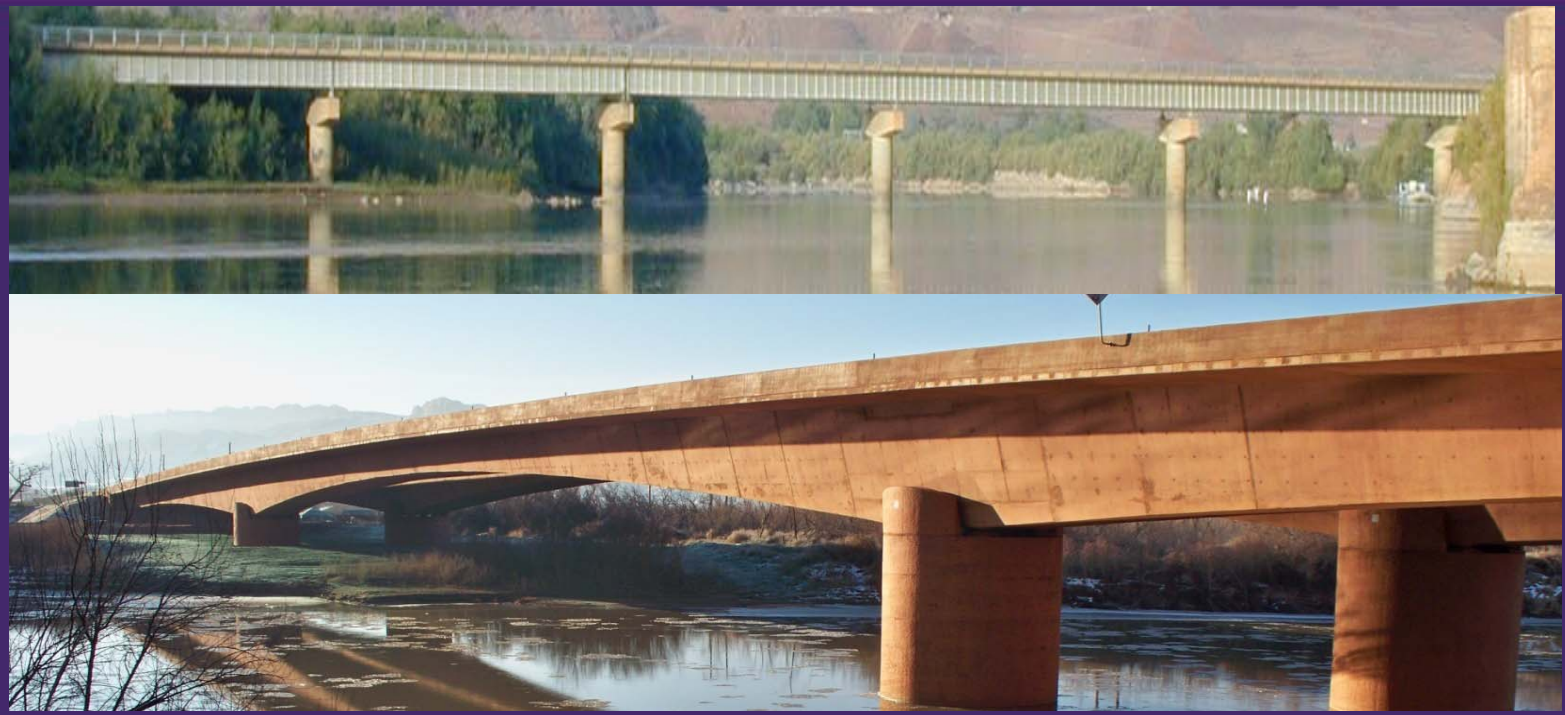
US 191 Load Rating Past and Present



By
Ron Pierce, PE, SE, CBI
David Evans and Associates, Inc.
Bridge Operations Services Practice Leader

DEA Bridge Operations Services

- Technical Practice Leader
  - Bridge Load Rating
  - Bridge Inspection
  - Bridge Management

Load Rating Experience

- First BRASS User Group (BUG) 1994
- President of VOBUG 1997
- Arizona DOT
  - State Load Rating Engineer
  - Seismic Retrofit Program Manager
- Utah DOT Load Rating
  - Program Development
  - Rating State Inventory

UDOT's Load Rating Program

- Current Program Implementation
- Started in 2006
- Virtis was selected as primary load rating software
- Utilizing the WYDOT BRASS Engines i.e. Girder LFD & Girder LRFD
- Truss Engine

UDOT's Load Rating Program- Cont'd

- AASHTO Manual for Condition Evaluations (MCEB) 1994 with 2003 interims
- Moving the AASHTO Manual for Condition Evaluation of Bridges (MBE) 2008, 2010 interims
- Utah's Bridge Inventory approx. 2917
  - State owned 1887
  - Local, RR, Others owned 1030

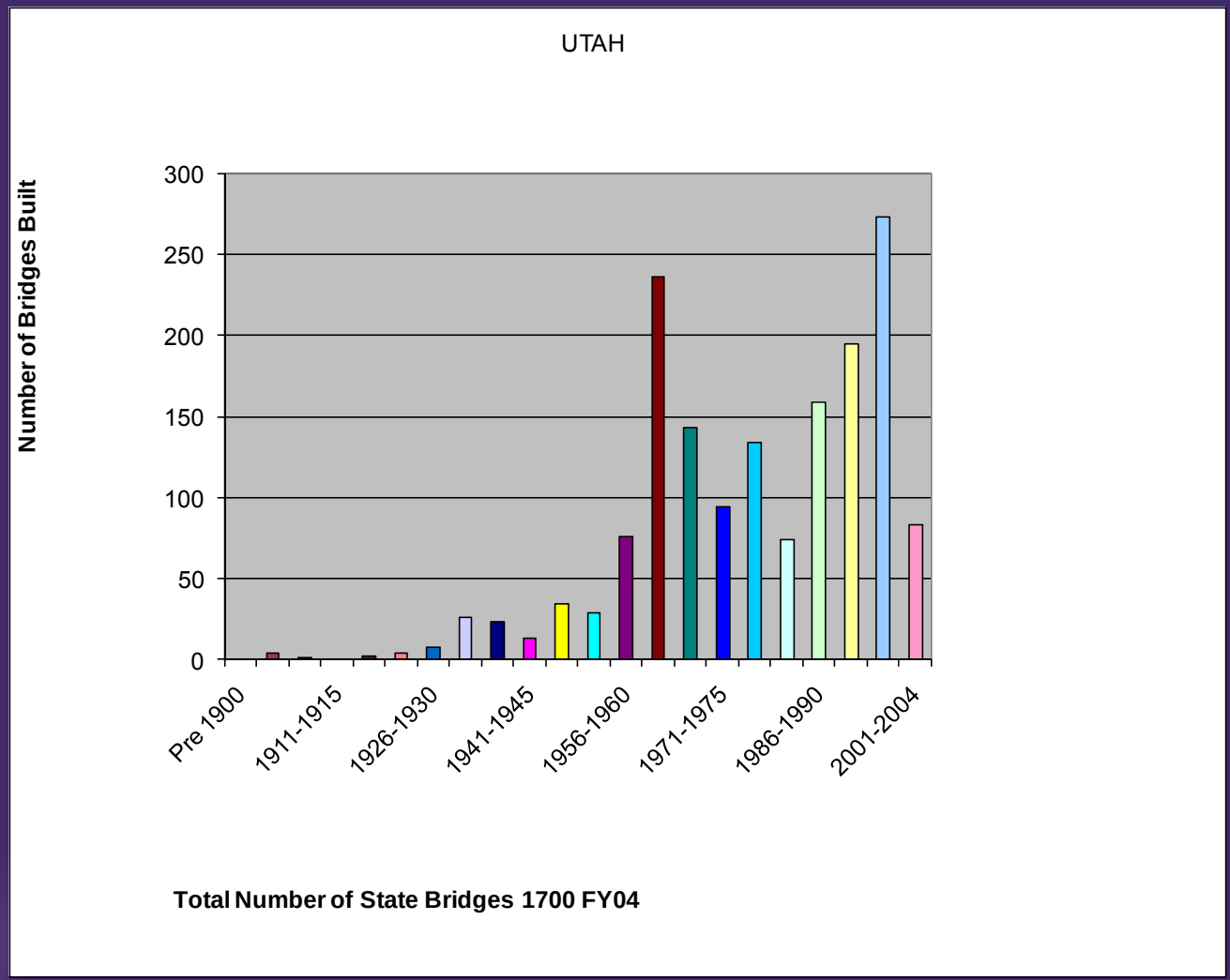
UDOT's Load Rating Program- Cont'd

- ASD & LFD Designed Bridges and rated by LFR method
- Design Load Ratings
  - HS20
- AASHTO Legal loads
  - Type 3
  - Type 3S2
  - Type 3-3

UDOT Bridge Inventory

- 918 Concrete Bridges
- 917 Steel Bridges
- 954 Prestressed Concrete Bridges
- 117 Wood & Timber
- 2 Masonry
- 6 Aluminum, Wrought Iron, Cast Iron
- 3 Other

