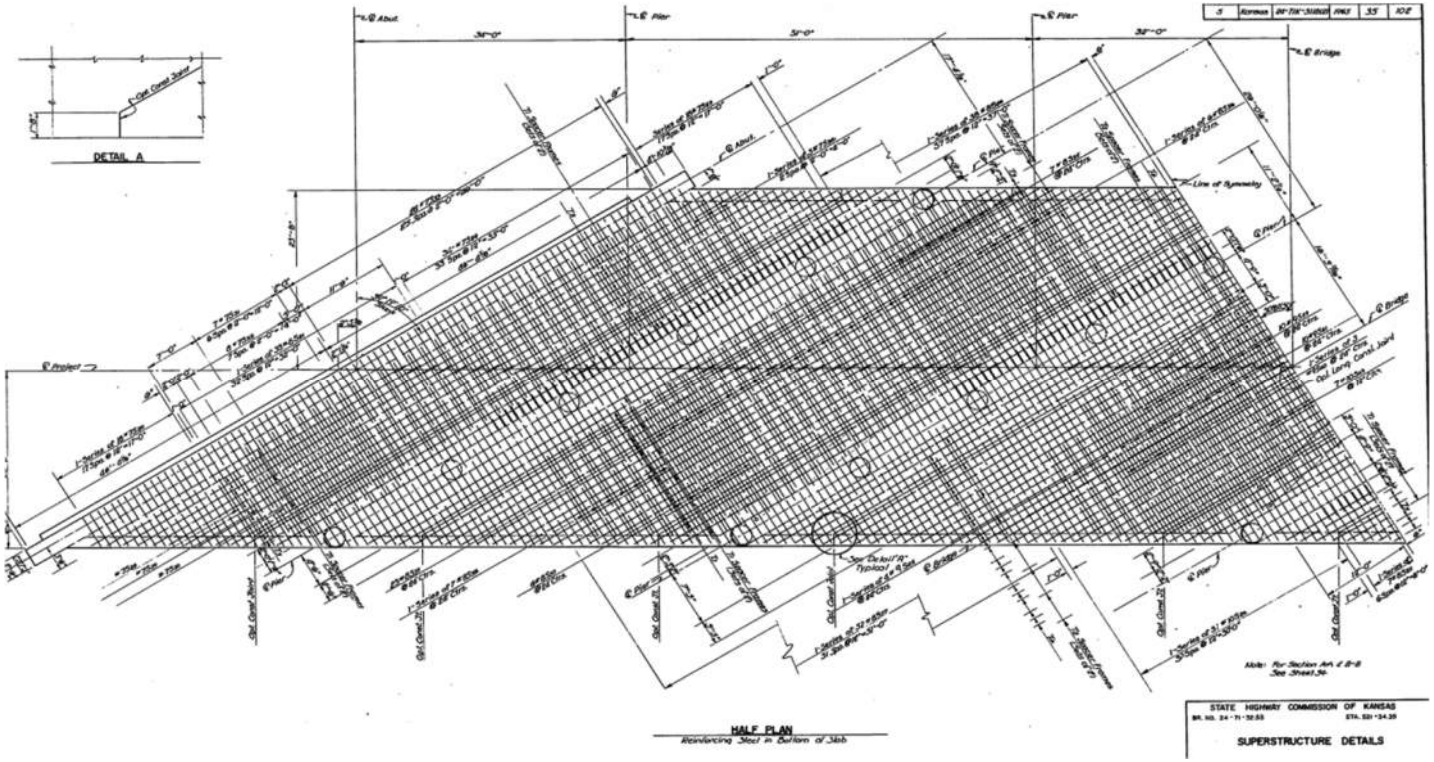
# Edge-Supported Skewed Slab




Bottom Slab Reinforcement

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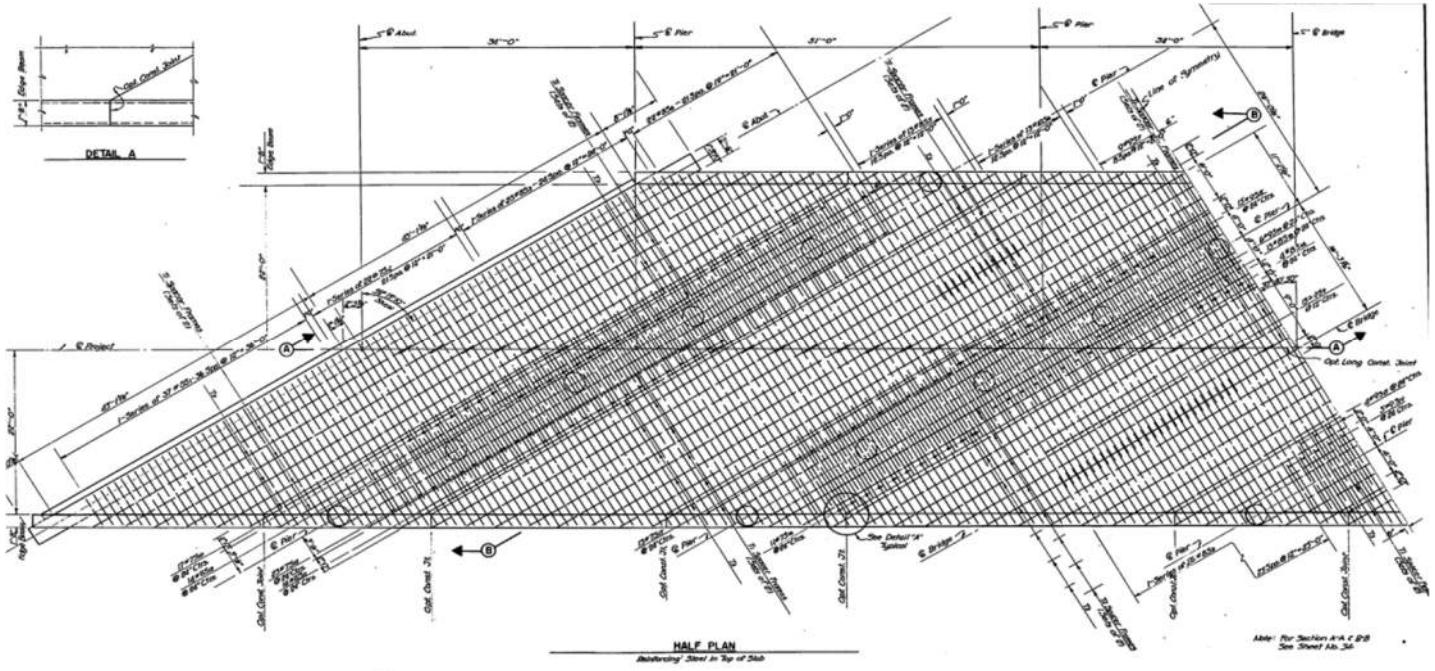
# Edge-Supported Skewed Slab




Top Slab Reinforcement

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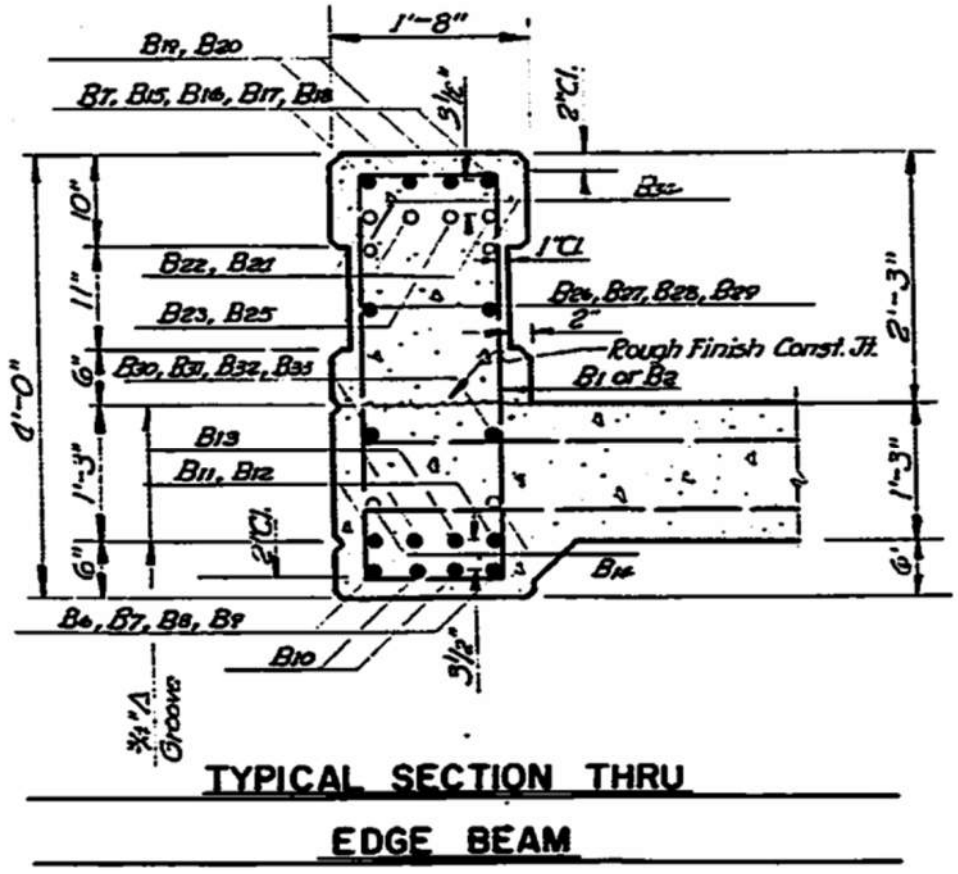
# Edge-Supported Skewed Slab

