Illinois Department of Transportation

Memorandum

To:	ALL BRIDGE DESIGNERS	24.5
From:	Jayme F. Schiff	
Subject:	Structural Services Manual Update – Section 4	Jayme F. Schiff
Date:	November 15, 2024	

All Bridge Designers (ABD) Memorandum 24.5 introduces updates to Section 4 (Load Rating) of the Structural Services Manual. Updates reflect the current standards and practices of the bridge ratings and permits unit. A summary of significant changes to policy for load ratings is provided below.

- Incorporated new load rating item coding from the Specifications for the National Bridge Inventory.
- Clarified LRFR live load distribution factor computation for exterior beams.
- Included additional detail on evaluating PPC deck beam keyway and member deterioration.
- Updated policy for raising the condition rating of steel superstructures with section loss caused by corrosion.
- Clarified procedure for modeling rebar in skewed culverts.
- Updated the rating factor and load posting table for the Rational Evaluation Method.
- Added a section on emergency vehicle load rating.

In concurrence with the release of the updated load rating section of the Structural Service Manual, a new version of IDOT Form BBS 2795 "Structure Load Rating Summary" (SLRS) has been uploaded to the website: https://idot.illinois.gov/doing-business/procurements/engineering-architectural-professional-services/consultant-resources/bridges-and-structures/bridge-load-ratings.html.

The Load Rating website has also been updated with the latest BrR import files, a new BrDR Setup Guide, and a set of BrR IDOT-specific tutorials.

While this updated section is provided as a stand-alone document, to get it to load raters as soon as possible, it will be incorporated in the update of the full Structural Services Manual to be issued later this year.

The policies found in the updated Section 4 shall be implemented on applicable projects as soon as feasible. Please direct questions and comments to Spencer Koehler, Bridge Ratings and Permits Unit Chief, at DOT.Bridge.Ratings@illinois.gov.

Table of Contents

4.1 General 5
4.1.1 Purpose and Scope 5
4.1.2 Load Rating Regulations 5
4.1.2.1 Federal Regulations 5
4.1.2.2 State Statutes 5
4.1.3 Structures Requiring Load Ratings 6
4.1.4 Qualifications and Responsibilities of Load Rating Personnel 6
4.1.5 Documentation and Deliverables 6
4.1.6 Load Rating Software 7
4.1.7 Quality Control and Quality Assurance 7
4.2 . Load Rating Requirements 8
4.2.1 Evaluation Methods 8
4.2.2 Rating Factors 8
4.2.3 Rating Factor Variables 9
4.2.3.1 Load Rating Inspection 9
4.2.3.2 Load Carrying Member Properties 9
4.2.3.2.1 Section Properties 9
4.2.3.2.2 Material Properties 10
4.2.4 Load Carrying Member Policies and Guidelines 11
4.2.4.1 Metric Reinforcement Bars 12
4.2.4.2 Decks 12
4.2.4.2.1 Concrete and Metal Decks 12
4.2.4.2.2 Timber Decks 12
4.2.4.3 Superstructures 13
4.2.4.3.1 Cast-in-Place Concrete Superstructures 14
4.2.4.3.2 Precast Concrete Superstructures 14
4.2.4.3.3 Precast Prestressed Concrete I Beam Superstructures 14
4.2.4.3.4 Precast Prestressed Concrete Box Beams (Deck Beams) 15
4.2.4.3.5 Steel Superstructures 17
4.2.4.3.6 Trusses 18
4.2.4.3.7 Cables and Hangers 19
4.2.4.3.8 Pin and Link Connections 20

4.2.4.3.9 Arches 20
4.2.4.3.10 Precast Concrete Three-Sided Structures 20
4.2.4.4 Substructures....20
4.2.4.4.1 Abutment and Pier Caps 20
4.2.4.4.2 Cantilever Abutment and Pier Caps 20
4.2.4.4.3 Piles 20
4.2.4.4.4 Scour 21
4.2.4.5 Culverts 21
4.2.4.5.1 Concrete Box Culverts/Rigid Frames 21
4.2.4.5.2 Concrete Pipe Culverts 23
4.2.4.5.3 Metal Pipe Culverts 23
4.2.4.5.4 Masonry Culverts 23
4.3 Design and Legal Load Ratings....24
4.3.1 Assignment of Responsibility....24
4.3.1.1 State Bridges 24
4.3.1.2 Public Agency Bridges 24
4.3.1.3 Other Bridges....25
4.3.2 Load Rating Frequency 25
4.3.2.1 Initial Load Rating 25
4.3.2.2 Revised Load Ratings....25
4.3.2.2.1 Modified Permanent Loads 25
4.3.2.2.2 Structural Deterioration 26
4.3.2.2.3 Structural Damage 26
4.3.2.2.4 Bridge Rehabilitation 26
4.3.2.2.5 Temporary Measures 27
4.3.3 Evaluation Methods....27
4.3.3.1 ASR and LFR Methods 28
4.3.3.2 LRFR Method 28
4.3.3.3 Rational Evaluation Method 28
4.3.3.4 Load Testing Method 29
4.3.4 Transient Loads 29
4.3.4.1 Design Load Rating 29
4.3.4.2 Legal Load Rating....30
4.3.4.2.1 Illinois Legal Vehicles 30
4.3.4.2.2 Illinois Routine Permit Vehicles 33

4.3.4.2.3 Emergency Vehicles 33
4.3.5 Weight Restrictions 34
4.3.5.1 Implementing Weight Restrictions 34
4.3.5.1.1 No Weight Restrictions 34
4.3.5.1.2 Weight Restricted to Illinois Statutory Loads (Legal Loads Only) 35
4.3.5.1.3 Weight Restricted Below Illinois Statutory Loads (Load Posting) 35
4.3.5.2 Posted Weight Restriction Signage 36
4.3.5.3 Removing and Altering Weight Restrictions 37
4.4 Overweight Permit Evaluation 38
4.4.1 Assignment of Responsibility 38
4.4.2 Routine Permit Evaluation 38
4.4.3 Special Permit Evaluation 38
4.4.3.1 Transient Load Configurations 39
4.4.3.2 Permit Restrictions 39
4.4.3.2.1 One Lane Loaded 39
4.4.3.2.2 Load Position 39
4.4.3.2.3 Reduced Impact Loading 39
4.4.3.3 Temporary Measures 39
4.5 Construction Load Rating 40
4.5.1 Project Development Phase 40
4.5.2 Project Implementation Phase 40
4.5.3 Evaluation Methods 41

List of Tables and Figures

Table 4.2.3.2.2-1: Structural Steel Material Properties 10
Table 4.2.3.2.2-2: Reinforcing Steel Material Properties 10
Table 4.2.3.2.2-3: Prestressing Strand Material Properties 10
Table 4.2.3.2.2-4: Concrete Material Properties 10
Table 4.2.3.2.2-5: Timber Material Properties 11
Table 4.2.3.2.2-6: Timber Deck Material Properties 11
Table 4.2.4.1-1: Reinforcement Bar Metric to English Conversion 12
Figure 4.2.4.3.5-1: Theoretical End of Cover Plate 18
Figure 4.2.4.5.1-1: Spacing detailed perpendicular to bars 22
Figure 4.2.4.5.1-2: Spacing detailed parallel to the sidewalls 22
Table 4.3.3-1: Rating Method for Existing Bridges 27
Table 4.3.3-2: Rating Method for New or Rehabilitated Bridges 27
Table 4.3.3.2-1: Condition Factor: φ_c 28
Table 4.3.3.2-2: System Factor φ_s for Flexural and Axial Effects 28
Table 4.3.3.3-1: Rational Evaluation Method Rating Factors and Load Postings 29
Figure 4.3.4.2.1-1: Illinois Legal Vehicles (Single Unit Vehicles) 31
Figure 4.3.4.2.1-2: Illinois Legal Vehicles (Combination Unit Vehicles) 32
Figure 4.3.4.2.2-1: Illinois Routine Permit Vehicles 33
Figure 4.3.4.2.3-1: Emergency Vehicles 34
Table 4.3.5.1.3-1: Combination Posting Method Groups 35
Figure 4.3.5.2-1: Typical Load Posting Signs 37

4.1 General

4.1.1 Purpose and Scope

The purpose of this section is to supplement the AASHTO MBE with IDOT policies, procedures, and guidelines for load rating bridges. The goals of load rating bridges are to ensure public safety, prevent structural damage, and assist in the evaluation of programming needs. By determining the safe load capacity of bridges, agencies are able to:

- Comply with federal regulations and state statutes
- Evaluate the as-built condition of a bridge
- Evaluate the effects of bridge damage and deterioration
- Establish appropriate bridge weight restrictions
- Evaluate the movement of vehicles that do not conform to the Illinois Vehicle Code
- Evaluate the feasibility of proposed structural modifications

4.1.2 Load Rating Regulations

4.1.2.1 Federal Regulations

Federal regulations governing load ratings are included in the Code of Federal Regulations (CFR) under the NBIS. The NBIS requires all structures defined as highway bridges on public roads, regardless of jurisdiction or ownership, be load rated and posted in accordance with the AASHTO MBE. The NBIS defines bridge as follows:

> *Bridge.* A structure including supports erected over a depression or an obstruction, such as water, highway, or railway, and having a track or passageway for carrying traffic or other moving loads, and having an opening measured along the center of the roadway of more than 20 feet between under copings of abutments or spring lines of arches, or extreme ends of openings for multiple boxes; it includes multiple pipes, where the clear distance between openings is less than half of the smaller contiguous opening.

Further, the NBIS distinguishes between publicly owned bridges and private bridges.

> *Private bridge.* A bridge open to public travel and not owned by a public authority as defined in 23 U.S.C. 101.

A private bridge is subject to NBIS requirements if both ends of the bridge are connected to a public roadway.

The NBIS also requires each agency prepare and maintain an inventory of all bridges subject to the NBIS, which includes load rating and load posting data. IDOT maintains this inventory in a database referred to as the Illinois Structure Information System (ISIS). ISIS data is annually provided to the FHWA for updating the NBI.

4.1.2.2 State Statutes

State statutes governing load ratings in Illinois are included in the Illinois Compiled Statutes (ILCS) under the Illinois Vehicle Code, the Illinois Highway Code, and the Structural Engineering Practice Act of 1989 (SE Act).

The Illinois Vehicle Code and Illinois Highway Code assign responsibility to IDOT for the load rating and load posting of bridges on state and PA highways, without regard to highway jurisdiction or bridge ownership. For bridges on tollways, load ratings and load postings are the responsibility of the bridge owner, but coordination with IDOT is still required.

The Illinois Vehicle Code defines the size and weight limitations of vehicles allowed to have unrestricted access to Illinois highways. The Illinois Vehicle Code grants authority to highway and bridge owners to issue permits to vehicles exceeding these limitations.

The SE Act requires the individual with overall responsibility for the load rating inspection, load rating analysis, and load posting recommendations to be licensed in the State of Illinois as a Structural Engineer.

4.1.3 Structures Requiring Load Ratings

Load ratings are required for the following structures on public roads:

- All structures subject to the NBIS requirements.
- Non-NBIS structures under IDOT jurisdiction enrolled in the Small Bridge Inspection Program (SBIP). This includes structures between 6 feet and 20 feet and multiple pipe installations where at least one pipe has an inside diameter of 60 inches or greater.

Additional information on the Small Bridge Inspection Program can be found in Section 3.

Load ratings are encouraged for Non-NBIS structures enrolled in a PA's Small Bridge Inspection Program or equivalent inspection program.

4.1.4 Qualifications and Responsibilities of Load Rating Personnel

All individuals involved with the bridge rating shall be knowledgeable in bridge design and familiar with standard load rating procedures, AASHTOWare BrR software, IDOT policies regarding load ratings, and the requirements of the AASHTO MBE.

Bridge ratings shall be prepared under the direction of an Illinois Licensed Structural Engineer acting as the Engineer of Record (EOR). At a minimum, the load rating team shall consist of an Engineer of Record (EOR), a load rater and a load rating checker. The EOR may assume the task of either the load rater or the load rating checker.

The load rater is responsible for gathering all the required materials, performing the necessary calculations, using judgement as needed to adjust the load rating results and filling out the load rating documentation. The load checker is responsible for confirming the assumptions used for the load rating, checking calculations and ensuring the load rating results are reasonable.

4.1.5 Documentation and Deliverables

The primary documentation of a load rating is IDOT Form BBS 2795, "Structure Load Rating Summary" (SLRS). The purpose of the SLRS is to provide documentation a load rating was performed, with a brief summary of its findings. The SLRS shall be sealed by an Illinois Licensed Structural Engineer and submitted to IDOT BBS where it will be placed in the structure's load rating file.

When load ratings of bridges on state and PA highways (excluding bridges owned by border states and federal agencies) are not completed by IDOT, the SLRS, load rating calculations, AASHTOWare BrR and/or other applicable software files, as-built bridge plans, and shop drawings, when applicable, shall be submitted to the BBS. Documentation of IDOT's concurrence with the load rating will be returned to the owner for inclusion in their bridge file. IDOT will update ISIS based on information on the SLRS.

For tollway bridge load ratings, a SLRS, sealed by an Illinois Licensed Structural Engineer, must be submitted to the BBS. IDOT concurrence is not required and the SLRS will serve as documentation a load rating was completed and the basis for updating ISIS.

All ratings, supporting calculations and AASHTOWare BrR files shall be in US Customary Units. Existing structures with plans in metric units shall be soft converted to US Customary Units.

4.1.6 Load Rating Software

Load ratings of bridges on state and PA highways, regardless of jurisdiction, should be completed, when possible, using AASHTOWare Bridge Rating™ (BrR) software in order to be compatible with the ITAP system and other software used by IDOT. If a load rating cannot be performed using AASHTOWare BrR, the load rater shall contact BBS to determine an acceptable alternative.

AASHTOWare BrR license requests, appropriate software version, setup, default settings, and modeling guidance may be found at https://idot.illinois.gov/doing-business/procurements/engineering-architectural-professional-services/consultant-resources/bridges-and-structures/bridge-load-ratings.html.

4.1.7 Quality Control and Quality Assurance

Quality Control (QC) and Quality Assurance (QA) are established procedures used to ensure load ratings are accurate and comprehensively evaluate the safe load capacity of bridges.

QC procedures must ensure:

- Load ratings are completed using an independent load rater and checker.
- Staff performing and checking the load ratings are appropriately qualified.
- Load rating forms are complete and have been sealed by an Illinois Licensed Structural Engineer.
- Records are maintained documenting the load rating calculations, assumptions made, specifications used, and identify the staff performing the load rating.

QA procedures must ensure:

- All established QC procedures have been followed.
- Load rating conclusions are reasonable given the bridge type and condition.
- The load rating has been sealed by an Illinois Licensed Structural Engineer and documented using the appropriate IDOT forms.

4.2 . Load Rating Requirements

Load ratings shall be completed using US Customary Units regardless of the units used in the original bridge plans. See Section 4.2.4.1 for IDOT reinforcement bar conversion standards.

4.2.1 Evaluation Methods

The AASHTO MBE provides both analytical and empirical methods for load rating bridges. The analytical methods include:

- Allowable Stress Rating (ASR)
- Load Factor Rating (LFR)
- Load and Resistance Factor Rating (LRFR)

The empirical methods include:

- Load ratings based on load testing
- Approximate load ratings based on rational criteria

Load ratings shall be completed using analytical methods when possible. Empirical methods should only be used when no plans are available for reinforced concrete bridges or masonry bridges, load testing has been performed, or an analytical load rating results in a less severe restriction than preferred given the condition of the structure. The BBS must concur with the use of empirical methods.

The evaluation method used depends on several factors including:

- Member(s) or bridge type being evaluated
- AASHTO specification used to design the bridge initially
- Bridge material type
- Availability of original design and rehabilitation plans and specifications

If existing plans cannot be located, the BBS shall be contacted for guidance on the load rating. Historic IDOT manuals, standards, and manufacturer's details may be used to augment empirical evaluations. A load rating inspection may be needed to verify the required measurements prior to these aids being used.

4.2.2 Rating Factors

A rating factor is a numerical representation of a bridge's capacity to safely carry a specific transient load having a defined magnitude and dimensional configuration. The general load rating equation for an individual load carrying member can be expressed as:

$$RF = \frac{(C - DL)}{(LL + IM)}$$

Where:

RF	=	Rating Factor
C	=	Capacity of load carrying member
DL	=	Load effect of all permanent loads
LL	=	Load effect of transient load
IM	=	Impact or dynamic load allowance, when applicable

An inventory load rating is comparable to a level of stress or reliability used during the design of a bridge to determine the proportions of load carrying members. An operating load rating is representative of the maximum load effect that can occasionally be tolerated by a bridge without causing appreciable damage.

See AASHTO MBE for more detailed information on calculating rating factors.

To determine a bridge's rating factor for a specific transient load, a rating factor must be calculated for each load effect of each applicable load carrying member in the bridge. The smallest of these factors is the bridge's rating factor for that specific transient load, and the corresponding load carrying member is the controlling member. This process is repeated for several different transient loads.