Bridges Built by Year



US 191 Original Bridge

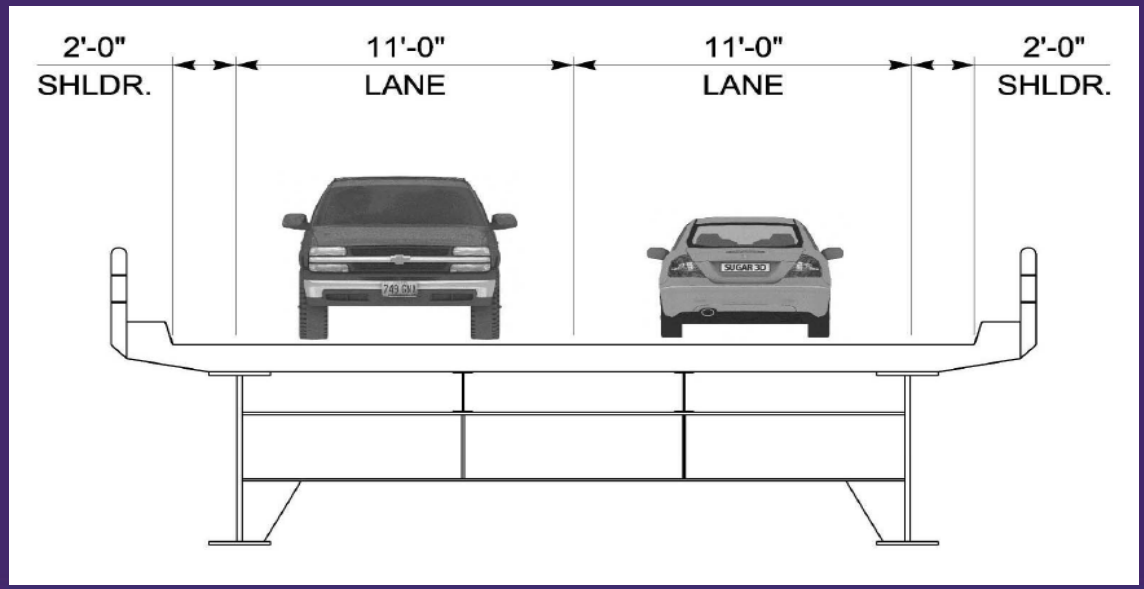
- Year Built 1955
- Designed AASHO 1953 edition
- Allowable Stress Design (ASD)
- Design Live Load H20-S16-44 Live Load
- ADT 8205 & 16% trucks

US 191 Original Bridge

- Bridge Length 1000’-0”
- Fracture Critical Steel Riveting Built Plate Girder with Stringers and Floor beams
  - 8 Spans, max span length =136’- 4 ½“

US 191 Original Bridge

- Bridge Width 29’-0”
- 2 -11’-0” lanes
- 2 - 2’-0” shoulders
- 1’- 6” curbs



US 191 Bridge NBI Condition

- NBI 58 Deck Rating - 6 Satisfactory
- NBI 59 Super Rating - 6 Satisfactory
- NBI 60 Sub Rating - 5 Fair

US 191 NBI Condition-Cont'd

- Functionally Obsolete
- Sufficiency Rating - 47

Core Element 107

- **Painted Steel Girder**
  - **CS 2, 75%; 1503 LF**
  - **CS 3, 25%; 502 LF**

Core Elements

- **113 Painted Steel Stringer**
  - **CS 1 80%; 1601 LF**
  - **CS 2 20%; 400 LF**

Core Elements

- **152 Painted Steel Floor Beam**
  - **CS 1 83%; 988 LF**
  - **CS 2 10%; 118 LF**
  - **CS 3 5%; 59 LF**
  - **CS 4 2%; 23 LF**

Core Elements

- **234 Concrete Pier Cap**
  - **CS 1 86%; 164 LF**
  - **CS 2 14%; 26 LF**

Core Elements

- 303 Deck Joint Assembly
  - CS 1 67%; 53 LF
  - CS 2 33%; 26 LF

Core Elements

- **334 Metal Railing Coated**
  - **CS 2 100%; 2070 LF**

US 191 Bridge Configuration

- 8 Spans
- Spans symmetrical about the center pier
- Expansion joints at Abutments and Center pier

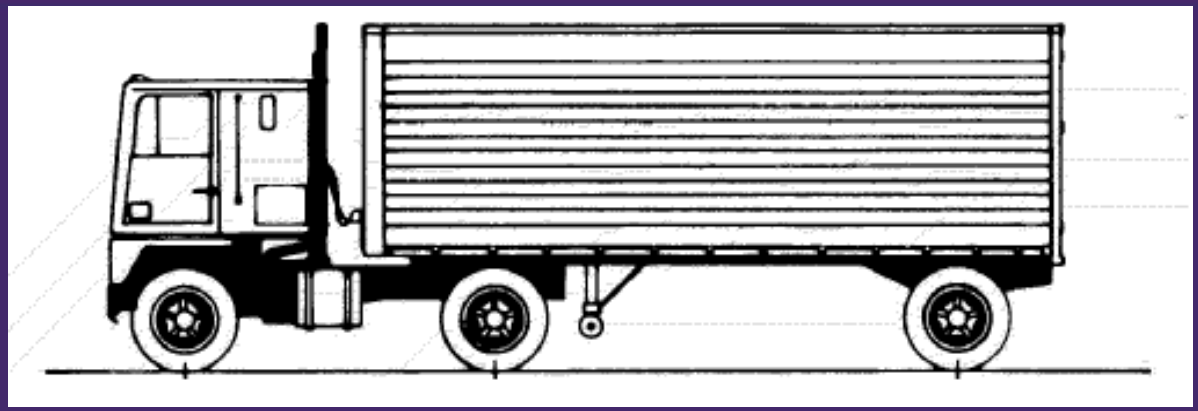
US 191 Load Rating

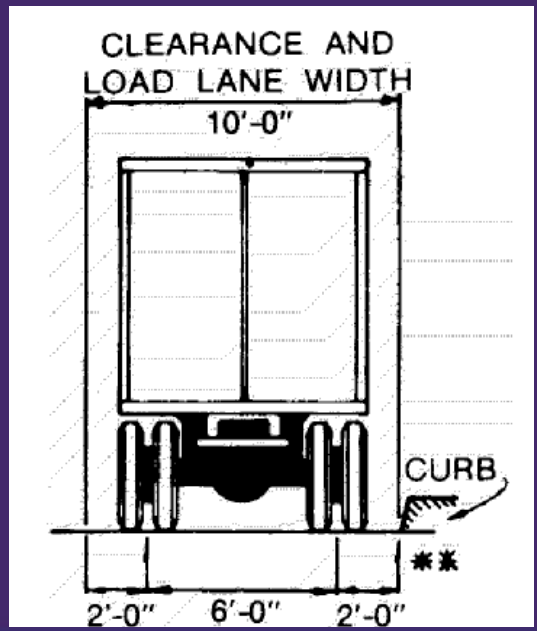
- Load Factor Rating (LFR)
- Steel Strength (A7-50 T) 33 ksi
- Steel Rivets (A141-39)
- Concrete Strength 3.0 ksi
- Reinforcing Steel A 305 Intermediate Grade 40 ksi
- Composite Construction

Load Rating Software

- AASHTOWare Virtis 6.2
  - Deterioration was modeled
- BRASS Engine 6.0.3
  - Main Girder
  - Stringer/Floor Beam System