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# Edge-Supported Skewed Slab


Top Slab Reinforcement

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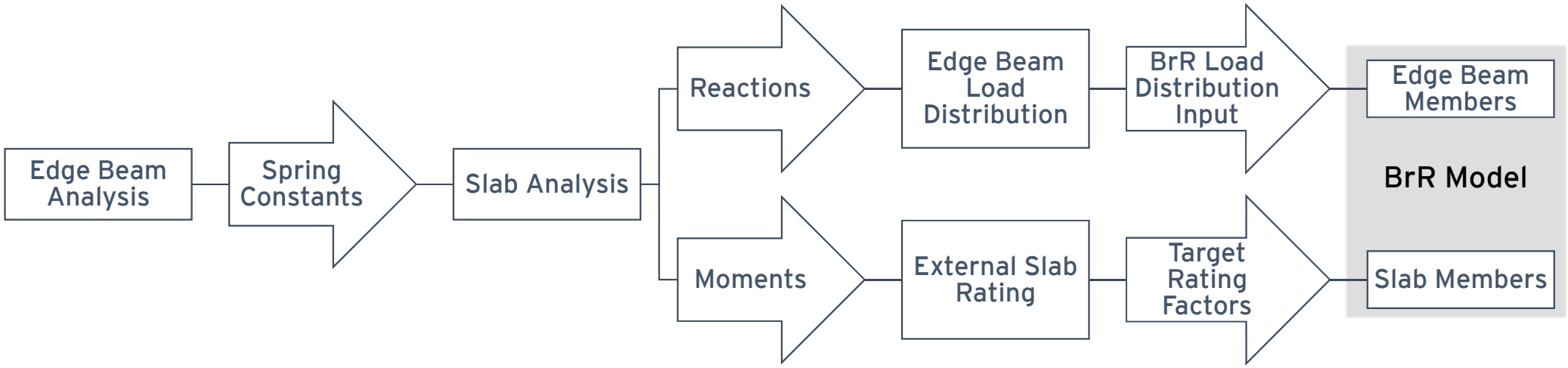
# Edge-Supported Skewed Slab

## Rating Procedure:

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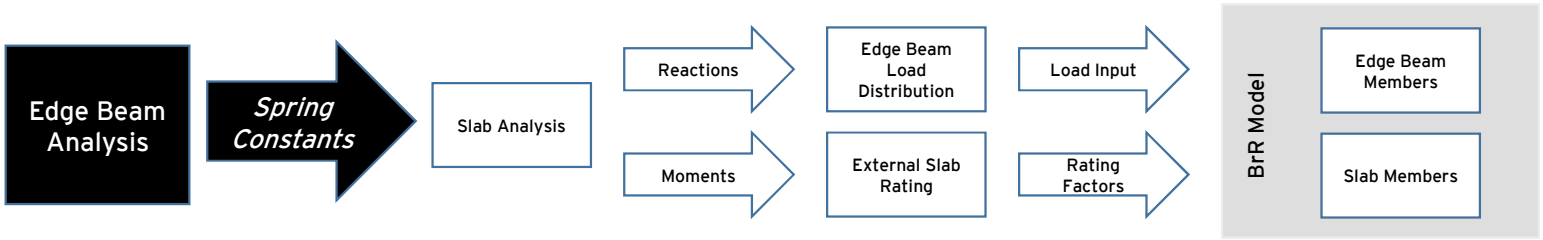
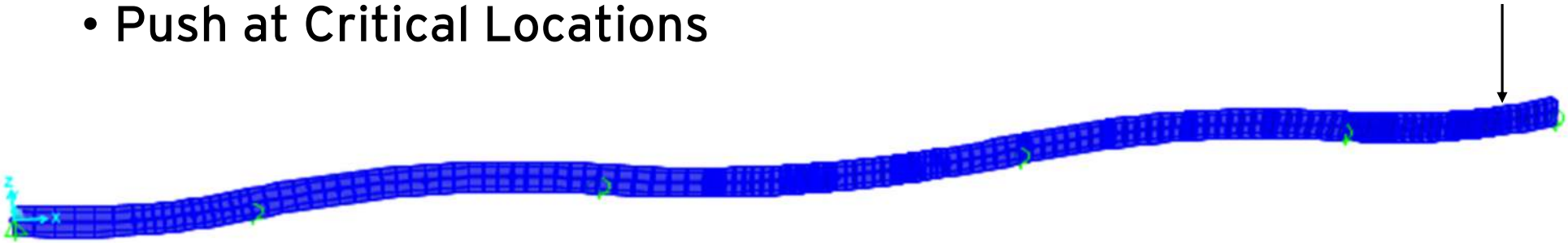
# Edge-Supported Skewed Slab




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



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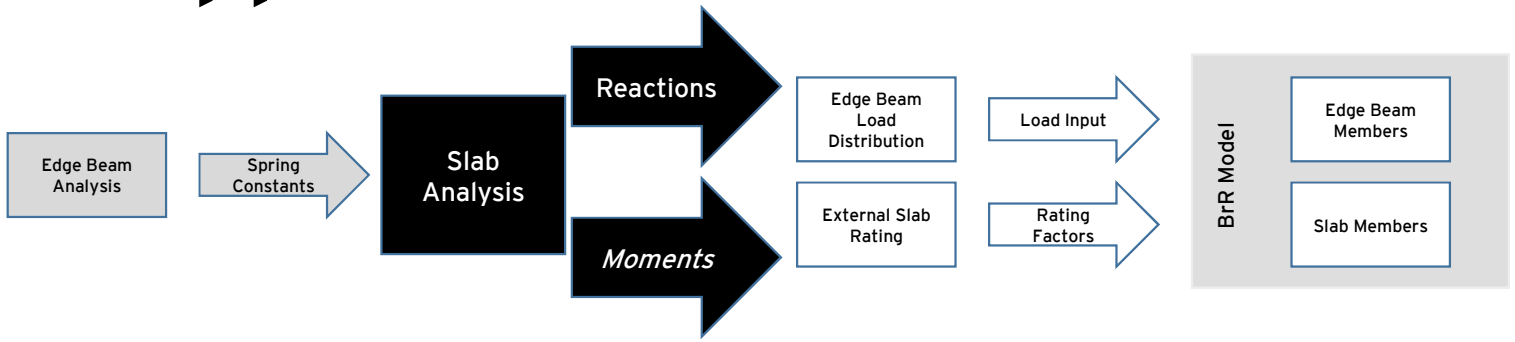
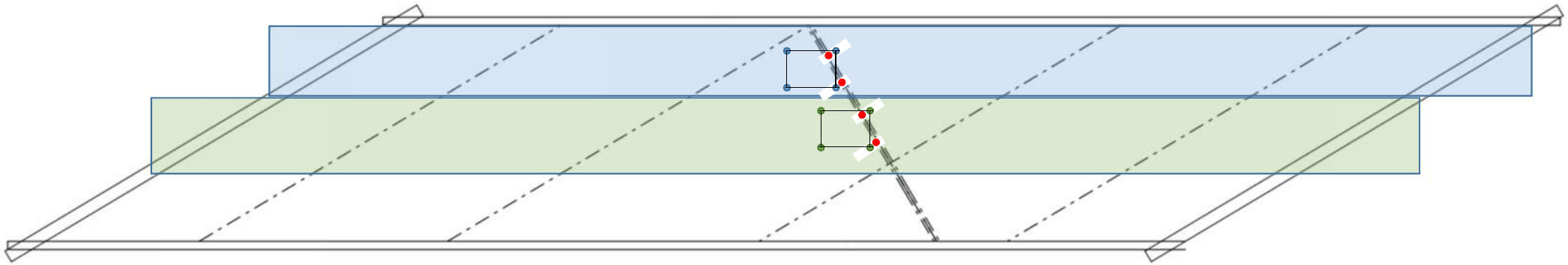
# Edge-Supported Skewed Slab