4.2.3 Rating Factor Variables

Accurately defining the variables necessary to calculate rating factors is essential for completing a quality load rating. This information can be obtained from sources including but not limited to:

- Original design and rehabilitation plans and specifications
- As-built plans and shop drawings
- Construction records
- Load rating inspection documentation
- Routine Inspection reports
- Special Inspection reports

4.2.3.1 Load Rating Inspection

Before a load rating is started, the load rating team reviews existing documentation and determines if a Load Rating Inspection (LRI) is necessary. This inspection may be performed by the load rating team or delegated to a separate inspection team. At a minimum, the LRI must:

- Confirm the condition and dimensions of the primary load carrying members
- Confirm the bridge geometric dimensions
- Confirm the presence, magnitude, and location of permanent loads with particular attention paid to utilities, attachments, and thickness of wearing surface
- Document any deterioration or repairs made to primary load carrying members

If necessary, the load rating team will discuss specific information to be collected or verified and how the information is to be documented. Section 3 contains information on recommended procedures for documenting LRI findings.

Additional information on LRIs can be found in Section 3.

4.2.3.2 Load Carrying Member Properties

Section and material properties of load carrying members are required to calculate the capacities of individual members and to determine load effects throughout the bridge.

4.2.3.2.1 SECTION PROPERTIES

Section properties are typically calculated using dimensions given in existing plans when available. Information taken from existing plans and the condition of the load carrying members may need to be field verified. If load carrying members are damaged or deteriorated, the section properties shall be modified accordingly. Unsound material is excluded from section property calculations.

If existing plans are not available, an LRI may be required to determine the section properties. Although devices are available for estimating the location and size of reinforcement bars, IDOT has not found these to be sufficiently reliable and has not adopted this technology for determining the section properties of reinforced concrete members. If section properties cannot be calculated or estimated with reasonable confidence, empirical methods may be used.

4.2.3.2.2 MATERIAL PROPERTIES

Material properties are based on information provided in the existing plans and specifications when available. If existing plans are not available, the following historical material properties shall be used:

		Allowable Stress Rating	
Year of Construction	Minimum Yield Strength, F_y (ksi)	Inventory ($0.55\ F_y$) (ksi)	Operating & Posting ($0.75\ F_y$) (ksi)
Before 1905	26.0	14.3	19.5
1905 - 1929	30.0	16.5	22.5
1930 - 1961	33.0	18.1	24.7
After 1961	36.0	20.0	27.0

TABLE 4.2.3.2.2-1: STRUCTURAL STEEL MATERIAL PROPERTIES

		Allowable Stress Rating	
Year of Construction	Minimum Yield Strength, f_y (ksi)	Inventory (ksi)	Operating & Posting (ksi)
Before 1905	26.0	14.3	19.5
1905 – 1920	32.0	17.6	24.0
1921 – 1944	33.0	18.1	24.7
1945 – 1979	40.0	20.0	28.0
After 1979	60.0	24.0	36.0

TABLE 4.2.3.2.2-2: REINFORCING STEEL MATERIAL PROPERTIES

Year of Construction	Tensile Strength, f_{pu} – LRFD f'_s – Std. Spec's (ksi)
Before 1963	228.0
1963 - 1976	248.0
After 1976	270.0

TABLE 4.2.3.2.2-3: PRESTRESSING STRAND MATERIAL PROPERTIES

	Year of Construction	Compressive Strength, f'_c (f_c) (ksi)
Cast in Place Concrete	Before 1930	3.0 (1.2)
	1930 to date	3.5 (1.4)
Precast Concrete	All years	4.5 (1.8)
Precast Prestressed Concrete	All years	5.0 (2.0)

TABLE 4.2.3.2.2-4: CONCRETE MATERIAL PROPERTIES

	Member Type	Allowable Inventory Stresses Normal Load Duration *(See Note 2)* (ksi)	
Members subject to bending and shear, dry service conditions	Stringer, Floor Beam, Pile Cap	Bending F_b = 1.15	Shear F_y = 0.155
Members subject to axial loading	Truss Member	Compression F_c = *(See Note 1)*	Tension F_t = *(See Note 1)*
Members subject to axial compression and bending, wet service conditions	Piling	Compression F_c = 1.25	Bending F_b = 1.95

TABLE 4.2.3.2.2-5: TIMBER MATERIAL PROPERTIES

Notes:

1. Truss member properties are dependent on member sizes. Stresses shall be the lesser of the Select Structural values found in the NDS for Douglas Fir-Larch, Red Oak, or Southern Pine.

2. Operating/Posting allowable stress is typically 133% of the inventory allowable stress, except for timber piles, which is 116.5% of the inventory allowable stress. This is to account for the eccentric loading at piers, and to a lesser extent at abutments, induced by the simple span configurations of many PA bridges.

Condition	Allowable Bending Stresses, F_b Normal Load Duration & Dry Service Conditions	
	Inventory (ksi)	Operating & Posting (ksi)
Good	1.650	2.195
Fair	1.485	1.975
Poor	1.320	1.755

TABLE 4.2.3.2.2-6: TIMBER DECK MATERIAL PROPERTIES

The AASHTO MBE shall be referenced for material properties not included in these tables.

It is reasonable to expect the original material properties of sound structural steel or iron have not changed. However, the strength of some sound materials, such as concrete or timber, may have changed over time. Material testing may justify using higher or lower strengths than originally expected.

4.2.4 Load Carrying Member Policies and Guidelines

Experience with load rating different types of load carrying members has led IDOT to develop various policies and guidelines, which are included in the following sections. The policies recognize it is not necessary to load rate every load carrying member on a bridge. However, it is the responsibility of the load rater to review the bridge's structural system and make the final determination if a load carrying member can be safely excluded from a load rating.

In general, policies and guidelines stated in the IDOT *Bridge Manual* for bridge design are also applicable for load ratings.

4.2.4.1 Metric Reinforcement Bars

When converting reinforcement bars from metric to English units, the following table shall be used:

Metric Bar	English Substitution
10	3
13	4
15	5
16	5
19	6
20	19 *(See Note 1)*
22	7
25	8
29	9
30	29 *(See Note 1)*
32	10
35	10 *(See Note 1)*
36	11

TABLE 4.2.4.1-1: REINFORCEMENT BAR METRIC TO ENGLISH CONVERSION

Notes:

1. Use the spacing that equates to the same area of steel per foot as the metric bar size and spacing

4.2.4.2 Decks

4.2.4.2.1 CONCRETE AND METAL DECKS

Concrete decks and metal decks supported by primary load carrying members typically do not need to be load rated. A deteriorated concrete deck or metal deck is usually a maintenance issue that requires patching or shielding to protect areas below the deck.

When concrete decks and metal decks are not maintained and have deteriorated to the point where weight restrictions need to be considered, the BBS shall be contacted for guidance.

The following are IDOT policies regarding concrete and metal deck load ratings:

Concrete Cracks: When a concrete deck is load rated, the Crack Control Parameter (ASR and LFR) and Exposure Factor (LRFR) are typically 130 k/in and 0.75, respectively, for the top reinforcement in the deck based on severe exposure condition.

Decks with Overlays: When a deck is load rated, the structural thickness of the deck is the thickness remaining after scarification. The overlay thickness shall not be included when calculating the section properties of the deck unless it meets the requirements given in Section 4.2.4.3 for Concrete Deck-Slabs with Concrete Overlays. The weight of the overlay shall be accounted for accordingly.

4.2.4.2.2 TIMBER DECKS

Timber plank decks supported by primary load carrying members must be included in a load rating.

Special attention is given to:

- Deteriorated timber planks
- Decks without running boards

- Decks with narrow running boards (Running boards are not expected to distribute wheel loads unless they are a minimum width of 2'-6" for each wheel path)

The following are IDOT policies regarding timber deck load ratings:

Load Rating Guidelines: Timber deck load ratings follow the procedures in the USDA Forest Service *Timber Bridges Design, Construction, Inspection, and Maintenance.*

Wheel Load Distribution: The distribution of wheel loads shall be determined based on loading and effective tire width. BBS practice is to distribute the wheel load to a single deck plank, except where running boards are present. When running boards are present, the wheel load is distributed vertically through the running boards at a 45° angle.

4.2.4.3 Superstructures

The following are IDOT policies regarding superstructure load rating:

Concrete Deck-Slabs with Concrete Overlays: When a superstructure with a scarified deck-slab and hard concrete overlay is judged to act composite with the original deck, the actual scarified deck and overlay thicknesses will be used as tributary for dead loads. The deck structural thickness will be the original, pre-scarification structural thickness.

A concrete overlay considered to act composite with the original deck-slab is expected to have the following characteristics:

- Scarification was performed with hydro-scarification. This is the case for scarification on state highway system bridges since 2003 inclusive. Prior to 2003, hydro-scarification would be indicated as a separate pay item on the overlay plans.
- The concrete overlay is in good condition, including physical structure and adherence to the original slab.

Future Wearing Surface: Future Wearing Surface shall not be included in any load ratings. Only as-built or as-inspected overlays and permanent loads shall be included in load ratings.

Exterior and Interior Beams: Both the exterior and interior beams of multi-beam superstructures shall be evaluated in a load rating. However, if the analysis results in the exterior beam governing and a restriction is required, the analysis can be refined by limiting the application of the vehicular live load(s) to the actual striped lanes. In some cases, the exterior beam can be neglected or omitted from the load rating. Examples of this would be physical traffic control devices installed to deter traffic or an approach roadway width that is less than the width of the bridge roadway.

Vehicle Lanes/Live Load Distribution: When performing load ratings, the number of traffic lanes to be loaded, and the transverse placement of wheel lines, shall be in conformance with the current AASHTO Standard Specifications or AASHTO LRFD Specifications and the following:

- Roadway widths from 18 to 24 feet shall have two traffic lanes, each equal to one half the roadway width.
- Roadway widths less than 18 feet shall have one traffic lane only.
- Timber decks with running boards shall have one traffic lane for every pair of running boards.

However, the following alternatives may be used with approval from the BBS:

- When lane striping is present: The number of traffic lanes and transverse placement of wheel lines may be determined by placing truck loads only within the striped lanes. When load rating a structure based on the existing striped lanes, the transverse positioning of the truck shall include placing the wheel load anywhere within the lane, including on the lane stripe.

- When lane striping is not present: If ADT is less than 2000 and ADTT is less than 400, one traffic lane may be used. PA owned structures with very low ADT, regardless of the presence of lane striping, may be rated for one lane.
- The BBS does not allow these alternatives for the Design Vehicle at the Inventory Level. An Inventory Level load rating is used to evaluate the bridge using the design loading and design specifications.

For the purposes of load ratings, the exterior beam LLDF shall be computed as follows:

- ASR or LFR: Use the Lever Rule exclusively.
- LRFR: Use AASHTO MBE 6A4.5.6. If the inventory load rating falls below 1.0, then the provisions found in IDOT Bridge Manual Article 3.1.12.1 may be used to reduce the LLDF to the exterior beam.

Approach Spans: An approach span supported by a vaulted abutment shall be evaluated in the load rating except when supported by backfill.

4.2.4.3.1 CAST-IN-PLACE CONCRETE SUPERSTRUCTURES

Cast-in-place concrete is used in a variety of superstructure systems. The slabs, stringers, beams, and girders in these superstructure systems are primary load carrying members and shall be evaluated in the load rating.

For slab bridge type structures, the rating shall all types of slab sections if the cross-section varies across the width of the bridge.

Concrete bridges constructed after the early 1940’s generally used air entrainment in the concrete mix to improve the long-term freeze/thaw durability of the bridge. Bridges constructed prior to this date did not use air entraining agents and generally can exhibit significant concrete deterioration due to internal damage caused by freeze/thaw cycles. Cores were taken on many state owned concrete bridges built prior to the 1940’s. The BBS should be contacted to verify if core reports and strengths are available. For more information see IDOT All Deputy Directors of Highways memos "Deterioration of Reinforced Concrete Structures" and "Inspection and Coring of Reinforced Concrete Structures" in the Appendix.

4.2.4.3.2 PRECAST CONCRETE SUPERSTRUCTURES

Precast concrete beams are commonly referred to as “Channel Beams”, “Nelsen Beams”, “Midwest Beams”, or “Precast Concrete Bridge Slabs”. They are primary load carrying members and shall be evaluated in the load rating.

IDOT uses the same policies regarding live load distribution factors for precast concrete superstructure load ratings as precast prestressed concrete box beams given in Section 4.2.4.3.4

4.2.4.3.3 PRECAST PRESTRESSED CONCRETE I BEAM SUPERSTRUCTURES

Precast prestressed concrete I beams (PPCI) is used in a variety of superstructure systems. These systems are primary load carrying members and shall be evaluated in the load rating. When present, diaphragms between the beams are included in the analysis model but are typically not evaluated in the load rating.

The following are IDOT policies regarding PPCI superstructure load ratings:

Beam Deterioration: Policies for load rating PPC box beams given in Section 4.2.4.3.4 are also applicable to PPCI superstructures. Deterioration in PPC box beams is more prevalent due to the tendency for shear key leakage. PPCI superstructures can also be exposed to deicing agents, especially below deck drains, scuppers, and leaking expansion joints.

PPCI superstructures occasionally receive impact damage that results in exposed prestressing strands. If the exposed strands are undamaged and the PPCI beam receives a structural concrete repair, as described in Section 2.14, the strands can be considered fully effective.

<u>Shear</u>: The 1994 & 2003 IDOT *Precast Prestressed Concrete Design Manual* directed engineers to neglect prestressing force effects when designing shear reinforcement in the negative moment region of continuous spans. Although not allowed by design, many beams were fabricated with non-conforming shear stirrup spacing, which were then reanalyzed using prestressing force effects to justify use in construction. For all precast prestressed concrete beams, use the contribution of prestressing force effects, even if neglected in the original design. In addition, the method for design of shear reinforcement presented in the 1979 Interim AASHTO *Standard Specifications for Highway Bridges* is not allowed for load rating.

4.2.4.3.4 PRECAST PRESTRESSED CONCRETE BOX BEAMS (DECK BEAMS)

PPC box beams (deck beams) are primary load carrying members and shall be included in the load rating.

The following are IDOT policies regarding PPC box beam load ratings:

<u>Live Load Distribution Factors</u>: For LFR, there are two primary methods used to calculate LLDF's for PPC box beams in Illinois: AASHTO *Standard Specifications for Highway Bridges 13th Edition* (AASHTO 1983) and *17th Edition* (AASHTO 2002). AASHTO 2002 is similar to current design practice and is generally more conservative for wider bridges (greater than or equal to 30 feet), while AASHTO 1983 is more conservative for narrower bridges (less than 30 feet). Thus, the preference is to use AASHTO 2002 for state bridges and AASHTO 1983 for PA bridges as described below:

- For state owned bridges being evaluated using LFR, the LLDF shall be calculated using AASHTO 2002, Section 3.23.4.
- For PA bridges being evaluated using LFR, the LLDF shall be calculated using AASHTO 1983, Section 3.23.4. AASHTO 2002 shall only be used if specified on the existing bridge plans.

<u>Shear Keyways</u>: The grouted shear keyways between individual PPC deck beams allow for the lateral distribution of load during application of live loads. If it is determined during inspection that a keyway has become ineffective, live load can no longer be distributed across the longitudinal joint between beams. The live load distribution factors for all beams in the span(s) with the ineffective keyway(s) must be re-calculated accordingly based on groups of beams that act together between ineffective keyways. However, when a PPC deck beam superstructure has a reinforced concrete overlay that is in good condition or has hairline reflective cracks, live load distribution to adjacent deck beams can be considered unaffected by ineffective shear keyways due to the overlay's ability to distribute live load between beams.

<u>Beam Deterioration</u>: Some PPC box beams have exhibited rapid deterioration rates. IDOT sponsored the University of Illinois at Urbana-Champaign to research this issue. The main finding of the research was once corrosion has initiated within a prestressing strand; the rate of corrosion is sufficient to expect the strand has lost the ability to carry load. In addition, if a strand is in the vicinity of corroding conventional reinforcement (stirrups, welded wire fabric, etc.), that strand is expected to be corroded as well.

Special attention is given to:

- Areas of delaminated concrete
- Areas of inadequate concrete cover
- Areas of longitudinal cracking
- Areas of transverse cracking
- Areas with spalls, exposed stirrups, or exposed prestressing strands

The following guidelines shall be used for estimating strand loss in PPC box beams.

Prestressed strands incorporated in PPC Deck Beams shall be disregarded during analysis for load carrying capacity as specified below. If deterioration is located within the center half of the span, disregard the entire length of prestressed strand. If deterioration is located within the end quarters of the span, disregard the prestressed strand from the beam end up to the extent of deterioration. This can be accomplished by debonding the strands up to this location.

LONGITUDINAL CRACKS

The intent is to disregard all strands that could intersect the crack and be exposed to air and moisture.

1. Cracks observed in the middle area of the beam underside, with or without rust stains or other discoloration of the concrete adjacent to the cracks:

    Disregard all strands from all rows of strands that may be located adjacent to the cracks.

2. Cracks observed along the edges of the beam underside, with or without rust stains or other discoloration of the concrete adjacent to the cracks:

    Disregard at least the strands located adjacent to the edge of the beam in the bottom row of strands. When the crack is extensive in length and its location varies in distance from the beam edge, disregard additional interior strands from all rows of strands that may be intersected by the crack.

3. Cracks observed along the outside face of the exterior beam, with or without rust stains or other discoloration of the concrete adjacent to the cracks:

    Disregard strands in the outside face of the beam adjacent to or intersected by the cracks.

4. Two longitudinal cracks observed crossing or meeting:

    Disregard all strands in all rows of strands located between the cracks and one strand from all rows of strands located adjacent to the outer edge of the cracks.

DETERIORATION

1. Exposed strands observed with sound concrete adjacent to and above the exposed strands:

    Disregard exposed strands only.