Rating HS 20 Standard Vehicle



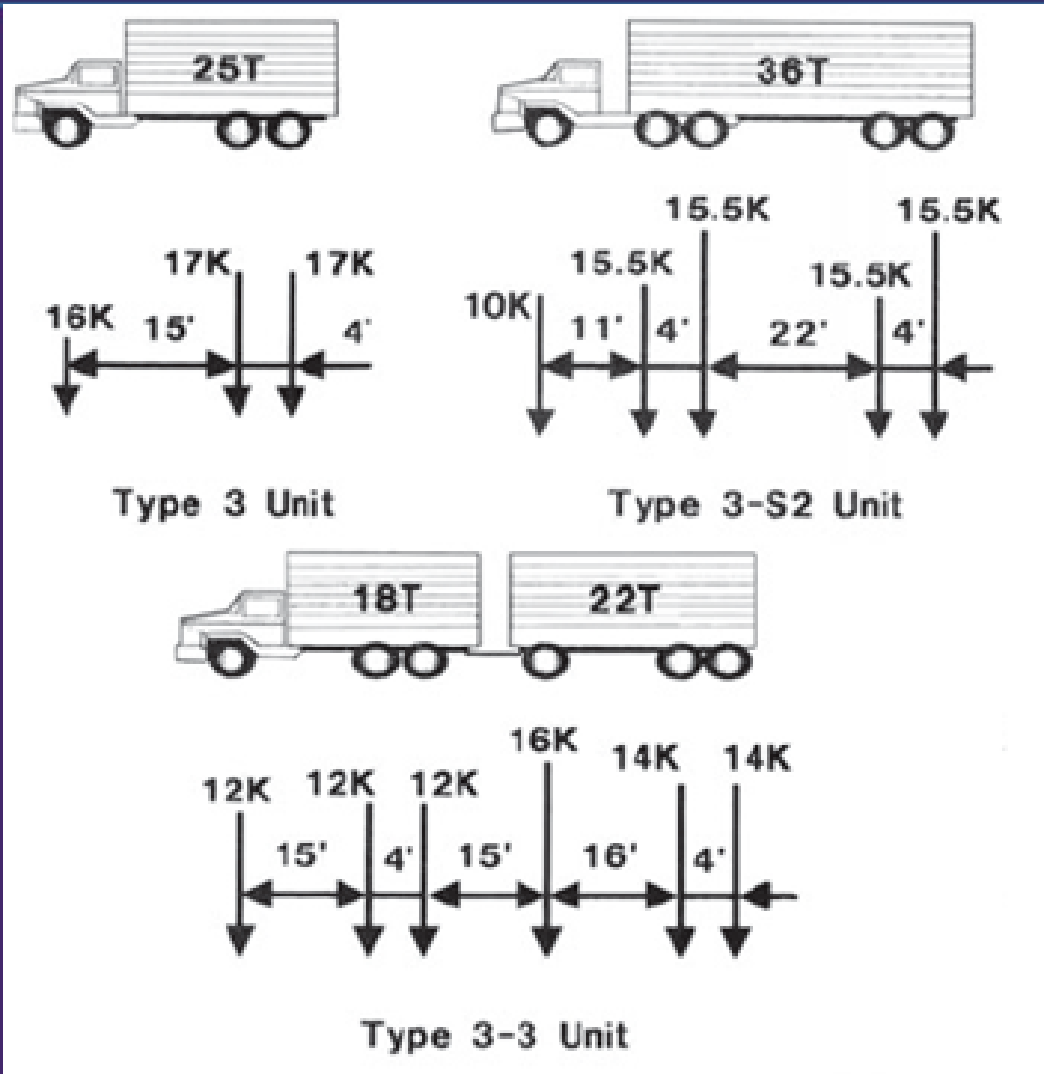


Weight = 72,000 lbs

US 191 Load Rating

- Superstructure Ratings (HS20)
  - Main Girders RF (Tons)
    - Inventory – 0.857 (30.85) Flexural Strength
    - Operating – 1.437 (51.73) Flexural Strength
  - Stringers RF (Tons)
    - Inventory – 0.868 (31.25) Serviceability
    - Operating – 1.449 (52.16) Serviceability
  - Floor Beams RF (Tons)
    - Inventory – 0.975 (35.10) Flexural Strength
    - Operating – 1.629 (58.64) Flexural Strength

AASHTO Legal Loads



Legal Loads- Results

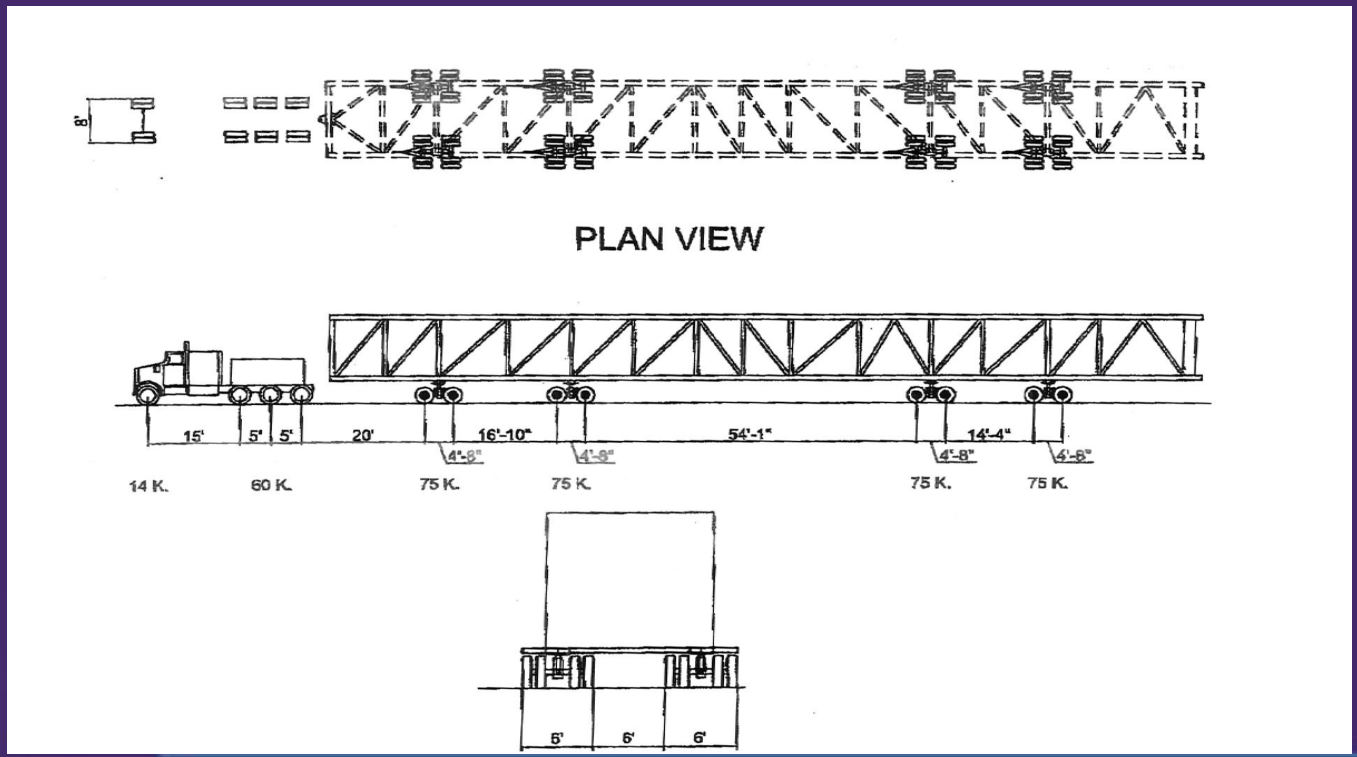
- Legal Load Ratings
  - Type 3 RF (Tons)
    - Inventory –0.977 (24.42) Flexural Strength
    - Operating – 1.606 (40.15) Flexural Strength
  - Type 3S2 RF (Tons)
    - Inventory – 1.116 (40.19) Flexural Strength
    - Operating – 1.861 (67.00) Flexural Strength
  - Type 3-3 RF (Tons)
    - Inventory – 1.165 (46.61) Flexural Strength
    - Operating – 1.916 (76.65) Flexural Strength

Overloads

- Bridge is on Critical Route carries to I70 & I15
  - Four Corners Area
  - 500 - 600 single trip permits of unadvisable loads up to 125,000 lbs

Overloads – Special permits

- Evaluation of single trip permits
  - 374,000 lbs, Tractor Standard gage Axles & 8 non standard gage Axles 18’ gage

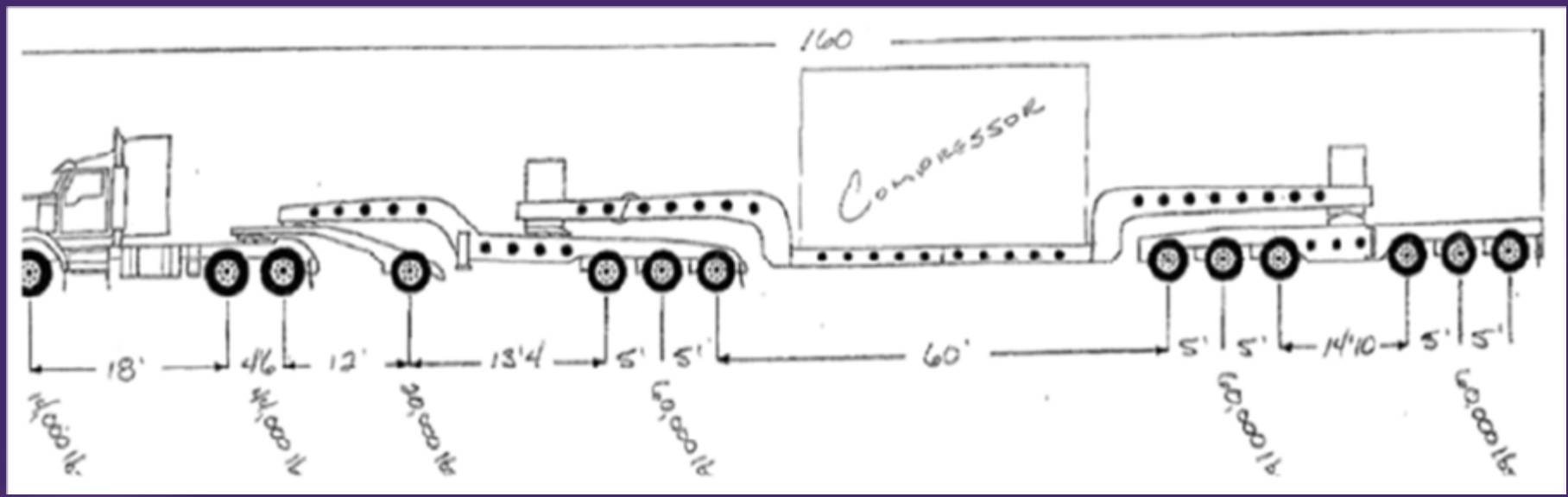


Overload Results

- Permit Ratings
  - Restrictions
    - Single lane (centerline bridge)
    - 5 mph (i.e. 0 impact)
    - No traffic on bridge while crossing
  - Overload RF (Tons)
  - Main Girder Controlled
    - Inventory – 0.661 (123.58) Flexural Strength
    - Operating – 1.104 (206.37) Flexural Strength