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



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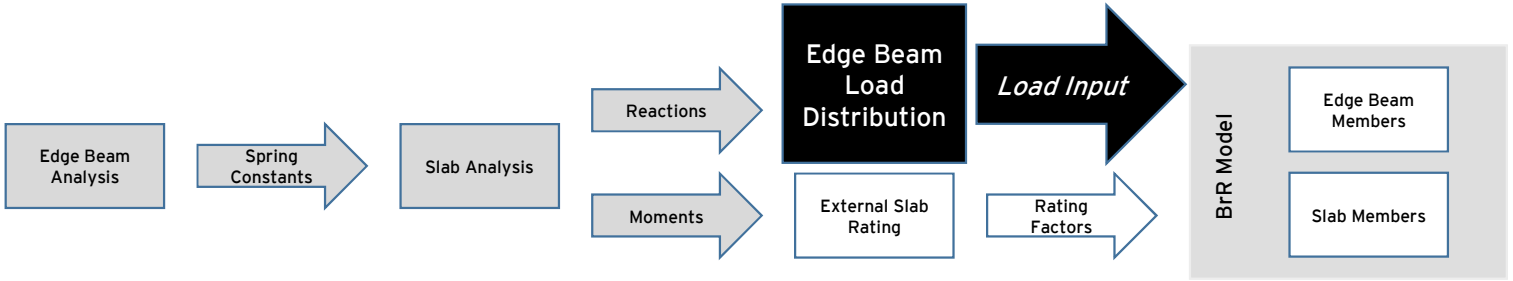
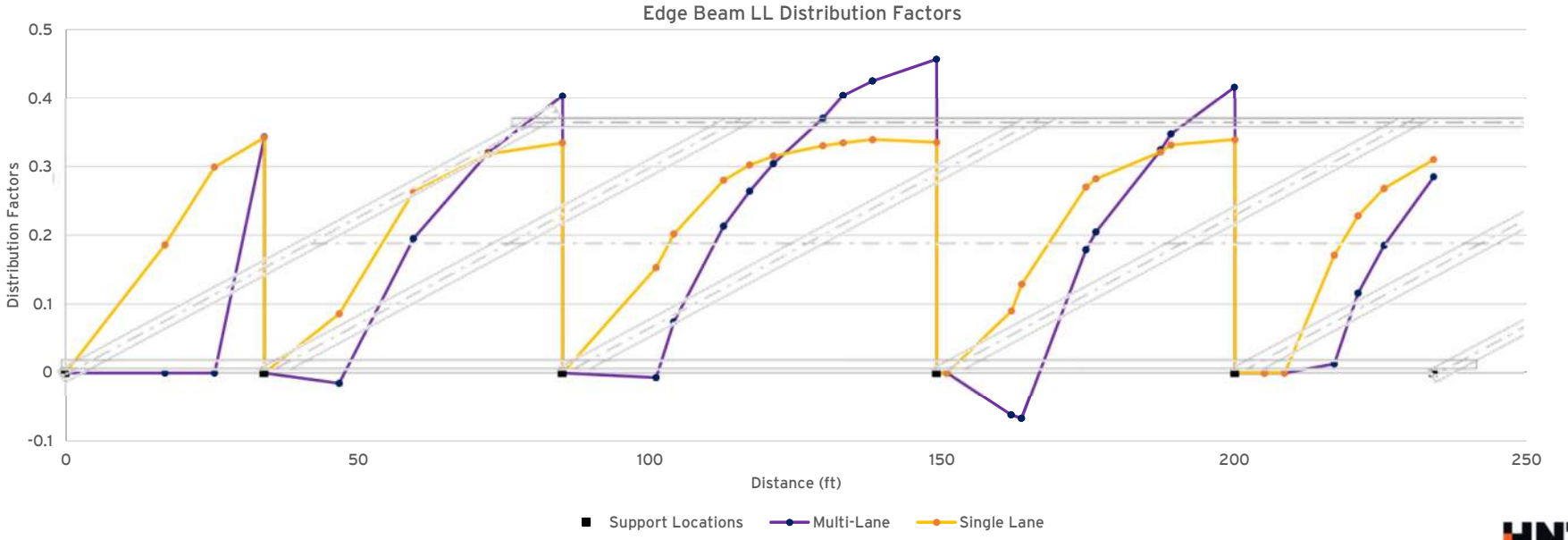
# Edge-Supported Skewed Slab




- Calculate from Slab Strip Reactions at Spring Supports

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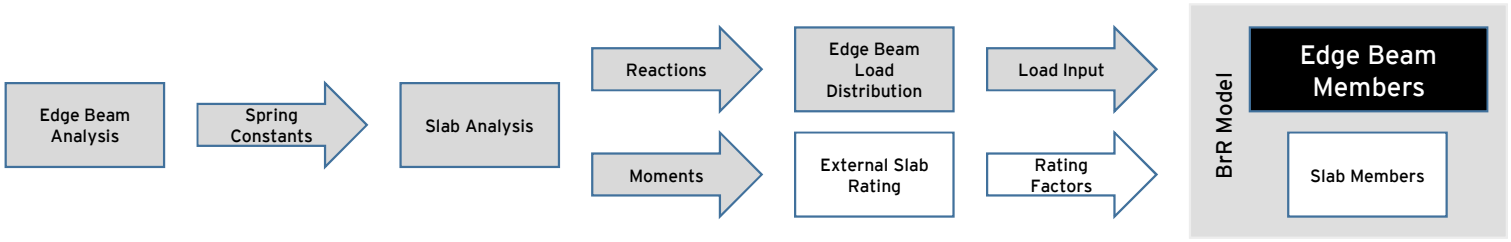
# Edge-Supported Skewed Slab




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


"Turn Off" Self Weight


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

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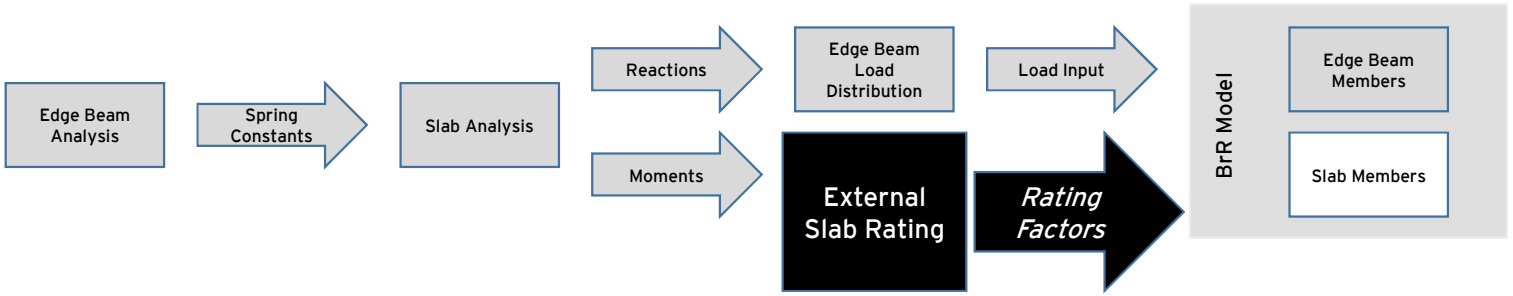
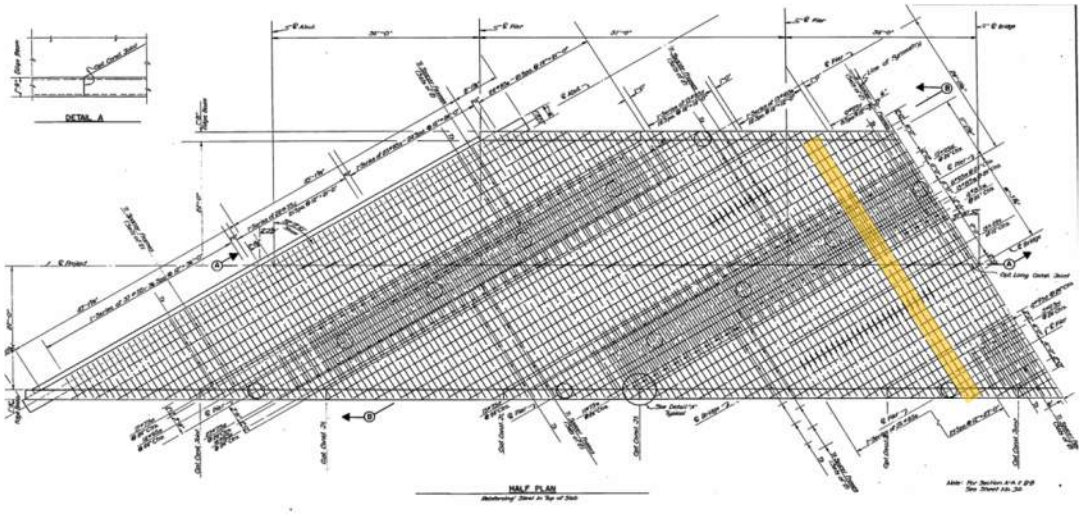
# Edge-Supported Skewed Slab