2. Exposed strands observed with unsound concrete adjacent to and above the exposed strands:

    Disregard exposed strands and all strands located in rows above and immediately adjacent to the area of unsound concrete.

3. Exposed welded mesh or reinforcement bars observed on the bottom corners and/or extending up the side face.

    Disregard the strands located at the edge of the beam in the bottom row directly above the exposed reinforcement. If the concrete is found to be unsound adjacent to the exposed reinforcement bars, disregard all strands in all rows located above the area of unsound concrete.

4. Exposed wire mesh or full width reinforcement stirrup bars observed on bottom of beam:

    Judge whether the wire mesh or reinforcement bars are in contact with the strands.

- If in contact, disregard all strands in the lower row directly above the exposed wire mesh or stirrups.
- If not in contact but the concrete adjacent to the exposed wire mesh or stirrups is found to be unsound, disregard all strands located above the area of unsound concrete.
- If not in contact and concrete adjacent to the exposed wire mesh or stirrups is sound, do not disregard strands during analysis.

5. Areas of delaminated concrete observed:

   Note: Patches are considered delaminated.

   Remove all delaminated concrete to determine the depth of concrete deterioration.

   - If reinforcement stirrup bars, wire mesh or strands are exposed, treat as in “1” through “4” above.
   - If no reinforcement, mesh or strands are exposed but there are indications that the exposed concrete is unsound within the affected area, disregard all strands located in the rows of strands above the area.
   - If no reinforcement, mesh or strands are exposed in the affected area and concrete in the area is found to be sound, do not disregard strands in analysis.

6. Wet or stained areas observed on bottom or side of beams:

   Closely inspect the wet or stained area to determine the soundness of the concrete.

   - If close inspection indicates the concrete is unsound or delaminated, treat as in “5” above.
   - If close inspection confirms the concrete is sound, do not disregard strands in analysis.

   Note: Wet and/or rust stained areas should be watched closely. These areas will be the next areas to experience significant deterioration.

4.2.4.3.5 STEEL SUPERSTRUCTURES

Steel is used in a variety of superstructure systems. The stringers, beams, girders, floorbeams, diaphragms, and crossframes on curved bridges are primary load carrying members and shall be evaluated in the load rating. Diaphragms and crossframes on straight bridges are included in the analysis model but are typically not evaluated in the load rating.

Special attention is given to:

- Fracture critical members
- Members with noted section loss

The following are IDOT policies regarding steel superstructure load ratings:

Plastic Capacity: The use of plastic capacity in steel members is not allowed when existing plans cannot be located or for steels with F_y greater than 70ksi.

Moment Redistribution: Moment redistribution in continuous steel members shall not be used.

Beam Splices: Steel beam splices are typically not evaluated in the load rating.

Bearing Stiffeners: Bearing stiffeners are included in the analysis model but are typically not evaluated in the load rating except when evaluating the bearing capacity of deteriorated beam ends.

Fatigue and Serviceability: Load ratings of steel members generally do not evaluate fatigue, overload, and live load deflections.

Cover Plates: The length used for analysis of cover plates is shorter than the actual end-to-end cover plate length. The Theoretical End of Cover Plate location is reduced 1.5 times the full width of the cover plate as shown in Figure 4.2.4.3.5-1.

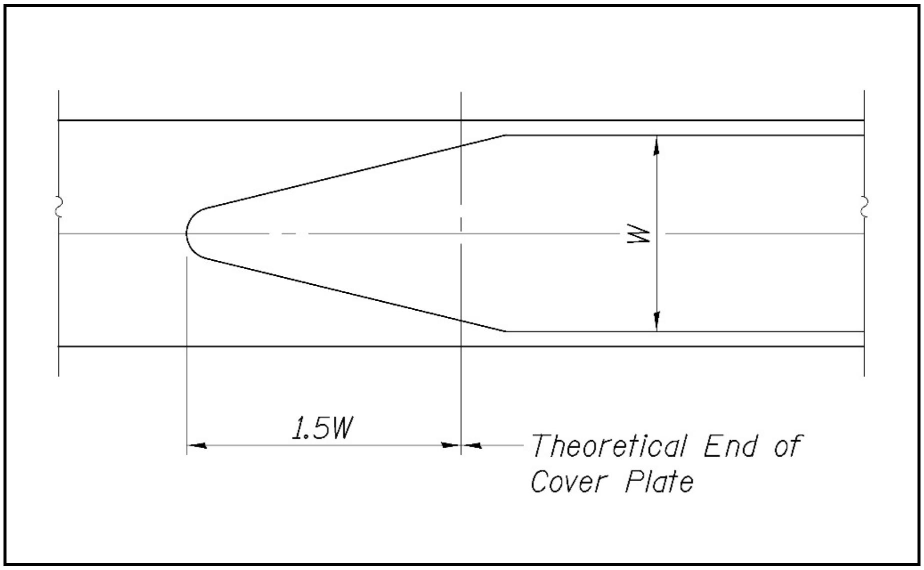


FIGURE 4.2.4.3.5-1: THEORETICAL END OF COVER PLATE

Section Loss: When the steel superstructure condition rating drops due to section loss caused by corrosion, the condition rating may be raised back to the previous rating if:

- Legal, Routine Permit, and Emergency Vehicle load rating operating rating factors are all greater than or equal to 1.00 (considering section loss)
- Corroded area is cleaned and painted

This may only be done with the approval of the BBS.

4.2.4.3.6 TRUSSES

Unless a structural analysis has identified a specific truss member as a non-load carrying member, all elements of steel trusses (including gusset plates and other connection elements) are considered primary load carrying members and shall be evaluated in the load rating. Tension members and floor beams of steel trusses are fracture critical members and may be given special attention.

The following are IDOT policies regarding steel truss load ratings:

Dead Load Forces: IDOT uses a minimum dead load factor of 0.90 when the dead load acts to reduce the overall loading (i.e. the dead load and live load are acting in opposite directions). The maximum dead load factors shall be as defined in the AASHTO MBE.

Live Load Force Effects: Live load force effects may be determined by either the maximum envelope method or concurrent force method. The maximum envelope method should be used for the individual member rating checks. However, using the maximum envelope method for the overall gusset plate shear rating checks may be unconservative and the concurrent force method should therefore be used.

Both maximum enveloped force effects and concurrent force effects can be attained using the AASHTOWare BrR software.

Additional policies specific to gusset plates:

Shear Reduction Factor, Ω: For the shear reduction factor, Ω, the BBS recommends using Ω = 0.88 for typical cases. This factor can vary from 0.74 to 1.00 and a more refined analysis may provide more favorable results. The BBS must approve the use of a factor other than 0.88.

Slip Critical Connections: Slip critical considerations need not be considered in the gusset plate load rating.

Partial Shear Planes: Based on research conducted on behalf of IDOT, the partial shear plane checks within the 2014 AASHTO MBE Interims may be overly conservative in some instances. Therefore, if partial shear plane checks control a load rating, a more refined analysis shall be performed.

Load Distribution between Gusset Plates: There are typically two gusset plates at each panel point node location; an inside gusset plate and an outside gusset plate. In some instances, there are multiple gusset plates on each side. Generally, half the loads shall be distributed to the inside gusset plate(s) and half to the outside gusset plate(s). However, for gusset plates with resulting substandard load ratings, load redistribution between inside and outside gusset plates at a given node may be based on the remaining capacity of each gusset plate(s).

The BBS uses a maximum redistribution of 30% of the load carried by the gusset plate(s) on one side of the member to the gusset plate(s) on the other side of the member. Under the design assumption of the gusset plates(s) on one side carrying 50% of the load, the maximum redistribution would result in the gusset plate(s) on the stronger side carrying a maximum of 65% of the total load and the gusset plate(s) on the weaker side carrying a minimum of 35% of the total load. If other load redistribution techniques are used, it must be with the approval of the BBS.

Section Loss: Load rating of the gusset plates for section loss shall be based on the AASHTO MBE procedures. However, when the AASHTO MBE procedures conclude the gusset plate is the controlling member, a more refined analysis is used. Procedures for the refined section loss calculations are outlined in the IDOT *Gusset Plate Evaluation Guide* (see "Refined Analysis Load Ratings" policy). If this refined section loss method is utilized, it must be done with approval from the BBS.

If there is no recorded corrosion of the gusset plates, splice plates, or fasteners, the load rating need not consider section loss. If there is recorded corrosion of the gusset plates, splices plates, and/or the fasteners, the load rating shall reduce the areas and capacities of the affected members to account for the greater of:

- The actual section loss based on the detailed measurements
- An assumed minimum section loss of 10%

If the member section loss is not proportional between the inside plate(s) and the outside plate(s), the load distribution between the plates must be verified (see "Load Distribution between Gusset Plates" policy).

Refined Analysis Load Ratings: The *Gusset Plate Evaluation Guide* prepared for IDOT by Wiss, Janney, Elstner Associates, Inc. provides examples to assist load raters with the refined analysis of gusset plates. This guide is available on the IDOT website under the "Bridges & Structures" and "Load Ratings" tabs.

Other refined analysis approaches, including the Truncated Whitmore Section method, are also acceptable.

4.2.4.3.7 CABLES AND HANGERS

Cables and hangers, along with their anchorage and end connections, are structural elements typically found in suspension and tied arch bridges. They are primary load carrying members and shall be evaluated in the load rating. Unless designed to provide load path redundancy, these are fracture critical members and may be given special attention.

4.2.4.3.8 PIN AND LINK CONNECTIONS

Pin and link plates as part of a pin and link connection are primary load carrying members and shall be evaluated in the load rating.

4.2.4.3.9 ARCHES

Arches utilize various types of material and construction techniques. The arch is a primary load carrying member and shall be evaluated in the load rating.

Although some arches may not be considered a culvert, the FHWA *Culvert Inspection Manual* provides information relating the observed field conditions of arches to structural deficiencies. This information can be useful in identifying conditions indicative of reduced load carrying capacity.

4.2.4.3.10 PRECAST CONCRETE THREE-SIDED STRUCTURES

Precast concrete three-sided structures are produced under several different proprietary names. They are primary load carrying members and shall be evaluated in the load rating. The initial load rating is typically provided by the manufacturer. In order to effectively evaluate these members, future load ratings must utilize software programs that take into account the soil structure interaction.

4.2.4.4 Substructures

Substructures are generally excluded from the load rating. However, the condition and configuration must be reviewed to confirm the primary load carrying members of the substructure can be safely excluded from the load rating.

4.2.4.4.1 ABUTMENT AND PIER CAPS

Abutment and pier caps can be made of steel, concrete, or timber. These are primary load carrying members and shall be evaluated in the load rating when the following conditions are observed:

- Pile deterioration affecting the ability to adequately support the cap
- Deteriorated areas of timber caps (identified by sounding or coring)
- Deteriorated areas of concrete cap with exposed reinforcement bars
- Concrete caps with flexure or diagonal shear cracks (width greater than 0.012 inches)
- Steel caps determined to be fracture critical members
- Deteriorated areas of steel caps with measurable section loss
- Loss of bearing area

4.2.4.4.2 CANTILEVER ABUTMENT AND PIER CAPS

Cantilever abutment and pier caps are typically made of reinforced concrete. These are primary load carrying members and shall be evaluated in the load rating when the following conditions are observed:

- Exposed tension or shear reinforcement
- Flexure or diagonal shear cracks (width greater than 0.012 inches)
- Loss of bearing area

4.2.4.4.3 PILES

Typical pile types in Illinois include timber, precast concrete, metal shell, and steel H-piles. When piles are not exposed, they are excluded from the load rating. When piles are exposed, they shall be evaluated in the load rating when the following conditions are observed:

- Scour has exposed the pile(s) under a footing
- Section loss due to damage or deterioration

Deterioration of timber piles is a major factor in the load posting and closure of PA bridges.

4.2.4.4.4 SCOUR

Scour is the leading cause of bridge failure. The loss of material supporting the bridge foundation can affect the stability of the bridge as well as the safe load capacity of the foundation. The effects of scour must be accounted for in the load rating.

4.2.4.5 Culverts

Individual elements of a culvert barrel are the primary load carrying members and shall be evaluated in the load rating. Wingwalls and headwalls are not evaluated in the load rating.

4.2.4.5.1 CONCRETE BOX CULVERTS/RIGID FRAMES

Reinforced concrete box culverts can be cast-in-place or precast. The top slab and sidewalls are the primary load carrying members and shall be evaluated in the load rating. Bottom slabs are typically excluded from the load rating. If existing plans cannot be located, the load rating shall be based on empirical methods. Empirical methods may also be used to evaluate non-NBIS culverts, even when existing plans are available. When following the LRFR method, the AASHTO MBE special live load factors for reinforced concrete box culverts shall be used.

The following are IDOT policies regarding all concrete box culvert load ratings:

Fill Heights: Load ratings shall consider both maximum and minimum fill heights, within the travel way, as shown on existing plans or as measured in the field.

Shear: Shear shall be evaluated for the top slab when required by the AASHTO Standard Specifications (LFR) or the AASHTO LRFD Specifications (LRFR).

Skew: Vehicles shall be assumed to travel perpendicular to the culvert sidewalls. For the rare case where vehicles travel parallel to the culvert sidewalls i.e. the culvert runs parallel with the centerline of roadway, the rater shall contact the IDOT Rating Unit for direction.

Barrel Walls: When the top slab is simply supported, the exterior and interior walls are typically excluded from the load rating. If the condition rating of the culvert is “4” (Poor) or less and the walls have horizontal cracks or show signs of distortion, the load rating of the culvert shall be based on the lower of:

- Rational evaluation method considering condition of sidewalls. See Table 4.3.3.3-1: Rational Evaluation Method Rating Factors and Load Postings
- Notes:

1. The upper and lower values relate to the seriousness of the deterioration or distress (i.e. is it closer to Poor / Fair (upper) or Critical / Serious(lower)). Rating factors and load postings may be linearly interpolated between condition categories.

2. The load rater may alternatively require a single load posting based on the Single Unit load posting. Weight restrictions on township roads are typically single load postings.

- Analytical top slab load rating

For rigid frames (i.e. moment connection between slab and wall) the walls shall be evaluated in the load rating regardless of condition.

Negative Moment Reinforcement: If the existing plans of a multi-cell box culvert do not detail negative moment reinforcement or if a construction joint with no reinforcement passing through it is detailed directly over the interior wall(s), the culvert shall be evaluated as multiple single cells.

Skewed reinforcement: Culverts with large skews often have reinforcement placed parallel to the centerline of the roadway or headwalls as shown in IDOT Culvert Manual Figure 3.5.2-1 rather than the more typical perpendicular to the sidewall configuration. The AASHTOWare BrR program currently cannot account for skewed reinforcement and assumes placement perpendicular to the sidewalls. This requires the rater to enter a perpendicular rebar spacing that results in an equivalent strength to a skewed bar. The adjustment is made as follows:

For culverts with the reinforcement spacing detailed perpendicular to the bars, the spacing shall be multiplied by sec^2(skew). For example, #8 bars at 7" cts placed parallel to a 25° skew; specify #8 bars at 8.52" cts. For culverts with the reinforcement spacing detailed parallel to the sidewalls, the spacing shall be multiplied by sec(skew). For example, #7 bars at 6" cts parallel to the walls for a culvert on a 40° skew; specify #7 bars at 7.83" cts. See Figure 4.2.4.5.1-1 and Figure 4.2.4.5.1-2.