Overloads – Special permits

- Evaluation of single trip permits
  - Standard gage Overload
  - 258,000 lbs, 13 Standard gage axles



Overload Results

- Permit Ratings
  - Restrictions
    - Single lane (centerline bridge)
    - 5 mph (i.e. 0 impact)
    - No traffic on bridge while crossing
  - Overload RF (Tons)
  - Main Girder Controlled
    - Inventory – 0.999 (128.86) Flexural Strength
    - Operating – 1.666 (215.19) Flexural Strength

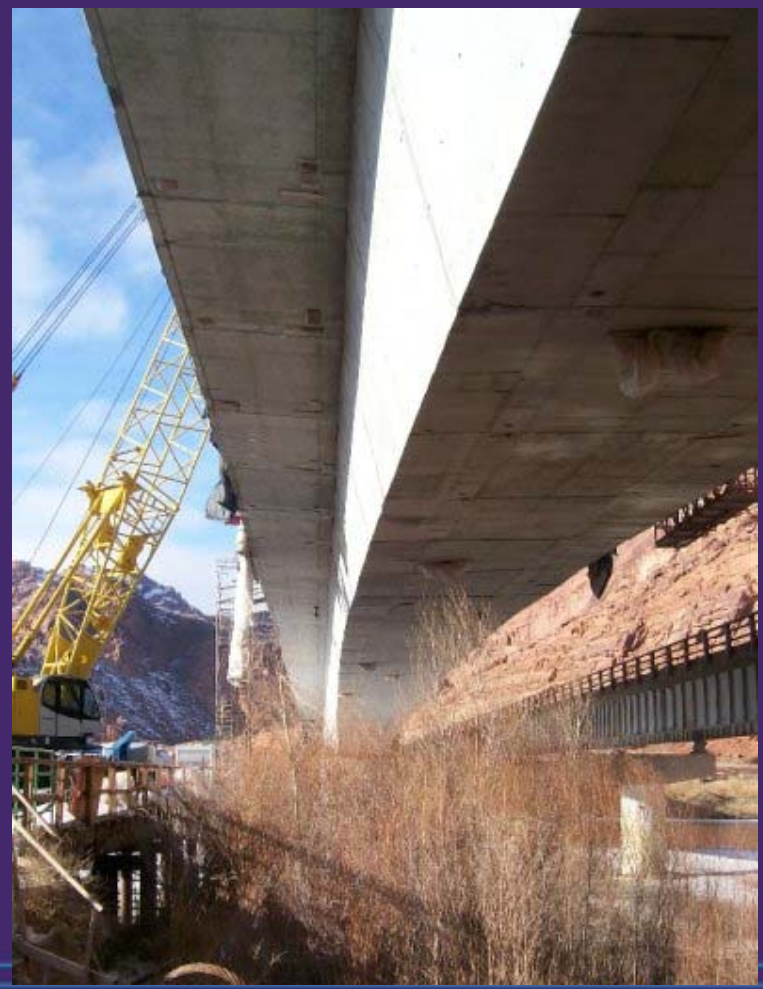
New US 191 Bridges

US 191 New Bridge

- Construction Awarded December 2008
- UDOT's Accelerated Bridge Construction Methods (ABC)
- Designer FIGG Engineers
- $38 million

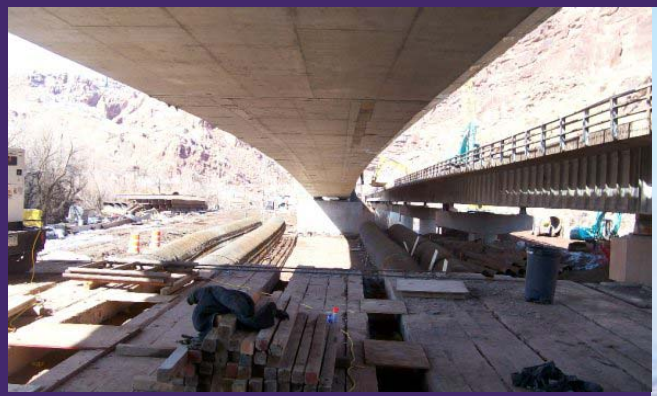
US 191 New Bridge

- Contractor Wadsworth Brothers
- Cast In Place Balanced Cantilever Construction



US 191 New Bridge

- Twin Bridge Lengths = 1022’-0”
- Spans Lengths 292’- 0”, 436’- 0”, 292’- 0”
- Box Girder Depth 9’- 2 1/2” to 19’- 2 ½ “

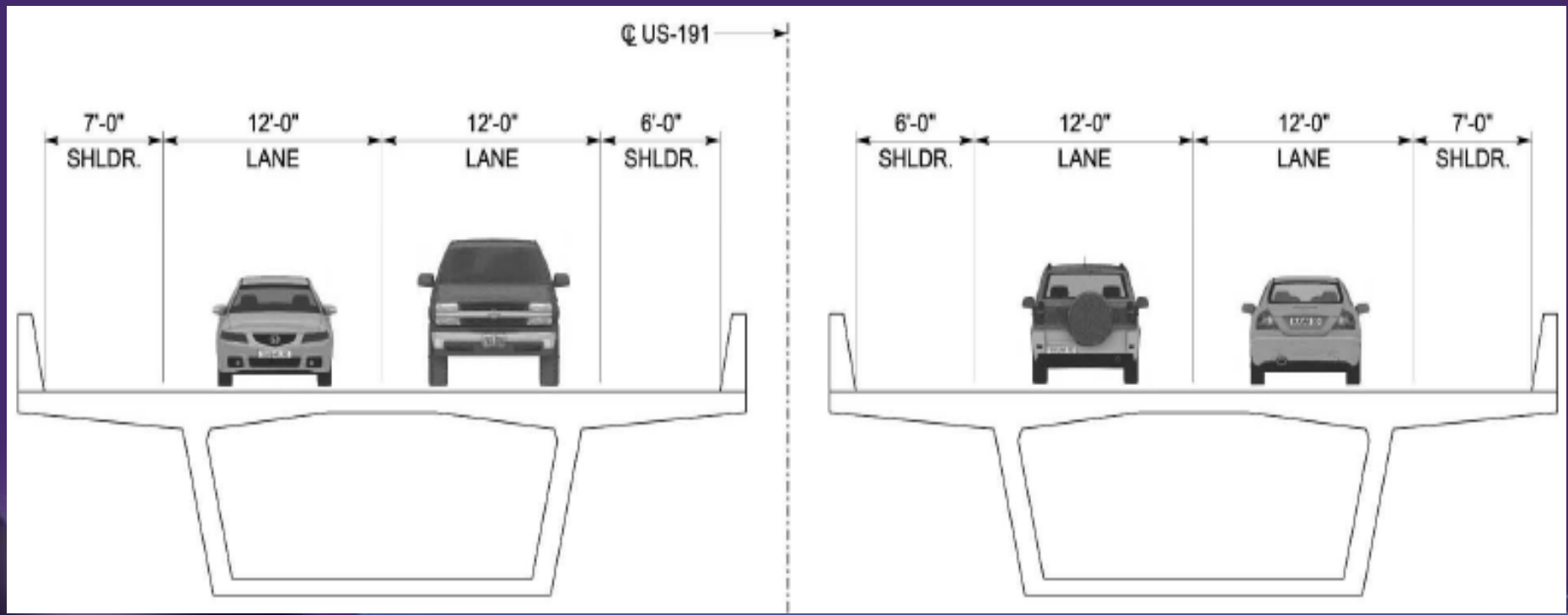


SR 191 New Bridge

- Open to traffic December 2010
- Designed AASHTO LRFD 2006 edition
- Load and Resistant Factored Design (LRFD)
- Design Live Load HL 93 Live Load
- Design Concrete Strength 6000 psi
- 2 ½ inch Integral Wearing Surface

US 191 New Bridges

- Bridge Widths 39’ - 10”
- 3 - 12’-0” Design Lanes each Direction
- 2 - 12’-0” Striped Lanes each Direction



In-Service Load Rating

- AASHTO MBE 2008
- Load Rating Method LRFR
- Construction Concrete Strength 7625 psi
- Concrete break records
- Actual tendon paths
- Enveloped stressing during construction
- Enveloped time dependant effects during construction