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



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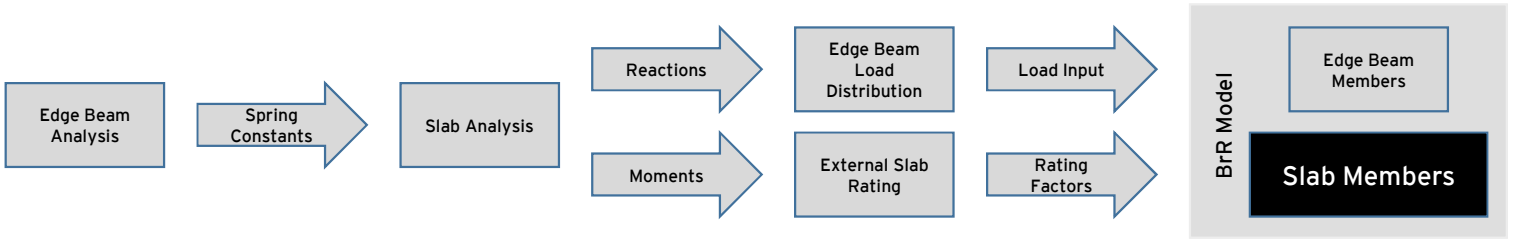
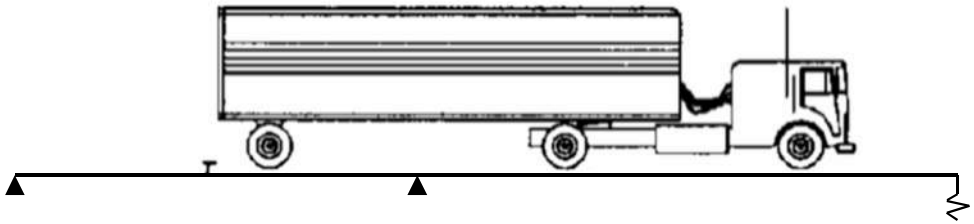
# Edge-Supported Skewed Slab



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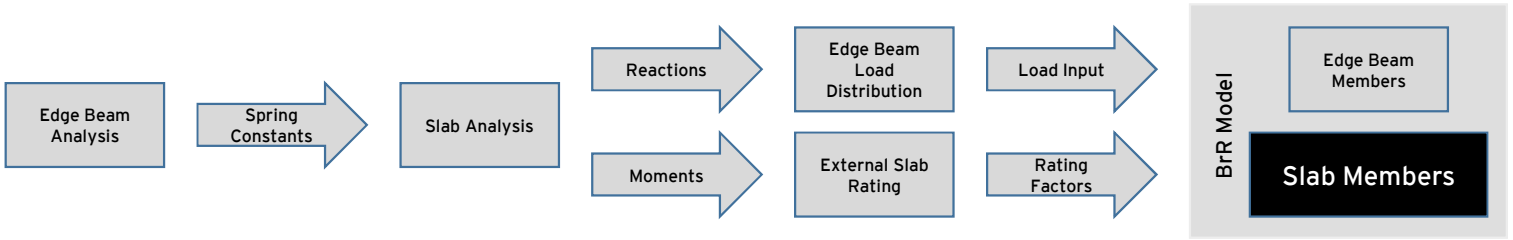
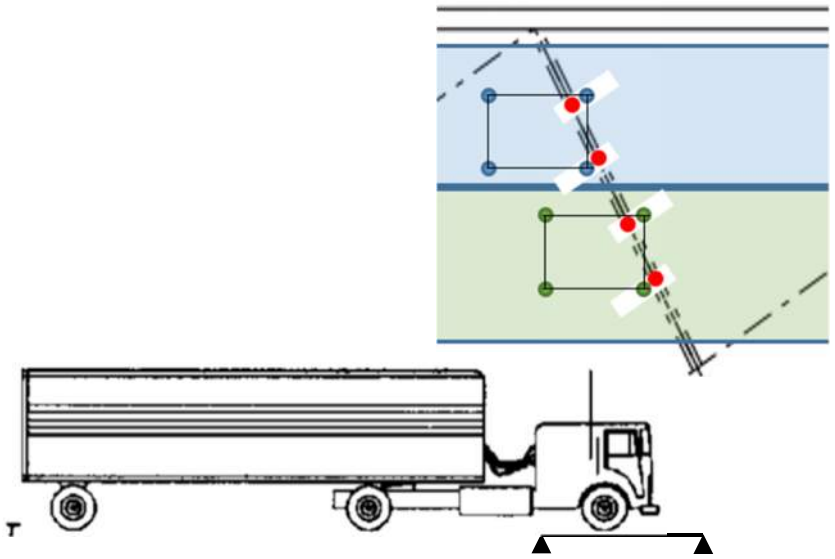
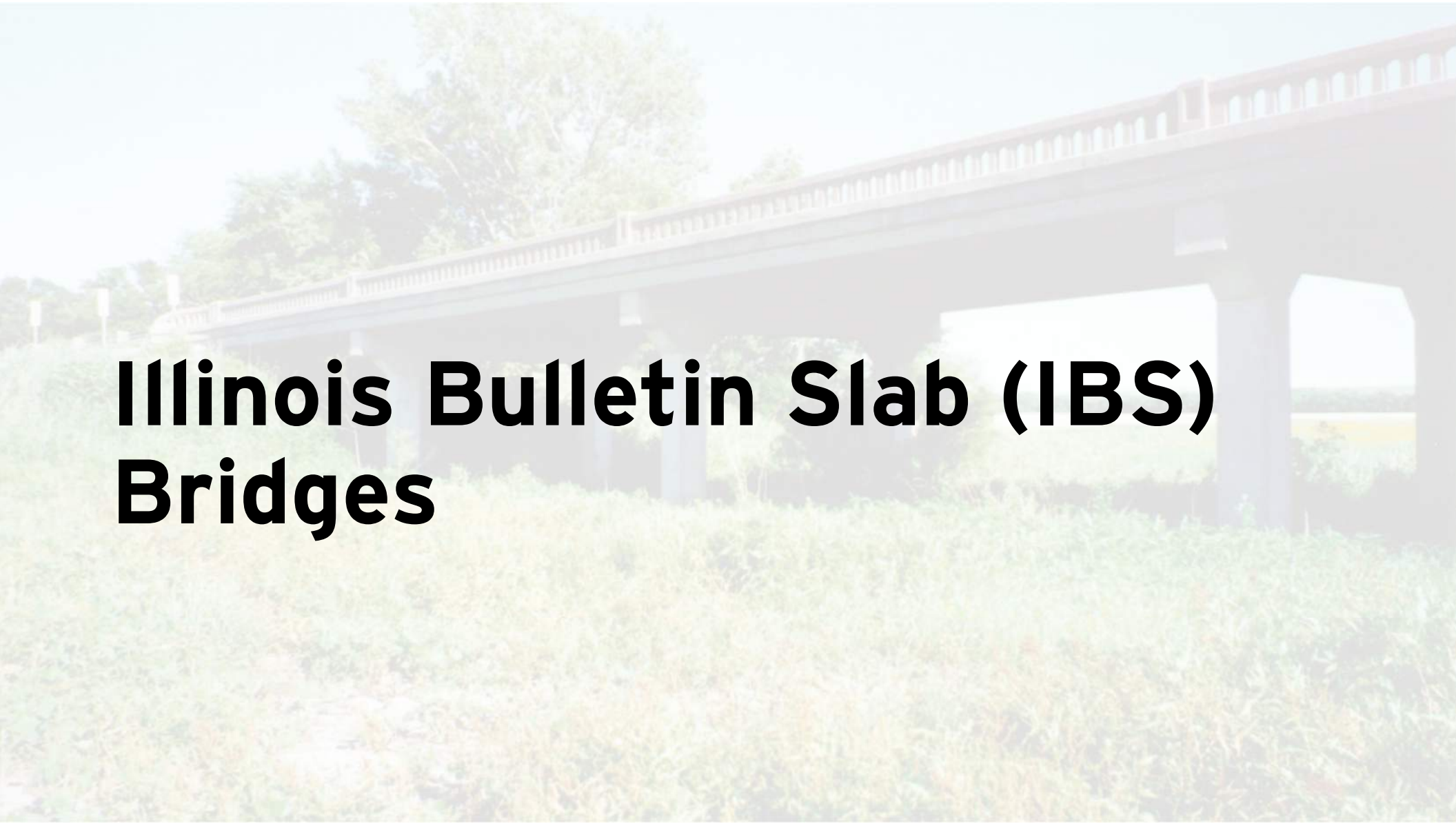
# Edge-Supported Skewed Slab





# Illinois Bulletin Slab (IBS) Bridges

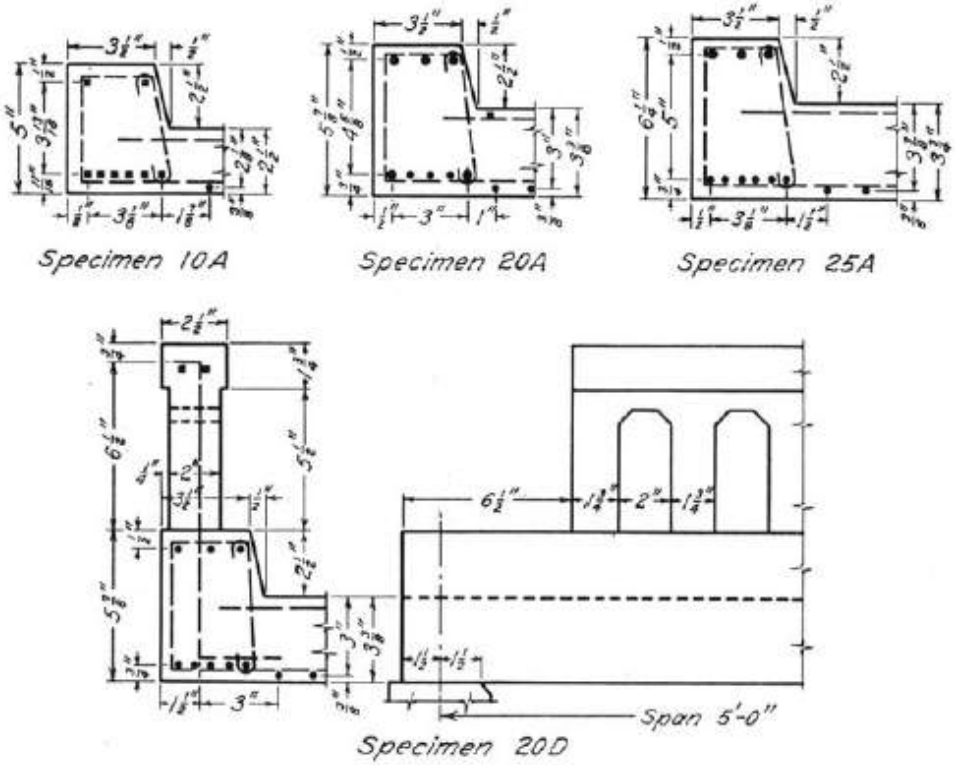
# Illinois Bulletin Slab (IBS) Bridges

General Description:

- Continuous Concrete Slabs
- 22-45 ft Spans

- Integral Edge Curbs
- 26-33 ft Widths

- Empirical Simple Span Design




Example Edge Curbs

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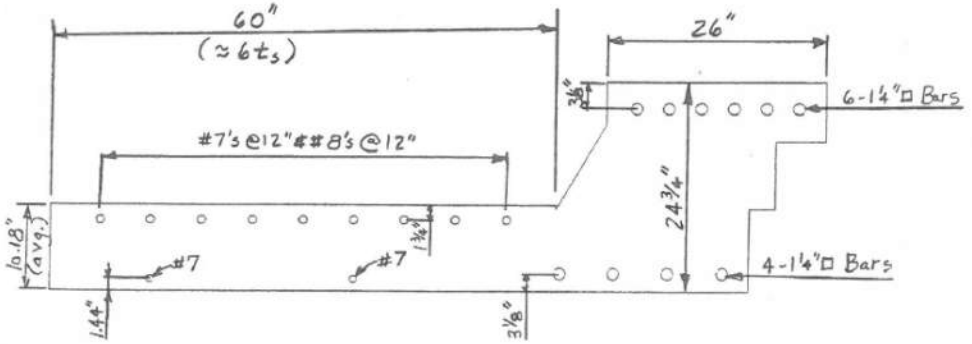
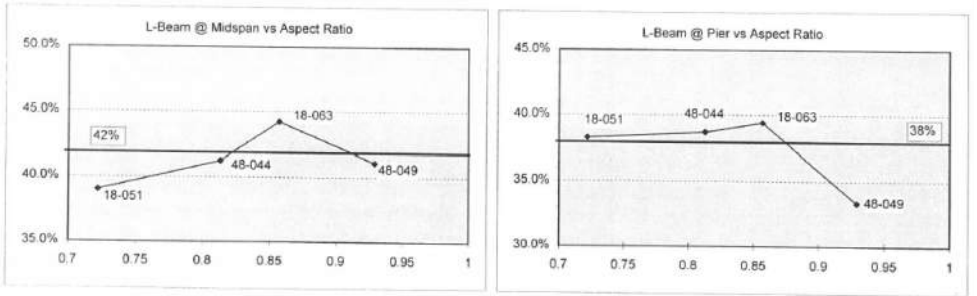
# Illinois Bulletin Slab (IBS) Bridges

Methodology:

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




Edge L-Beam Section




Load Distribution Plots

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# 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

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# Illinois Bulletin Slab (IBS) Bridges

Field Investigations:

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

Load Test Vehicles

Field Inspection

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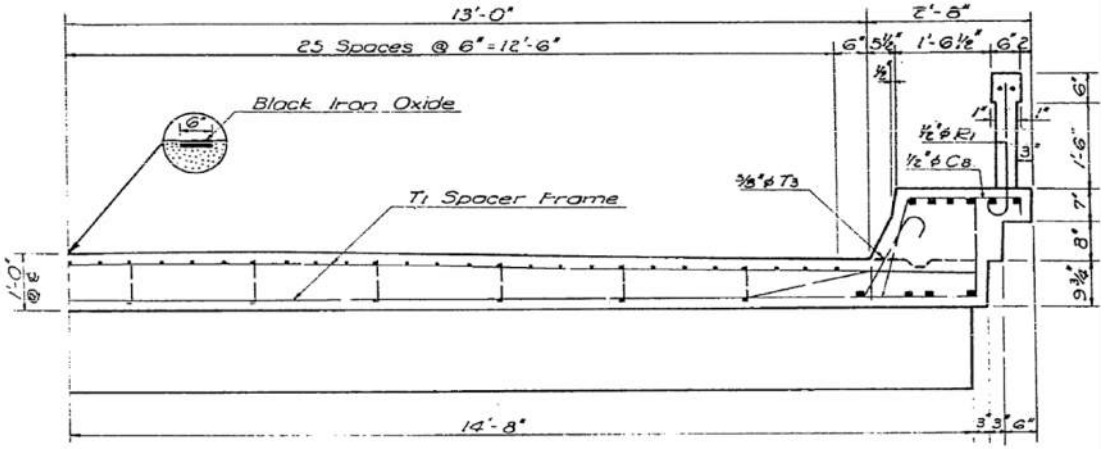
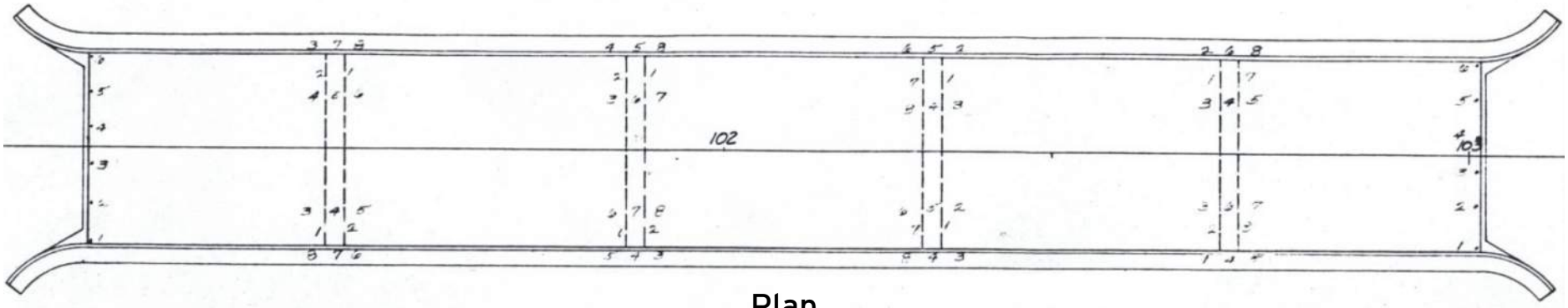
# Illinois Bulletin Slab (IBS) Bridges

Refined Analysis:

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




Half Section




Plan

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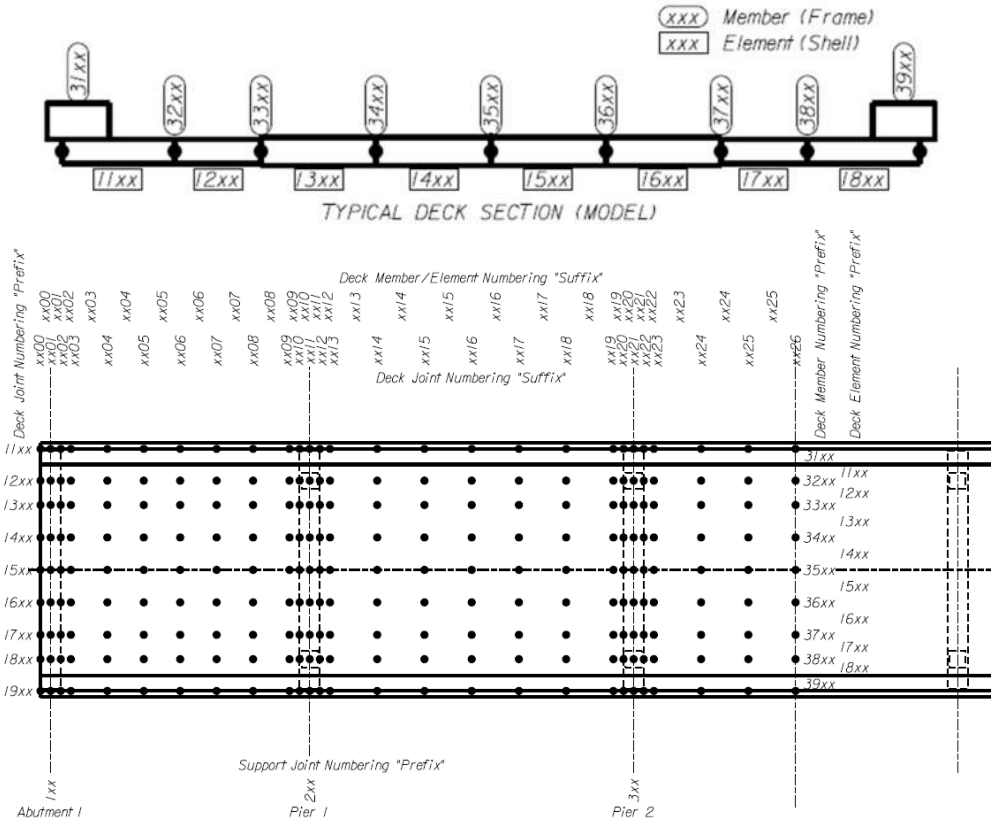
# Illinois Bulletin Slab (IBS) Bridges