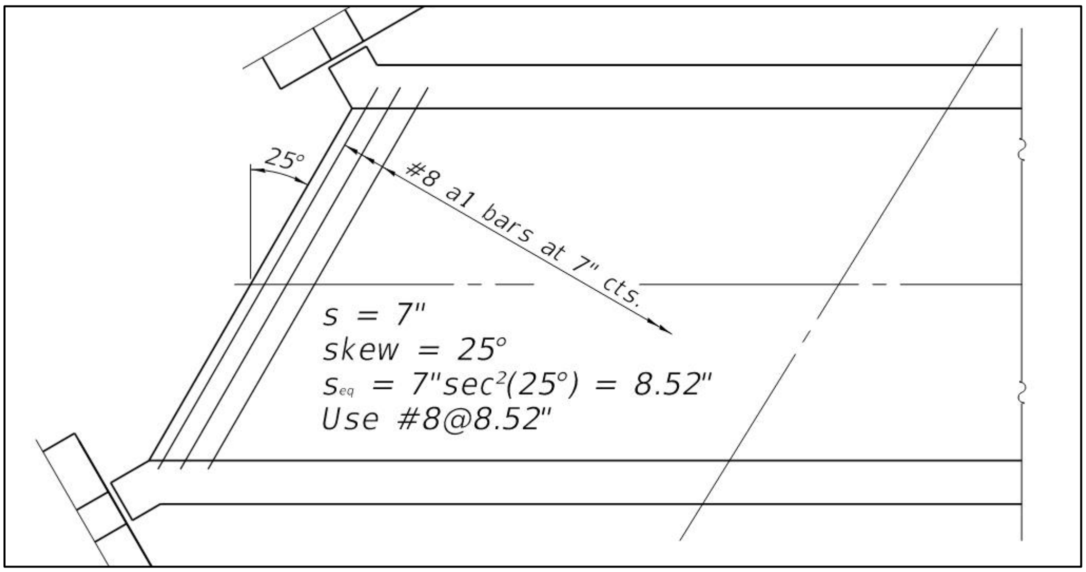


FIGURE 4.2.4.5.1-1: SPACING DETAILED PERPENDICULAR TO BARS

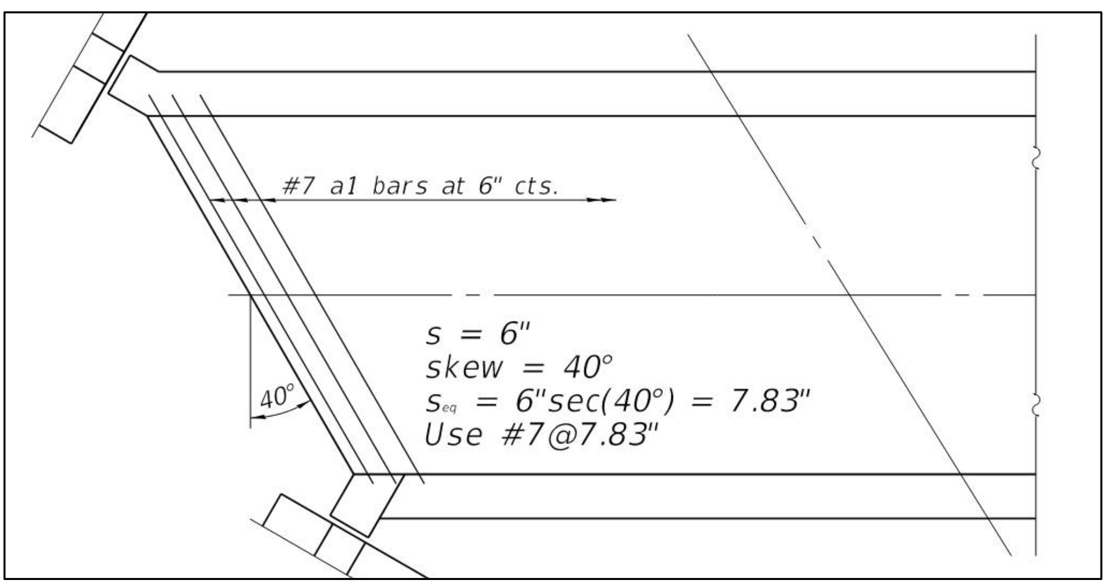


FIGURE 4.2.4.5.1-2: SPACING DETAILED PARALLEL TO THE SIDEWALLS

Precast Boxes: The as-built shop drawings, if available, shall be used when preparing the load rating for an in-service culvert. If the shop drawings are not available, the rater may either use an empirical method, load testing or the reinforcement details from the ASTM or AASHTO specification shown on the original contract plans. When no original contract plans are available, the empirical method or load testing shall be used.

For new precast boxes, the initial load rating performed during the design phase shall be based on the dimensions and reinforcement details of the precast box culvert specification noted on the contract plans or the referenced IDOT Standard Specification. The current specification is ASTM C1577. If the reinforcement or other details are changed during the shop drawing approval process, the initial rating shall be updated and forwarded to IDOT BBS. A note shall be added to the SLRS describing the source of information used to determine dimensions and reinforcement used for the rating.

4.2.4.5.2 CONCRETE PIPE CULVERTS

Regardless of the shape of the concrete pipe culvert, the pipe walls are the primary load carrying members and must be evaluated in the load rating. These load ratings are typically based on empirical methods.

4.2.4.5.3 METAL PIPE CULVERTS

The corrugated metal walls are the primary load carrying members in a metal pipe culvert and shall be evaluated in the load rating. The National Corrugated Steel Pipe Association (NCSPA) *Design Data Sheet No. 19*: *Load Rating and Structural Evaluation of In-Service, Corrugated Steel Structures* and the AASHTO Standard Specifications are the basis for load rating of metal pipe culverts.

The deflected shape of the culvert, distress at the joints of adjoining plates, and section loss must be included in the load rating. Both minimum and maximum fill depths must be considered. Impact shall be included for fill heights less than 3 feet. Rating factors can be controlled by either the structural capacity of the metal walls or the minimum cover.

4.2.4.5.4 MASONRY CULVERTS

Masonry culverts are typically box-shaped or arch-shaped. The sides of boxes, arches, and arch supports are the primary load carrying members and shall be evaluated in the load rating.

4.3 Design and Legal Load Ratings

A design load rating is the evaluation of a bridge's safe load capacity relative to the design live load defined as HS20 (ASR or LFR) or HL93 (LRFR) using dimensions and properties of the bridge in its present as-built or as-inspected condition. This evaluation is completed at both the inventory and operating levels. Regardless of what load or specification the original bridge was designed to, the design load rating shall be based on the HS20 or HL93 vehicle to provide a consistent basis of comparison across the nation.

A legal load rating is the evaluation of a bridge's safe load capacity relative to the Illinois Statutory Loads defined in the Illinois Vehicle Code. A legal load rating is only required when the design inventory load rating factor is below 1.0. This evaluation is generally completed at the operating level as further discussed in Section 4.3.5 . The purpose of a legal load rating is to determine if a weight restriction, to either Legal Loads Only or below legal loads, is required.

4.3.1 Assignment of Responsibility

IDOT's responsibility for load ratings is granted by 625 ILCS 5/15-317.

4.3.1.1 State Bridges

State bridges are those under the jurisdiction of IDOT, and include structures covered by the IDOT Small Bridge Inspection Program.

Design and legal load ratings for state bridges are typically completed by IDOT staff. When load ratings are completed by consulting engineers, IDOT must concur with the load rating and any subsequent weight restrictions.

4.3.1.2 Public Agency Bridges

Public Agency (PA) bridges include those under the jurisdiction of counties, townships, road districts, municipalities, park districts, forest preserve districts, and conservation districts.

Design and legal load ratings for all new construction, rehabilitations, and other work affecting the safe load capacity of an PA bridge must be completed by the PA or their designated representative.

IDOT typically assists PAs in completing design and legal load ratings for damaged or deteriorated bridges. The LBU monitors bridge condition ratings in ISIS and automatically schedules a load rating for bridges meeting the requirements of Section 4.3.2.2.2 . PAs may also request load rating assistance from IDOT by submitting IDOT Form BLRS 06510, "Local Agency Load Rating Request". If a rapid response is critical, the LBU shall be contacted directly to notify them of the situation.

Due to limited resources, IDOT is typically not able to assist PAs with load rating major bridges requiring under bridge inspection equipment or man-lifts to inspect, or bridges serving high traffic volume roadways requiring traffic control to safely inspect. In these cases, the load rating must be completed by the PA or their designated representative.

IDOT must concur with load ratings completed by PAs or their designated representative and any subsequent weight restrictions. Maintaining documentation of IDOT concurrence with weight restrictions is especially important for effective enforcement of load postings.

All PA load ratings shall be submitted to the LBU at 'dot.localbridgeunit@illinois.gov'. This submittal shall include:

- AASHTOWare BrR model (.xml file) or model from another program if AASHTOWare BrR is not capable of load rating the specific structure type

- Design Plans
- Shop Drawings, if available
- Rehab Plans, if applicable
- PDF of Analysis Output
- Inspection Sketches and Photographs, if model includes deterioration
- BBS 2795: Structure Load Rating Summary (SLRS)

4.3.1.3 Other Bridges

Other bridges include those which are not under IDOT or PA jurisdiction. Border state bridges are those with maintenance responsibility assigned to the adjacent state. These bridges may or may not carry state or PA highways.

Design and legal load ratings for bridges not under IDOT or PA jurisdiction must be completed by the bridge owner or their designated representative. Except for bridges owned by border states or federal agencies, IDOT must concur with the load rating and any subsequent weight restrictions if the bridge serves a state or PA highway. Maintaining documentation of IDOT concurrence with weight restrictions is especially important for effective enforcement of load postings. Load ratings and weight restrictions for bridges not serving state or PA highways do not require IDOT concurrence.

Regardless of the owner or the highway system, all load ratings and any weight restrictions must be submitted to IDOT for inclusion in ISIS.

4.3.2 Load Rating Frequency

4.3.2.1 Initial Load Rating

All new bridges and new structures in the NBI or covered by the IDOT Small Bridge Inspection Program require an initial analytical load rating. For practical reasons, the initial load rating is typically performed as part of the design process. The variables used in the initial load rating must then be verified with the as-built bridge. If variations are noted affecting the safe load capacity of the bridge, a new load rating must be completed, documented, submitted to the BBS if applicable, and ISIS information updated. For PA structures, the initial load rating should be completed in conjunction with the Final Design Plans. An as-built load rating submittal is required, if there were changes during construction that affects the load carrying capacity of the structure. An as-built load rating shall be submitted to the LBU prior to the structure being open to traffic.

4.3.2.2 Revised Load Ratings

When the safe load capacity of a bridge has changed, a load rating must be completed, documented, submitted to the BBS if applicable, and ISIS information updated.

4.3.2.2.1 MODIFIED PERMANENT LOADS

A load rating is required when a new feature is added to a bridge that increases or redistributes the existing permanent loads on a bridge. Common examples of this are the addition of a new or modified wearing surface or the attachment of new utilities to a bridge.

When a project proposes to modify existing permanent loads, a preliminary evaluation should be completed early in the project development phase to determine the project’s effects on the safe load capacity of the bridge. The preliminary evaluation findings may affect the project’s scope of work. After construction, the as-built improvements must be reviewed to verify the variables used in the preliminary evaluation are accurate. A final load rating must be completed, documented, submitted to the BBS if applicable, and ISIS information updated.

Existing permanent loads on a bridge are sometimes unintentionally modified as part of routine roadway maintenance. A typical example is when an oil and chip treatment is placed on a roadway and the bridge is not omitted. When this happens, the existing load rating must be reviewed to determine if the modifications warrant a new load rating.

Load ratings must be performed and submitted to the BBS for concurrence for resurfacing projects down to a zero-inch increase in surface thickness to verify the safe load capacity of the bridge. The condition of the bridge must be considered.

4.3.2.2.2 STRUCTURAL DETERIORATION

IDOT policies for load rating deteriorated bridges are as follows:

- Perform load rating when "Deck Condition" (SNBI Item B.C.01) rating drops to "3" or less, and for subsequent drops in the condition rating.
- Perform load rating when "Superstructure Condition" (SNBI Item B.C.02), "Substructure Condition" (SNBI Item B.C.03), or "Culvert Condition" (SNBI Item B.C.04) rating drops to "4" or less, and for subsequent drops in the condition rating.
- Perform load rating when "Bridge Bearings Condition" (SNBI Item B.C.07) rating drops to a "2" or less, and for subsequent drops in the condition rating.
- After an initial load rating due to deterioration, continue load rating at an interval determined by the BBS based on bridge type and anticipated deterioration rate. This interval shall not exceed 10 years.

Although IDOT has established procedures to automatically initiate load ratings based on condition ratings, the BBS must be contacted immediately if an inspection finds a condition that may significantly affect a bridge's safe load capacity.

4.3.2.2.3 STRUCTURAL DAMAGE

When structural damage is identified, a preliminary evaluation may be required to determine the effect of the damage on a bridge's safe load capacity. The preliminary evaluation will help determine a scope of work to repair the damage and identify temporary measures to be implemented until the repairs are completed.

After repairs are made, photographs and/or construction plans of the as-built improvements must be submitted to the BBS to verify the variables used in the preliminary evaluation are still accurate. A final load rating must be completed, documented, submitted to the BBS if applicable, and ISIS information updated.

4.3.2.2.4 BRIDGE REHABILITATION

A new load rating is required when a bridge is rehabilitated. Depending on the scope of work, a rehabilitation could include changes to permanent loads, capacity of load carrying members, or allowable travel way.

When a project proposes to rehabilitate a bridge, a preliminary evaluation should be completed early in the project development phase to determine the project's effect on the bridge's safe load capacity. This preliminary evaluation is critical in defining the project's scope of work. After construction, the as-built improvements must be reviewed to verify the variables used in the preliminary evaluation are accurate and the load rating shall be updated as required. A final load rating must be documented, submitted to the BBS if applicable, and ISIS information updated.

Although pavement milling/scarification reduces the overall dead load, it may also reduce the overall capacity of the bridge. The capacity of concrete slab bridges and composite decks on beams or stringers must be reduced to account for the loss of structural thickness caused by milling/scarification.

Funding for some rehabilitation projects is contingent on reestablishing a minimum level of the bridge's safe load capacity. Therefore, it is imperative to have IDOT concurrence with the project scope and preliminary evaluation before proceeding with a rehabilitation project.

4.3.2.2.5 TEMPORARY MEASURES

Temporary measures can be utilized to keep a bridge in service until permanent measures can be installed. These measures may involve temporarily increasing a load carrying member's capacity, providing alternative load paths within the bridge, or altering the allowable travel way. A special inspection shall be assigned while temporary measures are in place.

A preliminary evaluation should be completed to ensure the proposed temporary measures adequately restore the bridge's safe load capacity. After implementation, the as-built improvements shall be reviewed to verify the variables used in the preliminary evaluation are accurate and the load rating shall be updated as required. A final load rating must be documented, submitted to the BBS if applicable, and ISIS information updated.

Both the design load rating and legal load rating shall include the contribution of the temporary measures. Except for the case of altering the allowable travel way, all structures utilizing temporary measures shall be restricted to legal loads only.

Temporary measures in place more than five years shall be considered a permanent part of the bridge. The load ratings after this point shall consider the temporary measures as permanent measures, except when timber is used. When timber is used as a temporary measure, any positive contribution of the timber shall be ignored after five years. Thus, the load rating will ignore any bracing, stability, or transfer of load previously assumed.

4.3.3 Evaluation Methods

The analytical method to use for design and legal load ratings depends on the AASHTO specification used to design the original bridge. IDOT policies for this are given in Table 4.3.3-1: Rating Method for Existing Bridges and Table 4.3.3-2: Rating Method for New or Rehabilitated Bridges.

Original Design Specifications	Acceptable Rating Method
Allowable Stress Design (ASD)	Load Factor Rating (LFR)
	Load & Resistance Factor Rating (LRFR)
	Allowable Stress Rating (ASR) (*See Note 1*)
Load Factor Design (LFD)	Load Factor Rating (LFR)
	Load & Resistance Factor Rating (LRFR)
Load & Resistance Factor Design (LRFD)	Load & Resistance Factor Rating (LRFR)

TABLE 4.3.3-1: RATING METHOD FOR EXISTING BRIDGES

Notes:

1. ASR can only be used for timber and/or masonry bridges. Non-NHS bridges with design and legal load ratings using ASR completed prior to 1994 are allowed to remain in ISIS

Construction Type	Design Specification	Acceptable Rating Method
New	LFD	LFR
	LRFD	LRFR
Rehabilitation	LFD	LFR
	LRFD	LRFR

TABLE 4.3.3-2: RATING METHOD FOR NEW OR REHABILITATED BRIDGES

IDOT's policy regarding acceptable analytical rating methods is based on a FHWA Policy Memorandum "Bridge Load Ratings for the National Bridge Inventory" dated November 5, 1993 and the subsequent follow-up memoranda dated December 22, 1993 and October 30, 2006 which may be found at:

https://www.fhwa.dot.gov/legsregs/directives/policy

4.3.3.1 ASR and LFR Methods

Design and legal load ratings based on the ASR and LFR methods shall follow the provisions in the AASHTO MBE and AASHTO Standard Specifications.

4.3.3.2 LRFR Method

Design and legal load ratings based on the LRFR method shall follow the provisions in the AASHTO MBE and AASHTO LRFD Specifications except as modified herein.

IDOT provides the following condition and system factors for use with design and legal load ratings:

Structural Condition of Members	φ_c
Good or Satisfactory	1.00
Fair	0.95
Poor	0.85

TABLE 4.3.3.2-1: CONDITION FACTOR: Φ_C

Superstructure Type	φ_s
Welded Members in Two-Girder/Truss/ Arch Bridges	0.85
Riveted Members in Two-Girder/Truss/Arch Bridges	0.90
Multiple Eyebar Members in Truss Bridges	0.90
Three-Girder Bridges with Girder Spacing ≤ 6 ft	0.85
Four-Girder Bridges with Girder Spacing ≤ 4 ft	0.95
All Other Girder Bridges and Slab Bridges	1.00
Floorbeams with Spacing > 12 ft and Noncontinuous Stringers	0.85
Redundant Stringer Subsystems between Floorbeams	1.00

TABLE 4.3.3.2-2: SYSTEM FACTOR Φ_S FOR FLEXURAL AND AXIAL EFFECTS

The system factors in Table 4.3.3.2-2: System Factor φs for Flexural and Axial Effects shall only be applied when checking flexural and axial effects at the strength limit state of typical spans and geometries. A constant value of φ_s = 1.0 shall be applied when checking shear at the strength limit state or when evaluating flexure and shear of timber members.

4.3.3.3 Rational Evaluation Method

When the use of empirical methods is justified and approved by IDOT, the design and legal load rating can be assigned using the rational evaluation method. This method is based on the premise that the inventory rating, operating rating, and load posting are proportional to each other and can be assigned based on condition ratings. When using this method, the "Load Rating Method" (SNBI Item B.LR.04) shall be coded as "EJ" (Field evaluation and documented engineering judgement).