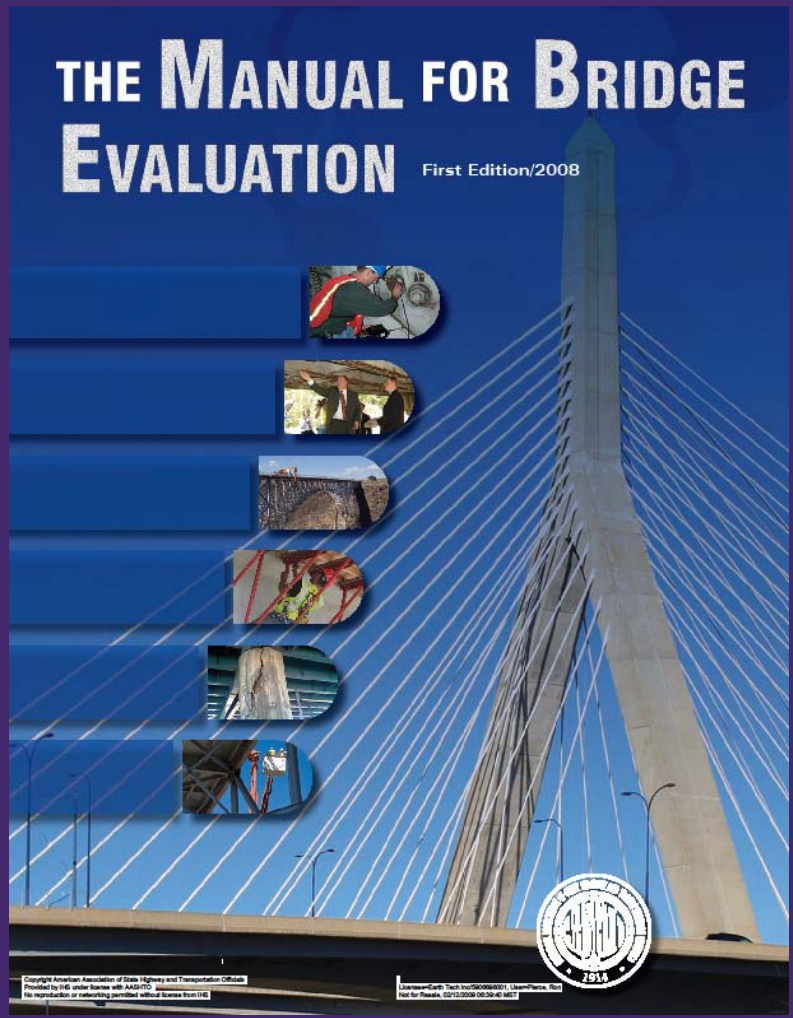
Load Rating Task

- Generate an In-Service Load Rating Report and Electronic model for UDOT
- Provide UDOT a process for Analyzing Overloads permits based on previous Permits
- Utilizing SAP 2000 and Bentley's RM 2000 to develop electronic load rating model

Load Rating Task - cont'd

- Developed a Load Rating Manual for processing Overload Permits

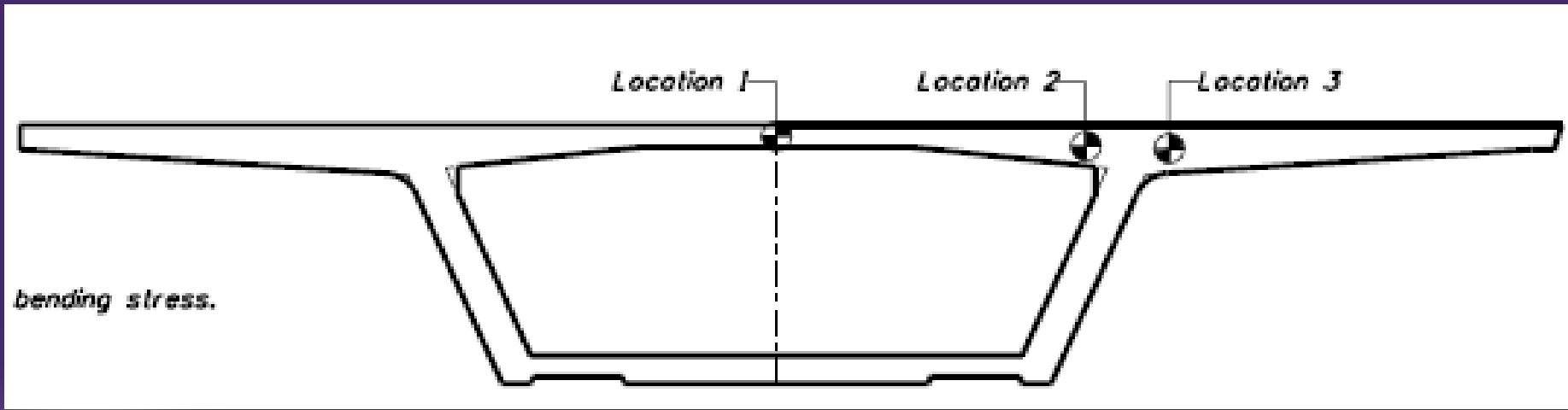
AASHTO Manual for Bridge Evaluation (MBE) 2008



LRFR for Segmental Bridges

MBE Section 6A.5.13

- Strength limit and Service limit states
- Longitudinal and Transverse Directions



LRFR for Segmental Bridges

MBE Section 6A.5.13

- **Strength limit state**
  - **Moment & Shear**
- **Service limit state**
  - **Tension, Compression, Principal Tension**

LRFR for Segmental Bridges

MBE Section 6A.5.13

- **Shear Modified**
  - **Compression Field Theory**
- **Principal Tension in Webs**
  - **Combined Shear and Torsion Stresses**
  - **MOHR Circle Analysis**

LRFR for Segmental Bridges

- **Inventory load limits (β = 3.5) (75 Yr)**
- **Moment Ratings**
- **Multiple Presence m = 1.2**
- **Use number on Design Lanes (3)**
  - Inventory: Service I (comp.), **Service III(ten.) (γ L=0.8), Strength I (γ LL = 1.75) (Live Load HL 93)**

LRFR for Segmental Bridges

Operating load limits(β = 2.5) (5 yr exposure)

- **Moment Ratings**
- **Multiple presence m = 1.0**
- **Use stripped lanes (2)**
  - Operating: Service I (comp.), **Service III(ten.) (γ L=1.0), Strength I (γ LL = 1.35) (Live Load HL 93, Legal Loads, Permit Loads)**

LRFR Load Rating Equation

$$RF = \frac{\phi_c \phi_s \phi_R - \gamma_{DC} DC - \gamma_{DW} DW \pm \gamma_P P}{\gamma_L (1 + IM)}$$

Capacity Factors

- Condition Factors = (ϕ c)
  - Inspection data
- System Factor = (ϕ s)
  - Calculated below
- Capacity Reduction Factor = (ϕ)
  - LRFD Spec
- R = Resistance

Capacity Factors

- **Strength Reduction Factor ϕ**
- **Condition Factors = (ϕ c)**

  ϕ c = 1.0 - New Bridge assumed

  - Verify by inspection

LRFR for Segmental Bridges

- System Factors (ϕ s)
- Longitudinal Shear & Torsion (ϕ s) =1.0
- Transverse Flexure (ϕ s) =1.0
- Longitudinal Flexure (ϕ s)
  - See the following slides

LRFR System Factors

Table 6A.5.13.6-1—System Factors for Post-Tensioned Segmental Concrete Box Girder Bridges

Bridge Type	Span Type	# of Hinges to Failure	System Factors (φ_s) No. of Tendons per Web[a]			
			1/web	2/web	3/web	4/web
Precast Balanced Cantilever Type A Joints	Interior Span	3	0.90	1.05	1.15	1.20
	End or Hinge Span	2	0.85	1.00	1.10	1.15
	Statically Determinate	1	n/a	0.90	1.00	1.10
Precast Span-by-Span Type A Joints	Interior Span	3	n/a	1.00	1.10	1.20
	End or Hinge Span	2	n/a	0.95	1.05	1.15
	Statically Determinate	1	n/a	n/a	1.00	1.10
Precast Span-by-Span Type B Joints	Interior Span	3	n/a	1.00	1.10	1.20
	End or Hinge Span	2	n/a	0.95	1.05	1.15
	Statically Determinate	1	n/a	n/a	1.00	1.10
Cast-in-Place Balanced Cantilever	Interior Span	3	0.90	1.05	1.15	1.20
	End or Hinge Span	2	0.85	1.00	1.10	1.15
	Statically Determinate	1	n/a	0.90	1.00	1.10

[a] For box girder bridges with three or more webs, table values may be increased by 0.10.

LRFR for Segmental Bridges

Longitudinal System Factors (ϕ s)

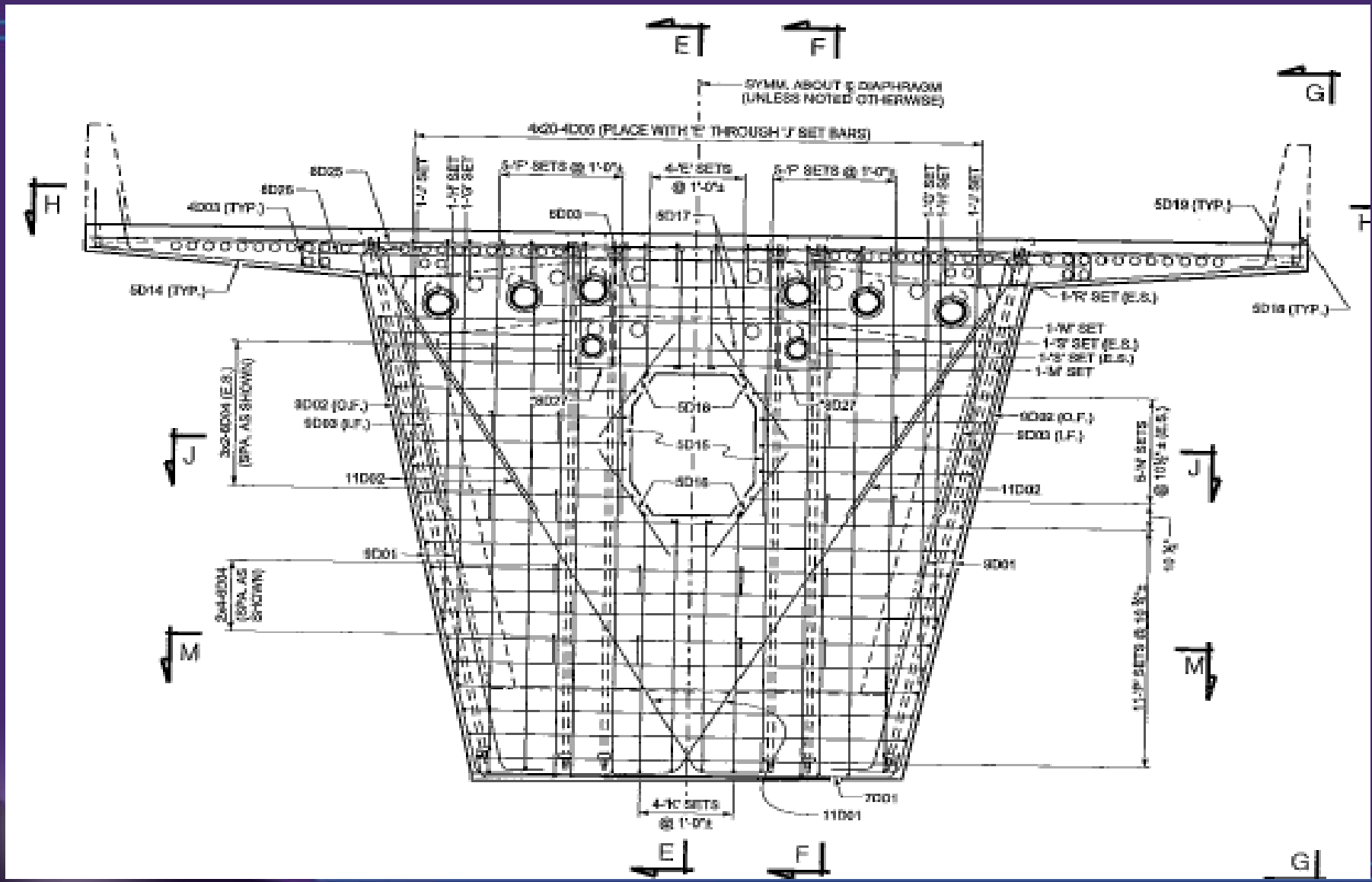
- Longitudinally Continuous
- Transverse Continuum of Closed Box
- Number of tendons per web (Multiple Tendon Paths)
- Numbers webs

LRFR for Segmental Bridges

US 191 Bridges

- CIP Balanced Cantilever Construction
- Number of Tendons per web
  - 3 Tendons per web
- Longitudinally continuous
  - Interior Span ϕ s = 1.15
  - End Span ϕ s = 1.10

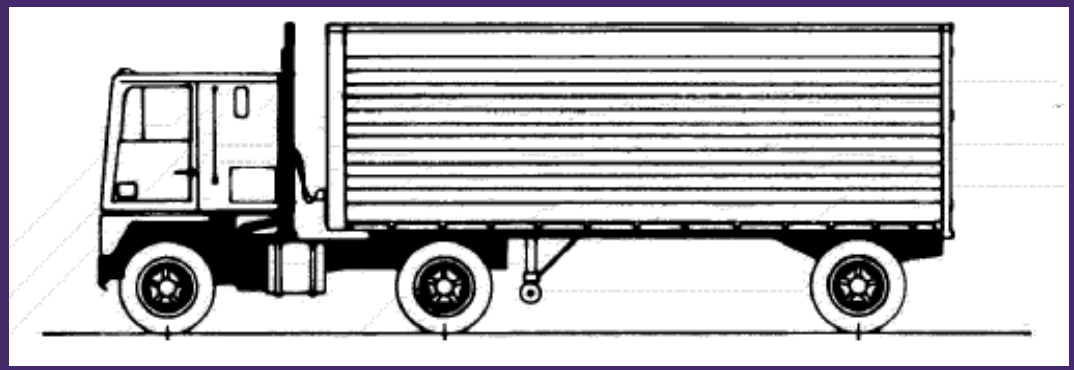
Bridge Cross Section



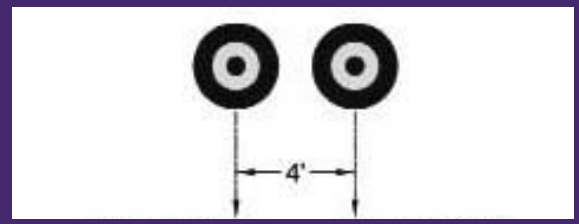
Service Limit State

CIP Joints	Tension	Compression
Long. & Trans.	$3.0\sqrt{f'c}$	$0.6\ f'c$
Principal Tension at N.A.	$3.5\sqrt{f'c}$	N/A

Design & Rating HL93



or



Truck

+

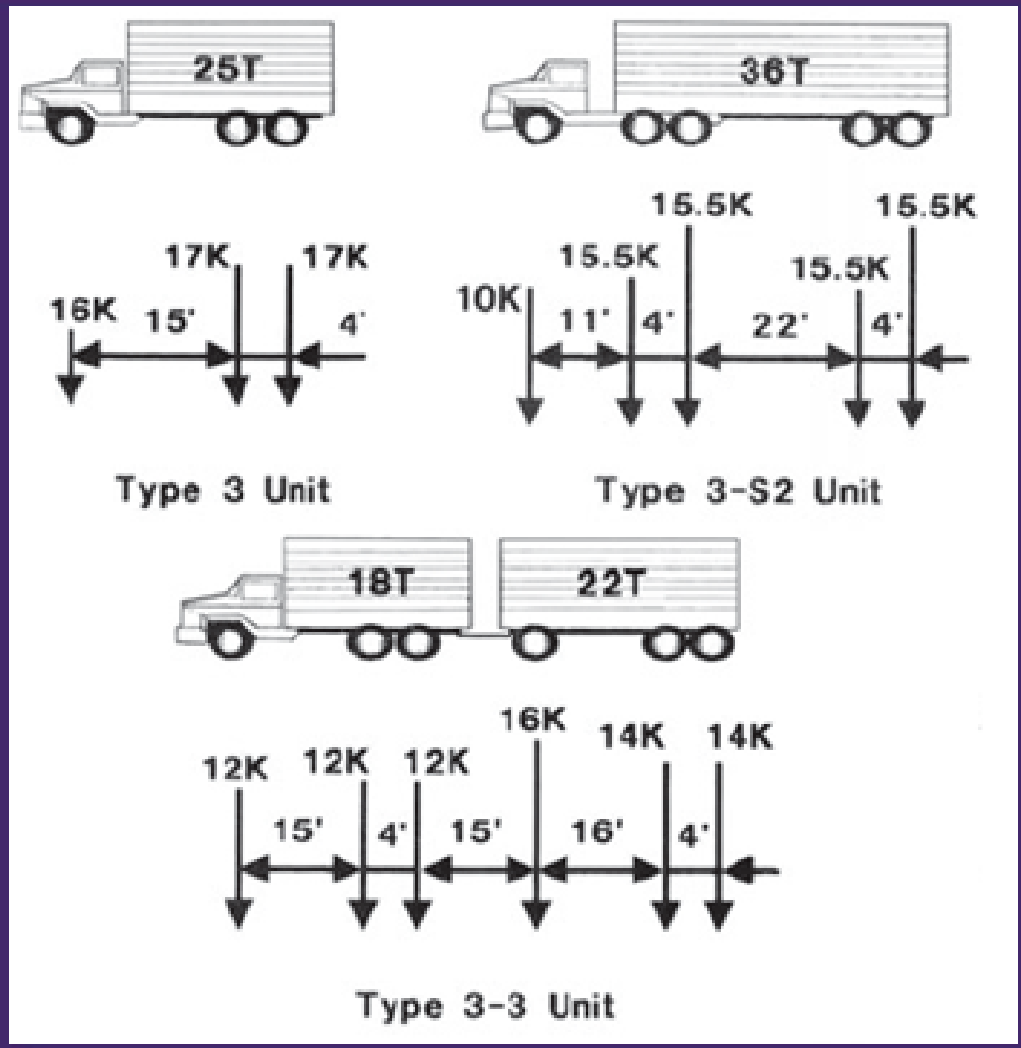
Tandem

Lane

LRFR Load Rating

- Superstructure Ratings (HL 93)
  - Longitudinal RF
    - Inventory – 1.30 Strength I Shear
    - Operating – 1.84 Principal Tension
  - Transverse RF
    - Inventory – 1.89 Strength I Moment
    - Operating – 2.29 Strength I Moment