Refined Analysis:

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




Example Node Map

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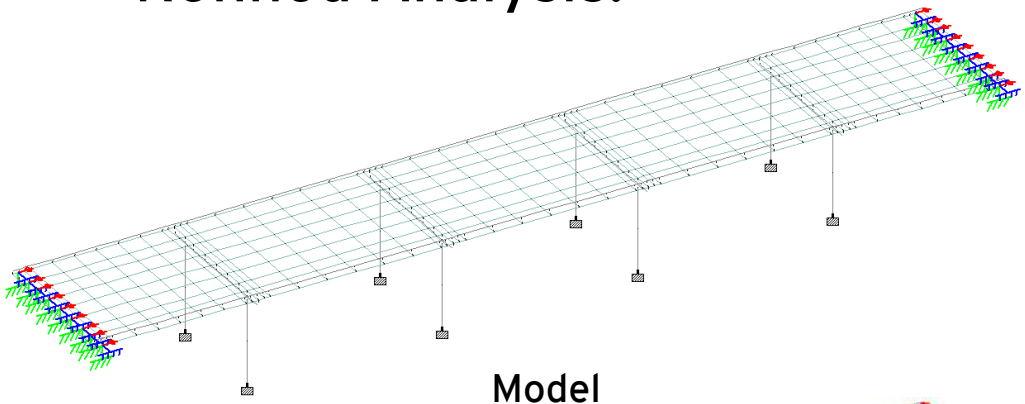
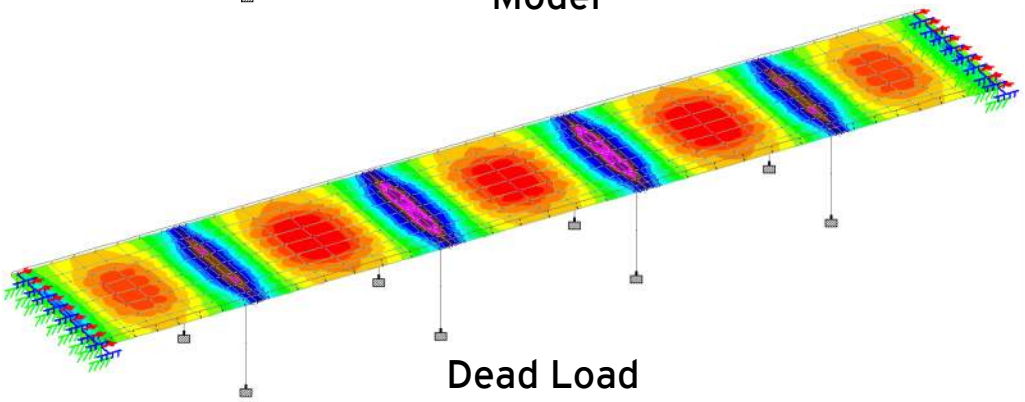
# Illinois Bulletin Slab (IBS) Bridges

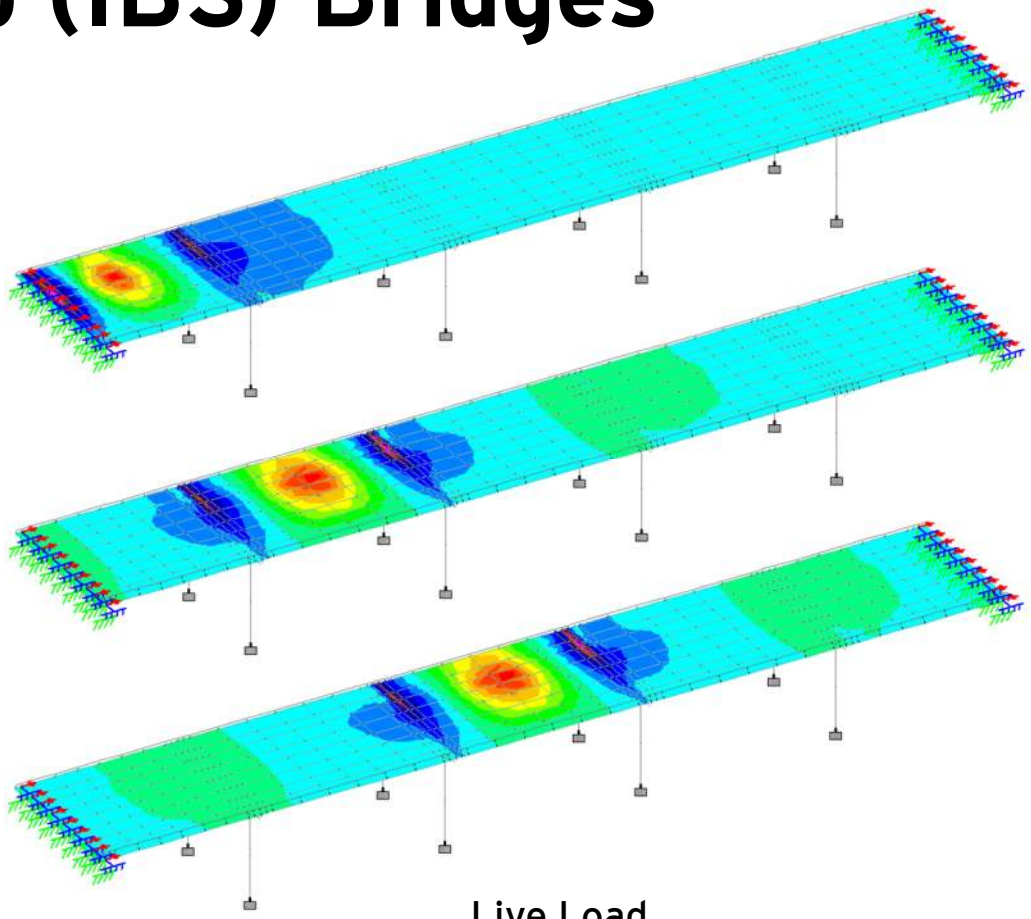
## Refined Analysis:



Model



Dead Load



Live Load

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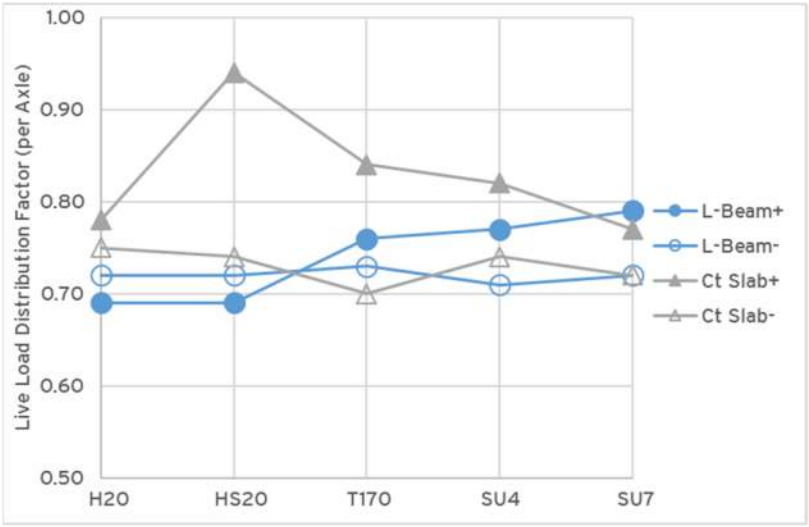
# Illinois Bulletin Slab (IBS) Bridges

Load Distribution:

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




LLDF – Vehicle Configuration

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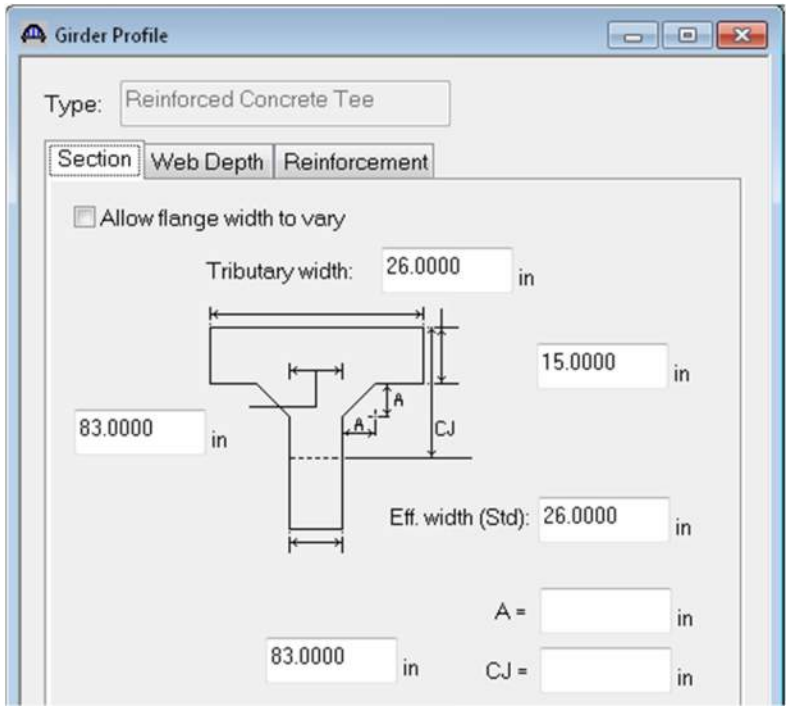
# Illinois Bulletin Slab (IBS) Bridges