Using this methodology, Table 4.3.3.3-1 gives **suggested** rating factors and load postings for a given superstructure, substructure, or culvert condition rating:

Condition Rating	Load Posting (tons)			Rating Factor	
	Single Unit	3 or 4 Axle Combinations	5 or More Axle Combinations	Design IRF	Design & Legal ORF
Good to Excellent - No signs of structural deterioration or distress.	No Restriction			1.00	1.67
Fair - Initial evidence of structural deterioration or distress.	No Restriction			0.80	1.33
Poor - Some structural deterioration or distress. *(See Note 1)*	No Restriction			0.70	1.17
	LLO			0.60	1.00
Serious - Advanced structural deterioration or distress evident. *(See Note 1 and Note 2)*	14	21	28	0.42	0.70
	8	12	15	0.23	0.39
Critical - Severe structural deterioration or distress evident.	5			0.14	0.24

TABLE 4.3.3.3-1: RATIONAL EVALUATION METHOD RATING FACTORS AND LOAD POSTINGS

Notes:

3. The upper and lower values relate to the seriousness of the deterioration or distress (i.e. is it closer to Poor / Fair (upper) or Critical / Serious(lower)). Rating factors and load postings may be linearly interpolated between condition categories.

4. The load rater may alternatively require a single load posting based on the Single Unit load posting. Weight restrictions on township roads are typically single load postings.

4.3.3.4 Load Testing Method

Design and legal load ratings based on load testing shall follow the provisions of the AASHTO MBE.

IDOT collaborated with the Illinois Center for Transportation and the University of Illinois at Urbana-Champaign on a research project for load testing of concrete bridges, ICT R27-205: Development of Bridge Load Testing Program for Load Rating of Concrete Bridges. The final report for this project can be viewed at: https://doi.org/10.36501/0197-9191/24-025. See Appendix A for the Manual for Using Wireless Instrumentation for Field Testing of Concrete Bridges.

4.3.4 Transient Loads

Transient loads may include pedestrian loading if there is expectation of high pedestrian usage. A reduced pedestrian loading may be appropriate.

4.3.4.1 Design Load Rating

The transient load used for a design load rating following either the ASR or LFR evaluation method is the HS20 loading defined in the AASHTO Standard Specifications. The transient load used for a design load rating following the LRFR evaluation method is the HL93 loading defined in the AASHTO LRFD Specifications. For all three evaluation methods, the appropriate impact load must also be included. Design load rating factors are reported to FHWA each year.

4.3.4.2 Legal Load Rating

The transient loads used for a legal load rating consist of several suites of vehicles. The transient loads are the same regardless of the evaluation method. For all three evaluation methods and each suite of vehicles, the appropriate impact load must also be included.

4.3.4.2.1 ILLINOIS LEGAL VEHICLES

The Illinois Legal Vehicles are shown in Figure 4.3.4.2.1-1 and Figure 4.3.4.2.1-2. The Illinois Legal Vehicles are notional loads, not actual vehicles. This means they produce load effects enveloping the load effects produced by the AASHTO Legal Loads and the Illinois Statutory Loads. This includes the Specialized Hauling Vehicles (SHVs) defined in the AASHTO MBE.

The IL-PD6-40 vehicle is only applicable in the negative moment region over interior supports. The IL-PD6-200' is only applicable for span lengths or influence lengths greater than 200 feet.

For span lengths or influence lengths greater than 200 feet, the transient load used for a legal load rating shall consist of a truck train composed of two trucks, spaced 30 feet apart head to tail, using each of the Illinois Legal Vehicles shown in Figure 4.3.4.2.1-1: Illinois Legal Vehicles (Single Unit Vehicles) and Figure 4.3.4.2.1-2: Illinois Legal Vehicles (Combination Unit Vehicles), in all lanes. The IL-PD6-40 and IL-PD6-200' are considered truck train configurations themselves, thus, do not require additional spacing at 30 feet. The Illinois Routine Permit Vehicles shown in Figure 4.3.4.2.2-1: Illinois Routine Permit Vehicles and Emergency Vehicles shown in Figure 4.3.4.2.3-1: Emergency Vehicles shall also be evaluated. However, truck train configurations are not required for these vehicles.

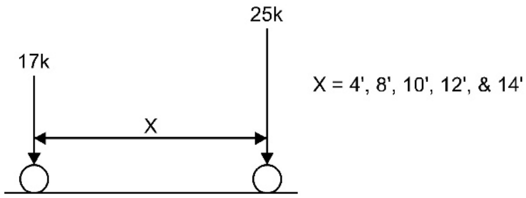
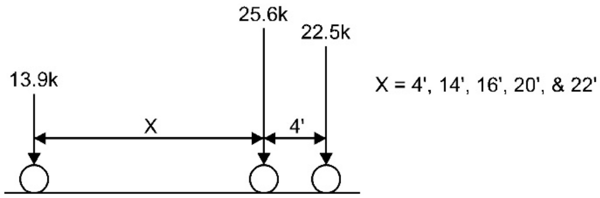
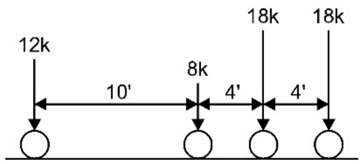
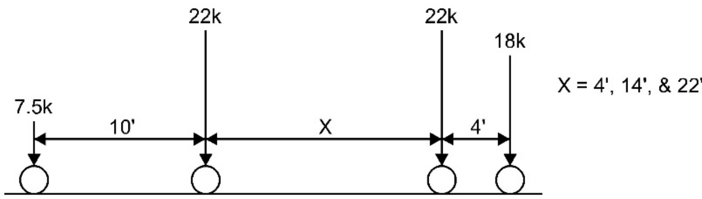
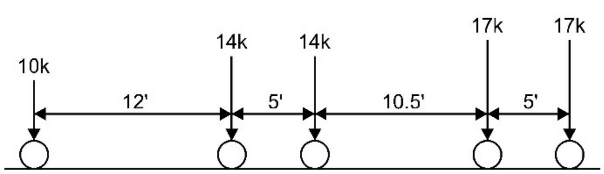
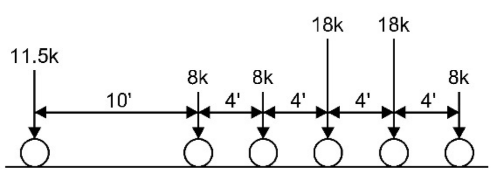
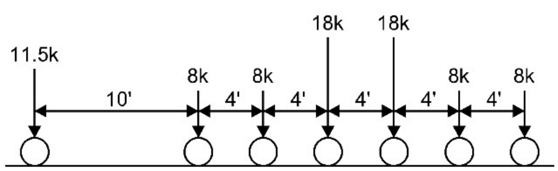
Vehicle Configuration	Name & GVW
	IL-PS2-21 GVW = 21 Tons
	IL-PS3-31 GVW = 31 Tons
	IL-PS4-28 GVW = 28 Tons
	IL-PS4-34.75 GVW = 34.75 Tons
	IL-PS5-36 GVW = 36 Tons
	IL-PS6-35.75 GVW = 35.75 Tons
	IL-PS7-39.75 GVW = 39.75 Tons

FIGURE 4.3.4.2.1-1: ILLINOIS LEGAL VEHICLES (SINGLE UNIT VEHICLES)

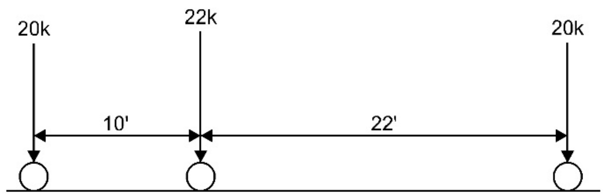
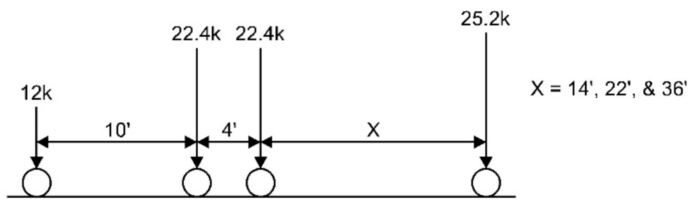
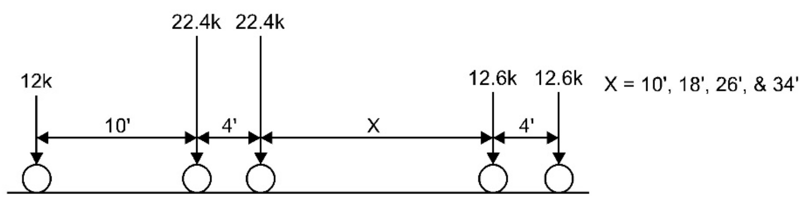
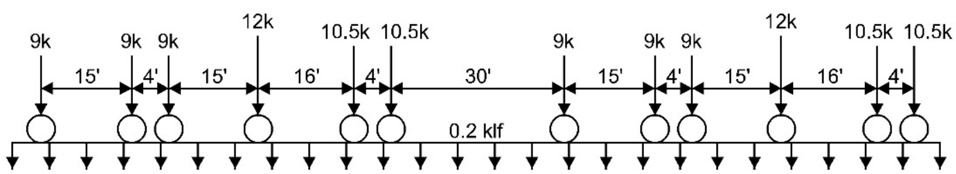
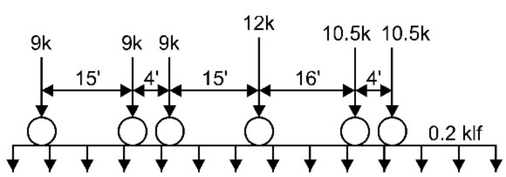
Vehicle Configuration	Name & GVW
	IL-PC3-31 GVW = 31 Tons
	IL-PC4-41 GVW = 41 Tons
	IL-PC5-41 GVW = 41 Tons
	IL-PD6-40 GVW = 40 Tons *(See Note 1)*
	IL-PD6-200' GVW = 40 Tons *(See Note 2)*

FIGURE 4.3.4.2.1-2: ILLINOIS LEGAL VEHICLES (COMBINATION UNIT VEHICLES)

Notes:

1. Only used for negative moments and interior reactions.

2. Used for all force effects when span length or influence length exceeds 200 feet.

4.3.4.2.2 ILLINOIS ROUTINE PERMIT VEHICLES

The Illinois Routine Permit Vehicles are shown in Figure 4.3.4.2.2-1: Illinois Routine Permit Vehicles. The Illinois Routine Permit Vehicles are notional loads, not actual vehicles. This means they produce load effects enveloping the load effects produced by limited continuous operation overweight permits allowed by the ILCS.

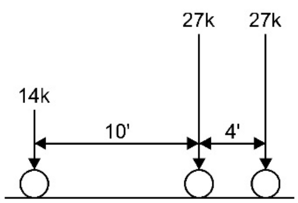
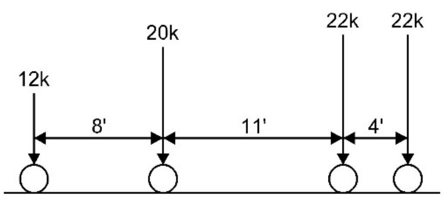
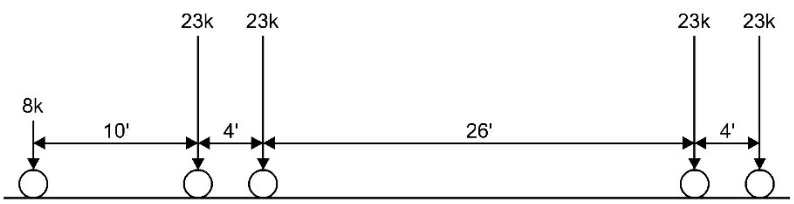
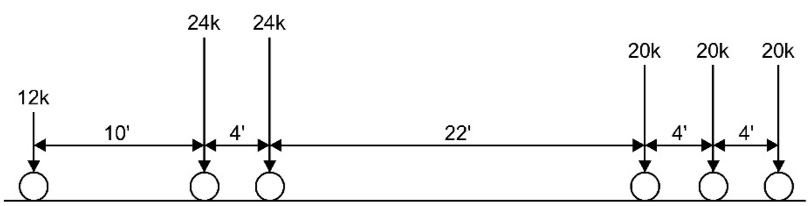
<table>
<tr><th>Vehicle Configuration</th><th>Name & GVW</th></tr>
<tr><td>
</td><td>IL-RS3-34
GVW = 34 Tons</td></tr>
<tr><td>
</td><td>IL-RS4-38
GVW = 38 Tons</td></tr>
<tr><td>
</td><td>IL-RC5-50
GVW = 50 Tons</td></tr>
<tr><td>
</td><td>IL-RC6-60
GVW = 60 Tons</td></tr>
</table>

FIGURE 4.3.4.2.2-1: ILLINOIS ROUTINE PERMIT VEHICLES

4.3.4.2.3 EMERGENCY VEHICLES

Emergency Vehicles are shown in Figure 4.3-8 – Emergency Vehicles. The Emergency Vehicles are notional loads, not actual vehicles. Emergency Vehicles must be evaluated as part of every legal load rating.

In general, Emergency Vehicles shall initially be evaluated similar to other legal load rating transient loads. However, this may result in an overly conservative legal load rating. If the rating factor for an Emergency Vehicle is below 1.00, the following modifications may be used:

- Emergency Vehicles need only to be considered in a single lane of one direction of the bridge with a multiple presence factor equal to 1.0.
- A live load factor of 1.3 may be utilized for both LFR and LRFR evaluations.
- Subject to approval by IDOT BBS Rating Unit, the recommendations of NCHRP 20-07 / Task 410 Load Rating for the Fast Act Emergency Vehicles EV-2 and EV-3 may be used.

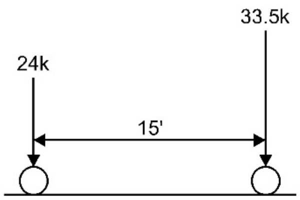
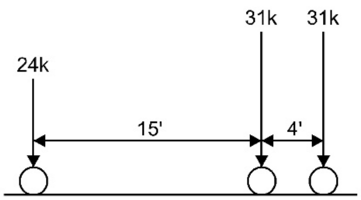
<table>
<tr><th>Vehicle Configuration</th><th>Name & GVW</th></tr>
<tr><td>
</td><td>EV2
GVW = 28.75 Tons</td></tr>
<tr><td>
</td><td>EV3
GVW = 43 Tons</td></tr>
</table>

FIGURE 4.3.4.2.3-1: EMERGENCY VEHICLES

4.3.5 Weight Restrictions

Load ratings can be determined at both the inventory and operating levels, which represent a range of safe load capacities for the bridge. Bridge weight restrictions are based on the operating level. The BBS must be contacted for concurrence when the load rater feels a situation may warrant more conservative weight restrictions.

4.3.5.1 Implementing Weight Restrictions

After calculating a rating factor for each of the Illinois Legal, Routine Permit Vehicles and Emergency Vehicles, the load rater will choose one of the following courses of action for the bridge:

- No weight restriction
- Restrict to Illinois Statutory Loads (Legal Loads Only)
- Restrict below Illinois Statutory Loads (Load Posting)
- Close the bridge

When choosing a course of action, the load rater should consider the enforceability of the weight restrictions. If there is concern significant disregard of the load posting will occur, the load rater may recommend closure of the bridge in the interest of public safety.

Occasionally, emergency situations will require a bridge owner to use judgment and temporarily load post or close a damaged or deteriorated bridge until an inspection and load rating can be completed by the appropriate personnel. These emergency load postings or closures may have limited legal enforceability, but owners are encouraged to implement and maintain such measures for the safety of the traveling public. While these temporary measures may be implemented immediately, the BBS must be notified as soon as practical for concurrence with their continued use.

4.3.5.1.1 NO WEIGHT RESTRICTIONS

When operating rating factors are greater than or equal to 1.00 for **all** Illinois Legal, Routine Permit Vehicles and Emergency Vehicles, the bridge can safely carry all legal loads and all routine permit vehicles. However, if weight restrictions are not required but the operating rating factor from the design load rating is less than 1.00, the SLRS must include commentary documenting the findings of the analysis.

4.3.5.1.2 WEIGHT RESTRICTED TO ILLINOIS STATUTORY LOADS (LEGAL LOADS ONLY)

When operating rating factors are greater than or equal to 1.00 for **all** Illinois Legal Vehicles and greater than or equal to 0.84 for both Emergency Vehicles but less than 1.00 for **any** Illinois Routine Permit Vehicle, the bridge can safely carry all legal loads but not all routine permit vehicles. Thus, the bridge must be restricted to Legal Loads Only. If an agency allows routine permit vehicles to travel on roadways under its jurisdiction, Legal Loads Only bridges shall be posted using the appropriate signage per the MUTCD and IMUTCD.

4.3.5.1.3 WEIGHT RESTRICTED BELOW ILLINOIS STATUTORY LOADS (LOAD POSTING)

When operating rating factors are less than 1.00 for **any** Illinois Legal Vehicle or 0.84 for either Emergency Vehicles, the bridge cannot safely carry all legal load configurations and the bridge must be load posted unless temporary measures are used to mitigate the load posting. The use of temporary measures must be documented on the SLRS.

The allowable weight limits used to load post bridges are based on the allowable GVW. The allowable GVW is determined by multiplying the operating rating factor for a given Illinois Legal Vehicle or Emergency Vehicle by the vehicle's GVW.

The Illinois Legal Vehicles are divided into three posting groups as shown in Table 4.3.5.1.3-1: Combination Posting Method Groups. A maximum allowable GVW limit is determined for each posting group.

Posting Group	Illinois Legal Vehicles
Single Unit	IL PS2-21
	IL-PS3-31
	IL-PS4-28
	IL-PS4-34.75
	IL-PS5-36
	IL-PS6-35.75
	IL-PS7-39.75
Combination Unit - 3 or 4 Axles	IL-PC3-31
	IL-PC4-41
Combination Unit - 5 or More Axles	IL-PC5-41
	IL-PD6-40
	IL-PD6-200

TABLE 4.3.5.1.3-1: COMBINATION POSTING METHOD GROUPS

The maximum allowable GVW limits for each posting group is determined as follows:

Single Unit: Determine the allowable GVW for all Illinois Legal Vehicles in the "Single Unit" posting group with an operating rating factor less than 1.00. The maximum allowable GVW for the "Single Unit" posting group is the smallest of these values.

Combination Unit - 3 or 4 Axles: Determine the allowable GVW for all Illinois Legal Vehicles in the "Combination Unit – 3 or 4 Axles" posting group with an operating rating factor less than 1.00. The maximum allowable GVW for the "Combination Unit – 3 or 4" posting group is the smallest of these values.

Combination Unit - 5 or More Axles: Determine the allowable GVW for all Illinois Legal Vehicles in the "Combination Unit – 5 or More Axles" posting group with an operating rating factor less than 1.00. The maximum allowable GVW for the "Combination Unit – 5 or More Axles" posting group is the smallest of these values.

The maximum allowable GVW for Emergency Vehicles with operating rating factors less than 0.84 is the smallest allowable GVW of the EV2 and EV3 vehicles. However, in almost all cases where the Emergency Vehicle operating rating factors fall below 0.84, the “Single Unit” posting group will have a maximum allowable GVW limit that controls over the Emergency Vehicles. In the rare cases when the Emergency Vehicle maximum allowable GVW limit does control over the “Single Unit” posting group, the “Single Unit” posting value shall be lowered to match the Emergency Vehicle maximum allowable GVW limit.

Consideration must be given to practical limitations when determining allowable weight limits. The minimum “Combination Unit - 3 or 4 Axle” load posting is 12 Tons and the minimum “Combination Unit - 5 or More Axle” load posting is 14 Tons. The AASHTO MBE requires a bridge to have a minimum allowable weight limit of 3 Tons to remain open. However, IDOT’s policy more conservatively limits this to 10 Tons on the state system and generally 5 Tons on the PA system.

A load posting may restrict the number of heavy vehicles allowed to simultaneously use a bridge. This restriction is referred to as a “One Truck at a Time” (OTAT) load posting. IDOT discourages OTAT load postings and restricts its use to bridges carrying roadways with low traffic volumes and adequate sight distance for opposing vehicles to easily identify one another and reduce speed.

After a weight restriction has been determined, ISIS must be updated accordingly.

4.3.5.2 Posted Weight Restriction Signage

When the decision is made to implement a load posting or closure, it is the responsibility of the agency with jurisdiction of the roadway carried by the bridge to erect the necessary signage and barricades. This must be completed within 30 days of notification for load postings and within 24 hours of notification for closures.

To ensure violations of the weight restrictions can be successfully enforced, the signage must comply with the MUTCD and IMUTCD. The provisions in the IMUTCD shall supersede the MUTCD when in conflict. In addition, owners of state or PA highways must have documentation of IDOT concurrence with the weight restriction and the posted weight limits <u>must match the allowable weight limits given in that documentation</u>.

The agency with roadway jurisdiction must notify appropriate school districts, emergency service providers, and other affected agencies of the weight restrictions as appropriate. School buses and emergency vehicles are not exempt from posted weight limits.

The agency with roadway jurisdiction must monitor signage and barricades for repair or replacement needs. The frequency of monitoring should be appropriate for the classification of the roadway carried by the bridge. Although IDOT standard procedures require routine NBIS safety inspections to review signage and barricades in the vicinity of the bridge, additional inspections should be performed more often when reasonable.

See Section 3 for additional posting and closure requirements. See the IDOT BLRS Manual for additional PA bridge posting and closure requirements.

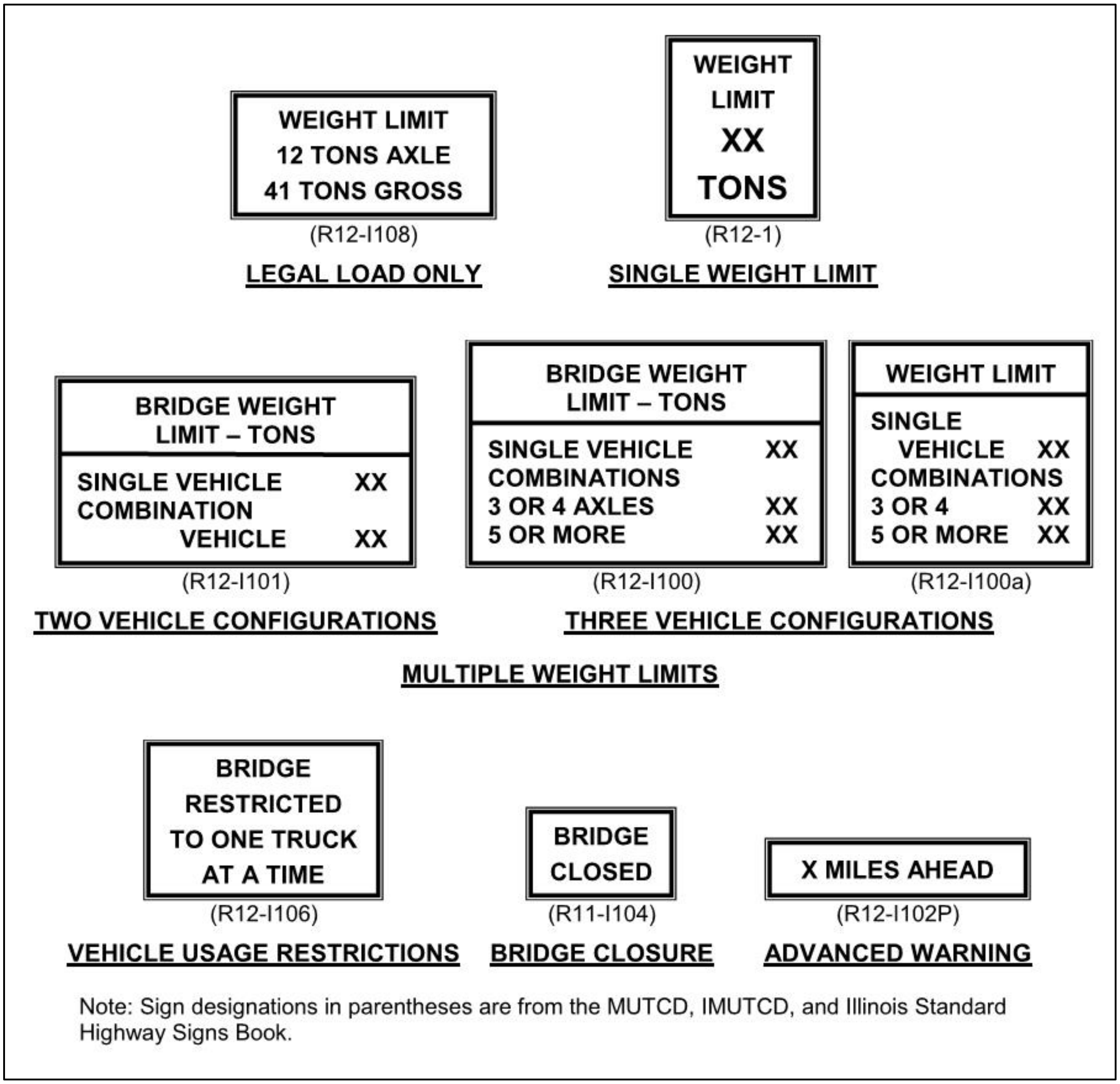


FIGURE 4.3.5.2-1: TYPICAL LOAD POSTING SIGNS

4.3.5.3 Removing and Altering Weight Restrictions

Once a weight restriction has been established for a bridge, it cannot be removed or altered without approval from IDOT. Modifying weight restrictions requires rehabilitation of the bridge or the installation of temporary measures. The load rating procedures for these courses of action are included in Section 4.3.2.2.4 and Section 4.3.2.2.5 , respectively.

IDOT **must approve** the installed improvements, final load rating, and proposed modified weight restrictions before the current weight restrictions can be removed or altered.

4.4 Overweight Permit Evaluation

The purpose of this section is to provide policies, procedures, and guidelines for evaluating bridges for overweight permits in Illinois. General information on issuing overweight permits is included for context purposes only. The detailed policies and procedures governing the issuing of overweight permits by an agency should be documented by the bridge owner.

The two types of overweight permits are a routine permit and a special permit. Routine permit vehicles may mix in the traffic stream and move at normal speeds without any movement restrictions but may be restricted to specific routes. Special permit vehicles are usually heavier and have more restrictions than routine permit vehicles. Each of these permit types has unique bridge evaluation requirements.

4.4.1 Assignment of Responsibility

The Illinois Vehicle Code assigns the responsibility of issuing permits to the highway owner. When a bridge and the highway it carries are under separate jurisdiction, a permit must also be obtained from the bridge owner. A separate permit must be obtained from each individual highway and bridge owner along every route the permit load plans to utilize.

Information governing IDOT's issuance of permits is included in a document titled "Oversize and Overweight Permit Movements on State Highways". For IDOT owned highways and bridges, the IDOT Bureau of Operations processes the permit load applications and the BBS completes the required bridge evaluation.

Non-IDOT bridge owners are responsible for processing the applications for permit loads to cross their bridges. Each agency should have policies and procedures in place to ensure permit load applications are properly evaluated. Overweight permit evaluations must be performed with the oversight of an Illinois Licensed Structural Engineer.

4.4.2 Routine Permit Evaluation

The load rating associated with the evaluation of routine permits is completed as part of a legal load rating. A routine permit authorizes the carrier to use any state route unless posted or restricted.

Routine permit applications are evaluated by comparing the proposed permit load to the Illinois Routine Permit Vehicles. To issue a permit, the proposed permit load must have an axle configuration similar to one of the Illinois Routine Permit Vehicles and axle weights equal to or less than those of that vehicle.

4.4.3 Special Permit Evaluation

A special permit application evaluation requires a special permit load rating comparing the safe load capacity of each bridge along a proposed permitted route relative to the proposed permit load. Special permit load ratings should follow the LFR method unless the bridge material or type precludes its use. ASR is used to evaluate timber and masonry load carrying members. LRFR is used on a selective basis when a less conservative, yet reliable load rating is required.

To issue a permit, the special permit load rating must result in an operating rating factor greater than or equal to 1.00 for that load.

The need to complete a load rating inspection is left to the discretion of the load rating team. This determination is typically based on the size of the permit load, the condition of the bridge, availability of as-built plans, inspection sketches and photographs, and whether a load rating inspection was completed for previous load ratings.

4.4.3.1 Transient Load Configurations

The proposed permit load is the transient load configuration used to evaluate a special permit. In order to complete a load rating, the following vehicle information must be provided:

- Gross Vehicle Weight
- Number of axles (utilized to carry the gross vehicle weight)
- Weight on each axle (steering axle to trailing axle)
- Axle spacing (distance center to center of axles)
- Non-standard gauge information (distance center to center of wheels along the width of vehicle, standard gauge = 6 feet)

The load rating of more complex permit loads may also require the configuration of the individual wheel loads on each axle.

4.4.3.2 Permit Restrictions

When a load rating follows standard procedures and determines a bridge does not have the safe load capacity required to issue a permit, special restrictions may be placed on the permit loads movement reducing the load effects on load carrying members. The load rating may be evaluated again with a restriction or a combination of restrictions in place. If the safe load capacity of the bridge is then sufficient, the permit may be issued with specific restrictions.

Some permits may require a police escort or other means of supervision to ensure compliance with permit restrictions.

4.4.3.2.1 ONE LANE LOADED

When a permit restriction specifies one lane loaded, the live load distribution factors given in either the AASHTO Standard Specifications or the AASHTO LRFD Specifications can be adjusted accordingly. This permit restriction is commonly specified as, “One lane loaded, at least 300’ between nearest vehicle.”

4.4.3.2.2 LOAD POSITION

A permit restriction may specify a permit load place its axles in a specific position relative to load carrying members. This may include specifying the permit load straddle the longitudinal centerline of the bridge or use methods such as crabbing (i.e. staggering front and rear axles in separate lanes) to distribute the load over more beam lines. Coordination with law enforcement may be required.

4.4.3.2.3 REDUCED IMPACT LOADING

A permit restriction may specify a permit load reduce speed to limit the effects of impact. It is generally acceptable to eliminate the effects of impact from a load rating when the permit load speed is 5 mph or less. It is generally acceptable to reduce the effects of impact to 10% for speeds up to 45 mph when there is a smooth riding surface at the approaches, along the bridge deck, and at expansion joints.

4.4.3.3 Temporary Measures

When a load rating determines a bridge does not have the safe load capacity required to issue a permit, the permit applicant may choose to investigate the use of temporary measures. Temporary measures may include systems that spread the load to additional superstructure members, provide alternative load paths for the structural system, strengthen existing load carrying members, or span partially or completely over the existing bridge.

The development and use of temporary measures are the responsibility of the permit applicant. An Illinois Licensed Structural Engineer must prepare and seal the plans and specifications for the proposed measures. The owner must approve the temporary measures before they are implemented, and a permit must be issued.

4.5 Construction Load Rating

A construction load rating is the evaluation of a bridge's safe load capacity relative to a specific special construction load along with other transient loads that may be allowed to access the bridge simultaneously. The load rating results are used to determine if a special construction load can be approved to access the bridge.

Approving special construction loads is the responsibility of the bridge owner.

4.5.1 Project Development Phase

Material Transfer Device: A Material Transfer Device (MTD) is used on hot-mix asphalt paving projects to aid in transferring material from the trucks to the paver. The axle spacing and weights are typically significantly higher than legal loads. For this reason, bridges within the paving contract limits must be evaluated for an MTD. A typical empty MTD configuration is Axle 1 = 38,500 pounds, Axle 2 = 40,500 pounds, spaced 14'-4". For more information see IDOT All Regional Engineers memo; "Special Provision for Material Transfer Devices".

BCR, TSL, and Final Plans: The Engineer of Record shall evaluate whether the existing bridge or any portion of the existing bridge planned for reuse is structurally adequate. It is the engineer's responsibility to notify the owner if the condition of the existing bridge warrants interim repairs, select member replacement, structural support, load restrictions, or bridge closure. For more information see IDOT All Deputy Directors of Highways memo, "Consultant Plan Responsibility for Existing Bridges" included in the Appendix.

4.5.2 Project Implementation Phase

Demolition Plan: The contractor shall submit a demolition plan to the owner for approval, including the proposed methods of demolition and the location(s) and type(s) of equipment to be used for the removal of existing bridge structures or bridge decks (except for box culverts), when such work will be adjacent to or over an active roadway, railroad, or waterway designated on the plans as "Public Waters". The demolition plan shall include an assessment of the bridge condition and an evaluation of the capacity and stability of the bridge during demolition. The plan shall be sealed by an Illinois Licensed Structural Engineer.

Special Construction Loads: The configuration and magnitude of a special construction load relies on the contractor's means and methods. The contractor is responsible for completing a load rating to ensure the bridge can safely support the anticipated loads.

For IDOT projects, the contractor must follow the procedures of IDOT Construction Memorandum No. 06-39, "Transportation or Operation of Heavy Equipment on Pavement or Bridges Within the Contract Limits" and the IDOT *Standard Specifications for Road and Bridge Construction* for obtaining permission for special construction loads within the limits of the construction section. IDOT Construction Memorandum No. 06-39 provides a means for the contractor to submit some common special construction loads for the BBS to complete the load rating. The contractor must allow IDOT a minimum of ten working days to complete the load rating. For other special construction loads specific to a contractor's means and methods, the contractor must retain the services of an Illinois Licensed Structural Engineer to complete the load ratings. The contractor must submit the sealed load ratings along with supporting calculations to IDOT for review and approval.

For non-IDOT projects, the contractor must follow the policies and procedures of the bridge owner for obtaining permission for special construction loads within the limits of the construction section. Construction load ratings must be completed and sealed by an Illinois Licensed Structural Engineer. When a special construction load is unusual compared to those typically employed during project implementation, the Engineer of Record for the bridge being constructed should be given the opportunity to review and comment on the evaluation.

Outside of the construction section, the contractor must obtain a special permit from the highway owner.

Structural Assessment Reports: Structural Assessment Reports (SARs) are required on a contract-by-contract basis when Guide Bridge Special Provision 67, “Structural Assessment Reports for Contractor’s Means and Methods" is included with the contract. Two primary criteria are as follows:

1. For any portion of the bridge that is not reused, the effects of the applied loads shall not exceed their capacity at operating level.
2. For any portion of the bridge that is reused, the effects of the applied loads shall not exceed their capacity at inventory level.

4.5.3 Evaluation Methods

Construction load ratings may utilize the ASR, LFR, or LRFR evaluation method. No preference is placed on any method. IDOT construction load ratings follow the LFR method unless the bridge material or type precludes its use. ASR is used to load rate timber and masonry load carrying members. LRFR is used on a selective basis when a less conservative, yet reliable load rating is required.

Appendix

Manual for Using Wireless Instrumentation for Field Testing of Concrete Bridges

Prepared By
Bassem Andrawes
Isaias Andres Colombani
Md Abdul Hamid Mirdad
Alexander Jai-syn Chen
University of Illinois Urbana-Champaign

Based on the findings of

ICT PROJECT R27-205

Development of Bridge Load Testing Program for Load Rating of Concrete Bridges

TABLE OF CONTENTS

CHAPTER 1: HARDWARE 4

BDI STS4 4

WIRELESS BASE STATION 4

NODE 5

LINEAR VARIABLE DIFFERENTIAL TRANSFORMER (LVDT) 5

STRAIN TRANSDUCER (ST350) 6

TILTMETER 8

LAPTOP 8

CHAPTER 2: SOFTWARE 9

STS-LIVE 9

STS-VIEW 11

TDMS PLUG-IN 13

CHAPTER 3: DATA INTERPRETATION 14

CHAPTER 1: HARDWARE

BDI STS4

The Bridge Diagnostics Inc. (BDI) 4th generation Structural Testing System (STS4) functions with various components that communicate via a wireless link to transmit the data to the computer. The system is built for rugged outdoor use to minimize environmental effects and prevent damage to the equipment during field tests. The system's main components are the wireless base station (WBS), which provides a wireless interface to the data acquisition system (DAQ) and the computer; the STS4 nodes, which transmit data to the computer and provide power to the connecting sensors; the sensors used for measuring the desired load effects of the bridge; and the computer, which is used to store and visualize the field data.

WIRELESS BASE STATION

The wireless base station (WBS) presented in **Figure 1** serves as the connection between the instruments and the laptop. It consists of a red control unit and a white dual-band wireless Access Point (AP) from which four antennas protrude. The control unit has a battery life of approximately 16 hours and is rechargeable. The control unit also functions on an external (wired) 24 VDC power supply in case of long-term monitoring applications. The WBS has ethernet ports for when a wired interface is preferred. In the most ideal conditions, the WBS has a range of 6.4 km (4 mi). However, this range is reliant on the line-of-site and is reduced with physical obstructions between the components. The antennas are detachable for easy storage but are not freely interchangeable. They are labeled, with two antennas for 2.4 GHz and two for 5.0 GHz. Pressing the blue power button on the red control unit briefly causes it to show the battery status without turning on. Pressing and holding the button will turn it on. This can be verified by checking if the light continues to blink. When the test is completed, press and hold the button to power it off.

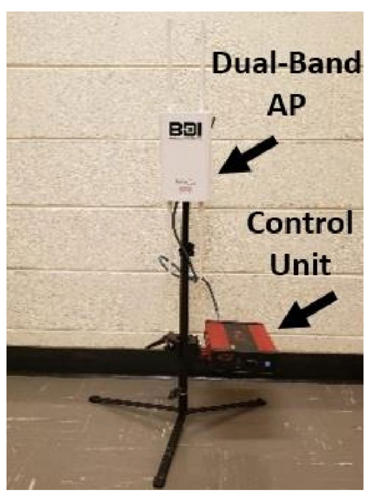


Figure 1. Base station

NODE

The nodes allow the various instruments to send information to the base station. Each node can connect up to four different sensors of any type as presented in **Figure 2**. A maximum of 128 nodes can be connected using a single WBS for the test. These nodes are equipped with a rechargeable internal battery that can supply power to the sensors for over 40 hours when used at the maximum sampling rate of 1,000 samples per second (S/s). The STS4 nodes have an internal memory of 8 GB for backup data storage. They also have temperature sensor inputs for each channel. The node can operate via a wireless connection to the WBS or ethernet cable. The nodes are lightweight and compact for easy transport during field tests. Each node also has two antennas. These can be removed for easier storage. Press the power button briefly to check the battery status. Press and hold the power button to turn on the node. A light will continuously blink to indicate that the node is on. Press and hold again to power off.

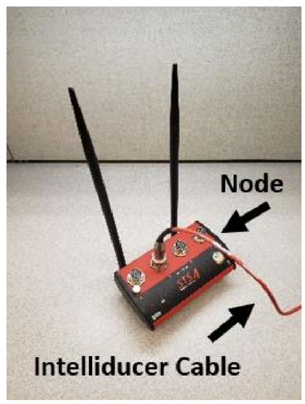


Figure 2. Node and a sensor cable

LINEAR VARIABLE DIFFERENTIAL TRANSFORMER (LVDT)

The LVDTs (**Figure 3**) measure displacement and are useful for providing global information about the bridge. They cannot be attached to the bridge directly and need a frame to attach to instead. They are typically placed at the midspan, because that is where deflection will be the greatest. To minimize error, keep the LVDT perpendicular to the concrete surface. The LVDTs have a range of ±25.4 mm (±1.0 in.). Their total length is 0.3 m (10.8 in.), and they have a supply voltage of 6 to 18 VDC.

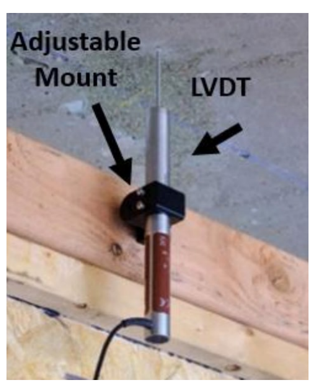


Figure 3. LVDT in the field

STRAIN TRANSDUCER (ST350)

The strain transducers (ST350) measure strain and are useful for providing local information about the bridge. The ST350s (**Figure 4**) are encased in a sealed aluminum shell making them ideal for outdoor use. They have an effective gauge length of 76.2 mm (3 in.) with the option to add an extension for installations up to 0.6 m (24 in.). The ST350s can be installed with the typical adhesive mounting technique by applying the adhesive to the reusable mounting tabs. They can also be installed using anchors because they have 6.4 mm (0.25 in.) mounting holes at both ends. To facilitate the installation of the extensions and ensure that the extensions are properly aligned, a jig was purchased to align the extensions to the ST350. This should be done prior to installing the ST350s to the concrete.

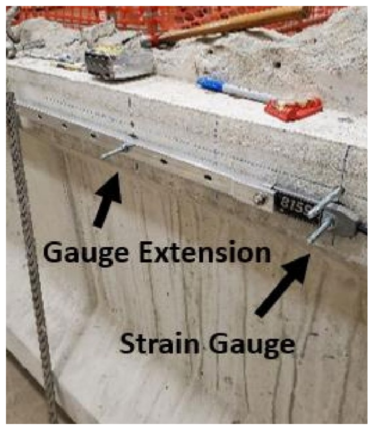


Figure 4. Strain gauge with gauge extension

The recommended gauge extension length used for the test is a function of the member type, member depth and span length. **Table 1** provides guidelines for choosing the appropriate gauge length based on these parameters.

Table 1. Ext. Multiplier for recommended gauge extension length

RECOMMENDED LOWER AND UPPER GAGE LIMITS		
STRUCTURE TYPE	LOWER LIMIT	UPPER LIMIT
SLABS & RECTANGULAR BEAMS	1.0 X DEPTH OF MEMBER	LENGTH OF SPAN / 20
T-BEAMS	1.5 X DEPTH OF MEMBER	LENGTH OF SPAN / 20

After obtaining the appropriate gauge length, the measurements must be reduced to account for the extension effects on the readings. The new reading can be determined from **Equation 1**, where the amplification factor and the ext. multiplier can be found using **Table 2**.

$$Adjustment\ Factor = \frac{Amplification\ Factor}{Ext.Multiplier} \quad (1)$$

Table 2. Adjustment factor

GAGE EXTENSION LENGTH	EXT. MULTIPLIER	AMPLIFICATION FACTOR
6 in	2	1.1
9 in	3	1.1
12 in	4	1.1
15 in	5	1.1
18 in	6	1.1
21 in	7	1.1
24 in	8	1.1

To minimize the force on the ST350s, BDI recommends keeping the maximum strain below ±1,000 με. There are also maximum strain ranges which depend on the extension and properties of the concrete. These maximum values are provided to ensure accuracy for the given gauge length. Greater strain values can be measured. However, BDI suggests that special attention be given to the gain settings on the DAQ being used when exceeding these ranges. These maximum strain ranges are provided in **Table 3**.

Table 3. Maximum strain gauge range for concrete and gauge length

EXT. MULT.	ACTUAL GAGE LENGTH WITH EXTENSION	MAXIMUM STRAIN RANGE	APPROX. CONC. STRESS FOR F'C = 3,000 PSI (20.7 MPA)	APPROX. CONC. STRESS FOR F'C = 4,000 PSI (27.6 MPA)	APPROX. CONC. STRESS FOR F'C = 5,000 PSI (34.5 MPA)	APPROX. STEEL RE-BAR STRESS
1	3 in (76.2 mm)	±1000 με	3.1 ksi (21.4 MPa)	3.6 ksi (24.8 MPa)	4.0 ksi (27.6 MPa)	30 ksi (207 MPa)
2	6 in (152.4 mm)	±500 με	1.6 ksi (11.0 MPa)	1.8 ksi (12.4 MPa)	2.0 ksi (13.8 MPa)	15 ksi (103 MPa)
3	9 in (228.6 mm)	±330 με	1.0 ksi (6.9 MPa)	1.2 ksi (8.3 MPa)	1.3 ksi (9.0 MPa)	9.9 ksi (68.3 MPa)
4	12 in (304.8 mm)	±250 με	780 psi (5.3 MPa)	900 psi (6.2 MPa)	1.0 ksi (6.9 MPa)	7.5 ksi (51.7 MPa)
5	15 in (381.0 mm)	±200 με	625 psi (4.3 MPa)	720 psi (5.0 MPa)	800 psi (5.5 MPa)	6.0 ksi (41.4 MPa)
6	18 in (457.2 mm)	±160 με	500 psi (3.4 MPa)	575 psi (4.0 MPa)	650 psi (4.5 MPa)	4.8 ksi (33.1 MPa)
7	21 in (533.4 mm)	±140 με	440 psi (3.0 MPa)	500 psi (3.4 MPa)	560 psi (3.9 MPa)	4.2 ksi (29.0 MPa)
8	24 in (609.6 mm)	±125 με	390 psi (2.7 MPa)	450 psi (3.1 MPa)	500 psi (3.4 MPa)	3.8 ksi (26.2 MPa)

TILTMETER

The tiltmeters (**Figure 5**) measure rotational information. They are typically attached at the ends of the bridge span to monitor the rotation near the supports, with a range of ±0.5° to ±60°. The tiltmeters can be attached to concrete directly by applying adhesives to the reusable mounting tabs. Remember to always keep the serial plate oriented facing up. There are mounting holes on all faces of the tiltmeter. For example, when installing upside down, use the mounting holes on the top of the tiltmeter instead of flipping the tiltmeter upside down.

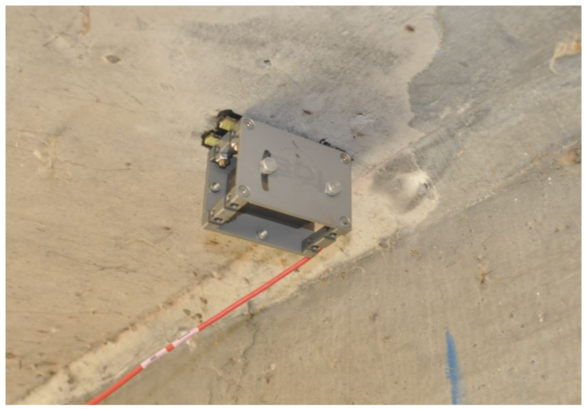


Figure 5. Tiltmeter

LAPTOP

The STS4 system is not complete without a laptop computer for data visualization and processing. BDI provides some recommendations for computer requirements. The computer used for the testing was equipped with an Intel Core i7 processor and 16 GB RAM. The computer has 512 GB SSD internal storage capacity. It also has up to 13 hours of battery run time. Windows 10 Pro was installed and recommended by BDI for using their software applications. The computer will run BDI’s STS-LIVE software, which is used for visualizing the sensor readings during the test. The computer was also equipped with the BDI’s STS-VIEW software for post-processing the results.

CHAPTER 2: SOFTWARE

STS-LIVE

The STS-LIVE software is provided with the STS4 package for visualizing the sensor data during the field tests. It gives control over all the connected devices, sensors, calibration files, and more, and is necessary for setting up the load tests and configuring the devices. Upon opening the STS-LIVE software, the user will see the Settings tab where the project name, description, file directory, and sampling rate can be selected (**Figure 6**). Recommended sampling rates depend on the type of test being conducted. For typical diagnostic tests where the truck moves at a crawling speed along the bridge span, the sampling rate should be between 50 and 20 S/s. For static load tests common in proof load testing, a 10 S/s rate is recommended. Under this same tab, there is a sub-tab where the user can set autozero on or off, which is typically turned "on." The final sub-tab allows the user to lock access to the calibration files for the sensors. The password to unlock or lock the sensor edit feature is "BDI."

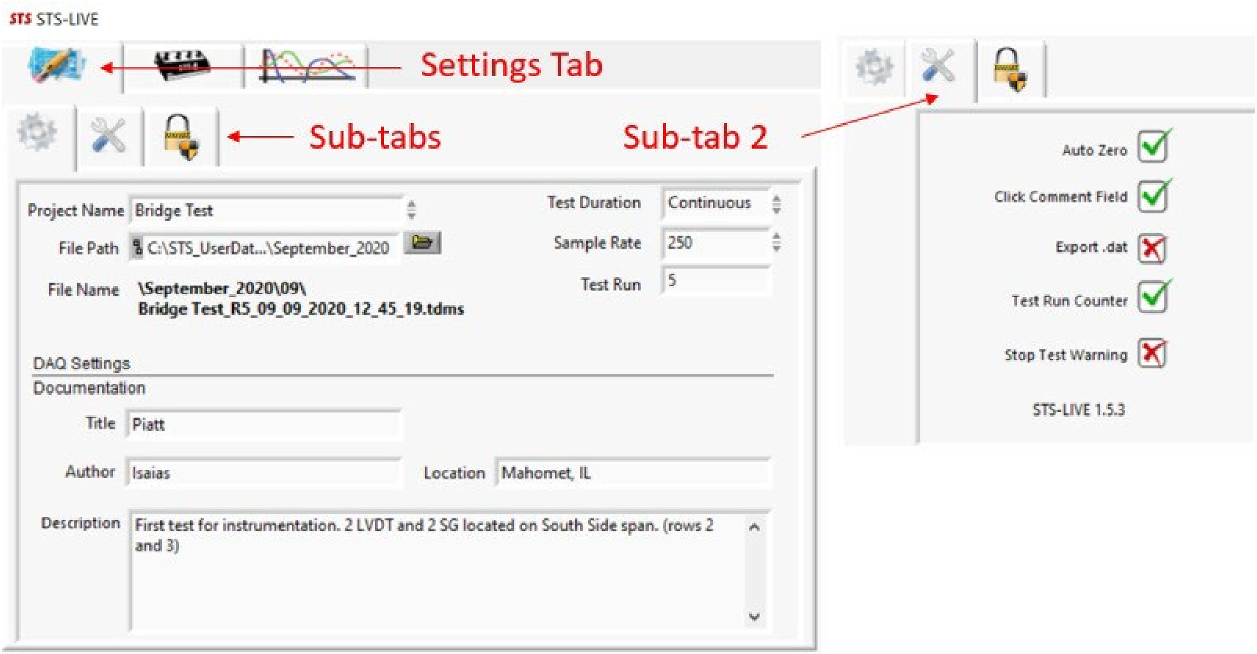


Figure 6. Settings tab

The second tab is the Hardware tab shown in **Figure 7** where the WBS, STS4 nodes, and sensors can be modified for the test. The connected STS4 nodes will appear in the window with their battery power and signal strength along with some other information. The signal strength is given by the RSSI in decibels (dB), which should be no greater than $\pm$80 dB to provide a good connection. If the RSSI is high, then the WBS should be relocated. The signal strength will update automatically in real-time in STS-LIVE as the WBS is moved closer or further from the computer.

Every node will show the sensors connected to its corresponding data channel in the drop-down list. When a sensor is selected, the window will display the maximum and minimum readings for each sensor, units of the measurements, and other information that is relevant to the test.

The Hardware tab is also where the user has access to the calibration factors and sensor limits. These parameters can be adjusted, but it is not recommended for most cases since the sensors are already calibrated.

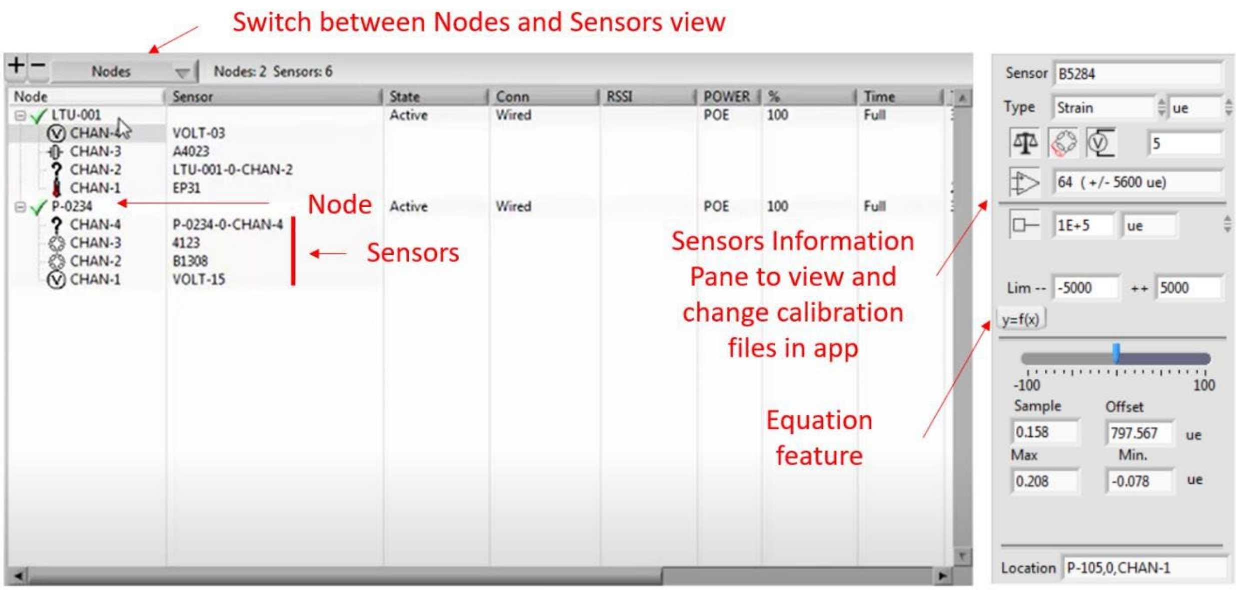


Figure 7. Hardware Tab

One useful feature in the sensor information pane is the equation feature. This is useful when converting the readings for the ST350s when they have extensions on them. An important consideration when using this feature is that the values which are recorded and saved into the TDMS file are the values after the operation is performed. This means that the raw readings from the sensors are not saved into the file for post-processing.

When setting up the hardware for the test, the computer must be connected to the appropriate IPN to connect to the WBS. Video tutorials on how to set up and use the STS-LIVE can be found at https://bditest.com/applications-tutorials/. Once the settings for the IPN are changed, the WBS can be turned on and the STS network will be available within minutes. The WBS will appear first in the Hardware tab with a checkmark to indicate that the connection has been established. It is important to first check the signal strength under the RSSI column to ensure that the signal strength is sufficient. This number should be no more than ± 80. The closer the number is to zero, the better the connection. After connecting the sensors to the nodes for the test, the nodes can be turned on. These should connect to the WBS and appear in the window when they have been successfully connected to the system.

The final tab in STS-LIVE is the Data Display tab where the data can be visualized during the load tests. The display window shows the sensor values for any sensors used. Multiple sensors can be shown on the same plot. The sensors can also be grouped to show only specific sensors during the load test. The display can be customized by the user with different visualization tools. Note that the more sensors being visualized at once, the more CPU is required. This window also has a “comment” feature in the bottom left-hand corner of the screen next to the start button. This comment feature can be used to place ticker marks (or time stamps) in the data during the load test. This is useful for marking the truck load position during the load tests, with each tick mark corresponding to a different truck position. When the test is completed, the clicker data with the time stamp will be saved in the TDMS file for post-processing.

Data is only recorded once the start button is pressed (**Figure 8**). A preview data button can be used to preview the measurements without storing the data on the hard drive. There are also controls for setting the nodes into sleep and standby modes to save battery during long field tests.

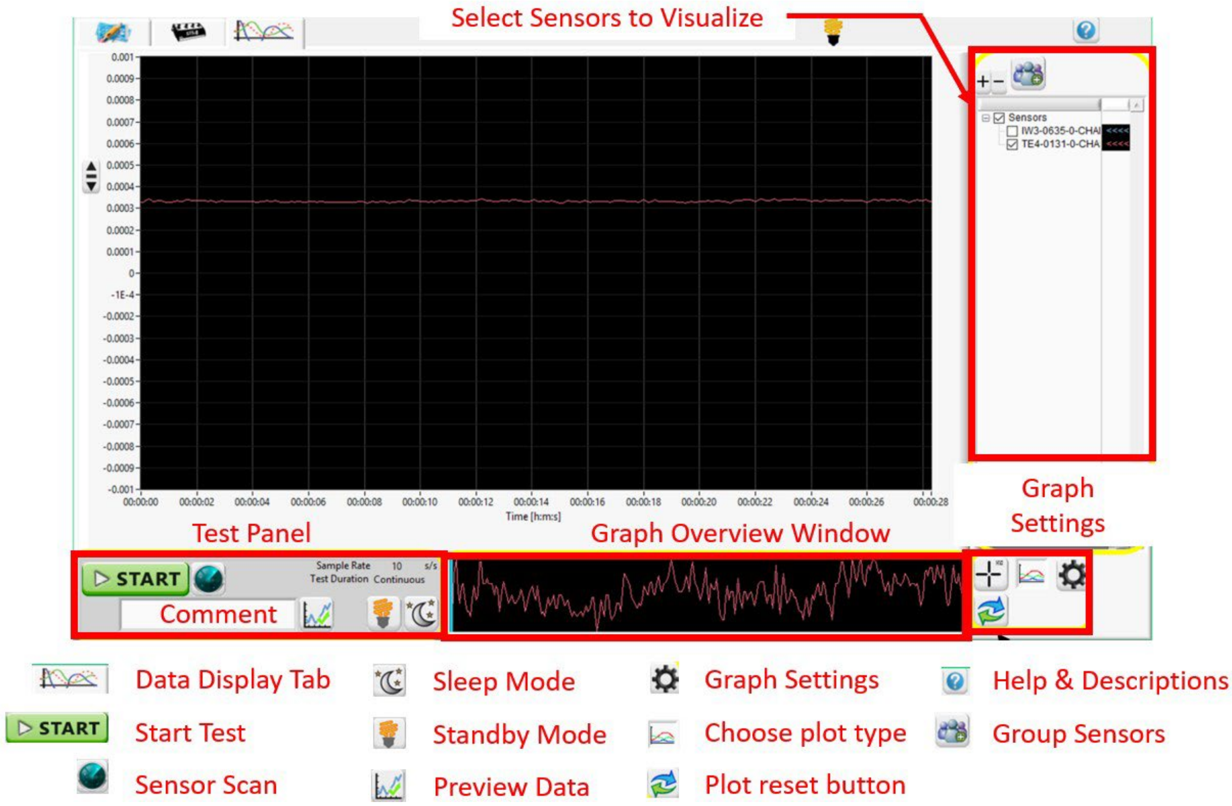


Figure 8. Data display tab

It is recommended that the instrumentation be turned on and left connected for at least 30 minutes before starting the load test. This will allow the random noise in the sensors to stabilize beforehand. For typical load tests, the start button is pressed before any loading is placed on the bridge to give the sensors a reference point for zero load. If the Autozero was checked in the Settings tab prior, the sensors will then automatically zero. The truck(s) can then start driving across the bridge to apply the loading. Markings can be placed on the roadway to represent the quarter spans of the bridge so that the comment feature can be used to track the position of the truck(s). Once the truck(s) have completely crossed the bridge, the test can be stopped after a few seconds to save the data to the TDMS file. The process is repeated for every load path. The results can then be visualized in Microsoft Excel with the TDMS file or in BDI's STS-VIEW software.

STS-VIEW

The software used for post-processing the results was BDI's STS-VIEW software. The software runs on MATLAB and allows the user to easily visualize the TDMS file data (MathWorks 2021). The data can be uploaded from the files menu tab and the user can upload multiple TDMS files at once. The clicker data taken during the test is automatically saved into this file with the time stamp corresponding to when the comment was clicked during the test. In the event that these markings do not give the maximum or minimum value that the user wants to process, new time stamp data points or modifications to the clicker data can be made to manually change where to inspect the data. This can be found under the clicker overrides option in the Edit Data tab shown in **Figure 9**. If position data is of interest, the positions of the truck between clicks can be input into the data to get a measurement versus truck position plot. The

Sample column is where the user can modify the position of the click or add new clicks to the data. The desired sample number can be calculated by finding the time where the desired point is to be taken and multiplying this time by the sample rate. The clicker override feature was used before in this study to obtain the peak magnitudes from the data and plot the distribution of the peak values across the slab after the field tests. It will often occur that the critical section of the bridge is not exactly at the position predicted by the analysis. For this reason, the clicker modification window is important for the analysis and post-processing.

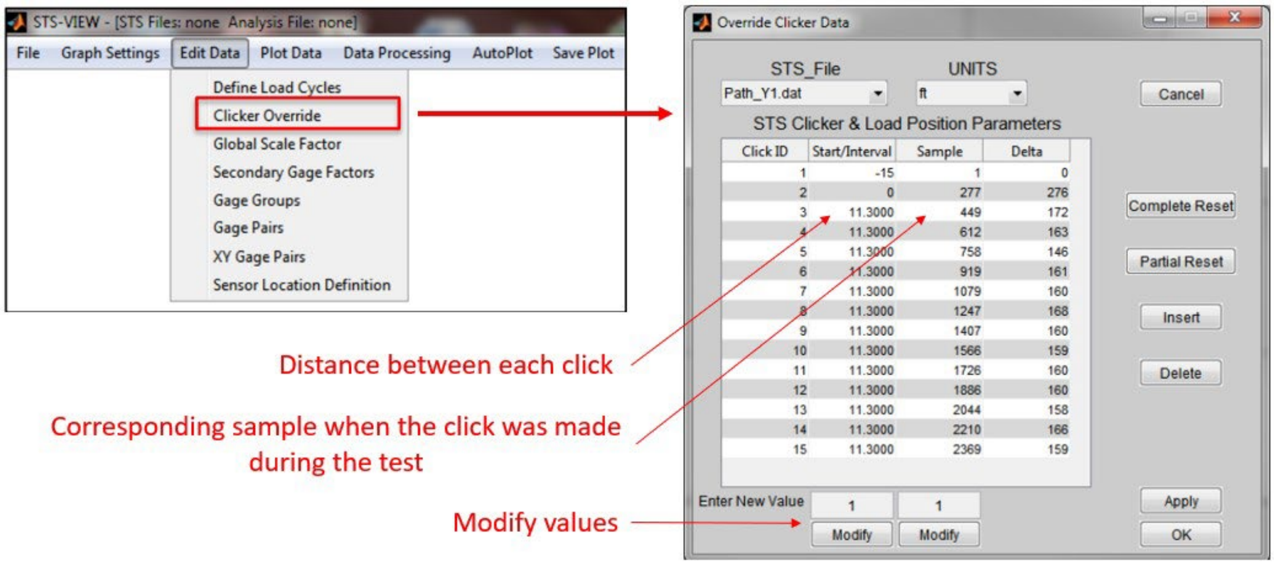


Figure 9. Clicker override feature

The software is useful for quickly obtaining the cross-sectional distribution of the sensor readings on the bridge from the load tests. This can be done by using the gauge groups window under the edit data tab as shown in **Figure 10**. The sensors should be organized such that they are in the order they appear on the cross section of the bridge. The group can then be saved and plotted based on the truck position specified in the clicker override window. The procedure for obtaining the group sensor distribution is shown in **Figure 10**.

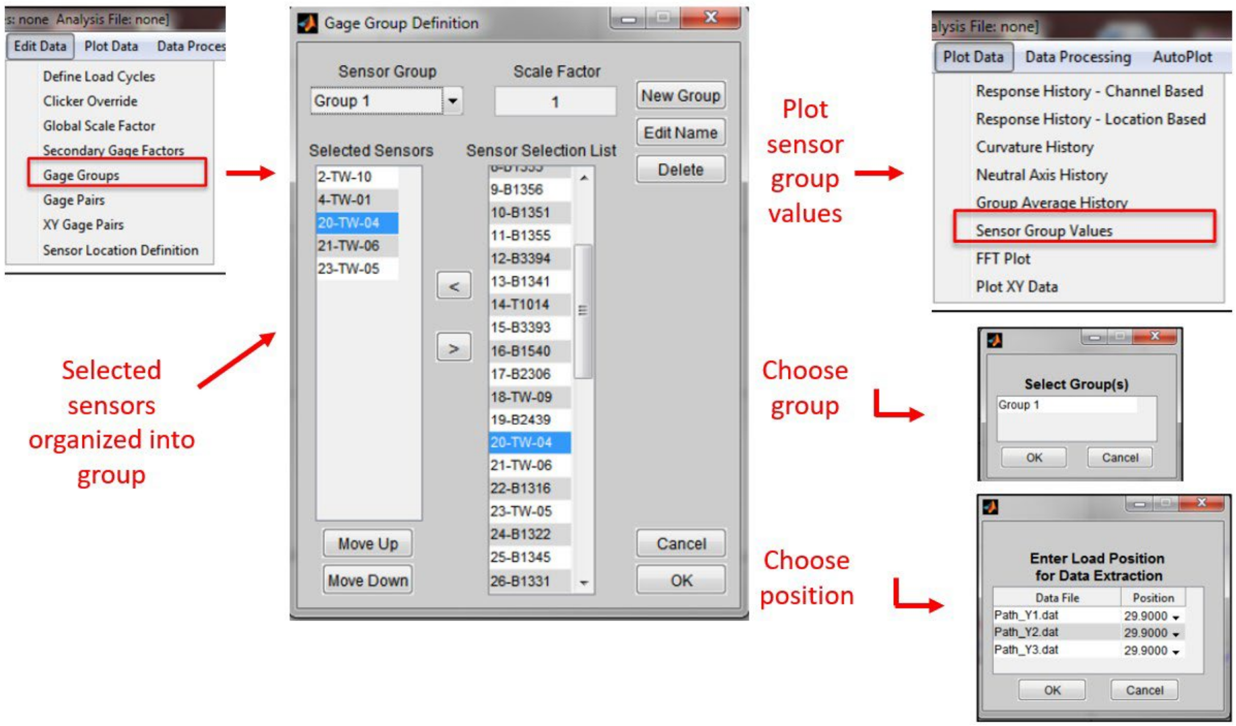


Figure 10. Gauge groups window and sensor group values plot

The sensor results can be plotted versus time by using the response history channel-based option in the Plot Data drop-down menu. When the user has input the position data in the clicker override window, a plot of the sensor response versus truck position can also be generated. This is useful for model calibration and for understanding the position of the axle loads that produced the responses. Note that multiple datasets can be displayed on a single plot for either option, which makes it easy to compare responses based on multiple load paths or compare repeat passes of the truck(s) on the bridge.

TDMS PLUG-IN

It may be desirable to use Microsoft Excel to plot and analyze the data. National Instruments provides software called “TDM Excel Add-In” to open .tdms files in Microsoft Excel. The download can be accessed through the following link: https://www.ni.com/en/support/downloads/tools-network/download.tdm-excel-add-in-for-microsoft-excel.html#378046. Once downloaded, right-click on the .tdms file, select “Open with” and then “excel add-in importer.”

CHAPTER 3: DATA INTERPRETATION

The safety of the bridge is dependent on many influencing factors. A trained professional should be present throughout the test and should rely on their experience to interpret the data as the test proceeds. Testing should terminate if there is any reason to believe that the structural integrity of the bridge has been impacted by the diagnostic or proof load test. The following figures from the Coles County bridge proof load test are included to illustrate concepts and should not be repurposed to justify any other bridges' safety.

General considerations when determining bridge safety include the stiffness of the bridge, residual displacements and/or rotations, peak strains, and crack development and growths. These factors are interdependent and thus should be considered simultaneously. The stiffness of the bridge should be monitored by plotting the demand on the bridge against the displacements from the LVDTs for each stage of the proof load test. A substantial decrease in the slope, as seen between the final few data points in **Figure 11**, suggests a loss of stiffness in the bridge. The residual deformation should also be tracked and judged together with the stiffness. Some residuals are to be expected throughout testing as gaps within the bridge close under loading. However, a substantial consistent increase in the residuals between any subsequent stages is unusual. A sudden growth can be seen in the final runs of Stages 3 and 4 in **Figure 12**. Additionally, the peak strains from the strain gauges at each stage should be compared with the predicted concrete cracking limit. If any strains approach the limit, the test should be stopped. The cracks underneath the bridge deck should also be monitored. Photographs of the cracks should be taken at the start of the test for comparison. It is also recommended to mark the ends of the cracks with a permanent marker, so any crack propagation is easily identifiable. During the Coles County test, these factors were weighed together and the team decided to not proceed to Stage 5.

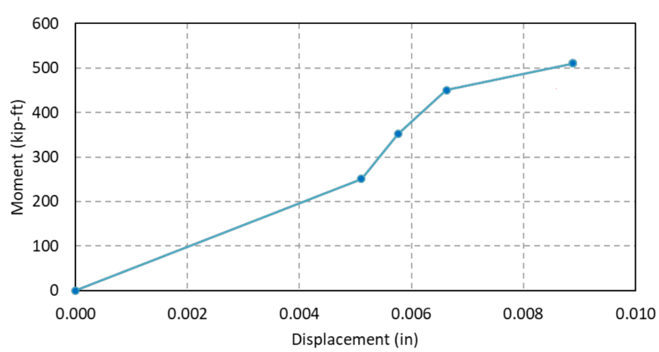


Figure 11. Coles County Proof Test Moment-Displacement Graph

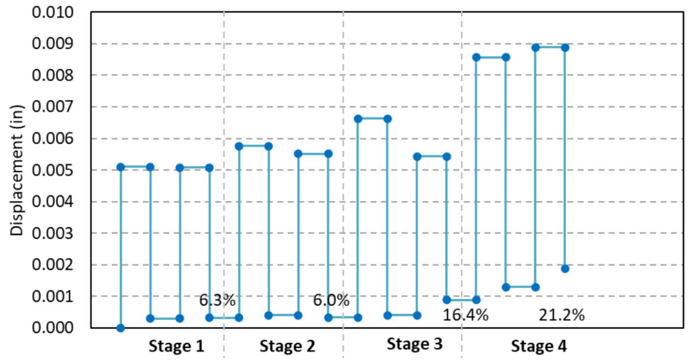


Figure 12. Coles County Proof Test Displacements