AASHTO Legal Loads

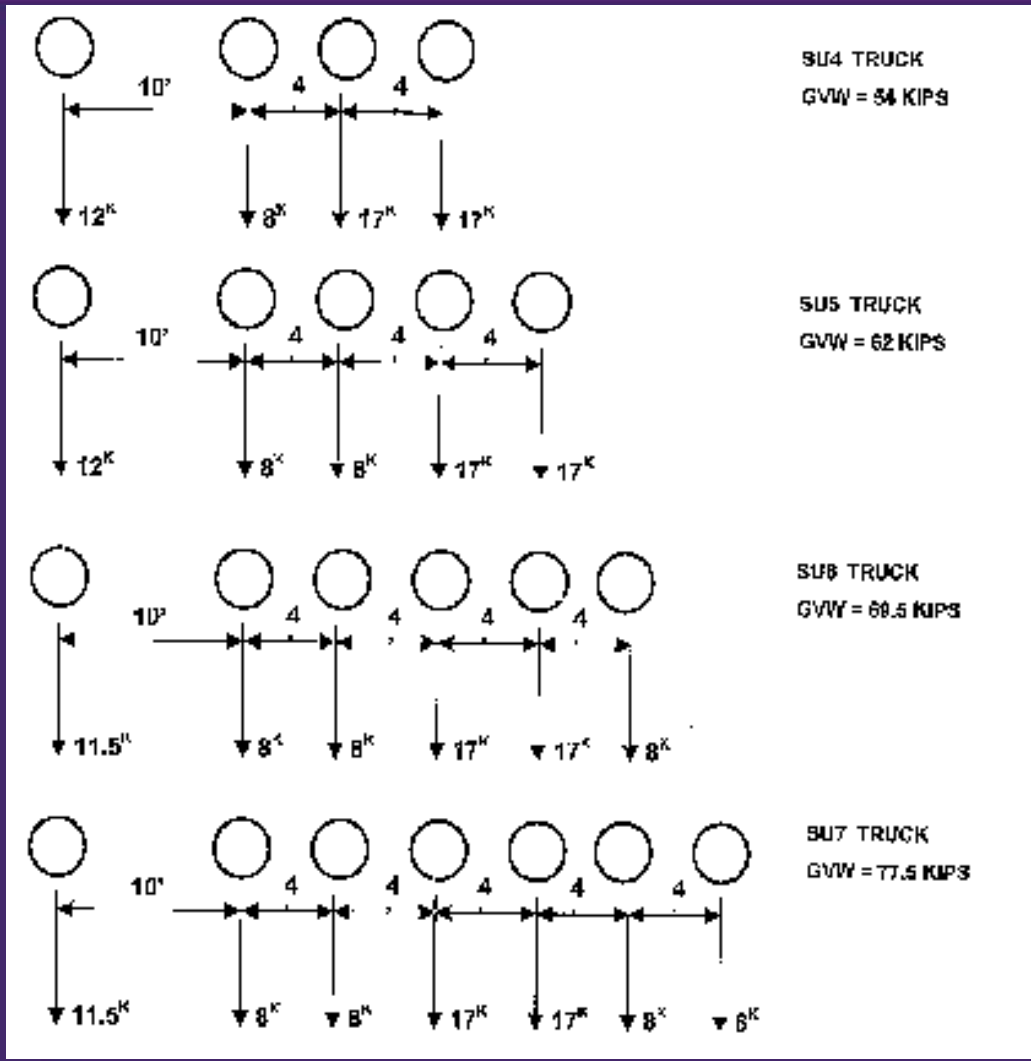


Legal Load Live Load Factors

MBE Table 6A.4.4.2.3a-1

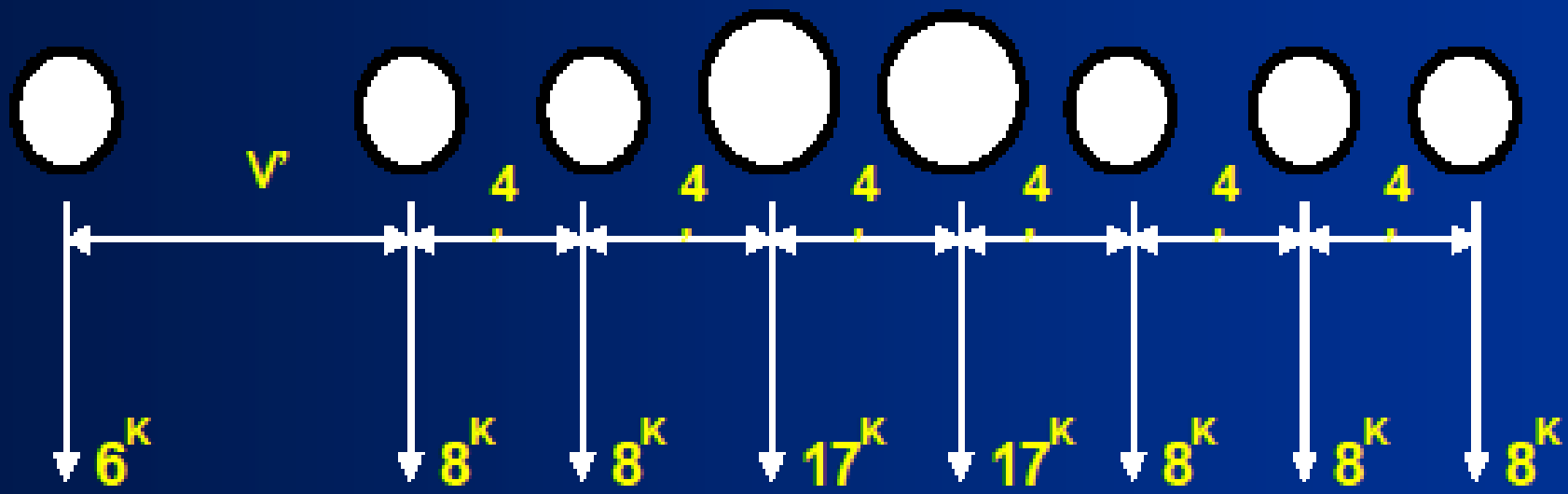
Traffic Volume	LF Type 3, 3S2, & 3-3
Unknown ADTT	1.80
ADTT >= 5000	1.80
ADTT = 1000	1.65
ADTT <= 100	1.40

New AASHTO Legal Loads (SHV's)



AASHTO Legal Loads (NRL)

- NRL Notional load envelops the SHV's



- GVW = 80 KIPS
- V — 6'0" TO 14'-0". SPACING

New AASHTO Legal Loads (SHV's)

- Specialized Hauling Vehicles (SHV)
- NCHRP 12- 63
- Vehicles that meet weight limits Federal Formula B
- Over stress short Bridges by more than 50%

New AASHTO Legal Loads (SHV's)

- **Specialized Hauling Vehicles**

Legal Load (SHV) Live Load Factors

MBE Table 6A.4.4.2.3b-1

Traffic Volume	LF Type SU4, SU5, SU6, SU7 & NRL
Unknown ADTT	1.60
ADTT > = 5000	1.60
ADTT= 1000	1.40
ADTT <= 100	1.15

Legal Load Factors Utilized

US191 Rating Load Factors

- AASHTO Legal Loads 1.80
- SHV Legal Loads 1.60

Legal Loads - Results

- AASHTO Legal Ratings(Operating)
  - Type 3 RF (Tons)
    - Longitudinal – 4.34 (108.50) Service III Moment
    - Transverse – 3.27 (81.75) Service I Moment
  - Type 3S2 RF (Tons)
    - Longitudinal – 3.26 (117.36) Service III Moment
    - Transverse – 2.72 (97.92) Strength I Moment
  - Type 3-3 RF (Tons)
    - Longitudinal – 3.05 (122.00) Service III Moment
    - Transverse – 3.56 (142.40) Strength I Moment

Legal Loads Results - Cont'd

- SHV Legal Ratings(Operating)
  - Vehicle SU 4 RF (Tons)
    - Longitudinal – 3.99 (107.73) Service III Moment
    - Transverse – 3.01 (81.27) Strength I Moment
  - Vehicle SU 5 RF (Tons)
    - Longitudinal – 3.51 (108.81) Service III Moment
    - Transverse – 2.91 (90.21) Strength I Moment
  - Vehicle SU 6 RF (Tons)
    - Longitudinal – 3.19 (110.85) Service III Moment
    - Transverse – 2.66 (92.44) Strength I Moment

Legal Loads Results - Cont'd

- SHV Posting Ratings(Operating)
  - Lane Type Legal Load RF (Tons) Span>200ft
    - Longitudinal 2.70 (N/A) Strength I Shear
    - Transverse - N/A
  - Vehicle SU 7 RF (Tons)
    - Longitudinal – 2.91 (112.76) Service III Moment
    - Transverse – 2.57 (99.59) Strength I Moment
  - Vehicle NRL RF (Tons)
    - Longitudinal – 2.83 (113.20) Service III Moment
    - Transverse – 2.53 (101.20) Strength I Moment

MBE Permit Live Load Factors

Table 6A.4.5.4.2a-1—Permit Load Factors: γ_L

Permit Type	Frequency	Loading Condition	*DF*[a]	*ADTT* (one direction)	Load Factor by Permit Weight[b]	
					Up to 100 kips	≥150 kips
Routine or Annual	Unlimited Crossings	Mix with traffic (other vehicles may be on the bridge)	Two or more lanes	>5000	1.80	1.30
				=1000	1.60	1.20
				<100	1.40	1.10
					All Weights	
Special or Limited Crossing	Single-Trip	Escorted with no other vehicles on the bridge	One lane	N/A	1.15	
	Single-Trip	Mix with traffic (other vehicles may be on the bridge)	One lane	>5000	1.50	
				=1000	1.40	
				<100	1.35	
	Multiple-Trips (less than 100 crossings	Mix with traffic (other vehicles may be on the bridge)	One lane	>5000	1.85	
				=1000	1.75	
				<100	1.55	

[a] *DF* = LRFD distribution factor. When one-lane distribution factor is used, the built-in multiple presence factor should be divided out.

[b] For routine permits between 100 kips and 150 kips, interpolate the load factor by weight and *ADTT* value. Use only axle weights on the bridge.

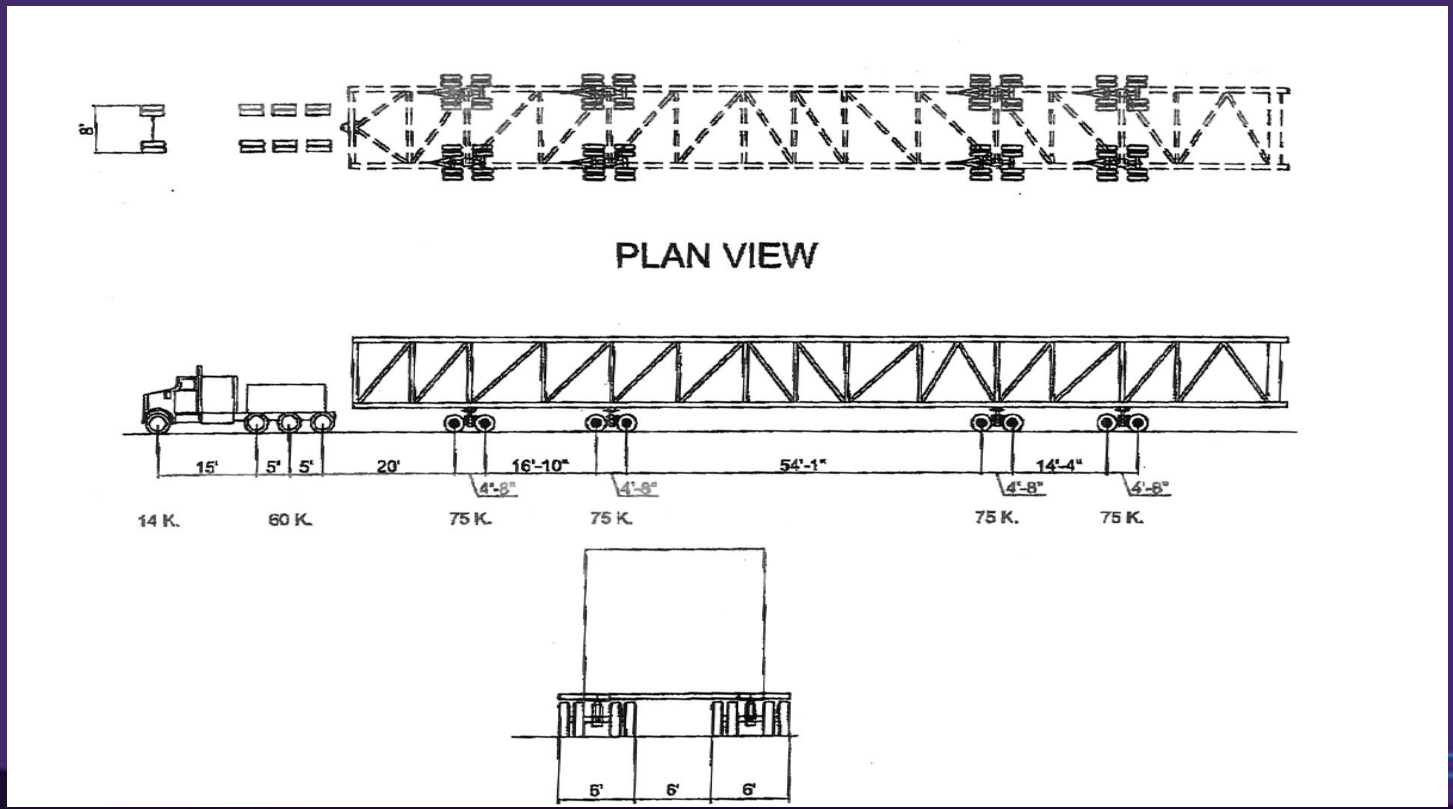
Project Permit Live Load Factors

Special or Single Trip Permit LF's

- **Single trip w/o traffic 1.15**
- **Single trip w/traffic 1.50**
- **Multiple trips w/traffic 1.85**

Overloads – Special permits

- Evaluation of single trip permits
  - 374,000 lbs, Tractor Standard gage Axles & 8 non standard gage Axles 18’ gage

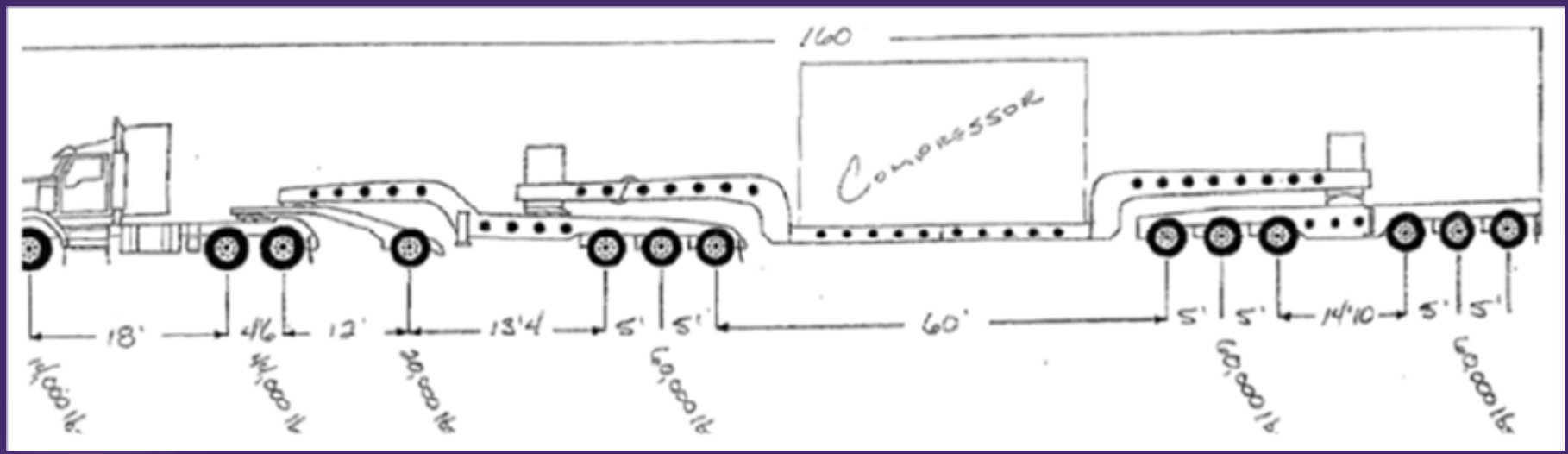


Overload Results

- Permit Ratings
  - Restrictions
    - Single lane (centerline bridge)
    - 5 mph (i.e. 0 impact)
    - No traffic on bridge while crossing
  - Overload RF (Tons)
    - Operating – 2.26 (422.62) Shear Strength
    - Operating – 2.19 (409.53) Service III (Principal Tension)

Overloads – Special permits

- Evaluation of single trip permits
  - Standard gage Overload
  - 258,000 lbs, 13 Standard gage axles



Overload Results

- Permit Ratings
  - Restrictions
    - Single lane (centerline bridge)
    - 5 mph (i.e. 0 impact)
    - No traffic on bridge while crossing
  - Overload RF (Tons)
    - Operating – 3.32 (473.10) Shear Strength I
    - Operating – 3.27 (421.83) Service III (Principal Tension)

Review of Results

Design Load Rating

- HL 93 Inventory Ratings
  - Strength Shear Rating
  - Longitudinal Direction
  - RF = 1.30
- HL 93 Operating Ratings
  - Service III Principal Tension
  - Longitudinal Direction
  - RF = 1.84

Review of Results

Legal Load Rating

- NRL Operating Rating
  - Strength
  - Transverse Direction
  - RF = 2.53

Review of Results

Permit Load Rating 1

- Overload Permit Operating Rating (374K)
  - Non Standard Gage Vehicle
  - Service III Principal Tension
  - Longitudinal Direction
  - RF = 2.19
  - Strength I Shear
  - RF = 2.25

Review of Results

Permit Load Rating 2

- Overload Permit Operating Rating (258K)
  - Standard Gage Vehicle
  - Service III Principal Tension
  - Longitudinal Direction
  - RF = 3.27
  - Strength I Shear
  - RF = 3.32

Inspection Photo’s

Inspection Photo’s

Inspection Photo’s

Inspection Photo’s

Inspection Photo’s

Questions ?