BrR Modeling:

- Line girder superstructure
  - Edge L-beams
  - Center slab

- T-Beam Member Type
  - Inverted L-beam
  - Wide "web" overpredicts shear capacity - not critical




T-Beam Input

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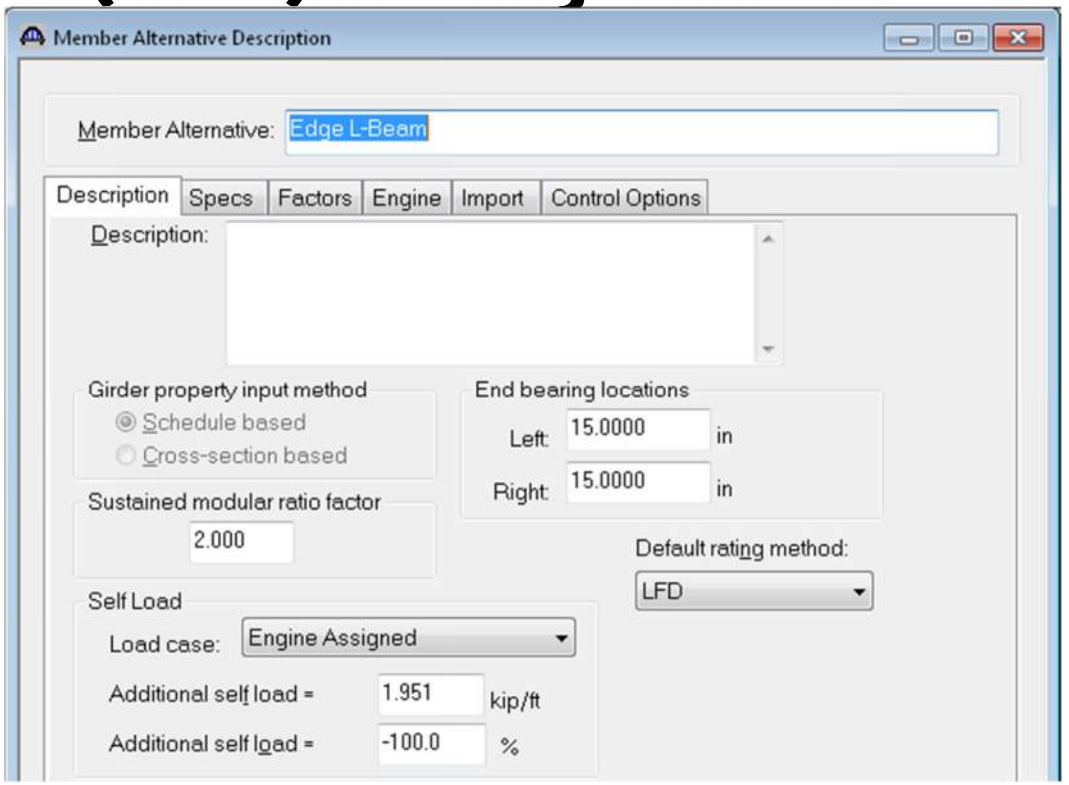
# Illinois Bulletin Slab (IBS) Bridges

BrR Modeling:

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




Self-Weight Input

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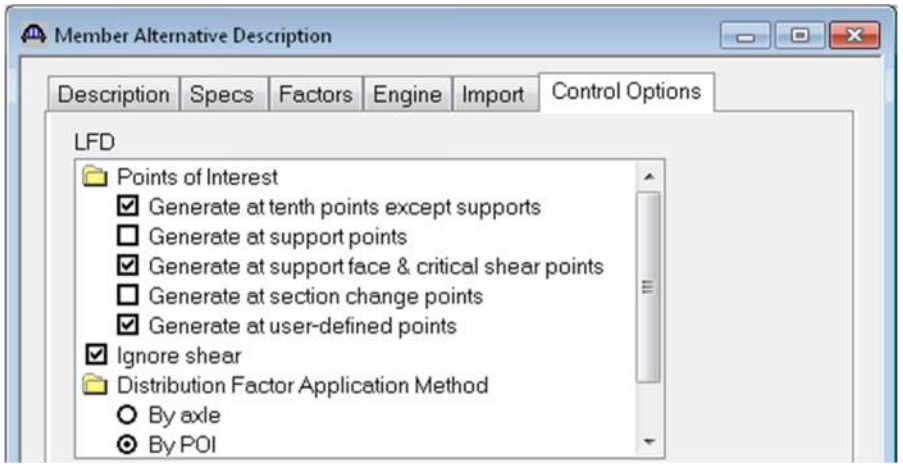
# Illinois Bulletin Slab (IBS) Bridges

BrR Modeling:

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




Control Options

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# 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

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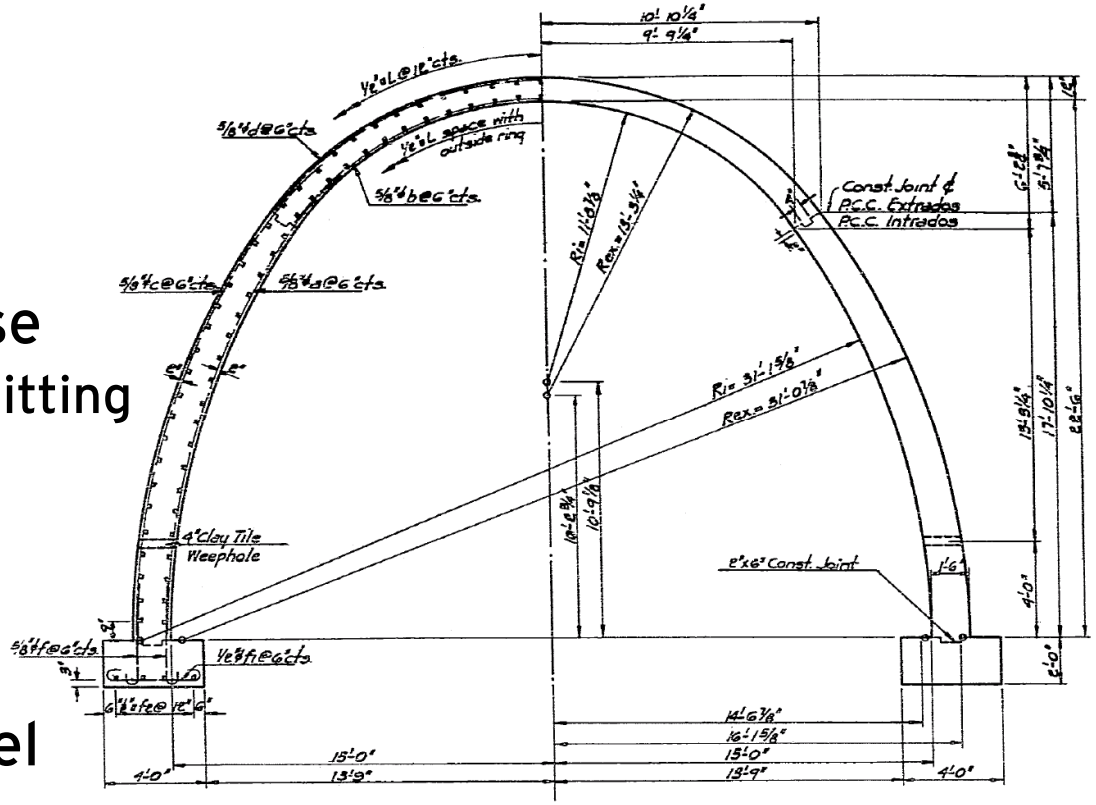
# Filled-Spandrel Arches

Procedure:

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




Reinforced Concrete Arch Typical Section

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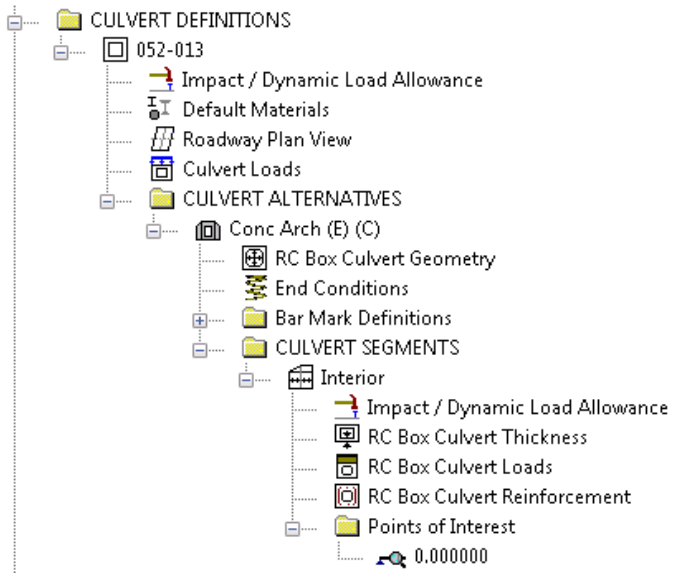
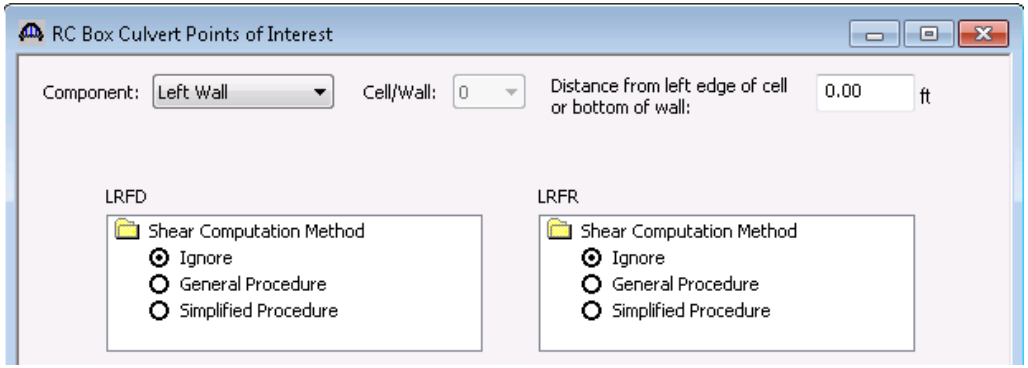
# Filled-Spandrel Arches

BrR Modeling:

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




BrR Definitions

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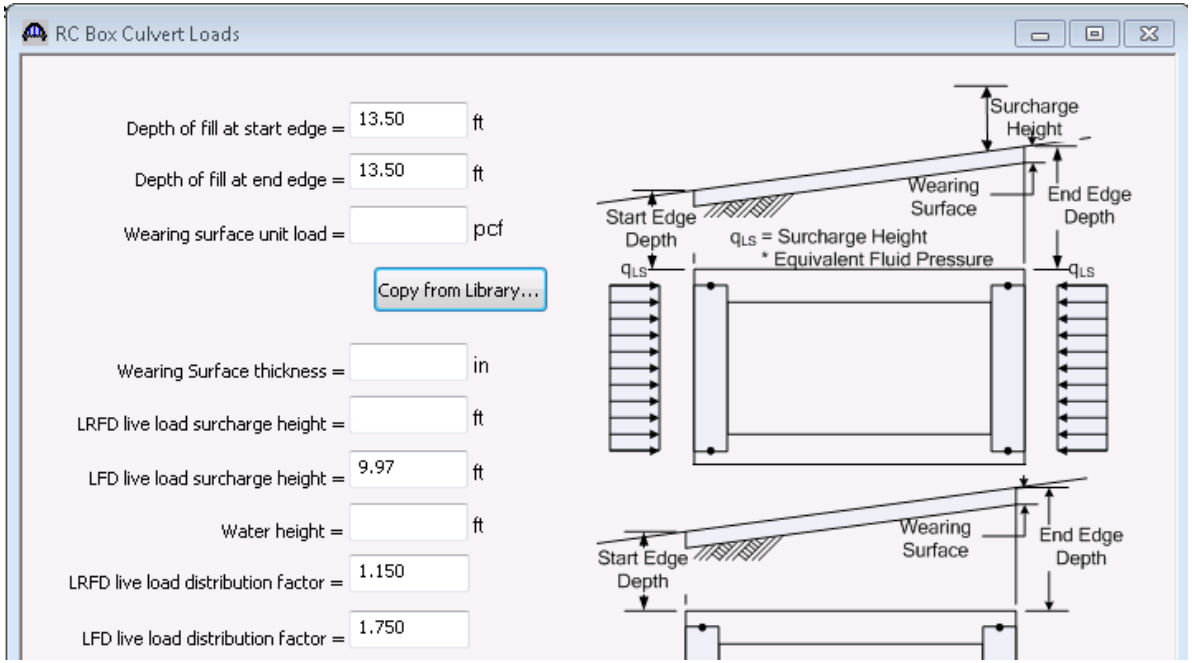
# Filled-Spandrel Arches

BrR Modeling:

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




BrR Culvert Loads

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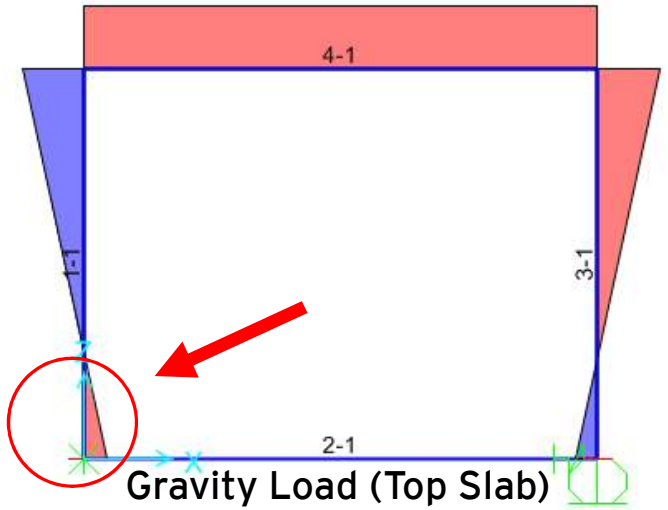
# Filled-Spandrel Arches

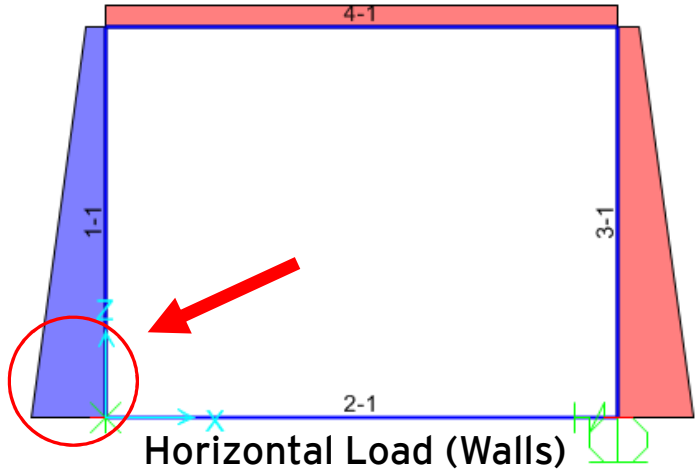
BrR Modeling:

- Moment at Wall Base POI
  - DL, EV and LL (+)
  - EH and LS (-)

  - Choose: EH > EV+DL
  - Choose: LS > (expected) LL
  - BrR uses LS (constant), but no LL
    - Vehicle approaching culvert



Gravity Load (Top Slab)



Horizontal Load (Walls)

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# Filled-Spandrel Arches

## BrR Modeling:

Analysis Results - Interior

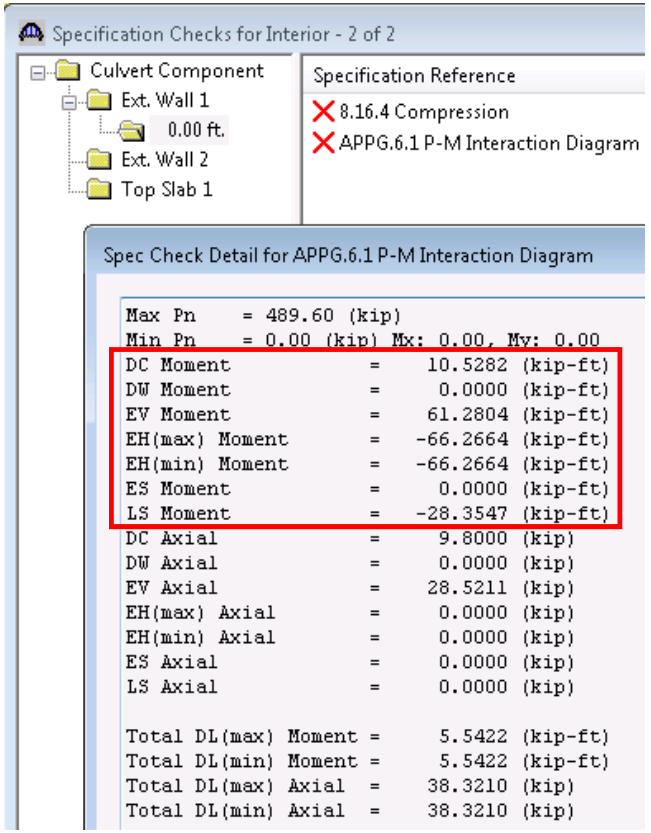
Report Type: Rating Results Summary

Lane/Impact Loading Type: (•) As Requested ( ) Detailed

Display Format: Mutiple 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




Spec Check Moment Components

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# 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

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# Questions?

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100+

YEARS OF
INFRASTRUCTURE
SOLUTIONS

Thanks to: