ENGINEERING POLICY BALLOT

Effective: October 1, 2022

Level 2

Level two revisions require the approval of the **Assistant Chief Engineer** and the **Federal Highway Administration** only. The **Senior Management Team** is encouraged to review the content and provide comment to the appropriate director. For all other parties, these revisions are posted for information only.

ENGINEERING POLICY BALLOT

Effective: October 1, 2022

Issue 1: Changes to EPG 501 Allowing for District Option on Concrete Aggregate Sampling - Non Contract Specific

Approval: **Level 2 – Assistant Chief Engineer**

Sponsor: Lawrence R. Brooks – CM

Summary: This new EPG guidance allows for QA aggregate tests to be performed at a two week minimum frequency for any plant supplying material to a state contract. The test results are then saved to one sample record, that can be later assigned to a specific contract. This option will also apply to QA split sample requirements.

Fiscal Impact: Reduces redundant aggregate testing allowing for District resources to concentrate on other duties. It is reasonable to assume a possible 84% reduction in QA aggregate testing costs, especially for metro districts.

Publication: EPG 501

Issue 2: Bridge Inspection Rating Guidance

Approval: **Level 2 – Assistant Chief Engineer**

Sponsor: David Koenig – BR

Summary: To meet federal compliance, Bridge Division has been working in conjunction with FHWA and executive management to update the load rating policy. This new policy will replace existing EPG 753.4 (Section 4) and create the new EPG 753.15 (Section 15). This is only one step of many to update other EPG guidance as it relates to bridge management. Since executive management has been made aware of these revisions and the fiscal impact, the revision is being approved at the Asst. Chief Engineer level.

Fiscal Impact: This is basically a federal mandate and it will have a large fiscal impact. Internal MoDOT as well as consultant resources will be used in the coming years to do the load rating updates on all the bridges in Missouri. Final cost will be impacted on the agreed upon timeline with FHWA. Presently, it is estimated to cost in the $50 million range in MoDOT and Consultant resources, assuming a 15-year timeline for doing these updates.

Publication: EPG 753

501.1.1 Material (Sec 501.2)

Sec 501.2 of the Standard Specifications include specific requirements of material to be used. Plant inspectors are responsible to the resident engineer for verifying acceptability of all materials before they are incorporated into the work.

The proportioning plant inspector is responsible for inspecting control of materials and batching operations. The inspector's duties will start at the time materials are being stockpiled and will continue until final records for the project are complete. The inspector must be provided information about source and type of aggregates intended for use, and mix proportions. The inspector must be familiar with inspection procedures for determining moisture content, scale weights, and inspection of batching equipment, the performance of tests, and reports. The inspector should become familiar with the contents of manufacturer's brochures on the proposed batching equipment to understand its operation. The contractor will normally have this information.

The proportioning plant inspector must be certain that all materials have been properly inspected and approved before permitting their use. Cement is normally accompanied by appropriate certification as described in Section 1019 of the Standard Specifications. Aggregate suppliers will be designated in AWP.

501.1.2 District Option for QA Aggregate Acceptance (Sec 501.2.1)

QA District Option for Non-Project Specific Plant Aggregate Sampling: all required QA tests will be performed on samples taken at the production plant at a minimum frequency of once every two calendar weeks, for any plant supplying material to a State contract. These test results will be recorded on one sample record which should be assigned to all contracts receiving material from the plant during the associated time period. Cognos Reports located in Public Folders > AASHTOWARE > Headquarters > Materials – Concrete and Cement should be used to track required testing along with District determined procedures and documentation. Regardless of the method, records must be generated and stored outlining successful completion of these requirements. This option shall not be used for material accepted on a Lot basis or for any material produced from a Central Mix plant supplying to a specific contract.

QC/QA Split samples – The District has the option to apply the same procedures and frequency stated above to QA split sample requirements relative to QC testing labs and the QA portion of the sample. The QA sample will be non-project specific and can be associated to any contract which received material represented by the split sample in the specific time period.

Ongoing adjustments to sampling and testing requirements on contracts associated to these samples will need to be made to remove unnecessary exceptions and requirements. A statement on the Materials Summary Cover letter documenting the use of this option should be made and should outline the changes in sample frequency requirements.

501.1.~~2~~3 Mix Design (Sec 501.3)

501.1.~~3~~4 Sampling (Sec 501.4)

501.1.~~4~~5 Consistency (Sec 501.5)

501.1.~~5~~6 Measurement of Material (Sec 501.6)

501.1.~~6~~7 Central and Truck Mixed Concrete (Sec 501.8)

501.1.~~7~~8 Volumetric Batched and Continuous Mixed Concrete (Sec 501.9)

501.1.~~7~~8.1 Calibration (Sec 501.9.3)

501.1.~~7~~8.2 Verification (Sec 501.9.4)

501.1.~~8~~9 Air-Entrained Concrete (Sec 501.10)

501.1.~~8~~9.1 Calibration

501.1.~~8~~9.2 Procedure for Determining Air Content of Concrete

501.1.~~9~~10 2AA Sheet For Concrete Pavement

501.1.~~9~~10.1 General

501.1.~~9~~10.2 Preparation

501.1.~~9~~10.3 Required Information

501.1.~~9~~10.4 Large Projects

LOAD RATING OF NON-STATE SYSTEM BRIDGES

INTRODUCTION

Any time a structure is built, rehabilitated, or reevaluated for any reason, inventory and operating ratings are required by the load factor method using the MS20 vehicle. Although the inventory and operating ratings are required to be done by the load factor method, postings may be established by either the working stress or load factor methods. Ratings shall be performed for the superstructure considering its current condition. However, ratings of the substructure are also required when in the judgment of the engineer its condition or unusual construction warrants lower ratings than allowed by the superstructure.

In Missouri, posting is established at the 68% stress level for the working stress method. For the load factor method, posting is established at 86% of the operating rating. Ratings for the H20 legal and 3S2 vehicles at the posting level are required in addition to the inventory and operating rating. These ratings are used to ensure that a bridge will support legal loads established for Missouri. Legal loads are defined as 23 tons for single unit vehicles and 40 tons for all others. Bridges located on low volume routes may be posted at a higher level as described below.

Inside commercial zones (established around cities with a population of 75,000 or more) state law also requires a limit of 22,400 pounds per axle. The MO5 vehicle is used to model this loading. Posting for this vehicle is established at no higher than the operating rating level and is used only when the legal limit at the posting level established for the remainder of the state has been exceeded.

RATING DEFINITIONS

INVENTORY RATING

The inventory rating level generally corresponds to the customary design level of stresses but reflects the existing bridge and material conditions with regard to deterioration and loss of section. Load ratings based on the inventory level allow comparisons with the capacity for new structures and therefore result in a live load which can safely utilize an existing structure for an indefinite period of time. The MS20 vehicle and the load factor method are required for the inventory rating.

OPERATING RATING

Load ratings based on the operating rating level generally describe the maximum permissible live load to which the structure may be subjected. Allowing unlimited numbers of vehicles to use the bridge at operating level may shorten the life of the bridge. The MS20 vehicle and the load factor method are required for the operating rating.

POSTING RATING LEVEL

Posting levels are established by each individual state and cannot exceed the operating rating. In Missouri posting is established at 68% of the allowable stress for the working stress method and at 86% of the operating rating for the load factor method except as follows:

1) Bridges located in commercial zones shall be posted at the operating rating. (Multiple lanes of traffic considered in the analysis for bridges carrying three lanes of traffic and ADT greater than 1800.)

2) Bridges where the controlling member is redundant with an average daily traffic of 1000 or less and no fatigue prone details may be posted at the operating rating value.

3) Bridges where the controlling member is redundant with an average daily traffic of 200 or less may be posted at the operating rating value.

The load factor <u>or</u> working stress method may be used to establish postings.

Postings are generally established based on one lane of traffic except where noted previously.

RATING METHODS

Allowable Stress

Load Factor

GENERAL RATING EQUATION

Working Stress

Rating (Tons) = $\dfrac{M_{cap} - M_{dl}}{M_{ll+i}}$ (Truck Weight - Tons)

M_{cap} = Moment Capacity [75% of yield stress - operating]
[68% of yield stress - posting]
[55% of yield stress - inventory]

M_{dl} = Actual Dead Load Moment

M_{ll+i} = Actual Live Load Plus Impact Moment

Load Factor

Rating (Tons) = $\dfrac{M_{cap} - 1.3\, M_{dl}}{A_1\, M_{ll+i}}$ (Truck Weight - Tons)

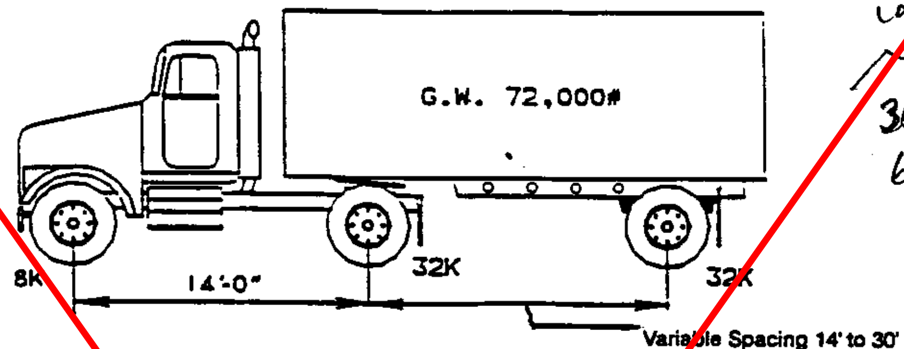
M_{cap} = Ultimate Moment Capacity
M_{dl} = Actual Dead Load Moment
A_1 = Load factor to be applied to live load plus impact
2.17 Inventory Rating → 60% operating
1.3 Operating Rating

Posting Rating = .86 (Operating Rating)

RATING VEHICLE

Ratings are required at the inventory and operating levels by the load factor method on each bridge for the following vehicle.

LOAD FACTOR
36T INVENTORY
60T operating



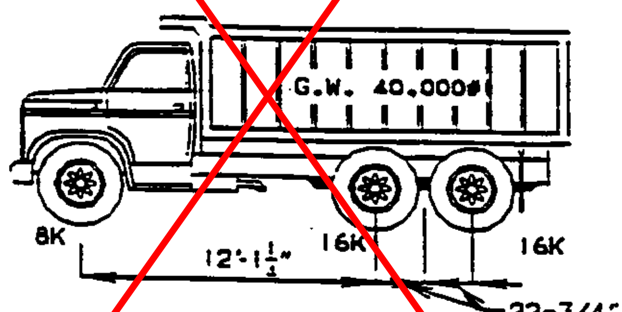
(HS20 Truck)

NOTE: To convert to the MS loading, multiply the HS20 vehicle and axle weights by 0.9.

See LPA Manual 3/23/2000
IX-3 Item 3. SI&A Report

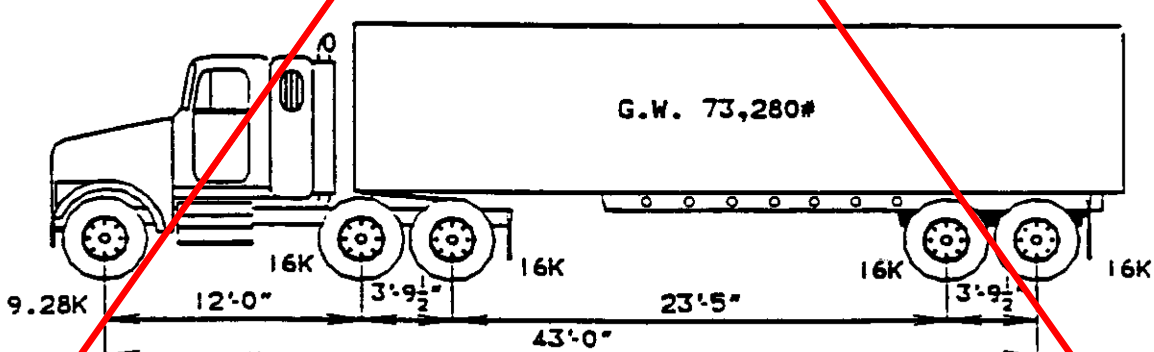
POSTING VEHICLES

Each bridge ~~designed below the HS20 level~~ should be checked to ensure proper posting. The following vehicles are established for this purpose. The H20 legal vehicle is used to model the load for single unit vehicles. The 3S2 vehicle is used as a model for all other vehicles. The MO5 vehicle is used to model the commercial zone loadings.



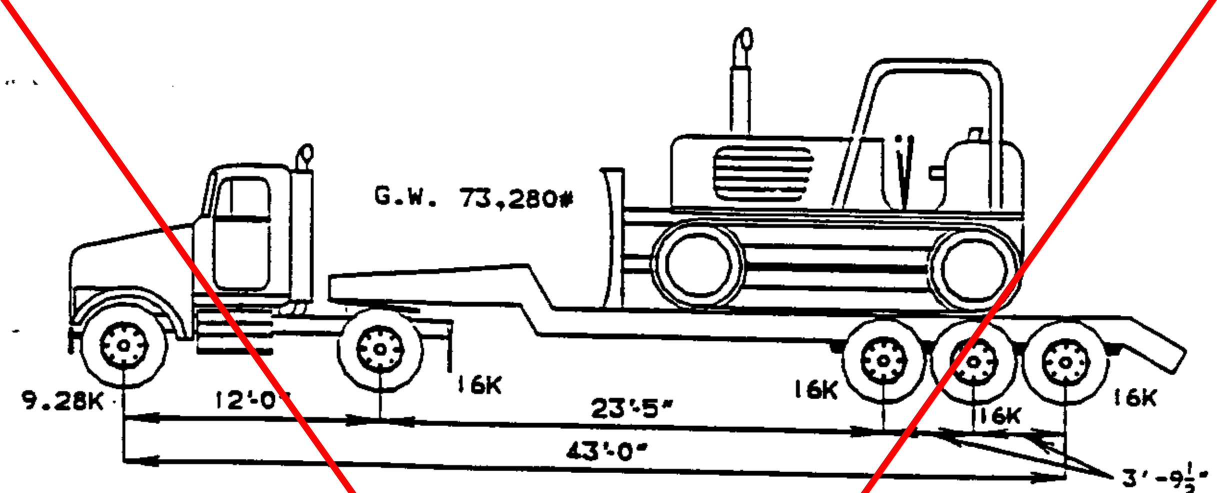
(H20 Legal Truck) (3 axle)

Single Unit Vehicle (Legal Limit = 23 Tons)



(3S2 Truck)

All Other Vehicles (Legal Limit = 40 Tons)



(MO5 Truck)

Commercial Zone Vehicle (Limit = 70 Tons)

22.4
4
89.6

LIVE LOAD DISTRIBUTION FACTORS

Live load distribution factors in accordance with AASHTO's Standard Specifications for Highway Bridges, except as follows:

A.) The distribution factor for exterior steel stringers supporting concrete floors shall be determined by assuming the flooring to act as a simple span between stringers or beams when the spacing from the adjacent interior girders to the face of rail or edge of curb is less than 5'-6" and the overhang is less than 18". Also, this method of distribution may be used for any girder spacing when there is no overhang. The first wheel load shall be placed no farther than 2'-0" from the face of rail or roadway face of curb.

B.) The live load distribution factor for a one-lane loading for slab-type structures may be calculated assuming the distribution of two wheel loads over the roadway width not to exceed 24 feet.

LOAD TESTING

Load testing of reinforced concrete bridges where the details of the reinforcement are unknown and an accurate loading history is not available will be permitted to establish load capacities. Allowable postings will be established at 75% of the proof load vehicle. The proof load vehicle shall be a single unit, 3-axle vehicle for short span bridges.

Load tests shall be performed by registered professional engineers. Load test reports shall include a description of how the test was performed, a summary of the gross weights, and axle weights and axle spacings of the vehicle used and the deflection under load.

POSTING CATEGORIES

*	S-CD	Bridge should be closed and barricaded to prevent use by all traffic.
	S-1	No posting.
*	S-3	Actual load posting required.
*	S-C3	Commercial zone posting (40 tons or greater).
	S-4	Traffic must use center line of bridge.
	S-5	Center line of bridge and trucks over ______ tons 15 mph on bridge.
	S-6	Center line of bridge and 6 axle trucks over ______ tons 15 mph on bridge.
	S-7	Trucks over ______ tons 15 mph on bridge.
	S-8	Trucks over ______ tons 15 mph on bridge except 6 axle trucks weight limit ______ tons.
	S-9	6 axle trucks over ______ tons 15 mph on bridge.
	S-10	6 axle trucks weight limit ______ tons.
	S-11	Trucks over ______ tons 15 mph on bridge except trucks weight limit ______ tons.
	S-12	Center line of bridge and trucks over ______ tons 15 mph on bridge except trucks weight limit ______ tons.
	S-13	Center line of bridge and truck weight limit ______ tons, two-way traffic.
	S-14	Truck weight limit ______ tons except single unit triple rear axle truck (MO-4) over ______ tons 15 mph on bridge.
	S-15	Truck weight limit ______ tons except single unit tandem rear axle truck (H-20) ______ tons weight limit. (May be used in a commercial zone.)
	S-16	Trucks over ______ tons 15 mph on bridge except single unit trucks (H-20) weight limit ______ tons and all other trucks weight limit ______ tons.
	S-17	Center line of bridge and trucks over ______ tons 15 mph on bridge except single unit trucks (H-20) weight limit ______ tons and all other trucks weight limit ______ tons.
	S-18	Single unit trucks over ______ tons 15 mph on bridge and all other trucks over ______ tons 15 mph on bridge.
*	S-19	Weight limit ______ tons at 15 mph on bridge. (For off-system use)
*	S-20	Center line of bridge and weight limit ______ tons at 15 mph on bridge. (For off-system use)
*	S-21	Center line of bridge and weight limit ______ tons. (For off-system use)
*	S-22	Speed limit 15 mph on bridge. (For off-system use)

* **Typical non-state posting categories.**

ACTUAL POSTING

Following is an explanation of coding for the computerized off-system inspection report:

Trucks Over ________ Tons (Lower Weight Limit) (2 digits)

Special Limit ________
Tons (Intermediate Weight Limit) or
Center line and speed limit = CS or
Speed Limit = SL or
Center line of bridge = CL

Weight Limit ________ Tons (Overall Weight Limit) (2 Digits)

Posting Category	Trucks Over	Special Limit	Weight Limit
* S-3			XX
* S-C3			XX
S-4		CL	
S-5	XX	CS	
S-6	XX	CS	
S-7	XX	SL	
S-8	XX	SL	XX
S-9	XX	SL	
S-10			XX
S-11	XX	SL	XX
S-12	XX	CS	XX
S-13		CL	XX
S-14		**XX/SL	XX
S-15		XX	XX
S-16	XX	XX	XX
S-17	XX	**CL/XX	XX
S-18	XX	**XX/SL	
* S-19		SL	XX
* S-20		CS	XX
* S-21		CL	XX
* S-22		SL	

* Typical Off-System Postings
** Input tonnage only; CL or SL is understood

ALLOWABLE MAXIMUM UNIT STRESSES

STRUCTURAL STEEL:

The allowable unit stresses used for determining safe load capacity of non-specification metals shall be obtained from the table. In order to use allowable stresses above the default value, it will be necessary to provide justification along with calculations. Acceptable justification includes coupon tests, mill test reports, or plans.

DATE BUILT	TYPE STEEL	YIELD POINT Fy(psi)	TYPE OF RATING (Working Stress Method)		
			INVENTORY 0.55 Fy(psi)	POSTING 0.68 Fy(psi)	OPERATING 0.75Fy(psi)
Prior To 1905	–	26,000	14,300	17,680	19,500
Default Value 1905-1936	–	30,000	16,500	20,400	22,500
1937-1962	A7	33,000	18,150	22,440	24,750
1963 on	A36	36,000	19,800	24,480	27,000
1954-1962	A373	32,000	17,600	21,760	24,000
1941 on	A242	42,000	23,100	28,560	31,500
1959 on	A440	46,000	25,300	31,280	34,500
1960 on	A441	50,000	27,500	34,000	37,500
		40,000	22,000	27,200	30,000
1941-1960	A8 (Nick)	55,000	30,250	37,400	41,250
1941-1960	A94 (Sil)	45,000	24,750	30,600	33,750
1966 on	A572	42,000	23,100	28,560	31,500
		45,000	24,750	30,600	33,750
		50,000	27,500	34,000	37,500
		55,000	30,250	37,400	41,250
		60,000	33,000	40,800	45,000
		65,000	35,750	44,200	48,750
1966 on	A588	42,000	23,100	28,560	31,500
		46,000	25,300	31,280	34,500
		50,000	27,500	34,000	37,500
1966 on	A514	90,000	49,500	61,200	67,500
		100,000	55,000	68,000	75,000

COUPON TESTING:

When non-specification metals are encountered, coupon testing may be used to determine yield characteristics. The nominal yield value should be substituted in the strength formulas and is typically taken as the mean test value minus 1.65 standard deviations. A coupon test is required on each girder in a span.

Sample Standard Deviation = $\sqrt{\dfrac{n\cdot\sum x^2-(\sum x)^2}{n(n-1)}}$

n = number of samples (include the mean value for small number of tests)
x = yield strength of sample

ALLOWABLE MAXIMUM UNIT STRESSES

WROUGHT IRON:

Allowable maximum unit stress in wrought iron for tension and bending .... 14,600 psi.

REINFORCING STEEL:

Known Grade Of New Steel	Yield Strength	Allowable Stresses: Inventory Rating	Posting Rating*	Operating Rating
40	40,000 psi	20,000 psi	25,200	28,000 psi
60	60,000 psi	24,000 psi	31,800	36,000 psi

* Allowable stress (posting) = Inventory Allowable Stress + .65 (Operating - Inventory Allowable Stress)

When the condition of the steel is unknown, the unit stresses in tension will be as follows:

Inventory Rating.. = 18,000 psi
Posting & Safe Load Rating .... = 22,550 psi
Operating Rating.. = 25,000 psi

The Fy for the above reinforcement is assumed to be 33,000 psi.

Default values are to be used in all cases unless the age of material is substantiated by mill test, bill of material, etc.

CONCRETE:

The value of "n" shall be varied approximately according to the following table:

			Default
f'c = 2,000-2,400	n	=	15
f'c = 2,500-3,000	n	=	12
f'c = 3,001-3,900	n	=	10
f'c = 4,000-4,900	n	=	8
f'c = 5,000 or more	n	=	6

Compression due to bending when the strength of concrete is unknown:

Inventory Rating	fc =	945 psi
Posting or safe load rating	fc =	1,175 psi
Operating Rating	fc =	1,300 psi

When the strength of the concrete is not known, the maximum f'c will be taken as $\frac{945}{.4} = 2363$.

When contract plans built to Missouri Standard Specifications are available, use the following concrete compressive strengths:

f'c (as shown on contract plans) (psi)	Allowable Compressive Strength (p.s.i.)		
	Inventory	Posting	Operating
3500*	1400	1740	1925
4000**	1600	1990	2200
4500	1800	2240	2475
5000	2000	2490	2750

* Use if plans call for f'c = 3,500 or 4,000 psi and bridge is built prior to and including 1965.

** Use if plans call for f'c = 4000 psi and bridge built after 1965.

TIMBER:

Inventory Stress:	Allowable stress for stress grade lumber given in AASHTO Design Specifications.
Posting Stress:	Stress established at 65% between the inventory and operating stress.
Operating Stress:	1.33 times the inventory stress.

When the type of lumber is unknown, the following values shall be used:

Inventory Stress:	1200 psi
Posting Stress:	1460 psi
Operating:	1600 psi

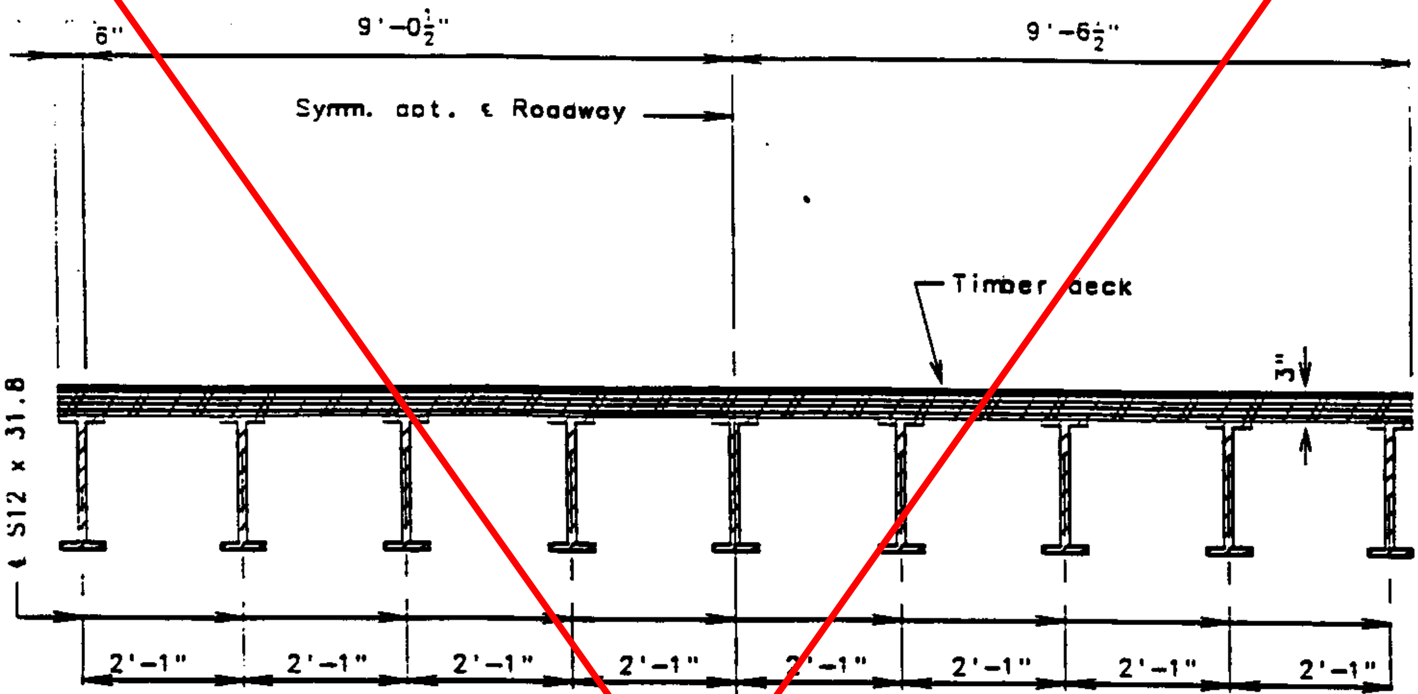
LIVE LOAD MOMENTS FOR SIMPLY SUPPORTED SPANS

Live Load Moments Including Impact
(Based on One Wheel Line) (Units K-ft.)

Span Length (ft.)	HS20	H20 (Legal)	3S2	MOS
5	26.0	13.0	12.7	13.0
6	31.2	15.6	15.6	15.6
7	36.4	18.2	17.9	18.0
8	41.6	21.9	21.9	22.9
9	46.8	27.1	27.1	29.7
10	52.0	32.3	32.3	37.5
11	57.2	37.5	37.5	45.0
12	62.4	42.7	42.7	53.1
13	67.6	47.9	47.9	61.5
14	72.8	53.1	53.1	69.3
15	78.0	58.3	58.3	76.5
16	83.2	63.5	63.5	85.3
17	88.4	68.7	68.7	93.1
18	93.6	73.9	73.9	99.9
19	98.8	79.1	79.1	107.0
20	104.0	84.3	84.3	115.5
21	109.2	89.5	89.5	123.9
22	114.4	94.7	94.7	130.7
23	119.6	99.9	99.9	137.9
24	125.3	105.1	105.1	145.7
25	134.8	111.3	110.3	154.1
26	144.4	117.8	116.7	162.9
27	154.1	124.3	123.6	170.1
28	163.8	130.8	130.4	175.8
29	173.6	137.3	137.3	185.0
30	183.4	143.8	144.1	193.5
31	193.2	150.3	151.0	198.8
32	203.1	156.8	157.9	210.1
33	213.1	163.3	164.7	213.8
34	223.3	169.8	171.6	225.7
35	234.8	176.3	178.4	229.5
36	246.3	182.8	185.3	240.3
37	257.8	189.3	192.1	246.4
38	269.3	195.8	199.0	253.8
39	280.9	202.3	205.3	264.3
40	292.4	208.8	211.6	268.5
41	303.9	215.3	218.0	277.5
42	315.3	221.7	224.2	287.6
43	326.4	227.9	230.2	291.6
44	337.5	234.1	236.2	298.6
45	348.6	240.2	242.2	309.1
46	359.6	246.4	248.2	315.5
47	370.6	252.5	254.2	319.7
48	381.6	258.6	260.1	328.0
49	392.6	264.7	266.1	338.1
50	403.6	270.8	272.1	345.2
51	414.6	276.9	278.0	349.7

Span Length (ft.)	HS20	H20 (Legal)	3S2	MO5
52	425.5	282.9	286.8	355.0
53	436.4	289.1	295.7	364.8
54	447.3	295.0	306.9	374.6
55	458.2	301.1	316.7	381.4
56	469.1	307.1	327.4	386.1
57	479.9	313.1	338.6	390.7
58	490.7	319.1	349.7	398.8
59	501.5	325.1	360.8	408.3
60	512.2	331.1	371.9	417.7
61	523.0	337.0	382.9	424.7
62	533.8	343.0	393.9	429.5
63	544.5	348.9	404.9	434.4
64	555.2	354.9	415.9	439.2
65	565.6	360.8	426.9	448.2
66	576.0	366.7	437.8	457.3
67	587.0	372.6	448.8	466.4
68	597.9	378.5	459.7	475.5
69	608.6	384.4	470.6	480.6
70	619.2	390.3	481.4	485.6
71	629.7	396.1	492.3	490.6
72	640.3	402.0	503.1	495.6
73	650.8	407.9	513.9	502.3
74	661.4	413.7	524.7	511.1
75	671.9	419.5	535.5	519.8
76	682.4	425.4	546.3	528.5
77	692.9	431.2	557.0	537.2
78	703.4	437.0	567.7	545.0
79	714.0	442.8	578.4	551.0
80	724.5	448.6	589.1	555.4
81	735.0	454.4	599.8	563.9
82	745.4	460.1	610.5	572.9
85	776.7	477.4	642.4	599.8
90	828.6	500.4	684.7	635.4
95	880.0	534.6	747.7	678.8
100	931.3	563.0	799.9	722.3

WORKING STRESS RATING EXAMPLE
(Simply Supported I-Beam With Timber Deck)



TYPICAL SECTION THRU DECK

Note: ∠ 2 x 2 provided at 3'-0" cts. for lateral support of compression flange.

Rating Criteria:

Rating Criteria:	Posting Rating at	68% of Allowable Stress
	Yield Strength =	30,000 psi (Provide documentation if assumed to be higher than this)

Lateral Support, Comp. Flange = 3' (No reduction in allowable stress is required

Timber Weight = 50 pcf
Steel Weight = 490 pcf
Span Length = 23 feet, Centerline - Centerline Bearings

STEEL I-BEAM RATING PROCEDURE

NOTE: ALL DIMENSIONS ARE INCHES UNLESS OTHERWISE NOTED

USE BACK OF THIS SHEET TO INDICATE DETERIORATION. [X]

PAGE NO. ______

DATE: January 3, 1994

COUNTY: Example

ROUTE: 999

BRIDGE NO.: 9990001

OVERLAY WEIGHT (PSF): ______

MAXIMUM LATERAL SUPPORT DIMENSION (TIMBER DECK): 3.0'

SPAN LENGTH(FT): 23.0

ROADWAY WIDTH(FT): 18.08

DECK MATERIAL: Timber

STRINGER SPACING(FT.): 2.0833

DECK THICKNESS(IN): 3

STRINGER DEPTH(IN): 12.0

WEB DEPTH (IN): --

WEB THICKNESS (IN): .35

FLANGE WIDTH(IN): 5.0

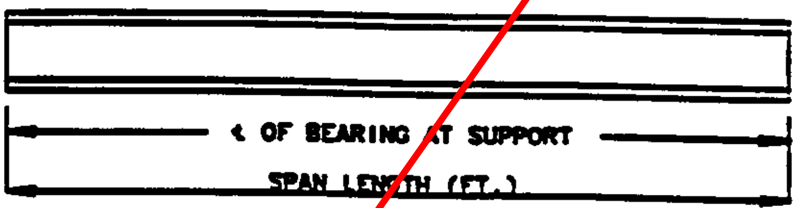
AVERAGE FLANGE THICKNESS(IN): ______

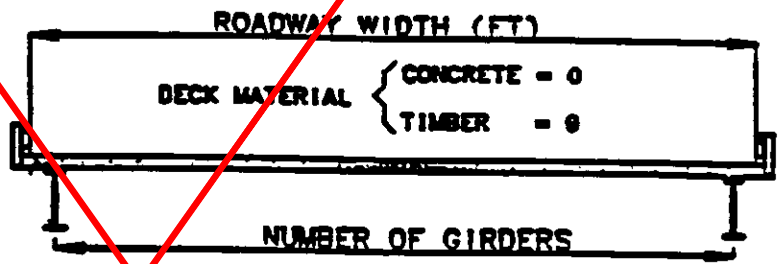
MAXIMUM FLANGE THICKNESS(IN): .74

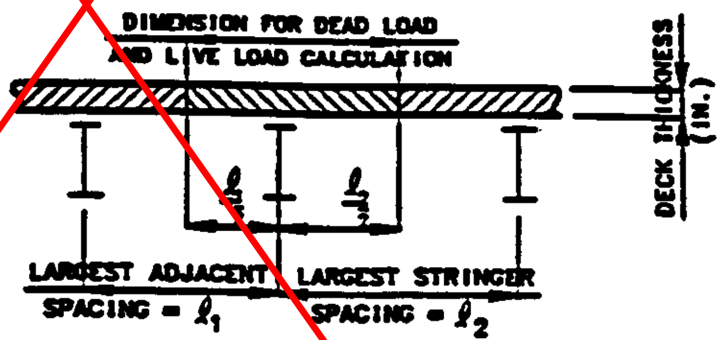
MINIMUM FLANGE THICKNESS(IN): .35

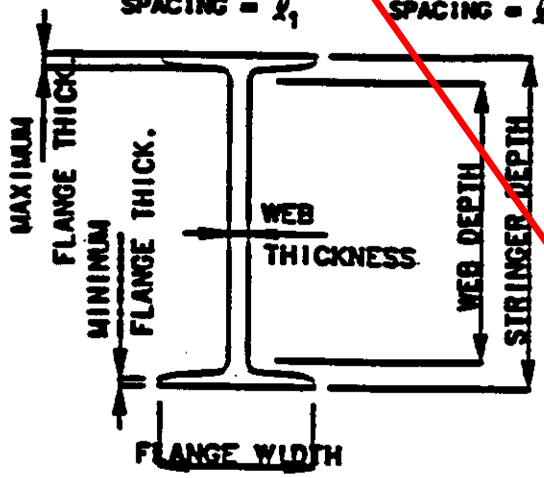
YIELD STRENGTH *: 30,000 psi

(DO NOT IDENTIFY BY AREA AND SECTION MODULUS)









* ATTACH DOCUMENTATION IF YIELD STRENGTH EXCEEDS 30,000PSI JUSTIFICATION INCLUDES MILL TEST REPORTS, COUPON TESTS, ECT.

REVISED: SEPT 1993

STEEL I-BEAM RATING DETERIORATION

Date January, 1994

County Example

Route 999

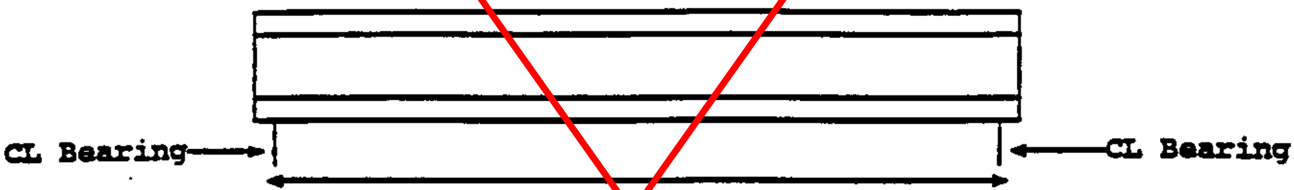
Bridge No. 9990001

OVERALL SECTION LOSS: 5 Percent

For localized deterioration, record the location of the hole or corroded area below.

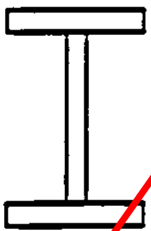
GENERAL ELEVATION:

Show dimension from CL bearing to bolt, hole, or heavily corroded area and show a sketch of the deterioration. Also show limits of cover plates.



TYPICAL SECTION

Show sketch of bolt, hole, or heavily corroded area and dimension from top or bottom of beam. Also show cover plate size and location.



DETERIORATION OF DECK:

Deck deterioration is not included in strength computations of Simple Steel I-Beams.

Dead Load Moment:

Stringer 31.8 lbs.
Deck: 2.083 x .25 x 50 = 26.0 lbs.
57.8 lbs.

Dead Load Moment $= \frac{wl^2}{8} = (.0578k/ft)(23)^2 (1/8)$
$= 3.8\ k'$

Live Load Distribution Factors:

One Lane: LLDF = $\frac{\text{Stringer Spacing}}{4.00} = \frac{2.083}{4.00}$ = .521 wheel lines

Check of distribution factor to exterior girder by assuming simply supported beam and 2.0' to wheel line load from inside edge of barrier curb or face of rail shows that it does not control.

Live Load Moments:

Note: Inventory and operating ratings are required to be done by the load factor method.

H20 Legal Vehicle (One Lane):(99.9k')(.521) = 52.0k'

3S2 Vehicle (One Lane):(99.9k')(.521) = 52.0k'

Moment Capacity:

Capacity @ 68% = (36.0 in³)(.95)[includes 5% deterioration](1/12)(20.4ksi) = 58.1K'

$$\text{Rating} = \frac{\text{Moment Capacity - Dead Load Moment}}{\text{Actual Live Load Moment Plus Impact}} \text{ (Truck Weight)}$$

$$\text{Posting (H20 Legal)} = \frac{58.1 - 3.8}{52.0} \text{ (20 Tons)} = 20.9^{T}$$

$$\text{(3S2)} = \frac{58.1 - 3.8}{52.0} \text{ (36.64 Tons)} = 38.3^{T}$$

Rating Summary

Posting: Category S-3: 19 Tons

or

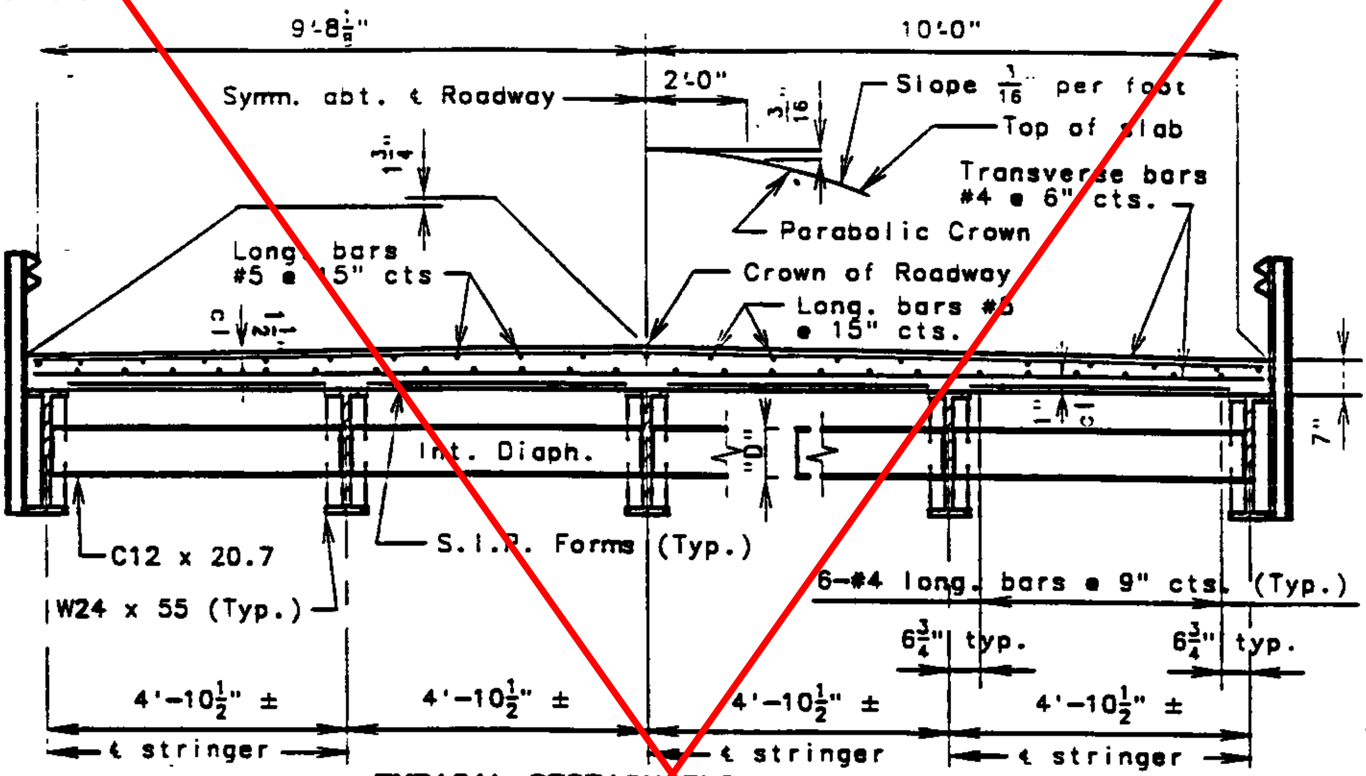
Category S-15: Single Unit 21 Tons; Others 38 Tons

or

Category S-7: Trucks over 21 Tons 15 MPH on bridge

NOTE: Inventory and operating ratings shall be done by the load factor method and are not illustrated here. Postings may be performed by the working stress method.

WORKING STRESS RATING EXAMPLE
(Simply Supported I-Beam with Non-Composite Concrete Deck)



TYPICAL SECTION THRU DECK

Rating Criteria:	Posting Rating at 68% of allowable stress		
	Yield Strength	36,000 psi	(Appropriate documentation provided)
	Concrete Weight	150 pcf	
	Steel Weight	490 pcf	
	Non Composite Deck		
	Span Length =	40 feet, Centerline - Centerline Bearings	

Dead Load Moment

Stringer — 55 lbs./ft.
Deck 4.875 x .66' x 150 pcf — 483 lbs./ft.
538 lbs./ft. of stringer

Dead Load Moment $= \frac{wl^2}{8} = (.538\ k/ft.)(40)^2(1/8) = 107.6k'$

Live Load Distribution Factors

One Lane LLDF $= \frac{\text{Stringer Spacing}}{7.0} = \frac{4.875}{7.0} = .696$ wheel line

Ext. Girder LLDF $= \frac{.2917 + 4.875 - 2.0}{4.875} = .650$ (Will not control)

Live Load Moments

Note: Inventory and operating ratings are required to be done by the load factor method.

H20 Legal Vehicle: (One Lane): (208.8k')(.696) = 145.3k'

3S2 Vehicle: (One Lane): (211.6k')(.696) = 147.3k'

Moment Cpacity

Capacity @ 68% = (114 in.^{3})(24.48ksi)(1/12) = 232.6k'

Rating $= \frac{\text{Moment Capacity - Dead Load Moment}}{\text{Actual Live Load Moment Plus Impact}}$ (Truck Weight)

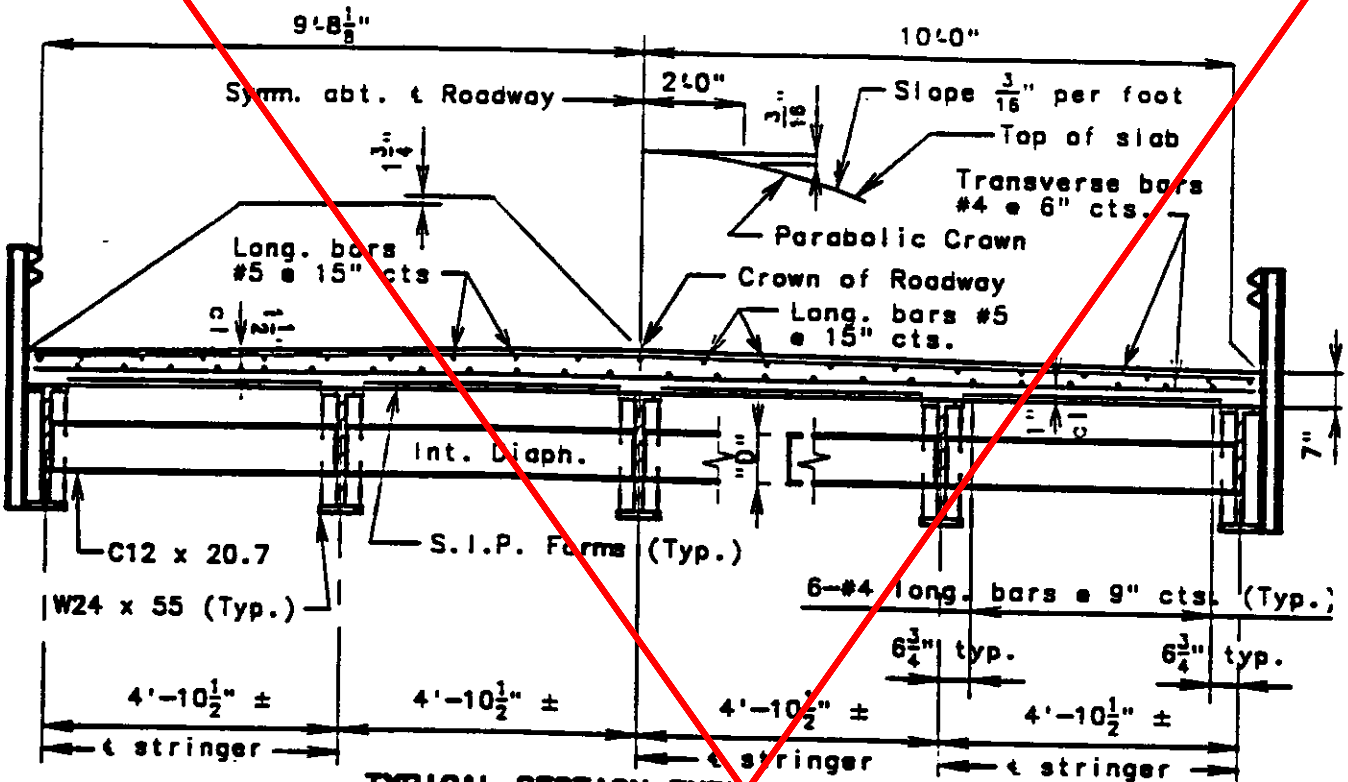
Posting (H20 Legal) $= \frac{232.6k' - 107.6k'}{145.3k'}$ (20 Tons)
= 17.2 Tons

(3S2) $= \frac{232.6k' - 107.6k'}{147.3k'}$ (36.64 Tons) = 31.1 Tons

Posting: Category S-3 17 Tons
or
Category S-15 17 Tons Single Unit
31 Tons Others

NOTE: Inventory and operating ratings shall be done by the load factor method and are not illustrated in this example. Postings may be done by the working stress method.

LOAD FACTOR RATING EXAMPLE
(Simply Supported I-Beam with Non-Composite Concrete Deck)



TYPICAL SECTION THRU DECK

Rating Criteria:	Posting Rating at	86% of Operating Rating
	Yield Strength	36,000 psi (Appropriate documentation provided)
	Non Composite Deck	
	Concrete Weight	150 pcf
	Steel Weight	490 pcf
	Span Length = 40 feet, Centerline - Centerline Bearings	

Dead Load Moment

Stringer		55 lbs./ft.
Deck	4.875 x .66' x 150 pcf	483 lbs./ft.
		538 lbs./ft. of stringer

Dead Load Moment $= \frac{wl^2}{8} = (.538\ k/ft.)(40)^2(1/8) = 107.6k'$

Live Load Distribution Factors

Int. Stringer
Two Lane LLDF $= \frac{\text{Stringer Spacing}}{5.5} = \frac{4.875}{5.5} = .886$ wheel line

Int. Stringer
One Lane LLDF $= \frac{\text{Stringer Spacing}}{7.0} = \frac{4.875}{7.0} = .696$ wheel line

Ext. Stringer LLDF $= \frac{.2917 + 4.875 - 2.0}{4.875} = .650$ (Will not control)

Live Load Moments

HS20 Vehicle: (Two Lane) 292.4k' x .886 = 259.1k'
(One Lane) 292.4k' x .696 = 203.5k'

H20 Legal Vehicle: (One Lane): (208.8k')(.696) = 145.3k'

3S2 Vehicle: (One Lane): (211.6k')(.696) = 147.3k'

Moment Cpacity

AASHTO 10.48.2
Projecting Flange Element $b/t = \frac{3.31"}{.505"} = 6.55 < \frac{2200}{\sqrt{36,000}} = 11.6$ O.k.

Web Thickness $D_c/t_w = \frac{11.28"}{.395} = 28.56 < \frac{15,400}{\sqrt{36,000}} = 81.2$ O.k.

Sides of compression flange are not embedded in concrete. Section cannot be considered compact. Friction should be satisfactory to assume this section is braced non-compact.

$Mu = Fy\ S$

$Mu = (36ksi)(114\ in.^3)(1/12) = 342k'$

Operating Rating = (For HS20, One Lane) $\dfrac{342k' - 1.3(107.6k')}{(203.5)\ 1.3}$ $(36^T) = 27.5$ Tons

Inventory Rating = (For HS20, Two Lanes) $\dfrac{342k' - 1.3(107.6k')}{(259.1k')(2.17)}$ $(36^T) = 12.9$ Tons

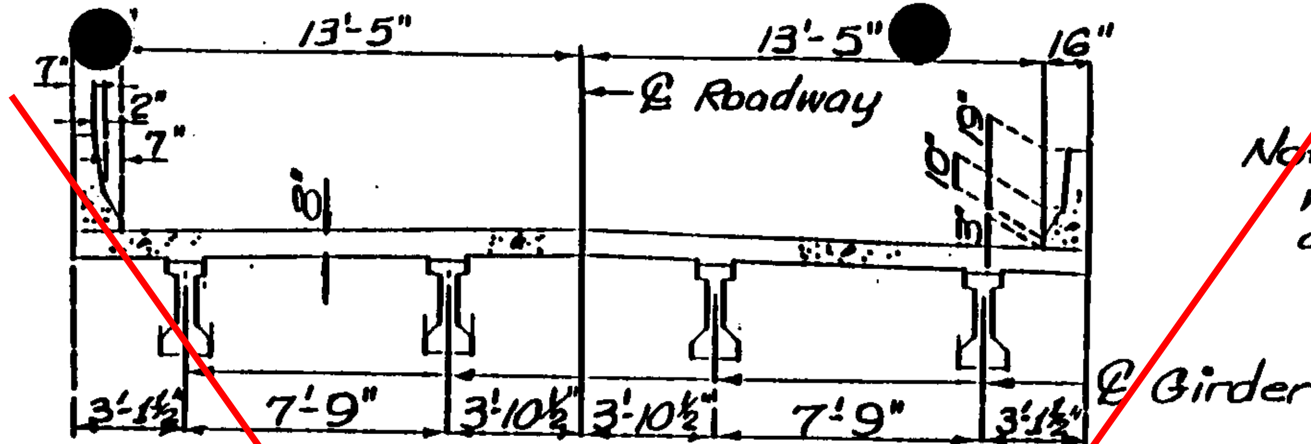
Posting Ratings For H20 Legal Vehicle = $\dfrac{342k' - 1.3(107.6k')}{(145.3k')(1.3)}$ $(20^T)(.86) = 18.4$ Tons

For 3S2 Vehicle = $\dfrac{342 - 1.3(107.6k')}{(147.3k')(1.3)}$ (36.64 Tons)(.86) = 33.3 Tons

Rating Summary

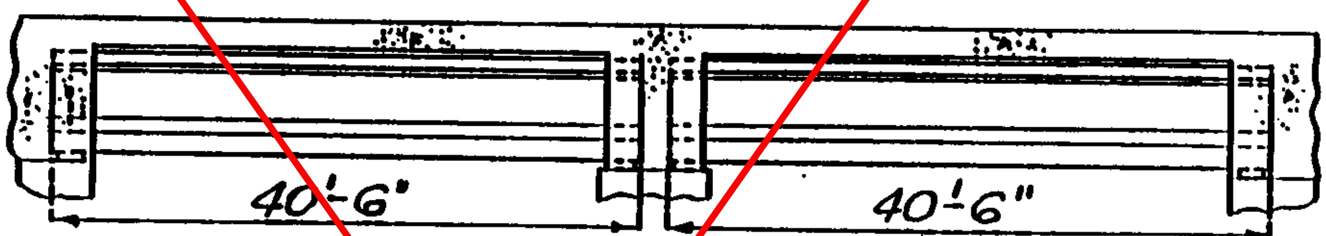
Item 64, Operating Rating: 27.5 Tons
Item 66, Inventory Rating: 12.9 Tons

Posting Category: S-3: 18 Tons
or
S-15: 18 Tons Single Unit
33 Tons Others
or
S-7: Trucks over 18 Tons 15 MPH on Bridge

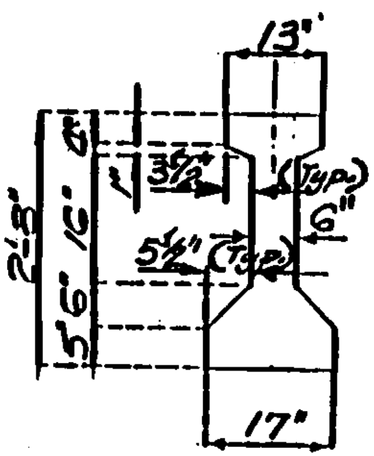


Note: 12#/sq. ft. future wearing surface is considered.

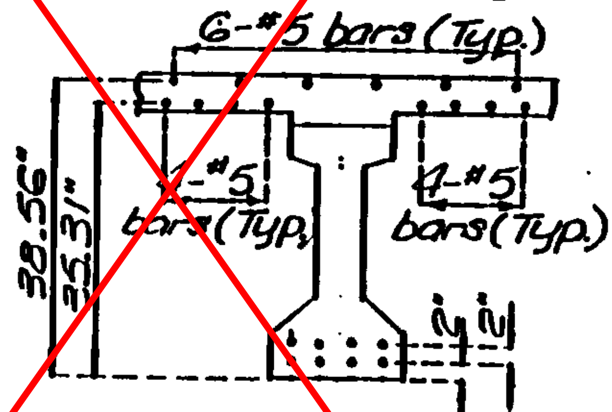
Section Thru Slab



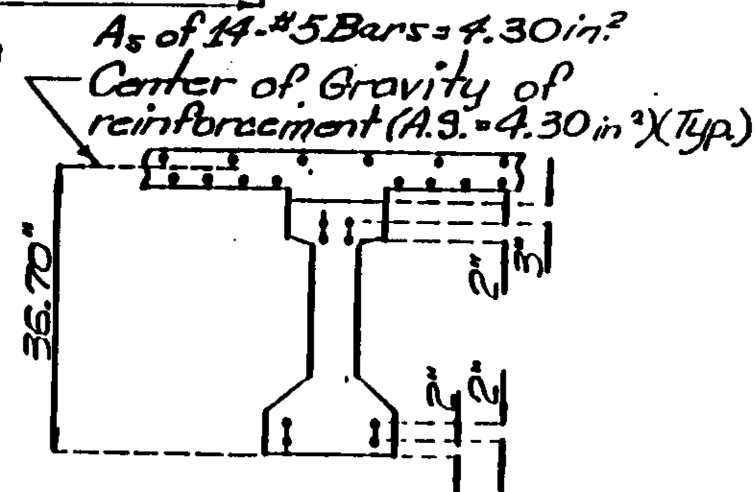
Part-Section Near Girders



Typical Section Thru Girder



Section at ℄ Girder



Elevation of End of Girder

DEFINITION OF TERMS

$f'c$	=	Compressive strength of concrete at point of consideration.
F_F	=	Force in prestressing strands after losses.
A_G	=	Gross area of section including transformed area of prestressing strands.
e_c	=	Distance from neutral axis to centroid of prestressing strands.
S_t^+	=	Section modulus, top fiber, positive bending.
S_t^-	=	Section modulus, top fiber, negative bending.
S_b^+	=	Section modulus, bottom fiber, positive bending.
S_b^-	=	Section modulus, bottom fiber, negative bending.
S_{tc}^+	=	Composite section modulus, top fiber, positive bending.
S_{tc}^-	=	Composite section modulus, top fiber, negative bending.
S_{bc}^+	=	Composite section modulus, bottom fiber, positive bending.
S_{bc}^-	=	Composite section modulus, bottom fiber, negative bending.
n	=	$\frac{E\ girder}{E\ slab}$ for composite action.

Use 3n to consider contribution of slab to section properties for "superimposed dead load."

Negative moment slab steel is neglected in the computation of section properties.

SECTION PROPERTIES (Near Mid Span)

Section Properties for Girder Only (For Dead Load):

A concrete = 311.5 in^2
AG = 317.6 in^2 (Includes consideration of 8 strands (.153 in^2)
Es = 28,000,000 psi
Ec = 57,000 $\sqrt{fc}$
P/S steel transformed using (n-1)

Iq = 34,815.4 in^4 — Bottom of Girder to Neutral Axis = 13.84"
Sb = 2515.7 in^3 — Top of Girder to Neutral Axis = 18.16"
St = 1917.0 in^3

Section Properties for Girder and Slab

$$n = \frac{E\ girder}{E\ slab} \text{ or } \frac{5000\ psi}{4000\ psi} = 1.25$$

Ac = 912.8 in.² Bottom of Girder to Neutral Axis = 29.19"
Ic = 152,760.9 in.³ Top of Girder to Neutral Axis = 2.81"
Sbc = 5,233.5 in.³ Top of Slab to Neutral Axis = 12.19"

Stc = 54,344.0 in.³

Section Properties (At Int. Bent)
Section Properties for Girder Only (for Dead Load)

A_G = 317.6 in.³ Bottom of Girder to Neutral Axis = 14.08"
I = 34,094.3 in.³
Sb = 2421.4 in.³ Top of Girder to Neutral Axis = 17.92"
St = 1902.6 in.³

Section Properties for Girder and Slab

Ac = 912.8 in.² Bottom of Girder to Neutral Axis = 29.27"
Ic = 149,700.9 in.³
Sbc = 5114.0 in.³ Top of Girder to Neutral Axis = 2.73"
Stc = 54,895.8 in.³ Top of Slab to Neutral Axis = 12.11"

PRESTRESSED STRANDS

F_F = Force in Stress Relieved Strands after losses = 183.4k
e_C = Neutral axis to centroid of strands
@ Midspan = 13.84" - 3" = 10.84"

ULTIMATE STRENGTH ANALYSIS @ MIDSPAN

$Mu = 0\,As^* fsu^* d\,[1 - 0.6p^* fsu^*/f'c]$
(See AASHTO 9.14 and 9.17.2)
0 = 1.0 for factory produced precast prestressed concrete
0 = 0.95 for cast-in-place concrete members

As^* = Area of prestressing steel = 8 x .153 = 1.224 in²
fsu^* = Average stress in prestressing steel at ultimate load AASHTO 9.17.4
$P^* = As^*/bd = \dfrac{(8)(.153\text{ in.}^2)}{(93)(38.38)} = .000343$

d = distance from extreme compressive fiber to centroid of the prestressing force or centroid to negative moment reinforcement @ intermediate bents = 32" + 1.38" + 8.0" - 3.0" = 38.38"

$fsu^* = fs'\,[1 - (\gamma^*/B1)(p^*\,fs/f'c)]$
$= (270\text{ Ksi})[1 - (.40/.80)\dfrac{(.000343)(270\text{ Ksi})}{(4.0\text{ Ksi})}$

$= 266.9$ Ksi

$Mu = (1.0)\,(1.224\text{ in.}^2)(266.9\text{ Ksi})\,\dfrac{(38.38")}{12\frac{\text{in.}}{\text{ft.}}}\,[1 - .6\,(.000343)(266.9\text{ Ksi})/4.0\text{ Ksi}]$
$= 1031.1$ K'

ACTUAL MOMENTS

At Mid Span

MDL = 257.1K' (Slab and Girder)
MDL = 26.1K' (superimposed dead load)

Live Load and Impact Moment for HS20 Vehicle	= 325.1 K'
Live Load and Impact Moment for MO5 Vehicle	= 308.6 K'
Live Load and Impact Moment for 3S2 Vehicle	= 238.9 K'
Live Load and Impact Moment for H20 Legal (3 axle) Vehicle	= 235.7 K'

At Intermediate Bent

MDL = 0.0 (Slab and Girder)
MDL = 50.7K' (Superimposed Dead Load)

Live Load and Impact Moment for HS20 Vehicle	= 207.3 K'
Live Load and Impact Moment for MO5 Vehicle	= 244.8 K'
Live Load and Impact Moment for 3S2 Vehicle	= 240.4 K'
Live Load and Impact Moment for H20 Legal (3 axle) Vehicle	= 129.9 K'

INVENTORY RATING NEAR MID-SPAN

Available Capacity for LL+I

<u>Top of Girder (Compression) (Elastic Analysis)</u>

$$M_{LL+I}\text{ (Available)} = \left[.4f'c - F_F/A_G + \frac{F_Fe_c}{S_t} - \frac{M_d}{S_t} - \frac{M_{SD}}{S_{tc}}\right]S_{tc}$$

$$= \left[(.4)(5\text{Ksi}) - \frac{183.4\text{K}}{311.5\text{in}^2} + \frac{183.4\text{K}(10.84")}{1917.1\text{ in}^3} - \frac{257.1\text{K}'(12)}{1917.1} - \frac{26.1\text{K}'(12)}{54{,}340.3\text{ in}^3}\right]\frac{(54{,}340.3)}{12} = 3772.9\text{K}'$$

<u>**Bottom of Girder (Tension) (Elastic Analysis)**</u>

$$M_{LL+I}\text{ (Available)} = \left[6\sqrt{f'c} + \frac{F_F}{A_{concrete}} + \frac{F_Fe_c}{S_b} - \frac{M_d}{S_b} - \frac{M_{sd}}{S_{bc}}\right]S_{bc}$$

$$= \left[\frac{6\sqrt{5000}}{1000\frac{\text{Lbs.}}{\text{K}}} + \frac{183.4\text{K}}{311.5\text{in.}^2} + \frac{(183.4\text{K})(10.84")}{2515.7\text{ in.}^3} - \frac{257.1\text{K}'(12)}{2515.7\text{ in.}^3} - \frac{26.1\text{K}'(12)}{5233.5\text{ in.}^3}\right]\frac{5233.5}{12} = 225.5\text{K}' \text{ Controls}$$

Ultimate Strength

$M_u = 1031.1\text{K}'$

$$M_{LL+I}\text{ (Available)} = (3/5)\ \frac{[1031.1\text{K}' - 257.1\text{K}' - 26.1\text{K}']}{1.3}$$

$$= 306\text{K}'$$

Inventory Rating @ Midspan = $\frac{225.5K'}{325.1K'}$ (36T) = 25.0 Tons

Weight of HS20 vehicle ↵

OPERATING RATING AT MIDSPAN

MLL + I (Available) = .77 (Mu) - Mdl - Msdl
= .77 (1031.1K') - 257.1K' - 26.1K'
= 510.7K'

Operating Rating = $\frac{510.7K'}{325.1K'}$ (36T) = 56.6 Tons

POSTING RATINGS AT MID-SPAN

Use 3S2 @ H20 Legal (3 axle) vehicles

Posting Rating H20 Legal (3 axle) Vehicle = $\frac{510.7}{235.7}$ (20T) (.86) = 37.3 Tons >23 Tons O.K.

Posting Rating (3S2) Vehicle = $\frac{510.7}{238.9}$ (36.64T) (.86) = 67.4 Tons >40 Tons O.K.

INVENTORY RATING AT INT. BENT

Analyze as a reinforced concrete section considering longitudinal slab steel as resisting superimposed dead load and live load moments.

Mu = As fy d[1 - .6 $\frac{(ePfy)}{f''c}$)]

p = As/bd = 4.30/(17")(36.70") = .00689

Mu = (4.30 in.^{2})(60Ksi)(36.70")[1 - .6 $\frac{(.00689)(60Ksi)}{5.0 Ksi}$)] 1/12

= 749.9K'

MLL+I(Available) = (3/5)[749.9 K'/1.3 - 50.7K'] = 315.7K'

Inventory Rating = $\frac{315.7K'}{207.3K'}$ (36 Tons) = 54.8 Tons

OPERATING RATING AT INT. BENT

Mu = 749.9K'

MLL+I (Available) = .77 Mu - M_{DL} - M_{SDL}
= .77 (749.9K') - 0K' - 50.7K'
= 526.7K'

Operating Rating = $\frac{526.7K'}{207.3K'}$ (36 Tons) = 91.5 Tons

POSTING RATINGS AT INT. BENTS

Posting Rating H20 Legal (3 axle) vehicle = $\frac{526.7K'}{129.9K'}(20^T)(.86)$ = 69.7 Tons > 23 Tons O.K.

Posting Rating 3S2 Vehicle = $\frac{526.7K'}{240.4K'}(36.64^T)(.86)$ = 69.0 Tons > 40 Tons O.K.

SUMMARY OF RATINGS

Inventory Rating = 25.0 Tons
Operating Rating = 56.6 Tons
No Posting Required

Note: An HS20 design should result in a minimum inventory rating of 36 Tons.

EPG 753.15 Load Rating Policy

753.15.1 Applicability of Load Rating Policy

EPG 753.15.1 provides policy direction for the performance of load rating analysis on bridges in Missouri. For locally owned bridges, this policy will apply to any structure that is part of the NBI and may be used on other bridges at the discretion of the engineer of record doing work for the local agency. For MoDOT owned bridges, this policy will apply to all structures that are part of the NBI and any other structure that has a load rating analysis completed because of load capacity concerns.

753.15.2 Definitions

AASHTO—American Association of State Highway and Transportation Officials.

AADT—Average annual daily traffic.

ADTT—Average daily truck traffic.

AISC—American Institute of Steel Construction.

Combination Vehicle—Commercial vehicle that consists of either a tractor unit or single unit vehicle in combination with one or more trailers. The most common example would be the standard tractor trailers traveling the highways. Another example would be a dump truck that is pulling a trailer.

Commercial Zone—Geographical area established by state law, where a commercial vehicle can legally travel with a maximum axle weight limit of 22,400 pounds with no maximum gross weight limit imposed. Commercial zones are subdivided into an inner area and an outer area. Within the inner area, vehicles with the additional axle weight allowance can travel on Interstate highways. Within the outer area, vehicles with the additional weight are not allowed to travel on Interstate highways.

Designated National Network—National network of state highways and interstate highways that meet the criteria defined in *23 CFR 658.0*.

FAST Act—Fixing America's Surface Transportation Act, which is the federal transportation bill that was passed by congress in December of 2015.

Federal Bridge Formula—Formula established in federal law that defines the maximum gross weight of a commercial vehicle on interstate highways, based on the number of axles, vehicle length, and spacings between axles.

Interstate Highway System—Network of highways that have controlled access and are a major part of the National Highway System.

Load Rating Engineer—Professional engineer overseeing the load rating and load posting of NBI bridges within Missouri. At MoDOT, this is primarily handled by the Bridge Rating and Inventory Engineer, but in some situations may be done by the Bridge Management Engineer.

Locally Owned—A roadway or structure that is owned by a city, county, or special road district within the State of Missouri.

Longer Combination Vehicle—Combination vehicles consisting of a tractor unit with two or more trailers that operate with a permit at a gross vehicle weight greater than 80,000 pounds. Maximum gross vehicle weights for these vehicles are defined in state law and will vary depending upon the border state the vehicle is entering from.

National Highway System—Network of highways that includes the interstate highway system and other highways and serves the major airports, ports, rail terminals, and truck terminals to allow for the efficient movement of goods.

NBI—National Bridge Inventory

NBIS—National Bridge Inspection Standards

NTI—National Tunnel Inventory

NTIS—National Tunnel Inspection Standards

OSOW—Abbreviation used in truck permitting, which stands for Over Size and/or Overweight.

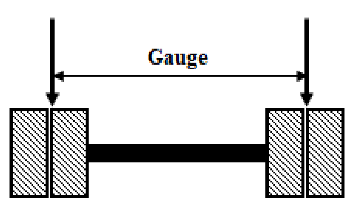
SHV—Special hauling vehicle. These are a subset of single unit vehicles that are four or more axles and take advantage of the allowances in the federal bridge formula. These vehicles can have legal gross weights that approach 70,000 pounds.

Single Unit Vehicle—Single Framed Commercial Vehicle without a Trailer. Common Examples would include Dump Trucks, Garbage Trucks, School Buses, and Concrete Trucks.

Trunion Axle—Specialized axle that may be used by companies that haul overweight loads with a permit. Typically, this axle type is only seen on truck configurations that have gross vehicles weights above 300,000 pounds. The axle will consist of two groups of two axles (4 tires total) separated by a variable space and then followed by another two groups of two axles (4 tires total). The gross weight of each axle line will typically be in the 30,000 to 60,000 pounds range. These vehicles are difficult to route on roadways around the state because of dimensional issues as well as bridge capacity issues. All though no trunnion axle limit is established in Missouri, history has shown that vehicles with these axles stand a better chance of getting a permit when the axle weights are kept below 40,000 pounds.

Missouri Vehicle Route Map—Map produced by the Motor Carrier Services section of MoDOT. The map displays commercial zone areas, the designated national network, and other items pertinent to the movement of oversize and overweight vehicles thru Missouri.

Wheel Gauge—Transverse Distance Between Centerline of Tires on an Axle



Typical Truck Axle

753.15.3 Reference Manuals and Reports

The following list of references includes items produced by national organizations as well as items produced by MoDOT. Information from some of these references was used as the basis for the development of this article. For items not specified in EPG 753.4, the Load Rating Engineer may consult these references for information or guidance on the best approach for addressing specific load rating issues.

Manual for Bridge Evaluation (MBE), 3rd Edition—AASHTO manual that provides national guidance on the different aspects of bridge inspection and bridge load rating evaluations.

Standard Specifications for Highway Bridges, 17th Edition—Older AASHTO design manual that includes design criteria for allowable stress design and load factor design.

LRFD Bridge Design Specifications, 9th Edition—Current AASHTO design manual for designing bridges using the Load and Resistance Factor Design methodology.

Iron and Steel Beams 1873-1952—Historical record produced by AISC that provides geometric properties of steel shapes produced prior to the standardization of steel mills. The record is out of print, but is available as a PDF download on the AISC website.

Manual of Steel Construction or Steel Construction Manual—National manual produced by AISC providing steel design requirements and information on the structural properties of various steel shapes. Multiple editions have been produced since the first edition around 1930.

Missouri Standard Plans for Highway Construction—Standard plans book that contains material, equipment, and construction requirements for items specified in the construction of Missouri's transportation infrastructure. The manual includes information on standard dimensions and reinforcement used in concrete box culverts. The manual has been in existence for many years and is periodically updated by MoDOT.

Load Posting Practice Evaluation, Statewide Normal Legal Loads—Report detailing the results of a statewide study of the load posting practice for normal legal loads. The study was completed by MoDOT, with a publication date of October 15, 2019.

Load Posting Practice Evaluation, Commercial Zone Legal Loads—Report detailing the results of a study of the load posting practice for vehicles that only operate within designated commercial zones in Missouri. The study was completed by MoDOT, with a publication date of December 10, 2019.

Load Posting Practice Evaluation, FAST Act Emergency Vehicles—Report detailing the results of a study of load posting needs for the emergency allowances included in the FAST Act. The study was completed by MoDOT, with a publication date of February 17, 2020.

Missouri OSOW Permit Regulations Book—Regulation book published by the Missouri Department of Transportation. The regulation book defines the requirements for movement of over dimension and overweight vehicles within Missouri.

Commercial Vehicle Regulations Handbook—Handbook produced by the Missouri State Highway Patrol that provides information on the requirements for commercial motor vehicles traveling in the State of Missouri.

Live Load Effects in Reinforced Concrete Box Culverts Under Soil Fill—Research report detailing the results of a study performed to measure actual live load stresses from commercial vehicles crossing reinforced concrete box culverts. This study was completed for MoDOT by the University of Missouri-Columbia, with the final report issued in February of 2014, and is the basis for MoDOT practice on the load rating analysis of culvert structures with fill.

753.15.4 Load Rating Software

The following software programs are utilized by MoDOT as part of the load rating evaluation process for bridges. This software may be supplemented with spreadsheets or hand calculations as part of the documentation and storage of the load rating information for bridges. The use of this software by local agencies and consultants is not mandatory unless specified by contract but is recommended for consistency when performing load rating analysis. Other software may be used for load rating analysis so long as rating result information and supporting calculations are provided in accordance with MoDOT's standard load rating results templates or other templates that may be designated for a specific project.

Transportation Management System (TMS)—This is a MoDOT developed software that is used to store all information related to the state transportation system in Missouri. One part of this system is for bridges, which includes NBI, inspection, and load rating information. This software is only available to MoDOT employees.

AASHTOWare Bridge Rating—Load Rating software that was developed and is maintained by AASHTO. The program was previously named Virtis.

Bridge Rating and Analysis of Structure Systems (BRASS)—Suite of structural analysis programs that includes the capability to perform load rating analysis on bridges. The software is owned and maintained by the Wyoming Department of Transportation.

LARS Bridge—Third party load rating software owned and maintained by Bentley Systems, a software development company.

LARS Complex Truss—Third party software owned and maintained by Bentley Systems. The software is utilized for load rating analysis on complex truss systems.

Bentley Superload—Third party software owned and maintained by Bentley Systems. The software is utilized for the issuance of oversize and overweight permits and includes a module that checks bridge capacities for the configurations that are being permitted.

753.15.5 Legal Loads Allowed Statewide

The legal loads allowed on the highways in a state are defined by federal law as well as state law. EPG 753.15.5 very generally defines what legal loads can travel on the highways within the state of Missouri.

753.15.5.1 Federal Law Allowances

Legal loads that can travel on the interstate highway system are defined by federal law using the federal bridge formula, which is shown below. In the formula, L is the length (in feet) between sets of axles (also called bridge), N is the number of axles, and W is the maximum gross weight (in pounds) allowed.

$$W = 500\left[\frac{LN}{N-1} + 12N + 36\right]$$

In general, single axles are limited to 20,000 pounds and tandem axles are limited to 34,000 pounds. All other axle combinations are required to meet the federal bridge formula. The maximum gross weight of any vehicle traveling on the interstate highway system is 80,000 pounds.

Special Allowances for Emergency Vehicles

The FAST Act federal transportation bill added to federal law special allowances for gross vehicle weight and axle weights on emergency vehicles. The allowances for fire trucks can be found in *23 U.S. Code § 127. Vehicle weight limitations—Interstate System*. EPG 753.15.5.1 allows for emergency vehicles to have a maximum gross weight up to 86,000 pounds, single steering axle weights up to 24,000 pounds, single drive axle weights up to 33,500 pounds, and tandem axle weights up to 62,000 pounds.

The emergency vehicle provisions in federal law only apply to the Interstate System of highways and reasonable access routes. Reasonable access routes generally are the ramps and overpasses that allow direct access to interstate highways. The allowances in federal law have been adopted in Missouri state law in *Section 304.180 RSMo.*

753.15.5.2 State Law Allowances

Section 304.180 RSMo defines the general length and weight regulations that apply to all commercial vehicles traveling on public highways in Missouri. This section of state law includes a legal vehicle weight table that is based on the federal bridge formula. In general, state law requires vehicles to meet the federal requirements.

Missouri law does allow for a small tolerance on axle weights whenever determining if a vehicle complies with the federal bridge formula. Essentially, this allows a configuration to exceed the maximum allowable gross weight for that vehicle, as defined with the federal bridge formula, by 2,000 pounds. The 2,000 pounds could be on a single axle, or on any of the internal axle combinations, but the total gross weight allowed can only be exceeded by this amount. This law essentially accounts for the small variations that may be seen on tandem axles and other axles because the load distribution is not perfectly equalized.

There are many exceptions in state law that allow vehicles to exceed the federal bridge formula requirements on non-interstate highways. These exceptions are highlighted below.

<u>Milk Trucks</u>
Special allowances for vehicles hauling milk are defined in state law, *Section 304.180 RSMo.* Milk trucks can have a maximum gross vehicle weight up to 85,500 pounds. This allowance applies to the total gross weight of the vehicle and not to the individual axle weight versus length combinations that exist on a vehicle.

<u>Local Log Trucks</u>
Single unit vehicles hauling logs are called Local Log Trucks. The definition and gross weight allowances for these vehicles are defined in *Section 301.010 RSMo* of state law. Local log trucks can be either a single unit vehicle or they can become a combination vehicle by pulling a "pup" trailer behind the main vehicle.

Since the weight of harvested trees can significantly vary, state law is written to confine these vehicles within a certain volume (25 cubic yards) of material for each tandem set of axles. Vehicles meeting these requirements can legally travel within a 100 mile radius of the forest site. When the vehicle is traveling outside of the 100 mile radius or is operating on the interstate highway system, they are required to meet the normal legal weight requirements in state and federal law.

The travel radius for these vehicles is adjusted periodically during the legislative session, so the assumption is made that these vehicles can essentially travel anywhere within Missouri. Currently, there are proposals to remove the 25 cubic yard criteria and replace it with the same weight limit criteria specified for local log tractors. The combination versions of this vehicle essentially match the local log tractor vehicles, in terms of length and the number of axles per the gross weight of the vehicle.

<u>Local Log Tractor</u>
State law defines a vehicle called a local log tractor. The definition and gross weight allowances for these vehicles are defined in *Section 301.010 RSMo* of state law. A local log tractor is a combination vehicle that is used for longer distance transport of logs.

From a dimensional standpoint and to take advantage of the weight allowances in state law, this configuration will resemble the normal flatbed semi configurations common on state highways. State law allows for these configurations to have axle weights up to 22,400 pounds on a single axle and 44,800 pounds on a tandem axle. A configuration that has a length and enough log bunks for the standard harvested log lengths can fully take advantage of the allowances in state law for these vehicles and have gross weights in the 100,000 pound range.

Refuse Trucks

Special allowances for vehicles hauling refuse are defined in state law, *Section 304.184 RSMo.* For refuse trucks, state law allows for a maximum single axle weight of 22,400 pounds and a maximum tandem axle weight of 44,800 pounds. This law applies to single unit refuse trucks that tend to operate within a small area and to combination configurations that are used to transport refuse longer distances. With the allowances in state law, combination configurations can have gross vehicle weights that approach 100,000 pounds and single unit configurations can have gross vehicle weights that approach 60,000 pounds.

Grain Trucks

Special allowances for vehicles hauling grain are defined in state law, *Section 304.180 RSMo.* These special weight provisions are only allowed during harvest season and apply to single unit and combination configurations. The term "harvest season" is not defined in state law, but is generally assumed to be year round with the types of farm products raised in Missouri. With these allowances, vehicles hauling grain can exceed the normal legal weight limits by ten percent, which would result in a maximum gross vehicle weight of 88,000 pounds for a combination configuration.

Livestock Trucks

Special allowances for vehicles hauling livestock are defined in state law, *Section 304.180 RSMo.* These special weight provisions are allowed statewide and apply to combination configurations that are transporting livestock. With these allowances, vehicles hauling livestock can have gross vehicle weights up to 85,500 pounds.

Longer Combination Vehicles

Federal law has special allowances for longer combination vehicles to travel on the interstate highway system. With these special allowances, these vehicles can have gross vehicle weights that exceed the normal 80,000 pound gross weight limit. These longer combination vehicles will be double trailer and triple trailer configurations that operate in states on the Western border of Missouri.

Missouri state law only addresses length requirements for longer combination vehicles, so the normal gross weights of these vehicles would violate state law. To facilitate the efficient movement of goods to trucking terminals on the Western side of Missouri, these vehicles are required to have an overweight permit. The requirements for these permits are defined in state regulations in *7 CSR 10-25.020 Oversize Overweight Permits*.

The overweight permit limits these configurations to the legal gross weight for the vehicle in the state that it originates from and only allows those configurations to travel a maximum of 20 miles into Missouri on the interstate system and state designated routes. Vehicles entering from these states can have maximum gross vehicles of 95,000 pounds for Nebraska, 120,000 pounds for Kansas, and 90,000 pounds for Oklahoma.

753.15.6 Legal Loads Allowed in Commercial Zones

There are five urban areas in the state that have unique weight regulations. These areas are called commercial zones, which are defined in state law in *Section 304.190 RSMo*. The five areas are St. Joseph, Kansas City, Columbia, St. Louis, and Springfield.

Commercial zones are divided into two areas. The inner area is tied to the corporate limits of cities meeting the requirements of state law, with the boundary of that area defined as two miles from the corporate limits. The outer area boundaries are based on a certain distance from the corporate limits in relation to the population of the urban area. The commercial zone boundaries can be found on the *Missouri Vehicle Route Map*, which is periodically published by the Motor Carrier Services Division at MoDOT.

Within a commercial zone area, vehicles weights are controlled by axle weights, with no overall gross weight limitation on a vehicle. The axle weight limit is 22,400 pounds and applies to all commercial vehicles operating within the area. Vehicles meeting these requirements can travel on all roadways (including interstate highways) within the inner area. When a vehicle is traveling in the outer area, vehicles are restricted from traveling on the interstate highway system.

Single Unit Vehicles

Within the commercial zone areas, industry has adapted to take advantage of the weight allowances for the different types of vehicles. This has primarily happened with the different variations of the AASHTO SHVs, which are basically the multi-axle dump trucks that are commonly used. Three, four, and five axle SHVs are common within the commercial zone areas. Six and seven axle SHVs are not as prevalent as the other ones, but are still found in significant numbers. Special hauling vehicles that take full advantage of the allowances in state law can be very heavy and have significant impacts on bridges. Gross vehicle weights in the 80,000 to 90,000 pound range are possible on SHVs traveling within the commercial zone areas.

Cranes are another single unit vehicle that is present within the commercial zone areas. When traveling outside of commercial zone areas, cranes typically require an overweight permit. Within the commercial zone areas, it is common for cranes to travel without an overweight permit because of the lack of a gross weight limit. This will happen when axle weights on the crane configuration are less than 22,400 pounds.

Combination Vehicles

For combination configurations, the primary concern in the commercial zone areas are the resource trailers that are used by the construction industry. These configurations are typically five, six, or seven axle configurations and are typically hauling sand or gravel. The configurations may consist of only standard axles, or they may consist of a combination of standard axles and pusher axles. Many of the resource trailers that are manufactured tend to be short, so these configurations can be short and heavy resulting in a significant loading to bridges. Gross vehicle weights in the 100,000 to 120,000 pound range are possible on the resource trailer configurations traveling within the commercial zone areas.

753.15.7 Loads Allowed by Overweight Permits (OSOW)

Commercial vehicles that have gross vehicles weights, axle weights, or dimensions that exceed the requirements in state law are required to have a permit to travel on state highways within Missouri. These permits are issued by the Motor Carriers Services Division within MoDOT and are referred to as OSOW permits. The requirements for issuance of these permits can be found in the *Missouri OSOW Permit Regulations Book*. MoDOT does not issue permits for travel on locally owned roadways.

Requests submitted for overweight permits are divided into two categories for processing. The two categories are Routine Overweight Permits and Superload Overweight Permits. The permits issued under these two categories are classified as single trip permits, with travel allowed on a designated route within a specified time period.

Routine Permits

Commercial vehicles applying for routine permits must meet specific dimensional and axle weight requirements in the regulation handbook and have a gross vehicle weight that is less than or equal to 160,000 pounds. Configurations that violate axle weight requirements for routine permits are pushed to the superload permit category.

When overweight permit traffic crosses bridges, the ability of a bridge to safely support the overweight configuration must be reviewed. For routine permits, this is done using an automated analysis/screening routine that is part of the software that the Motor Carrier Services Division uses for issuing permits.

Superload Permits

Commercial vehicles that have gross vehicle weights that exceed 160,000 pounds or violate any of the routine permit requirements are categorized as superload permits. No maximum gross weight limit exists on superload configurations. There is an axle weight limit of 22,400 pounds for normal standard axles used on most configurations. For configurations utilizing trunnion axles, no maximum weight limit exists for these axles. However, experience has shown that configurations that have trunnion axles with axle weights exceeding 40,000 pounds are very unlikely to be approved for a permit because of bridge capacity issues.

All superload movements that cross over bridges shall be reviewed and approved by Bridge Division prior to movement. Length and axle weights for superload permits are submitted to Bridge Division for review and analysis using structural engineering software. Analysis is done at the operating level using the Load Factor or Allowable Stress load rating methods.

Bridge Restrictions

Approval of overweight permits may be conditioned based on a vehicle following certain restrictions. The restrictions will include lane (i.e. centerline) and/or speed restrictions. Speed restrictions require the load to slow down to a crawl speed. These restrictions will be included in the permit that is issued to the trucking company.

When significant condition or emergency issues arise on a bridge, the bridge may be temporarily or permanently restricted from use by overweight permits. When these situations happen, Bridge Division will notify the Motor Carrier Services Division so that they can add the restriction into their software system. The restrictions will remain in place until they are lifted by Bridge Division.

Bridge Division may also flag certain structures for further review before approval of an overweight permit move. These flags are entered into TMS and are reviewed as part of the permit analysis. Depending upon the flag entered in the system, final approval of the permit from Bridge Division may require review by the Bridge Rating and Inventory Engineer or the Bridge Management Engineer.

753.15.8 Load Rating of Bridge Decks

EPG 753.15.8 applies to bridges that are constructed by the placement of primary members that have a deck constructed on top of the members at a later stage in the construction of the bridge. The primary members may be placed parallel to the centerline of roadway (stringers, girders) or they may be placed transverse to the centerline of roadway (floorbeams). The bridge deck may be constructed of any material but will typically be constructed with reinforced concrete or timber.

753.15.8.1 Reinforced Concrete

In general, load rating of concrete decks is not required. Concrete decks have performed very well over the years in Missouri, even when they are in poor or serious condition. Failures in concrete decks are typically localized and are the result of the deteriorated condition of the deck. Localized areas of deck failure can typically be repaired by removal and replacement of the bad concrete, which results in an extended service life for the bridge deck.

Inspectors should only be concerned about the load carrying ability of a concrete deck whenever there is widespread advanced deterioration and the deck is showing signs of widespread localized failures that may present a safety hazard to the traveling public. When this is encountered, the inspector should provide photos and other information to the load rating engineer and ask for a load rating review of the bridge based on the deck concerns.

Load posting of a bridge because of the condition of a concrete deck is rare, but when it happens it will typically be based on engineering judgment after a review of the submitted material by the load rating engineer as well as other engineers. For decks with widespread localized failures, consideration should be given to closure of the bridge. The decision to close a bridge because of the condition of a concrete deck should be made collaboratively with input from engineers within the Bridge Division as well as engineers and other appropriate staff from the District Office.

753.15.8.2 Timber

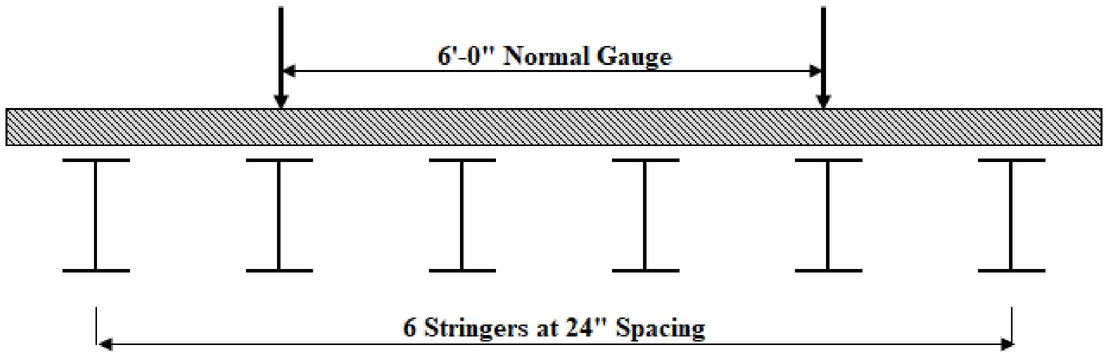
Timber decks are typically found on older bridges that have either steel or timber stringers for the main load carrying system. Timber decks are also commonly found on older truss bridges. Although bridges with timber decks are very uncommon on the state system, there are a small number that exist. For local system bridges, timber decks are more common and can be found on about 5% of the bridge inventory.

Timber deck construction in Missouri typically consists of three-inch thick timbers that are placed transversely on a bridge. Occasionally, bridges are found with timber decks made from railroad ties. Older timber decks were typically made with rough sawn white oak boards. For newer decks, the boards are typically made from treated pine or poplar boards that are commonly found at home improvement stores or lumber yards. Many of the timber decks will also have runners placed longitudinally over the top of the transverse boards. Two runners will be present and are installed on the bridge to place the wheel lines of a vehicle at a specific location on the bridge. Spacing of the runners will typically be around six feet (center to center), which matches the standard gauge of the commonly used vehicles on the roadway system. Most timber decks have out to out widths in the range of twelve feet, so the vehicle crossing the bridge will travel down the center of the deck.

Many bridges with a timber deck will already have a load posting because of the load capacity of the stringers. The load capacity of the timber deck starts to be concerning as the stringer spacing increases. In Missouri, historical performance of timber decks has shown that no concern about the timber deck capacity is warranted whenever the spacing between stringers is twenty-four inches or less. If the stringer spacing exceeds twenty-four inches, then the load rating engineer needs to take a closer look at the structure to determine if the load capacity of the deck is less than the load capacity of the stringers. Things that need to be considered are the condition of the timbers, location of the wheel lines on the deck, whether runners are present, and the spacing of the stringers where the wheel lines are likely to be traveling.

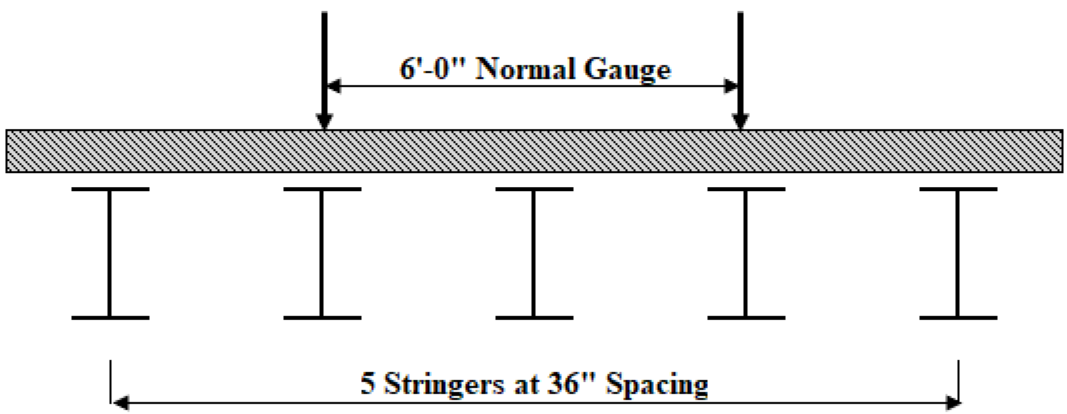
Some illustrative examples are shown below to provide some guidance on whether the load capacity of a timber deck should be concerning to the load rating engineer that is reviewing a bridge.

<u>Example A</u> shows a timber deck with six steel stringers spaced equally at 24 inches. This deck has good placement of the stringers and would not cause any concerns about the load capacity of the deck, even without runners, since the wheel lines would never be in a girder bay with spacing that exceeds 24 inches.



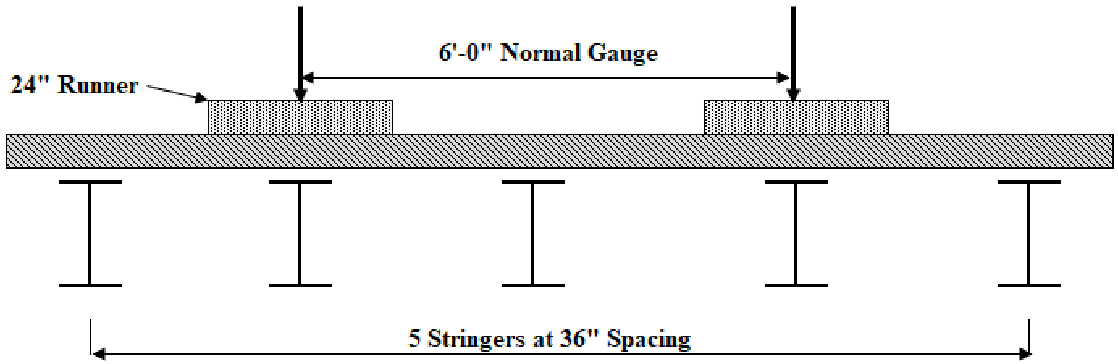
Timber Deck Example A

Example B shows a timber deck with five steel stringers spaced equally at 36 inches. This deck does not have good placement of the stringers. With the 36 inches spacing of the stringers and the lack of runners, there is a high probability that the wheel lines will get to the center of one of the bays. The load capacity of the timber deck would be a concern on this bridge. If the stringers have a high load capacity, then a low load posting could be warranted because of the timber deck. If the stringers have a low load capacity, then it might not be as concerning, but the capacity of the timber deck needs to be considered when making the final determination of the load posting level for the bridge.



Timber Deck Example B

Example C is basically the same as Example B, but runners have now been added to the timber deck. The addition of the runners forces the traffic to cross the bridge so that the wheel lines are close to the interior stringers. This layout does a good job of mitigating the major concerns about the capacity of the timber deck. However, there is still a small possibility that a vehicle could go off the runners. The engineer may want to consider that possibility as well as the traffic patterns on the bridge as part of a final determination of a load posting level for the bridge.



Timber Deck Example C

753.15.8.3 Other Materials

On local system bridges, bridge inspectors will occasionally find decks that are not constructed of timber or reinforced concrete. Examples that are known to exist in Missouri are steel plates, steel channels, un-filled corrugated forms, corrugated forms filled with compacted waste rock, and fiber reinforced polymer units. These situations should be individually reviewed by the load rating engineer to determine if there are any concerns about the ability of the deck to safely support live loads at a level that is equal to or greater than the safe load capacity of the primary members.

If a load capacity review is being performed on one of these deck types, things that should be considered include the field condition of the material, the amount of deflection in the deck from live load traffic, the spacing of the primary load carrying members, and the historical performance (when available) of this type of material. When the load rating engineer determines that a load posting based on the deck is warranted, this decision can be based on actual calculated capacities for the deck material, or it can be based on engineering judgment. If concerns about the deck capacity are used to determine the approved load posting for a structure, then that should be specified in the load posting correspondence when it is sent out to the District Office.

753.15.9 Load Rating of Substructure Units

In general, load rating analysis of the substructures on a bridge is not required. The designs on substructure units are very conservative and a failure of a substructure element from live load induced forces from a vehicle is extremely rare. Most substructure unit failures result from issues going on in the waterway from scour or excessive debris buildup. EPG 753.15.9.1 through EPG 753.15.9.7 discusses some situations where a load rating engineer may want to consider substructure capacity as part of the process of evaluating a bridge for load posting needs. If concerns about the capacity of a substructure unit control the level of load posting on a bridge, then the load rating engineer should include that in the load posting letter issued for the bridge.

753.15.9.1 Excessive Steel Pile Exposure

It is common to find excessive pile exposure on bridges as part of an inspection. The pile exposure typically has resulted from scour at the substructure units on a bridge. Excessive pile exposure can lead to concerns about the ability of the substructure unit to support normal legal loads. The amount of exposure is more concerning whenever a bridge is not currently load posted and less concerning as the load posting level gets more restrictive. Most bridges that have excessive pile exposure are on the local system and already have load posting levels that are very restrictive based on superstructure capacity.

Consideration of the live load capacity of piles with excessive unbraced lengths may be done using actual engineering calculations that are based on methods consistent with current or past design codes for bridges. The load rating engineer may also use engineering judgement based on experience when making determinations on the capacity of substructure units.

When reviewing excessive pile exposure, the engineer should review comments in inspection reports as well as current and historical photographs of the bridge. Things to consider include the current posting level on a bridge, the type and size of the piles, the number of piles, and the level of deterioration that is present. The placement of the pile along the beamcap should be reviewed as well since it may adversely affect the capacity of the beamcap. Also, the presence of bowing or buckling of the pile should be a big factor in the review because that is evidence that the piling is likely being stressed at levels that exceed the yield strength.

753.15.9.2 Excessive Concrete Pile Exposure

Reinforced concrete and prestressed concrete piles are found all around the state. They are typically found in situations where many piles exist on an individual substructure unit. Failure of concrete piles from deterioration or buckling is rare, so load posting restrictions based on deterioration of concrete piles will be uncommon.

The primary concern with concrete piles is the level of pile exposure. In many situations, concrete piles are used as friction piles, so the ability of the pile to support the loads from the superstructure is reduced as the level of pile exposure increases. If the piles are designed to primarily be bearing piles, then excessive levels of exposure may lead to concerns about the slenderness of the piles.

Experience has shown that the frictional capacity of the pile starts getting significantly impacted when the amount of pile remaining in the ground is less than fifteen feet and it becomes critical once the pile embedment remaining is ten feet or less. When exposure levels of that amount are found, the load rating engineer should review the capacity of the substructure unit to determine if a load posting is warranted.

753.15.9.3 Excessive Timber Pile Exposure

Timber piles are still commonly found in service around the state. Bridges with timber piles will typically have four or more piles on a substructure unit and the piles are typically considered friction piles. The primary load capacity concern on timber piles is advanced deterioration and excessive pile exposure.

Bridges that have timber pile that exhibit advanced deterioration, such as rotting or section loss, should be reviewed for load posting considerations when the inspector has concerns about the pile capacity in relation to the load posting level on the structure. Crushing of the pile is also a major concern because it indicates that the pile is failing. Since bridges with timber piles typically have a timber beamcap, the impact of deteriorated or failing piles on the live load capacity of the beamcap should be considered.

The level of exposure on timber piles has similar concerns as concrete piles. The guidance provided for concrete piles can be used in a similar manner for timber piles.

Most bridges with timber piles present were built prior to 1950. As a result, most of those structures were designed for lighter live loads and will already have a load posting because of the superstructure capacity. When the superstructure load posting values are low (10 tons or less), the load capacity of timber piles is typically not a big concern. The most concern exists on structures that have higher load posting values as well as bridges that do not require a load posting based on the superstructure analysis.

753.15.9.4 Piles with Advanced Deterioration

It is common to find piles on older structures that have deterioration present. In some cases, this deterioration could be considered as advanced. The following guidance can be used by inspectors to develop a level of concern about advanced deterioration on piling and whether a load rating review is warranted.

When the inspector has concerns about the capacity of a deteriorated piling, they should consider the impact that a failure of the pile would have on the load carrying capacity of the substructure unit as well as the stability of the structure. Things to consider are the current load posting level on the bridge, the number and spacing of the piling on the bridge, and the condition of the remaining piling. When major concerns exist, the inspector should flag the structure for a review by the load rating engineer to determine if load restrictions are needed.

Advanced deterioration is commonly found on steel piling at the groundline. Piles that are in reactive soils or in continual wet/dry cycles will develop section loss in the areas of the piling subjected to this environmental exposure. As the level of section loss increases, the concern about the pile capacity should increase.

The primary concern on timber piling is the loss of section in the pile, typically due to rot over an extended period. Section loss on timber piles is commonly found at the waterline or groundline level where the pile experiences wet/dry cycles over the life of the bridge. Deterioration is also commonly found at the top of the piles where it connects with the beamcap. Significant concern starts to develop once the section loss exceeds 50% of the cross sectional area of the pile and in situations where the interior of a pile is hollow, and the outer shell of the pile is crushing or bulging out.

Concrete piles typically have vertical reinforcement as well as lateral shear reinforcement (stirrups). The shear reinforcement is typically wrapped around the vertical reinforcement, providing confinement of that steel to increase the compressive capacity of the pile. Deterioration can happen at any point on the piling and typically starts on the shear reinforcement, since it is the closest to the outside surface of the pile. Section loss on stirrups that has advanced to the point that the stirrups are completely rusted through is a big concern. Severed stirrups reduce the confinement of the vertical steel and increase the potential for bulging of the vertical reinforcing steel from the compressive loadings in the pile.

753.15.9.5 Concrete Columns and Beamcaps

On older concrete structures, it is common to find different types of deterioration. This deterioration will be more prevalent on substructure units that have exposure to drainage and chlorides through expansion joints in the superstructure as well as spray from roadway traffic running under the bridge. Most substructure designs are conservative, but the level of deterioration can advance to a point where it should be considered as part of a load posting review on a bridge.

For beamcaps, the primary concern is for section loss in high flexural stress or high shear stress areas. For shear areas, the level of section loss needs to be determined, including whether the stirrups are completely rusted through. For flexural areas, the percentage of section loss in the main reinforcement needs to be captured. Existing or past design codes can be used to analyze the deterioration that is present and a load posting value can be determined based on the level of overstress that is estimated. Engineering judgement may also be used to make determinations on any load restrictions that are needed.

For columns, significant section loss to the main flexural reinforcing steel can be a major concern. Section loss on stirrups can also be concerning because of the loss of full confinement of the flexural reinforcement. Columns that are significantly compromised will typically exhibit symptoms such as crushing of the concrete, bulging of the vertical reinforcement, and wide-open cracks. Some older columns will have minimal flexural steel in them and in some cases may only have reinforcement in the corners of the column. As a result, section loss in the vertical steel on older columns should be closely reviewed by the load rating engineer when considering a load posting for a structure. Load posting recommendations can be based on load capacity calculations consistent with current or past design codes and/or engineering judgment.

753.15.9.6 Steel Columns and Beamcaps

Steel columns and beamcaps are found on a significant number of bridges in Missouri. Steel columns are most likely to be found on older locally owned bridges. Steel beamcaps can be found on older as well as newer bridges and are very common on the local system.

The primary deterioration modes that are found are section loss, buckling of flanges and webs, and bowing of members. For section loss, a calculation of the reduction in capacity can be determined and then used to come up with a percentage reduction in load capacity. Buckling of flanges and webs as well as bowing of members is an indication that the member has yielded in some manner and should be considered when reviewing the load posting needs on a bridge. Load posting recommendations can be based on load capacity calculations consistent with current or past design codes and/or engineering judgment.

753.15.9.7 Unusual Construction Types

In highly congested areas where multiple roadways cross, the substructure units may have features that are unusual when compared to the construction techniques used on most bridges. An example of this would be a substructure unit that consists of a long-span fracture critical beamcap that is supported on each end by columns. The designs in these situations are usually very conservative because of the complexity of the loading scenarios that the beamcap may encounter. When doing load posting reviews on bridges with unusual substructure units, the load rating engineer should consider the capacity of the substructure units as part of the review and decide whether the capacity of the substructure is likely to control over the capacity of the superstructure. When there is a concern about the live load capacity of a substructure unit, a load rating analysis of the substructure unit should be performed.

753.15.10 Load Rating of Bridges and Culverts

The AASHTO *MBE* provides national guidance for the load rating of bridges. The following sections provide guidance on various aspects of the load rating process used in Missouri. For items not specifically addressed in these sections, the *MBE* should be used for guidance by the load rating engineer.

753.15.10.1 Unit Weight of Materials

For load rating purposes, the unit weights shown in the following table should be used for calculating dead loads on bridges. For materials not shown below, the load rating engineer should consult the *MBE*.

Unit Weights for Load Rating Purposes

Material Type	Unit Weight [pcf]
Asphalt	145
Lightweight Concrete	115
Plain Concrete	145
Reinforced Concrete	150
Soil/Gravel	120
Steel	490
Water	62
Timber	50

753.15.10.2 Material Strengths for Load Rating

EPG 753.15.10.2 provides guidance on materials that are known to have been used on bridges in Missouri. The values shown for the different allowable stresses may differ slightly from what is found in the *MBE*. When differences are found between the various tables and the design plans, it is acceptable to use what is on the design plans. For materials not covered in EPG 753.15.10.2, the load rating engineer should consult the *MBE* for the appropriate material strength to use in a load rating.

753.15.10.2.1 Steel Strengths

Table 753.15.10.2.1.1 lists the steel strengths that were commonly used on many bridges within Missouri. The table also provides guidance on the appropriate steel strengths to use on a load rating when the type of steel is unknown.

Common Structural Steel Used in Missouri				Allowable Stress Levels [psi]		
Steel Type	Date Built Range	Ultimate Strength (Fu) [psi]	Yield Strength (Fy) [psi]	Inventory	Posting	Operating
Unknown	Prior to 1905	52,000	26,000	14,300	17,680	19,500
Unknown	1905 to 1936	60,000	30,000	16,500	20,400	22,500
Unknown	1937 to 1962	60,000	33,000	18,150	22,440	24,750
Unknown	1963 to Present	60,000	36,000	19,800	24,480	27,000
A7[a]	1937 to 1962	60,000	33,000	18,150	22,440	24,750
A36[b,1]	1963 to Present	60,000	36,000	19,800	24,480	27,000
A572[1]	1963 to Present	60,000	50,000	27,500	34,000	37,500
A588[1] (Weathering Steel)	Generally in 1990's +	70,000	50,000	27,500	34,000	37,500
A709 Grade 36[1]	Generally in 1990's +	60,000	36,000	19,800	24,480	27,000
A709 Grade 50[1]	Generally in 1990's +	65,000	50,000	27,500	34,000	37,500
A709 Grade 50W[1]	Generally in 1990's +	65,000	50,000	27,500	34,000	37,500

a--Plans will show allowable stress of 18,000 psi, b--Plans will show allowable stress of 20,000 psi, 1--Metric Equivalents: A36 (A709M Grade 250), A572 (A709 Grade 345), A588 (A709 Grade 345W).

Table 753.15.10.2.1.1

Table 753.15.10.2.1.2 provides a listing of various steels that were infrequently used on bridges within Missouri. These steel materials were typically used in special situations, such as long span plate girder bridges or on large through trusses.

Uncommon Structural Steel Used in Missouri				Allowable Stress Levels [psi]		
Steel Type	Date Built Range	Ultimate Strength (Fu) [psi]	Yield Strength (Fy) [psi]	Inventory	Posting	Operating
A94[b]	1920' thru 1950's	70,000	45,000	24,750	30,600	33,750
A94[b]	1920' thru 1950's	75,000	50,000	27,000	34,000	37,500
A242[a]	1950's	70,000	50,000	27,500	34,000	37,500
A373	1954 to 1962	60,000	32,000	17,600	21,760	24,000
A440[2]	1960's	63,000	42,000	23,100	28,560	31,500
A440[2]	1960's	67,000	46,000	25,300	31,280	34,500
A440[2]	1960's	70,000	50,000	27,500	34,000	37,500
A441[2]	1960's	60,000	40,000	22,000	27,200	30,000
A441[2]	1960's	63,000	42,000	23,100	28,560	31,500
A441[2]	1960's	67,000	46,000	25,300	31,280	34,500
A441[2]	1960's	70,000	50,000	27,500	34,000	37,500
A517[2]	1970's	115,000	100,000	55,000	68,000	75,000
A572[1]	Around 1969+	63,000	42,000	23,100	28,560	31,500
A572[1]	Around 1969+	60,000	45,000	24,750	30,600	33,750
A709 Grade 70W[a]	Generally in 1990's +	90,000	70,000	38,500	47,600	52,500

a--Limited use on long span plate girder bridges, b--Silicon steel used in some major river trusses, 1--Typically, A572 was Grade 50, but this lesser grade may be encountered on older bridges, 2--Limited use in some major river trusses.

Table 753.15.10.2.1.2

753.15.10.2.2 Reinforcing Steel Strengths

Reinforcing Steel Used in Missouri			Allowable Stress Levels [psi]		
Steel Type	Date Built Range	Yield Strength (Fy) [psi]	Inventory	Posting	Operating
Unknown	1920 thru 1940	33,000	16,000	22,550	25,000
Unknown	1930 thru 1953	33,000	18,000	22,550	25,000
Unknown	Prior to 1954	33,000	18,000	22,550	25,000
Unknown	1954 to Present	40,000	20,000	25,200	28,000
Grade 40	1954 to Present	40,000	20,000	25,200	28,000
Grade 60[a]	1960 to Present	60,000	24,000	31,800	36,000
Grade 75	2000's+	75,000	NA[b]	NA[b]	NA[b]

a--Metric equivalent is Grade 420.

b--Allowable Stress Load Ratings are not Allowed for Grade 75 Rebar.

Table 753.15.10.2.2

Table 753.15.10.2.2 lists the common strengths of reinforcing steel found on bridges within Missouri. The table also provides guidance on the appropriate steel strength to use based on the year built for bridges without plans.

Around the year 2000, fabricators in Missouri started widely using welded wire fabric for the reinforcement in precast culvert sections. This welded wire fabric is also used for the shear reinforcement on some prestressed concrete girders. The most common wire fabric used has a yield strength of 70 ksi and meets AASHTO M221 (ASTM A497) material specifications. The load rating engineer should consult the design plans to verify the appropriate strength for any welded wire fabric that is used on bridges and culverts. If the use of welded wire fabric was allowed as an option on design plans, the shop drawings (when available) from the girder manufacture should be reviewed to determine what was used for the structure.

753.15.10.2.3 Prestressing Strands

Prestressed girders have commonly been used on Missouri bridges since the 1970s. Table 753.15.10.2.3 lists the three types of prestressing strands that can be found on bridges within Missouri. Stress relieved strands were only used on some of the early prestressed girder designs. All current designs use low relaxation strands.

Typical Prestressing Strands Used in Missouri

Type	Diameter (in)	Tensile Strength (Fu) [psi]	Time Period in Use
7W-270 Low Relaxation[1]	0.50	270,000	1982 to Present
7W-270 Stress Relieved	0.50	270,000	1973 to 1984
7W-270 Low Relaxation[2]	0.60	270,000	2000 to Present

1--Metric Equivalent is 7W-1860, 12.7 mm diameter.

2--Metric Equivalent is 7W-1860, 15.2 mm diameter.

Table 753.15.10.2.3

753.15.10.2.4 Prestressed Concrete

Prestressed concrete bridges are the most common type of bridge currently being constructed in Missouri. The use of this structure type became common in the 1970s. The designer is concerned about the long-term stresses on concrete as well as the initial stresses on a girder when the strands are released at the manufacturing plant. These designs will specify a minimum compressive strength that is required before the strands can be released and a final minimum compressive strength that the girder must reach.

When reviewing plans for prestressed girders, the load rating engineer will find that the final compressive strengths used in Missouri will vary from 4,000 psi to 10,000 psi. There may be multiple instances of a specific final compressive strength found on design plans, with the only difference being the initial compressive strength that was specified for the girder design. As a result, the load rating engineer should consult the design plans for the appropriate concrete material properties to use during an analysis for the girders in each span of the structure.

Metric compressive strengths were used on plans for a brief period during the 1990s. The metric equivalents used were: 5,000 psi (35 MPa), 6,000 psi (42 MPa), 7,000 psi (50 MPa), and 10,000 psi (70 MPa).

753.15.10.2.5 Reinforced Concrete

Reinforced concrete bridges are very common on the local system and on the MoDOT system. Typically, many of the local system bridges will not have any design plans available. Table 753.15.10.2.5.1 provides some guidance on the appropriate compressive strength of concrete to utilize for bridges where no plans exist.

Reinforcing Concrete Used in Missouri--No Plans			Allowable Stress Levels [psi]		
Bridge Owner	Year Built Guidance	Compressive Strength (f 'c) [psi]	Inventory	Posting	Operating
Local System	<1960	2,500	1,000	1,240	1,375
Local System	1960 to Present	3,000	1,200	1,490	1,650
MoDOT System	<1950	2,500	1,000	1,240	1,375
MoDOT System	1950 to 1960	3,000	1,200	1,490	1,650
MoDOT System	1960 to Present	4,000	1,600	1,990	2,200

Table 753.15.10.2.5.1

Table 753.15.10.2.5.2 lists concrete strengths that may be found on existing bridge plans when they are reviewed. Many of the older bridge plans will show an allowable stress for the concrete instead of the compressive strength. The following guidance is provided for the load rating engineer to determine the appropriate compressive strength that was used on older bridges. Inventory stresses below 1,000 psi may be found on older plans, but they are typically assumed to have a compressive strength of at least 2,500 psi.

Reinforcing Concrete Used in Missouri			Allowable Stress Levels [psi]		
Comments	Year Built Guidance	Compressive Strength (f 'c) [psi]	Inventory	Posting	Operating
***	<1960	2,500	1,000	1,240	1,375
----	1950's	3,000	1,200	1,490	1,650
----	1950's	3,500	1,400	1,740	1,925
Very Commonly Used*	1960 to Present	4,000	1,600	1,990	2,200
Minimally Used	2010 to Present	4,500	1,800	2,240	2,475
Minimally Used	2000 to Present	5,000	2,000	2,490	2,750
Minimally Used	2000 to Present	5,500	2,200	2,735	3,025
Minimally Used	2000 to Present	6,000	2,400	2,985	3,300
Minimally Used	2000 to Present	6,500	2,600	3,230	3,575

*** Plans may show inventory stresses below 1,000 psi, but the values in this table may be used.

* Metric equivalent compressive strength is 28 MPa.

Table 753.15.10.2.5.2

When load rating a bridge, the engineer should review the condition of the structure to determine if any adjustments to the compressive strength might be warranted. For structures that are in poor condition and have extensive saturation and concrete deterioration present on the main load carrying members, it is recommended that the engineer consider lowering the compressive strength of the concrete used for the rating analysis. This may also be warranted on newer structures where the quality of the concrete is questionable.

Table 753.15.10.2.5.3 provides guidance on suggested modular ratios for different ranges of the concrete compressive strength. It is recommended that the load rating engineer follow this guidance when determining the section properties on reinforced concrete members.

Modular Ratio Table

f 'c Range [psi]	n
2,000 to 2,400	15
2,500 to 3,000	12
3,001 to 3,999	10
4,000 to 4,999	8
5,000 or higher	6

Table 753.15.10.2.5.3

753.15.10.2.6 Timber Strengths

Timber bridges are found on the local system and the MoDOT system. They are more common on the local system and include bridges with timber decks and timber girders. These structures are always older bridges that lack design plans, so the specific timber used for the bridge will typically not be known. Table 753.15.10.2.6 should be used for determining the appropriate allowable stresses whenever a load rating is performed on a timber bridge.

Timber Allowable Stresses

Type-Stress Level	Allowable Stress [psi]	Comment
Unknown-Inventory	1,200	----
Unknown-Posting	1,460	1.2167xInventory
Unkown-Operating	1,600	1.3333xInventory

Table 753.15.10.2.6

753.15.10.3 <u>Load Rating Methods</u>

The *MBE* defines three different methods for performing load ratings on bridges. The three methods are the Allowable Stress Method (ASR), the Load Factor Method (LFR), and the Load and Resistance Factor Rating Method (LRFR). The *MBE* also contains example bridges where load rating calculations for each one of these methods have been provided.

753.15.10.3.1 ASR and LFR

The Allowable Stress Method (ASR) is an older method that has been around since load ratings were started on bridges. Some people also refer to this method as the Working Stress Method. With this method, a rating factor is determined for a bridge based on the actual stresses from dead loads and live loads and a capacity that is based on a percentage of the yield strength of the material. Many of the older load ratings on bridges in Missouri were done using this method. This method is also still in use for timber and masonry structures.

The Load Factor Method (LFR) was created and put into use in the late 1980s. For this method, a rating factor is determined using factored dead loads, factored live loads, and a factored member capacity. For most bridges built in the last twenty five years, this is the primary method that is used for determining bridge capacities for posting and overweight permitting purposes.

For the ASR and LFR methods, AASHTO defines rating levels of Inventory and Operating for load capacity determinations on bridges. The Inventory level is equivalent to a design capacity of the bridge where stress levels from the loadings that are on a bridge are kept within the design limits. The Operating level allows for occasional loadings that cause higher stress levels than the inventory level and may have some minor adverse impacts on the bridge.

The basic rating equation for ASR and LFR is shown below. More detail on the calculation of individual items in the equation can be found in the *MBE*.

$$RF = \frac{C - A_1 D}{A_2 L(1 + I)}$$

RF = *Live load rating factor, which is converted to tons by multiplying by the gross weight of the vehicle being analyzed.*

C = *Nominal capacity of the member, determined based on the rating method. For ASR, calculations are typically done in terms of stresses. For LFR, calculations are done in terms of moments or shears.*

D = *Dead load effect on the member. For ASR and for serviceability checks in LFR, dead load stresses are calculated differently for composite versus non-composite loads.*

L = *Live load effect on the member.*

I = *Live load impact factor.*

A_1 = *Factor applied to dead loads.* $A_1 = 1$ *for ASR and* $A_1 = 1.3$ *for LFR.*

A_2 = *Factor applied to live loads.* $A_2 = 1$ *for ASR. For LFR,* $A_2 = 2.17$ *for the Inventory level and* $A_2 = 1.3$ *for the Operating level.*

States are free to make their own determinations on how to determine load posting levels for bridges analyzed with these two methods. Some states use the Inventory level to determine load posting needs for bridges while other states use the Operating level for determining load posting needs for bridges. Other states, including Missouri, use a level in between these two levels for load posting determinations.

Missouri uses a Posting level of 86% of the Operating level for determining if a bridge requires load posting based on LFR analysis. If ASR analysis is used, the posting level is determined using a member capacity determined at 68% of the yield strength of materials used in the construction of the bridge.

753.15.10.3.2 LRFR

The Load and Resistance Factor Rating Method (LRFR) is a newer load rating method that was introduced around the year 2000. The use of this method has become more widespread on newer bridges after FHWA mandated the use of the method for reporting of NBI load rating data on new bridges starting in 2010.

This method is similar to LFR in that it uses factored loads and a factored capacity to determine a rating factor. The difference for LRFR, is that the load factors and resistance factors have been statistically calibrated to achieve a consistent reliability across the bridge inventory.

The basic rating equation for LRFR is shown below. More detail on the calculation of individual items in the equation can be found in the *MBE*.

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{\gamma_{LL}(LL + IM)}$$

RF =   Live load rating factor. LRFR is generally reported in terms of a rating factor. For vehicle capacity (in tons), you would multiply the gross weight of the vehicle model times the rating factor.

C = *Capacity for limit state.*

$C = \varphi_c \varphi_s \varphi R_n$ *for the strength limit states.*

$\varphi_c \varphi_s \geq 0.85$ *lower limit on combined factors.*

$C = f_R$ *for the service limit states.*

f_R = *allowable stress from LRFD design code.*

R_n = *Nominal resistance based on inspection information.*

DC = *dead load effects from structural components and attachments.*

DW = *dead load effects from wearing surface and utilities.*

P = *permanent loads other than dead loads.*

LL = *live load effect.*

IM = *dynamic load allowance (i.e. impact).*

γ_{DC} = *LRFD load factor for structural components and attachments.*

γ_{DW} = *LRFD load factor for wearing surfaces and utilities.*

γ_P = *LRFD load factor for permanent loads other than dead loads = 1.0.*

γ_{LL} = *evaluation live load factor.*

φ_c = *condition factor.*

φ_s = *system factor.*

φ = *LRFD resistance factor.*

LRFR load rating has three different types of load ratings that will be performed on a bridge. The three types of load ratings are design load rating, legal load rating, and permit load rating. The live load factors used in the rating equation will vary depending upon the type of rating being performed.

A design load rating is used to evaluate a bridge in relation to current design criteria in the LRFD design specification and uses the HL93 design load as a rating vehicle. For a design load rating, an inventory level and operating level rating factor are calculated, which is similar to the other rating methods. Bridges with a design load rating factor that is greater than 1.0 are considered to have sufficient load capacity for the normal legal loads that are traveling on highways.

A legal load rating is used to evaluate a bridges capacity for the legal loads within a state. Per the *MBE*, this rating is only required when the design level rating results in a rating factor that is less than 1.0. This criteria assumes that the legal loads traveling within a state are similar to the legal load models that are included in the *MBE*. Many states have legal loads that are different than the models in the *MBE*, or they may have permitting procedures that allow for uncontrolled crossing of bridges by heavier loads. Because of these variations in different states, it is common for most states to go ahead and perform a legal load rating analysis on all structures using state specific vehicles to determine whether a load posting is needed on a structure.

Missouri currently does not utilize the LRFR method in determining the need for load posting on a structure. In 2021, MoDOT initiated a university research project to develop an LRFR posting methodology using the current load posting models used in Missouri. The research will also address other concerns that have been identified in relation to the LRFR methodology. The goal of the research project is to come up with a load posting methodology for LRFR that gives similar results to the LFR method.

A permit load rating is used to evaluate a bridges adequacy for the overweight vehicles that are traveling on the highways by an overweight permit. Overweight permits in Missouri are classified as Routine and Superload. Both types are single trip issued permits that have movement restricted to the routes designated on the permit.

753.15.10.4 Dynamic Load Allowances (Impact)

The consideration of dynamic load allowances (impact factor) is required for load rating analysis that are being performed on bridges in Missouri. The methodology for calculation of the impact factor should be consistent with the design code that corresponds with the rating method that is being used for analysis purposes.

In the past, Missouri has used speed reduced postings to justify elimination of the impact factor in load rating calculations. Starting in 2021, Missouri has moved away from this practice for normal load posting evaluations on bridges.

Overweight permit practices allow for the elimination of the impact factor when determining the acceptability of a bridge for a specific permit vehicle. When this additional capacity is utilized for an overweight permit, the permit language requires them to slow down to a crawl speed when crossing a specified bridge. Since the permit includes language related to the speed reduction needed, this practice will still be utilized moving forward.

Culvert Exception

When doing a load rating analysis on box culverts, modified impacts factors can be used for the analysis in accordance with the AASHTO *Standard Specifications for Highway Bridges*, Section 3.8.2.3. The modified impact factors are chosen based on Table 753.15.10.4.

Culvert Load Rating Impact Factors	
Impact Factor	**Fill Depth (ft)**
30%	Fill ≤ 1
20%	1 ≤ Fill ≤ 2
10%	2 ≤ Fill ≤ 3
0%	Fill > 3

Table 753.15.10.4

753.15.10.5 Live Load Distribution Factors

For ASR and LFR, live load effects on structures are calculated using a single wheel line to represent the vehicle being analyzed. The resulting live load effects are multiplied by a distribution factor to account for both wheel lines on a given truck as well as the potential for adjacent trucks to be contributing to the loading on a member.

In LRFR, the live load effects are calculated in terms of lanes instead of wheel lines. As a result, both wheel lines are multiplied by the distribution factor to get the total live load carried by the member being analyzed. The formulas for calculating the distribution factors account for possibility of truck traffic in adjacent lanes. Because of the lane approach versus a wheel line approach, the distribution factors for LRFR will be smaller than the ones calculated for ASR and LFR.

Methodologies for calculating live load distribution factors can be found in the AASHTO design specification that corresponds to the rating method being used for analysis. For load rating purposes in Missouri, live load distribution factors should be calculated in accordance with the design specification that corresponds with the rating method that is being used for an analysis. The exceptions to this general policy are shown below.

753.15.10.5.1 Refined Analysis

The distribution factors presented in the various AASHTO design specifications apply to most design situations that are encountered. There are limitations on the applicability of some of the distribution factor formulas and those limitations are typically presented in the design specifications. These limitations are typically encountered on more complicated bridges, such as major river bridges with long spans. More complicated structures are typically designed using a refined analysis method such as finite element analysis.

The AASHTOWare software is still used to model some of the longer span bridges for load rating purposes, even though the AASHTO distribution factor formulas may not be valid. Because the standard distribution factor formulas are used by default, an analysis may result in values that are excessively low or excessively high.

When normal load rating results are not considered accurate, modified live load distribution factors may be calculated based on the refined analysis method used for the design of the structure. These modified live distribution factors are then substituted into the

AASHTOWare structure model so that the rating model will provide results that are consistent with the design approach. Whenever the need for this load rating approach is identified, the load rating engineer should contact the Bridge Rating and Inventory Engineer for further discussion.

753.15.10.5.2 Reinforced Concrete Slab Structures

The allowable stress and load factor design methodologies determine a distribution factor for slab bridges that is based on the live load effects from a wheel line being distributed over a calculated width (E) of slab. The effective distribution factor is then determined by dividing the width of the section being modeled by the distribution width, which essentially results in the number of wheel lines assumed to be carried by the modeled section.

E = 4 + 0.06(S)*
E = distribution width in feet
S = effective span length in feet

Many slab bridges are modeled using a one foot wide section of the slab. Other models may be based on the actual distribution width or the total bridge width. Because of the complexities of the reinforcement patterns in some slab bridges, it can be advantageous to model the entire width of slab in a rating program versus trying to determine an equivalent amount of steel in a one foot wide strip. The distribution factors for these scenarios are shown below.

DF = 1/E	*[one foot wide model]*
DF = E/E = 1	*[model width equal to E]*
DF = (Out to Out Slab Width) / E	*[model using the entire slab width]*

Distribution factors calculated using the above methodologies are considered multi-lane distribution factors. Unlike distribution factors for girders, the slab distribution methodology does not account for a single lane condition where only one truck may be on a structure. This can result in some very conservative load rating results, which may unnecessarily restrict the vehicles that may use a slab bridge.

For load posting and permitting considerations, MoDOT calculates a modified distribution factor for the analysis model, which assumes that only one vehicle is on the bridge. This modified distribution is called a single lane distribution factor and is calculated assuming that the loading of the vehicle is distributed over a wider portion of the bridge when compared with the normal AASHTO distribution width. Historically, MoDOT determined this modified distribution factor by dividing the number of wheel lines by the width of the slab, with a lower limit for the distribution factor set at 0.0833. Around 2010, this approach was simplified to just take the two-lane distribution factor and divide by 1.70. This methodology is only used for cast in place reinforced concrete slabs.

DF (Single Lane) = DF/1.70
DF = calculated multi-lane distribution factor from above

753.15.10.5.3 Reinforced Concrete Box Culverts

Box culvert designs using the allowable stress and load factor methods are very conservative. The level of conservativeness increases as the depth of fill increases because the amount of live load being carried by the culvert dramatically decreases with fill depths. The drop off in actual field measured live load stresses in culvert slabs is primarily attributed to "arching effects" from the roadway pavements and fill above the top slab of the culvert. The *MBE* does account for the drop off in live load effects, but there is wide disagreement about the direction provided in the *MBE*.

The *MBE* states that live load can be ignored in single cell culverts when the fill depth exceeds eight feet. This cutoff for single cell culverts is conservative, but seems somewhat reasonable when viewed from a practical standpoint.

For multi-cell culverts, the *MBE* states that live load can be ignored whenever the fill depth exceeds the dimension between the stream face of the exterior walls. As an example, if you have a three cell culvert with fifteen foot clear spans and one foot thick walls, the *MBE* is stating that live load can be ignored whenever the fill depth exceeds forty seven feet (i.e. 3x15 + 2x1). This requirement does not pass a "common sense" test and is ignored by most states whenever determining the distribution of live loads to culverts.

Based on the results of research that was done for MoDOT, the following modifications to the live load distribution factors may be made when doing load rating analysis for box culverts under fill. These modifications are based on the AASHTO methodologies for load factor design. The load rating model is assumed to be a simple or continuous reinforced concrete slab modeled in accordance with the direction provided in EPG 753.15.10.7.

<u>*Multi-Lane Analysis*</u>
The culvert is modelled in AASHTOWare as a slab structure using the distribution factor shown below.

E = 4 + 0.06(S)*
E = distribution width in feet
S = effective span length in feet
DF = 1/E

<u>*Single Lane Analysis*</u>
Results from the AASHTOWare program are modified to determine a single lane distribution factor calculated as shown below. The single lane results are used in conjunction with the multi-lane results for load posting and permitting decisions.

MSLDF = (AASHTO DF)(0.50)* *[Fill < 4']*
MSLDF = (AASHTO DF)[1 – ([12 - Fill] / [16])]* *[4' ≤ Fill ≤ 12']*
MSLDF = (AASHTO DF) *[Fill > 12']*
Fill = fill height (in feet) above culvert

AASHTO DF = multi-lane slab distribution factor
MSLDF = modified single lane distribution factor

The modified single lane distribution factors for box culverts are intended for use in load posting and permitting decisions. It is assumed that the culvert is in good condition with no issues that would adversely impact the structural capacity for the culvert to carry live loads. When the load rating engineer encounters culverts with structural problems, the Bridge Rating and Inventory Engineer should be consulted for modifications to current MoDOT practice.

753.15.10.5.4 Concrete Slab on Exterior Steel Stringers

The allowable stress and load factor design methodologies determine distribution factors based on formulas provided in the design specifications. Variables that are considered when determining the formula to use for a bridge include the girder spacing, girder material, type of deck construction, and the number of girders present. MoDOT uses the formulas provided in the design specifications, except as noted below.

For local system bridges, the girder spacings typically are a lot smaller than what is found on MoDOT structures. Local system bridges will also have small cantilever lengths on the concrete slab, which limits the potential for exterior stringers to experience live load effects. When determining live load distribution factors for allowable stress and load factor analysis, the distribution factors should be calculated as shown below.

Cantilever Length ≤ 2.50 Feet

Step A: Calculate distribution factor for exterior stringers by placement of wheel lines assuming the slab between the exterior stringer and the adjacent interior stringer to act as a simple span. The first wheel line shall be placed 2.0 feet from the face of the curb when the face of the curb is inside the edge of slab. When the face of the curb is outside the slab edge, or the bridge does not have a curb, the first wheel line shall be placed 2.0 feet from the edge of slab.
Step B: Calculate the distribution factor based on the formulas provided in the design specifications.
Step C: The minimum value calculated in Step A or Step B should be used for the live load distribution factor during the rating analysis.

Cantilever Length > 2.50 Feet

Calculate the distribution factor for exterior stringers in accordance with AASHTO.

753.15.10.5.5 Structures with Timber Slabs

Older structures with slabs constructed from timber planks are common on the local system and are occasionally found on the MoDOT system. Calculation of live load distribution factors on bridges with timber slabs should generally follow the guidance provided in the AASHTO design specification that was used for the bridge.

Some structures with timber planks placed transversely will also have timber runners that are placed on top of the transvers planks and run longitudinally on the bridge. The placement of the runners essentially directs the live load effects from the vehicle wheel lines to specific stringers on the structure. In these situations, the Bridge Rating and Inventory Engineer should be consulted on the appropriate live load distribution factors to use for the analysis.

753.15.10.6 Load Rating of Gusset Plates

The collapse of the Mississippi River bridge in Minneapolis was caused by the failure of a gusset plate connection on a truss. At that point in history, most connections that were designed in accordance with standard design codes were believed to have substantially more capacity than the main load carrying members on a bridge. After the failure of the IS 35 bridge was investigated, it was determined that gusset plate connections needed to be evaluated on truss bridges to ensure that the connections had sufficient capacity to handle the loads on the bridge.

After the investigative findings on failure of the IS 35 bridge were released, FHWA worked with various researchers to come up with a methodology for evaluating the load capacity of gusset plates. This methodology was provided to states by FHWA so that states could start working on analyzing gusset plates on their truss inventory. This methodology was later incorporated into the *MBE*.

Gusset plate analysis on truss bridges is complicated and very time consuming. MoDOT has been gradually working on completing this analysis on the inventory of trusses within the state. Priority has been given to bridges that carry higher volumes of traffic and on bridges that have major rehabilitation work planned.

For analysis of gusset plates, Missouri uses the procedures outlined in the *MBE*. Some of the analysis approaches in the *MBE* are considered overly conservative by some researchers and they have proposed other methods of doing some of the analysis checks. Missouri does allow for more refined analysis approaches and methods to be used for gusset plate analysis whenever the *MBE* procedures indicate that a gusset plate has marginal capacity. The use of alternative approaches on gusset plate analysis should be discussed with the Bridge Rating and Inventory Engineer or the Bridge Management Engineer prior to being used.

When an engineering analysis identifies a gusset plate that has a capacity that is not enough for normal legal loads, the Bridge Management Engineer should be immediately notified and provided the information about the concern. The Bridge Management Engineer will then provide direction on any additional action that is needed to address the gusset plate concern.

753.15.10.7 Load Rating Models for Box Culverts

As part of the yearly review of state's compliance with NBIS requirements, FHWA has evaluated the various processes that states have in place for load rating on bridges, including box culverts. Historically, many states have not load rated box culverts under fill because it was rare for these structures to exhibit any inspection problems that would indicate a load capacity concern. During the compliance reviews, FHWA has asserted that load rating analysis for box culverts is required by NBIS regulations and that the *MBE* does not have language in it that exclusively states that load rating of box culverts under fill is not required. As a result, they have been requiring states to do a load rating analysis on culverts that had not been previously analyzed.

Historically, Missouri has not performed a load rating analysis on box culverts when the fill depth exceeded two feet. This practice is believed to be based on design practice that required a live load distribution factor to be calculated based on the assumption of no fill depth whenever the fill depth was less than two feet. This would result in the culvert being designed more like a slab structure.

In 2012, Missouri started a research project with the University of Missouri. The purpose of this research project was to determine a fill depth at which live load effects could be ignored on box culvert structures. This project involved field testing of ten existing box culverts under varying amounts of fill. This research showed that the effects of live load dropped below 10% of the dead load effects above fill depths of six feet.

The following practice is used for the load rating of box culverts in Missouri and is based on the results of the research project that was completed as well as load rating practice that was already being used by MoDOT. LFR shall be used for performing load ratings on culverts. Methodology for load rating of culverts with LRFR will be developed at a later date.

753.15.10.7.1 Culvert Load Rating Requirements

The requirements for load rating of box culverts will vary based on the fill height on the culvert. The fill height will be defined as the distance from the top slab of the culvert to the roadway surface. When the fill height varies within a culvert section being evaluated, the fill height to be used for evaluation should be the average of the fill heights at the beginning, end, and center of the section.

Fill Height < 6.0 Feet—Load rating analysis of the culvert is required.

Fill Height ≥ 6.0 Feet (Good Condition)—Load rating analysis of the culvert is generally not required for culverts that are in good condition. Good condition is generally considered to be a condition rating of 5 or above for NBI Item 62.

Fill Height ≥ 6.0 Feet (Poor Condition)—When an inspection identifies structural deficiencies that are significant enough to lower the member capacity on a culvert and the location of these deficiencies is within an area that may see live load effects, the culvert may need a load rating analysis performed. The Bridge Rating and Inventory Engineer should be consulted to determine whether the culvert requires a load rating analysis.

753.15.10.7.2 Culvert Load Rating Models

Historically, different design approaches have been used for culvert design in Missouri. For load rating analysis, the top slab of the culvert is modeled as a continuous slab using the AASHTOWARE Bridge Rating software. The slab models are then subcategorized based on whether the culvert top slab to wall connection is predominately considered to be a pinned connection design or a rigid frame design.

Method A—Pinned Connection Culverts
Older culvert designs used in Missouri were considered pinned connection designs. This is determined by examining the vertical reinforcement that runs from the culvert walls into the top slab. When this reinforcement just runs vertically into the top slab, it is considered a pinned design.

Method B—Rigid Frame Culverts
Newer culvert designs used in Missouri are considered rigid frame designs. The easiest way to identify a rigid frame design is by the presence of a triangular haunch from the culvert wall to the culvert slab. These haunches will have reinforcement within them that runs from the culvert wall through the haunch and then extends horizontally within the top slab for a short distance. For rigid frame models, MoDOT does use some procedures for modelling the stiffness of the culvert walls and includes some extra loadings to mimic the effects of soil pressures on the culvert walls. For more detail on these additional procedures used on fixed culverts, please contact the Bridge Rating and Inventory Engineer.

Culverts with Low Ratings
Culverts should be modeled using either Method A or Method B. These two methodologies will occasionally produce low rating results on some culverts, which may result from the limitations of these simplified models. There are some workarounds that can be done within the AASHTOWare Bridge Rating model to improve the results of the rating. The Bridge Rating and Inventory Engineer should be consulted for information on the workarounds for low rating values. Low rating values determined using the normal AASHTO LFD distribution factors are H20L ≤ 13 tons, MO5 ≤ 28 tons, and HS20 Inventory ≤ 16.5 tons.

753.15.10.7.3 NBI Reporting Values for Culverts

The following guidance is provided for entering load rating results into the TMS data system used for NBI reporting purposes. Load rating results for other purposes should be entered based on current internal MoDOT practice.

Fills < 6’

Load rating results are determined using a structural model from AASHTOWare. The results of that analysis are loaded into the TMS data system in accordance with current internal MoDOT practice.

Fills ≥ 6' [Analysis performed]
Load rating results are determined using a structural model from AASHTOWare. The results of that analysis are loaded into the TMS data system in accordance with current internal MoDOT practice.

Fills ≥ 6' [No analysis performed]
Load rating results for NBI reporting purposes are loaded into the TMS data system based on Table 753.15.10.7.3. This table was derived based on a sample of culverts with known design information. The results were averaged to come up with the values shown in the table and are based on a load factor analysis. For NBI reporting purposes, the method may be coded as Load Factor or Engineering Judgment.

Inventory/Operating Default Rating Values			
Culvert Fill > 6'			
Culvert Type	**Design Load**	**Inventory**	**Operating**
Cast in Place	None (Pre-1940)	24	40
	H10	24	40
	H15	36	60
	H20	48	80
	HS20	58	97
	HS20 Mod or HL93	72	120
Precast	HS20	36	60
	HS20 Mod or HL93	45	75

Table 753.15.10.7.3

753.15.11 Load Posting Policy in Missouri

When determining the need for load posting on bridges within Missouri, there are three distinct items that need to be reviewed. The three items are: load posting needs for statewide legal loads, load posting needs for commercial zone legal loads, and load posting needs for FAST Act emergency vehicles. These items should be reviewed in sequential order when evaluating load posting needs and they should only be reviewed on a structure whenever they are applicable to that structure.

753.15.11.1 Statewide Legal Loads—Step 1

Statewide legal loads are required to be evaluated for all bridges in Missouri. The first step in any load posting analysis on a bridge should be a review of the bridge capacity for the two statewide legal load models that are shown below. Posting levels are determined by using 86% of the operating rating for the Load Factor Method and by using 68% of the yield strength for member capacity calculations using the Allowable Stress Method.

The legal load model for single unit vehicles will be the H20L, which is shown in Fig. 753.15.11.1.1. Load posting for single unit vehicles will be needed when the load capacity for the H20L vehicle is less than 30 tons. This posting threshold has been set so that it will identify the need for load posting for all legal loads within the state of Missouri and result in a load posting value that is at or below the gross vehicle weights allowed for the different single unit vehicles in operation.

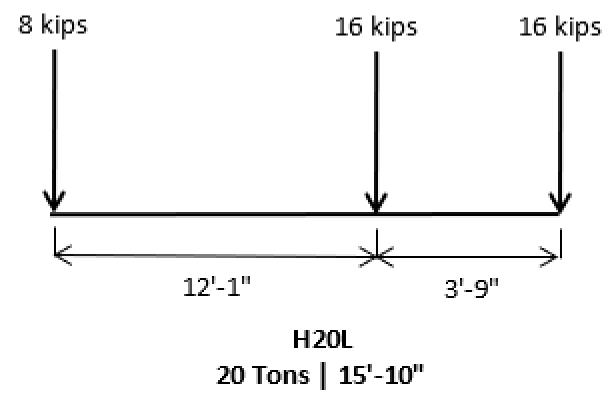


Fig. 753.15.11.1.1

The legal load model for combination configurations will be the MO3S2, which is shown in Fig. 753.15.11.1.2. Load posting for combination configurations will be needed when the load capacity for the MO3S2 vehicle is less than 45 tons. This posting threshold has been set so that it will identify the need for load posting for all legal loads within the state of Missouri and result in a load posting value that is at or below the gross vehicle weights allowed for the different combination vehicles in operation.

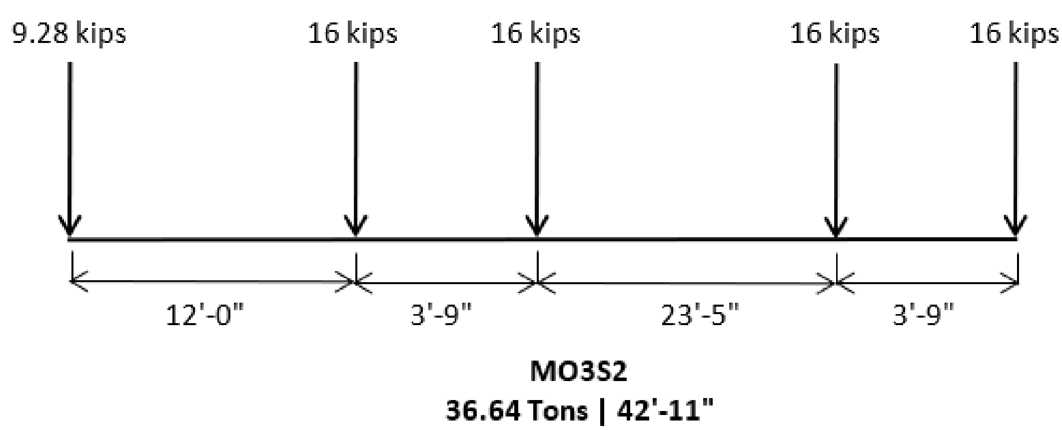


Fig. 753.15.11.1.2

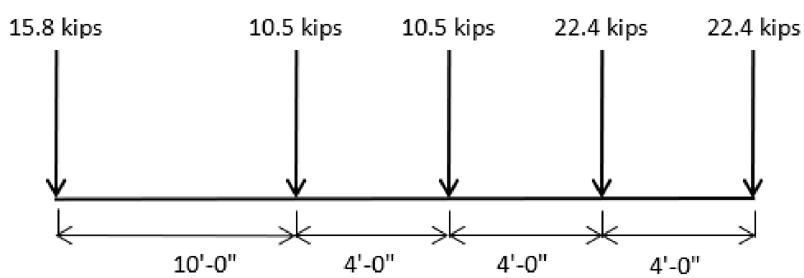
753.15.11.2Commercial Zone Legal Loads—Step 2

There are currently five commercial zones within Missouri: St. Joseph, Kansas City, Columbia, St. Louis, and Springfield. The boundaries of the commercial zones are defined in Missouri state statutes that have been passed by the legislature at some point. Within a commercial zone, gross weight limits have been replaced with an axle limit. The axle limit is 22,400 pounds.

The commercial zone boundaries can be found on the *Missouri Vehicle Route Map* that is published by the Motor Carrier Services Division within MoDOT. On this map, there will be an inner and outer area (defined by different colors) within a commercial zone boundary. For the inner area, the commercial zone requirements apply to all roadways, including the Interstate system. For the outer area, the commercial zone requirements only apply to the non-Interstate highways.

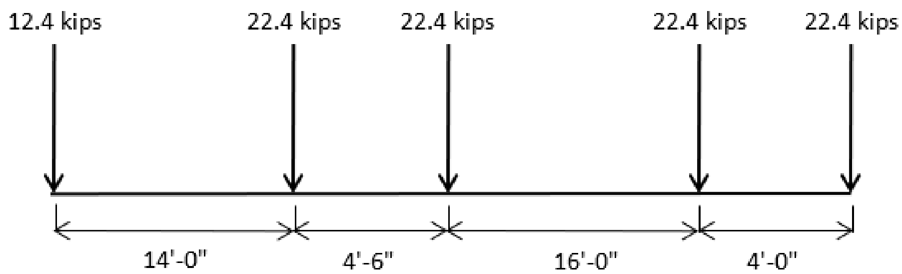
Bridges that are located within commercial zone boundaries and have passed the screening for load posting needs based on statewide legal loads, will need to be evaluated for load posting needs based on the two commercial zone vehicle models. Posting levels are determined by using 86% of the operating rating for the Load Factor Method and by using 68% of the yield strength for member capacity calculations using the Allowable Stress Method.

The commercial zone model for single unit vehicles will be the CZSU, which is shown below. Load posting for single unit vehicles will be needed when the load capacity for the CZSU vehicle is less than 45 tons.



CZSU
40.8 Tons | 22'-0"

The commercial zone model for combination configurations will be the CZRT, which is shown below. Load posting for combination configurations will be needed when the load capacity for the CZRT vehicle is less than 70 tons.



CZRT
51 Tons | 38'-6"

753.15.11.3 <u>FAST Act Emergency Vehicle Loads—Step 3</u>

The FAST Act defined two emergency vehicle configurations that are legal for travel on the interstate highway system. They are also allowed to travel on overpasses that cross the interstate highway system in order to allow for reasonable access.

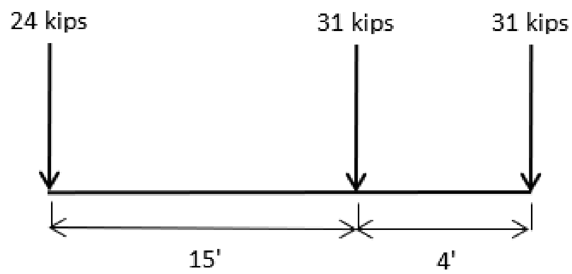
In 2020, Missouri completed a study on these two vehicles, with the results of that study presented in the report: *Load Posting Practice Evaluation, FAST Act Emergency Vehicles*, dated February 17, 2020. This research compared the emergency vehicle configurations to other load posting models that are used in Missouri. The study also reviewed the assertion by FHWA that there was a need to post bridges for gross weight limits as well as axle weight limits on fire truck configurations. This research found that there was no need to post for both axle weights and gross weights on fire trucks. A bridge that has been posted for axle weights on fire trucks will adequately control the maximum gross weights of fire trucks, or vice versa.

The load posting practice for emergency vehicles is presented below. This posting practice will only apply to bridges on the interstate highway system and overpasses that allow for access to the interstate highway system. Posting values are determined using the operating rating for the Load Factor Method and the Allowable Stress Method.

The EV2 is a two-axle fire truck that is depicted below. Bridges in Missouri that have been screened for load posting needs for the H20L single unit vehicle will be considered as having adequately covered the potential for load posting needs for the EV2 fire truck.

EV2
28.75 Tons | 15'-0"

The EV3 is a three-axle fire truck that is depicted below. Bridges in Missouri that are located within commercial zones and have been screened for load posting needs for the CZSU single unit vehicle will be considered as having adequately covered the potential for load posting needs for the EV3 fire truck. Bridges in Missouri that are outside of the commercial zones and do not require load posting for the H20L single unit vehicle will need to be evaluated for load posting needs for the EV3 fire truck. When the EV3 fire truck has a gross weight capacity less than 43 tons, a gross weight limit for single unit vehicles should be established for the bridge based on the capacity for the EV3 vehicle.



EV3
43 Tons | 19'-0"

The summary table shown below can be followed when evaluating posting needs for emergency vehicles.

Emergency Vehicle Review Summary Table

Analysis Category	Single Unit Vehicle	Posted-Single Unit Vehicle	Check EV2*,1	Check EV3*,1
Statewide Legal Load	H20L	Yes	No	No
Statewide Legal Load	H20L	No	No	Yes
Commercial Zone Loads	CZSU	Yes	No	No
Commercial Zone Loads	CZSU	No	No	No

*-No means that single unit vehicle covers posting needs for EV2 or EV3.
1-Yes means that an emergency vehicle load posting evaluation is needed.

753.15.11.4 <u>Load Rating Methods for Load Postings</u>

The Load Factor Method should be used for determining the load posting needs on all bridges within Missouri, except as noted below. When using this method, the appropriate load posting value for statewide legal load models and commercial zone legal load models should be determined by calculating the operating rating (in tons) and then multiplying that result by 0.86 (i.e. 86%). For emergency vehicle models, posting levels are determined at the operating rating, so the calculation of a posting level value is not required.

The Load Factor Method is not available for analysis on structures that are constructed of timber. As a result, the Allowable Stress Method will be used when determining the load posting needs on timber bridges within Missouri. When using the Allowable Stress Method, the appropriate load posting value for a specific vehicle should be determined by using a member capacity that is based on 68% (i.e. 0.68) of the yield strength of the timber material used for that member.

The Load and Resistance Factor Method is currently not utilized for determining load posting needs for bridges in Missouri. A research project to develop a posting practice for the Load and Resistance Factor Method was started in 2021. Once that project is completed, the BIRM will be updated to include guidance on determining load posting needs using this method.

753.15.11.5 Lane Considerations for Load Posting

When a load rating analysis is completed on a structure, standard templates are typically used by most states. Part of that template will be the calculation of load capacities for individual vehicles for a single lane loaded situation and multi-lane loaded situation using the live load distribution factors.

Historically, Missouri has utilized single lane loaded conditions when determining the posting level for a structure based on statewide legal loads. In commercial zone areas, multi-lane loaded conditions were utilized for determination of load posting values.

The general direction provided by AASHTO manuals is to determine the use of single lane and multi-lane distribution factors based only on the roadway width. The guidance provided indicates that bridges with widths less than or equal to eighteen feet should be considered single lane bridges and bridges with roadway widths greater than eighteen feet should be considered multi-lane bridges. The AASHTO guidance does not account for the actual operational conditions on a structure and can lead to load postings that are overly conservative and unnecessarily restrict commercial vehicles from using a structure.

When determining which values to use for the load posting on a structure, the load rating engineer should review the load rating results and consider the actual operational conditions at a structure site. Operational conditions would include the ADTT, the approach roadway width, the bridge width, and the predominate way the truck traffic crosses a structure.

The following table provides guidance on determining whether to use single lane or multi-lane rating results for determination of the load posting values on a bridge.

Posting Considerations Based on Roadway Width and ADTT			
Roadway Width (ft)	**ADTT**	**Single Lane DF***	**Multi-Lane DF**
≤ 18.0	≤ 100	Yes	----
	> 100	Yes	----
> 18.0	≤ 100	Yes	----
	> 100	----	Yes

*For emergency vehicle posting considerations, always use the single lane DF

Exceptions to this policy can be made upon approval of the Bridge Rating and Inventory Engineer or the Bridge Management Engineer. The reasoning for approving an exception to this policy should be documented by the engineer and included as part of the overall documentation of the load ratings on a structure. An example could be a higher traffic volume ramp structure that has a roadway width greater than 18', but is being used as a single lane structure.

753.15.12 Load Posting Categories

After a comprehensive review of legal loads allowed in Missouri, MoDOT revised load posting practices statewide in 2020. With this revision, new load posting categories were developed and are shown in EPG 753.15.12.1. Implementation of these revised load posting categories will be a multi-year effort and will start in the latter part of 2021. EPG 753.15.12.2 shows the legacy load posting categories that have been in place since the 1980s.

753.15.12.1 Current Load Posting Categories

The legacy load posting categories that have been in use since the 1980s included lane restrictions, speed restrictions, and gross vehicle weight restrictions. Experience has shown that the speed restrictions are typically not complied with and are not enforceable by law enforcement in most situations. Signs with multiple restrictions have proven to be confusing and hard to read by trucks that are traveling at normal highway speeds. As a result, a need to simplify the load posting approach and corresponding signage was identified.

With the changes to load posting policy, the load posting categories have been updated. The load posting categories have been simplified and grouped into the four types that are shown in EPG 753.15.12.1.1 through EPG 753.15.12.1.4. The use of speed restricted load postings will no longer be allowed without prior approval from the Bridge Management Engineer or the Bridge Rating and Inventory Engineer. As load ratings are updated, bridges that are currently load posted with the legacy posting categories should be updated to one of the new posting categories presented in EPG 753.15.12.1.

For load posting purposes, the maximum gross vehicle weight (in tons) for single unit vehicles and combination vehicles is determined during a load rating analysis. This vehicle tonnage is compared to the appropriate load posting threshold and if this tonnage is less than the load posting threshold, then the bridge requires load posting for that vehicle. Load posting of bridges with maximum axle weight limits is not required in Missouri.

753.15.12.1.1 Statewide Normal Legal Load Postings

Statewide Legal Load Posting Gross Weight Categories			
Classification	**Category**	**Description**	**Sign Verbiage**
Normal Legal	SW-1	No Posting Required	----
Normal Legal	SW-2	General Gross Weight Limit	Weight Limit xx Tons
Normal Legal	SW-3	Single Unit Vehicle Gross Weight Limit	Weight Limit Single Unit xx Tons
Normal Legal	SW-4	Combination Vehicle Gross Weight Limit	Weight Limit Combination xx Tons
Normal Legal	SW-5	Single Unit Vehicle and Combination Vehicle Gross Weight Limits	Weight Limit Single Unit xx Tons Combination xx Tons

The table shown above provides five different posting categories for normal legal loads that can travel statewide. All bridges are required to be evaluated for the normal legal loads. Bridges that have adequate load capacity for all normal legal loads should be coded as Category SW-1, indicating that no load posting is required. Bridges that do not have adequate capacity for normal legal loads should be assigned the SW-2 through SW-5 category that best fits the situation. Category SW-2 should always be used for local agency bridges requiring a load posting, unless the local agency requests that a distinction be made between single unit and combination vehicles.

753.15.12.1.2 Statewide Normal Legal Load Postings with Lane Restriction

Situations may be encountered where a lane restriction is warranted on a bridge, with a common example being deterioration along the slab edges as well as on the exterior girders. On older bridges, it was common to have exterior girders that were smaller than the interior girders, resulting in the exterior girder controlling the load posting level for the bridge. With both scenarios, lane restrictions can be implemented to allow for heavier vehicles to safely use the bridge. Lane restrictions on a bridge will basically consist of striping the bridge with a single lane so that the traffic travels down the center of the structure. This repositioning of the traffic on the bridge will keep the vehicle from loading the exterior girder in a manner that would exceed the capacity of the girder.

Statewide Legal Load Posting Centerline Restriction with Gross Weight Categories			
Classification	**Category**	**Description**	**Sign Verbiage**
Lane Restricted	LR-1	Lane Restriction Only	----
Lane Restricted	LR-2	Lane Restriction with General Gross Weight Limit	Weight Limit xx Tons
Lane Restricted	LR-3	Lane Restriction with Single Unit Vehicle Gross Weight Limit	Weight Limit Single Unit xx Tons
Lane Restricted	LR-4	Lane Restriction with Combination Vehicle Gross Weight Limit	Weight Limit Combination xx Tons
Lane Restricted	LR-5	Lane Restriction with Single Unit Vehicle and Combination Vehicle Gross Weight Limits	Weight Limit Single Unit xx Tons Combination xx Tons

The table shown above provides five different posting categories consistent with the normal legal load posting categories from EPG 753.15.12.1.1, but also include a lane restriction. These categories should only be used for a bridge that has been striped for a single lane of traffic and includes other appropriate roadway signage such as yield signs and other signs to indicate that it is a single lane structure. These categories would not be used for a bridge that is narrow and just naturally used as a one lane structure. The use of these categories on the local system should be uncommon because most local agencies will not install the additional signage necessary to operate a bridge as a single lane structure. When evaluating bridges for this option, the load rating engineer should pick the category that best fits the posting needs on the bridge. If the decision is made to use a lane restricted posting on a local agency bridge, Category LR-2 should be used.

753.15.12.1.3 Commercial Zone Area Load Postings

The table shown below provides five different posting categories for load posting needs in the commercial zone areas of the state. In commercial zone areas, bridges should be first evaluated for the normal statewide legal loads. When a bridge has insufficient load capacity for normal statewide legal loads, one of the posting categories listed in EPG 753.15.12.1.1 or EPG 753.15.12.1.2 should be used.

When a bridge is within a commercial zone area and has adequate load capacity for normal legal loads, the commercial zone vehicles should be reviewed to determine if a commercial zone load posting is needed. Bridges that have adequate load capacity for commercial zone vehicles should be coded as CZ-1, indicating that no load posting is required for normal legal loads as well as commercial zone legal loads. Bridges that do not have adequate load capacity for commercial zone legal loads should be assigned the CZ-2 through CZ-5 category that best fits the situation. Category CZ-2 should always be used for local agency bridges requiring a load posting, unless the local agency requests that a distinction be made between single unit and combination vehicles.

Commercial Zone Areas Gross Weight Categories			
Classification	**Category**	**Description**	**Sign Verbiage**
Commercial Zone	CZ-1	No Posting Required	----
Commercial Zone	CZ-2	General Gross Weight Limit	Weight Limit xx Tons
Commercial Zone	CZ-3	Single Unit Vehicle Gross Weight Limit	Weight Limit Single Unit xx Tons
Commercial Zone	CZ-4	Combination Vehicle Gross Weight Limit	Weight Limit Combination xx Tons
Commercial Zone	CZ-5	Single Unit Vehicle and Combination Vehicle Gross Weight Limits	Weight Limit Single Unit xx Tons Combination xx Tons

753.15.12.1.4 Other Miscellaneous Load Postings

Other Miscellaneous Load Posting Categories			
Classification	**Category**	**Description**	**Sign Verbiage**
Fire Truck	FT-1	General Gross Weight Limit for Emergency Vehicles Included in the FAST Act, Federal Reauthorization Bill	Weight Limit xx Tons
Closed Bridge	K-CD	Closed to All Traffic	----
Closed Bridge	K-CIF	Closed to All Traffic as the Result of a Critical Inspection Finding	----
Other	OT-1	For Local Agency Bridges that have Signage that Doesn't Fit the Normal Legal, Lane Restricted, or Commercial Zone Categories	----

The posting categories shown in the above table should be used for the miscellaneous purposes identified in the description. Bridges that have adequate load capacity for all legal loads, but require a load posting for one of the FAST Act fire trucks should be coded as FT-1 with a single gross weight limit sign. Categories K-CD and K-CIF are used for closed structures. Occasionally, a local agency may have their own load posting policy and utilize signs that are different than what is used in the rest of the state. When a local agency uses signage that is different than the standard posting categories listed above, a Category OT-1 should be assigned.

753.15.12.2 <u>Legacy Load Posting Categories</u>

The table shown below provides the legacy load posting categories that have been in use since the 1980s. The legacy posting categories consisted of speed, lane, and gross weight restrictions, or some combination of these three restrictions. Beginning in late 2021, these legacy posting categories should not be used for new load posting recommendations unless approved by the Bridge Management Engineer or the Bridge Rating and Inventory

Engineer. Legacy posting categories for existing bridges will be phased out in the coming years as part of a review of load posting needs on the bridge inventory in Missouri.

Legacy Posting Categories--Used Since Early 1980's	
Category	**Description**
S-CD	Bridge Closed and Barricade to Prevent Use by all Traffic
S-CD-CIF	Bridge Closed as the Result of a Critical Inspection Finding
S-1	No Posting
S-3	Actual Load Posting Required
S-C3	Commercial Zone Load Posting
S-4	Traffic Must use Centerline of Bridge
S-5	Centerline of Bridge and Trucks Over xx Tons 15 MPH on Bridge
S-6	Centerline of Bridge and 6 Axle Trucks Over xx Tons 15 MPH on Bridge
S-7	Trucks Over xx Tons 15 MPH on Bridge
S-8	Trucks Over xx Tons 15 MPH on Bridge Except 6 Axle Trucks Weight Limit xx Tons
S-9	6 Axle Trucks Over xx Tons 15 MPH on Bridge
S-10	6 Axle Trucks Weight Limit xx Tons
S-11	Trucks Over xx Tons 15 MPH on Bridge Except Trucks Weight Limit xx Tons
S-12	Centerline of Bridge and Trucks Over xx Tons 15 MPH on Bridge Except Trucks Weight Limit xx Tons
S-13	Centerline of Bridge and Truck Weight Limit xx Tons, Two-Way Traffic
S-14	Truck Weight Limit xx Tons Except Single Unit Triple Rear Axle Truck (MO-4) Over xx Tons 15 MPH on Bridge
S-15	Truck Weight Limit xx Tons Except Single Unit Tandem Rear Axle Truck (H-20) xx Tons Weight Limit
S-16	Trucks Over xx Tons 15 MPH on Bridge Except Single Unit Trucks (H-20) Weight Limit xx Tons and all Other Trucks Weight Limit xx Tons
S-17	Centerline of Bridge and Trucks Over xx Tons 15 MPH on Bridge Except Single Unit Trucks (H-20) Weight Limit xx Tons and all Other Trucks Weight Limit xx Tons
S-18	Single Unit Trucks Over xx Tons 15 MPH on Bridge and all Other Trucks Over xx Tons 15 MPH on Bridge
S-19	Weight Limit xx Tons at 15 MPH on Bridge
S-20	Centerline of Bridge and Weight Limit xx Tons at 15 MPH on Bridge
S-21	Centerline of Bridge and Weight Limit xx Tons
S-22	Speed Limit 15 MPH on Bridge

753.15.13 Load Posting Signs

EPG 903.5.36 provides direction/guidance on the proper load posting signs to use as well as the placement of those signs and any additional signage that is needed in conjunction with a load posting limit. The criteria in EPG 903.5.36 should be followed for all load postings that are implemented for bridges on MoDOT owned roadways.

The criteria in EPG 903.5.36 is recommended for use on load postings for bridges on local agency owned roadways. However, local agencies may also follow their own established guidance or criteria. In general, load posting signs should have a white background and use black lettering to indicate the limits being placed on the bridge.

With the simplification of the load posting categories, there will essentially be four weight limit signs that will cover all cases where some form of a weight restriction is needed. The sign designations and the posting categories applicable for each sign are shown below.

R12-1

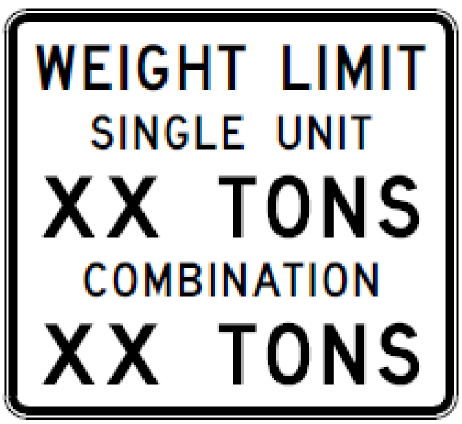
This is a general weight limit sign that will be used for posting categories: SW-2, LR-2, CZ-2, and FT-1.

R12-12

This is a weight limit sign that only applies to single unit vehicles and will be used for posting categories: SW-3, LR-3, and CZ-3.

R12-13
This is a weight limit sign that only applies to combination vehicles and will be used for posting categories: SW-4, LR-4, and CZ-4.

R12-14
This is a weight limit sign that provides limits for single unit vehicles and for combination vehicles. This sign will be used for posting categories: SW-5, LR-5, and CZ-5.

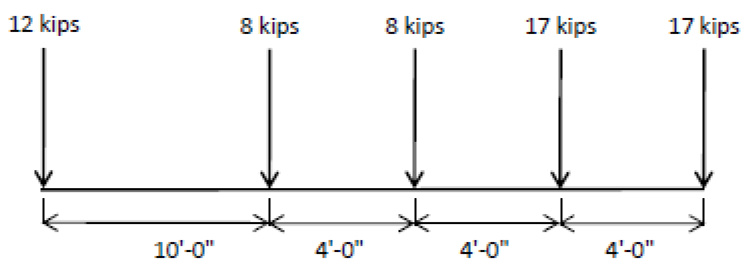


753.15.14 Load Rating Vehicles for Standard Analysis

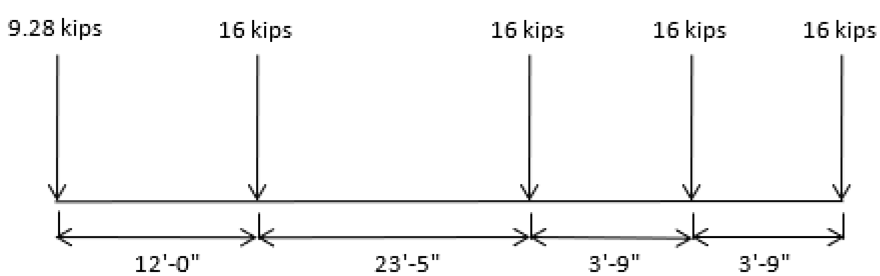
Load rating software allows for users to define specific trucks to be analyzed as part of a load rating analysis. Users also have the capability to analyze a group of trucks. The following table identifies ten different vehicles that rating results will need to be determined for and includes which rating levels are required in the analysis. These results are required for all bridges that have a load rating analysis performed. When load ratings are done using the load and resistance factor rating method, values at the inventory and operating levels are also required for the HL93 design vehicle.

	Rating Levels Required		
Truck	**Inventory**	**Operating**	**Posting**
HS20	X	X	
H20L	X	X	X
MO3S2	X	X	X
CZSU	X	X	X
CZRT	X	X	X
SU5	X	X	X
EV2		X	
EV3		X	
MO5		X	
4S3P		X	

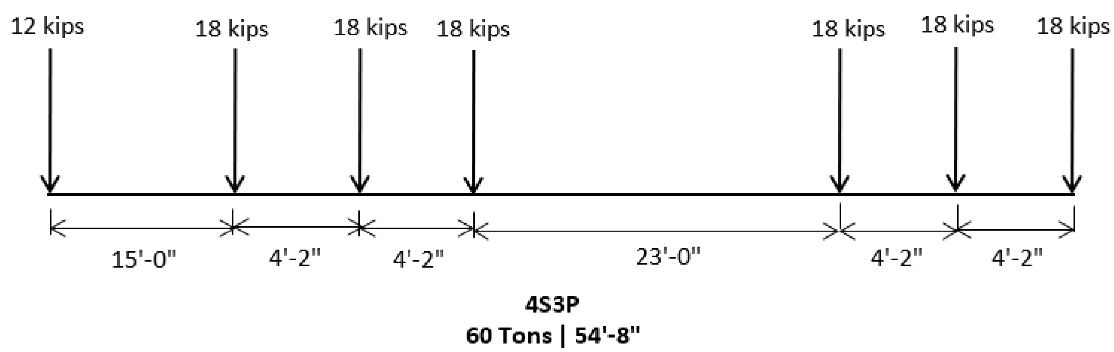
Dimensions and axle weights for the 4S3P, MO5, and SU5 are shown in the following truck diagrams. Dimensions for the HS20 vehicle can be found in the *Standard Specifications for Highway Bridges, 17th Edition*. The MO5 was previously used for commercial zone posting needs and routine overweight permit screening. Starting in 2022, the MO5 will no longer be used for commercial zone posting needs.



SU5
31 Tons | 22'-0"



MO5
36.64 Tons | 42'-11"



753.15.15 Minimum Load Posting Values and Increments

To ensure the safety of the traveling public, bridges need to be capable of carrying a minimum gross vehicle weight that would be representative of the non-commercial vehicle weights that are common on roadways. EPG 753.15.15 defines minimum acceptable load posting thresholds for different bridge classifications within Missouri and provides direction on the actions needed whenever these minimum thresholds are violated.

753.15.15.1 Local Agency Owned Bridges

Most locally owned bridges are on roadways with very low traffic volumes, with most of the traffic being cars. All locally owned bridges shall have a minimum live load capacity of 3 tons, including the normal allowances for impact loadings. Bridges that are determined to not have enough load capacity to meet this minimum threshold are required to be closed to vehicular traffic.

753.15.15.2 MoDOT Owned Bridges

The system of roadways that MoDOT is responsible for will range from low traffic volume roadways in rural areas to high traffic volume roadways in major urban areas. Generally, all bridges on MoDOT roadways are expected to have a load capacity of at least 20 tons, with the exceptions listed below. When a load rating analysis on a bridge determines that this minimum capacity requirement is violated, the Bridge Management Engineer shall be consulted for direction on the appropriate course of action.

753.15.15.2.1 Interstate Bridges

The interstate system of roadways was built to facilitate the efficient movement of goods across the United States. As a result, the interstate system is expected to be maintained in a manner such that all commercial truck traffic meeting federal weight and length requirements should be able to travel without any restrictions.

In general, the maximum gross weight of normal legal vehicles traveling on the interstate system is 40 tons. If a load rating analysis on an interstate bridge determines that a load posting for normal legal loads is needed, the Bridge Management Engineer shall be consulted for direction on the appropriate course of action. This requirement does not apply to the segments of the interstate system within commercial zones that allow for heavier vehicles to legally travel without an overweight permit.

753.15.15.2.2 Non-Mainline Roadway Bridges

There are MoDOT owned bridges that are not part of the mainline roadway system. Typically, these bridges provide entrances to private properties such as farm fields or residences, so the only people using the bridges are the property owners. In these situations, the general expectation is that the structures will be capable of carrying at least 10 tons. When a load rating analysis on a bridge determines that this minimum capacity requirement is violated, the Bridge Management Engineer shall be consulted for direction on the appropriate course of action.

753.15.15.2.3 Emergency Situations

Situations may arise where a load posting on a bridge is needed that will violate the minimum posting thresholds established in EPG 753.4 for MoDOT owned bridges. These situations typically result from collision damage to a structure or from serious findings as the result of a bridge inspection. Temporary load posting recommendations are generally determined based on a group discussion of the situation. These group discussions should include at least one of the following people: State Bridge Engineer, Assistant State Bridge Engineer, or the Bridge Management Engineer. The results of this discussion will include the final load posting recommendation and direction on the appropriate group of people to communicate this information to.

753.15.15.3 Load Posting Increments

In general, load rating results should be rounded to the nearest ton for determining the appropriate tonnage value to be displayed on a posting sign. The following tonnage increments are recommended for use when evaluating bridges for a load posting. The load rating engineer may recommend posting bridges at levels in between these increments, except as noted.

Local Agency Owned Bridges

Sign vandalism is a continual problem on the local system. To allow local agencies to have efficiencies in sign management, it is recommended that the following load posting increments be used: 3 tons, 5 tons, 10 tons, 15 tons, 20 tons, 25 tons, 30 tons, 35 tons, and 40 tons. Using this approach will allow for local agencies to maintain sign inventories at these standard increments to facilitate a quicker replacement of damaged signs. If requested by the local agency, it is still acceptable to load post bridges at values in between these increments.

MoDOT Owned Bridges

For MoDOT owned bridges, it is recommended that load posting values be recommended in even increments of two tons (i.e. 30 tons, 32 tons, etc.). Values in between these may be used at the discretion of the load rating engineer or upon request by the MoDOT District Office.

Commercial Zone Increments
Bridges in commercial zones may require load postings for single unit vehicles, combination vehicles, or both. Load posting values for commercial zone requirements should be done in five ton increments (i.e. 45 tons, 50 tons, etc.). The maximum load posting value shall be 45 tons for single unit vehicles and 70 tons for combination vehicles.

753.15.16 Load Testing of Bridges

The AASHTO *MBE* includes a section that provides information on non-destructive load testing of bridges. There are two types of load testing defined in the manual: diagnostic load testing and proof load testing. The load testing approaches presented in the AASHTO *MBE* are based on the LRFR load rating methodology.

Diagnostic load testing of bridges is done to validate analytical load rating models that have been developed based on design plans for the bridge. MoDOT's general expectation is that load ratings should be based on the available plans for a bridge, so diagnostic load testing is not allowed for structures in Missouri. Any exception to this practice shall be approved by the Bridge Management Engineer.

Proof load testing of bridges is used to establish a load capacity for bridges where no bridge plans exist. MoDOT does allow for proof load testing on bridges, but restricts the use of the approach to reinforced concrete bridges where no information on the reinforcement used in the structure is available. Load testing of a bridge should generally be done to justify a higher load posting level on a bridge and not as a means for removing a load posting on a bridge.

Proof Load Testing Requirements

Proof load testing can be performed on reinforced concrete bridges in Missouri when no design plans exist. Use of proof load testing will generally be restricted to shorter span bridges on the local system to justify an increase in the current load posting level on a structure. The load testing shall be supervised by an individual that is a licensed professional engineer for the state.

The first step of a load test should include a review of existing information on the bridge. This should include documentation from the most recent inspection of the bridge to ensure that the bridge is in an acceptable condition for performance of a load test. Proof load testing should not be done on poor condition bridges or on fair condition bridges that have significant deterioration of the primary superstructure members.

The engineer should review existing dimensional information on the structure, including the span length and cross sectional dimensions of the concrete members. This information should be used to predict the expected response of the bridge during the load test, assuming the bridge has at least the minimum amount of reinforcement required by design codes at the time of construction. The results of this initial analysis should be used to establish an upper threshold on the test vehicle weights to ensure that the strain/stress response of the bridge stays well within elastic limits.

Load testing should be done with a three-axle single unit vehicle, with known vehicle dimensions and axle weights when the vehicle is empty. The empty vehicle should be driven across the bridge and the bridge response measured. The vehicle should then be loaded with increasing amounts of load and driven across the bridges each time for collection of strain and/or deflection measurements.

During load testing, the truck should be positioned on the bridge to produce the maximum loading condition and the maximum deflection. If at any point, the bridge response is observed or believed to be exceeding elastic limits, the load testing should be stopped. For each pass of the test vehicle, gross vehicle weights, axle weights, and the maximum deflection shall be recorded for presentation in a table to be included in the final report.

A final report for the load test should be submitted to MoDOT for review and approval. The revised load posting to be placed on the bridge shall be determined as 75% of the gross vehicle weight of the last test vehicle run that demonstrated a bridge response that was still within elastic limits.

The final report shall include engineering calculations done prior to and after the load test to justify the load testing process that was used. A recommendation for the revised load posting level for the bridge shall be included in the report. The report shall also include a table with the field measured results from each pass of the load test vehicle. A recommendation for HS20 inventory and operating capacities that are consistent with the recommended load posting shall be provided for inclusion in the NBI data for the bridge. The final report shall be signed and sealed by a registered professional engineer for the state of Missouri.

753.15.17 Concrete Bridges without Plans

Concrete bridges that have no plan information available is a common occurrence across the United States. In Missouri, this issue is commonly found on locally owned bridges that were built prior to the 1950s. Concrete bridges without plans are found on the MoDOT roadway system as well, but typically are bridges that were on the local system at some point and later absorbed into the MoDOT system.

The AASHTO *MBE* addresses this common situation with a general statement about the length of service for the bridge as well as the overall condition of the bridge. Bridges that have been in service for an extended period and show no signs of distress do not require a load posting for normal legal loads.

The load rating engineer can follow the general guidance presented in the *MBE* when evaluating the load posting needs for concrete bridges without plans. This practice would be applicable to concrete bridges that are generally in good condition and have been functioning for an extended period with no signs of distress. The engineer should also consider the geometric proportions (i.e. span length, slab thickness, etc.) on the structure to see if they are consistent with known engineered structures from the same time period.

HS20 inventory and operating rating values for NBI reporting purposes should be determined based on the age of the structure and the likely design load that was in use at the time the bridge was built. With this scenario, the NBI rating method should be coded as Engineering Judgment.

753.15.18 Railroad Flat Cars

On the local system, bridges that are constructed from used railroad flat cars will occasionally be encountered. The bridges are typically constructed as single spans by placing two railroad flat cars side by side and pouring a concrete deck on top.

The ability to reasonably perform a load rating analysis on railroad flat car bridges is dependent upon the type of construction utilized when the flat car was manufactured. Some of the flat cars are constructed with main beams down the center of the car with cantilevered beams going out to support the edges of the car. Others are constructed with plates that are bent in different directions across the cross section of the car. Ones constructed with a main beam can reasonably be load rated, while the ones constructed with bent plates are very difficult to analyze.

Railroad flat cars are typically very strong and have routinely carried loads that are well in excess of 200,000 pounds while in service for the railroad. With these flat cars only being used on low volume roads that are part of the local system, there is no need to load post these bridges whenever a load rating analysis is not practical because of the manufacturing method on the cars.

When reviewing railroad flat car bridges for load posting needs, the load rating engineer should consider the overall condition of the flat cars during the review. The load rating engineer should also consider the amount of deflection that may have been noted by an inspector when vehicles were crossing the bridge. The flat cars are typically very stiff, so noticeable deflections from light weight vehicles would provide an indication that the bridge may need a load posting.

HS20 inventory and operating rating values for NBI reporting purposes should be determined based on the load rating engineer's final assessment of the load capacity of the flat cars, when no load rating analysis is performed. For bridges determined to not require a load posting, inventory and operating rating values consistent with an HS20 design (i.e. 36 and 60) may be recorded on the NBI. When a load posting is determined to be necessary, the inventory and operating values should be determined so that they are consistent with the load posting used on the structure. In both cases, the NBI rating method should be coded as Engineering Judgment.

753.15.19 Culvert Pipes

Culvert pipes are commonly used for bridge crossings on smaller streams. This may include a single pipe or a group of pipes. Whenever a group of pipes meets the requirement to be included on the NBI, some form of a load rating is required. Additionally, the structure will need to be reviewed to determine if a load posting is necessary.

Culvert pipes are designed so that they can be used in multiple applications around the country, including highways and railroads. These pipes are routinely manufactured to meet AASHTO HS20 or HL-93 design load requirements. As a result, the structures will be strong when they have been properly installed.

Load rating of culvert pipes is not required for most situations. For reporting of inventory and operating ratings (in tons) on the NBI, the load rating engineer should utilize values consistent with the HS20 vehicle (i.e. 60 and 36). For this situation, the NBI rating method should be coded as Engineering Judgment.

As culvert pipes age and start to exhibit significant signs of deterioration, a review of the load capacity of the structure should be completed. This review should be done by the load rating engineer utilizing information (photos, comments, etc.) from the most recent inspection on the bridge. If the culvert pipe is deemed to have a significant reduction in load capacity, then a load posting should be placed on the bridge and the inventory and operating ratings adjusted to be consistent with the load posting.

753.15.20 Load Rating for Design Build Contracts

The design build approach is used by MoDOT for delivery of some transportation projects around the state. When this method is used on projects that include bridges, one of the deliverables in the request for proposals will include providing load ratings for each of the project bridges that are eligible to be included on the NBI.

The specific requirements for the load rating deliverables on design build projects will be detailed in the request for proposals that is provided to each team. With the structure of design build projects, the specific bridges types used may include types that are not easily modeled with conventional load rating software. Because of this possibility, load rating information for an extensive list of truck models is required so that enough information exists to do normal load posting and overweight permit checks for bridges. The list of trucks may be narrowed down at the discretion of the Bridge Management Engineer or the Bridge Rating and Inventory Engineer.

753.15.21 Load Rating by Consultants and Local Public Agencies

Engineering consultants provide load rating submittals as part of the deliverables for bridge replacement and rehabilitation projects that they may be working on for MoDOT or local agencies. Some local agencies also perform load rating calculations or have a consultant provide load rating calculations as part of the maintenance of their bridge inventory. Load ratings shall be submitted to MoDOT for inclusion on the NBI and for documentation of load posting evaluations made on structures.

For the purpose of EPG 753.15.21, load rating calculations will be defined as manual and/or automated engineering calculations as well as the load rating summary sheet discussed below. Automated calculations would include the input and output summaries for the program that was used to do the load rating analysis. If the engineer of record is using AASHTOWARE Bridge Rating for the rating analysis, then the input/output summary requirements may be met by exporting the bridge model and providing it to MoDOT for incorporation into their rating program database. Questions related to the submittal of the rating calculations can be directed to the email address shown below.

Load rating calculations that are submitted shall include a summary sheet for the controlling interior and controlling exterior member on all bridges. For truss bridges, summary sheets shall be submitted for the controlling truss members, floorbeams, and interior/exterior stringers. For girder/floorbeam system bridges, summary sheets shall be submitted for the controlling main girder, floorbeam, and interior/exterior stringers.

Submitted load rating calculations shall identify the local agency or consultant firm that performed the load rating analysis as well as the engineer that is responsible for the calculations. The rating summary shall include the rating date, wearing surface thickness used for the rating analysis, and the rating software used for the analysis. The submitted load rating calculations shall be signed and sealed by a professional engineer registered in the State of Missouri. The engineering seal may be placed on a letter provided with the submittal of the load rating calculations or it may be placed on the load rating summary sheet submitted for a structure.

Load rating summaries shall identify the loading mode, which would include moment (M), shear (V), serviceability (S), compression (C), and tension (T). The impact factor, controlling location, rating factor, and rating value in tons shall be included in the summary. Additionally, results shall be provided for single lane and multi-lane distribution factors for all members and include the value of the distribution factor.

For all three load rating methods, the rating level shall be provided in the rating summary. The rating levels for load factor and allowable stress ratings are inventory, posting, and operating. For load and resistance factor rating, the rating levels would be inventory and operating and would only apply to ratings done at the design level.

When submitting load and resistance factor ratings, the limit state shall be provided for the controlling load rating that is being reported. The limit states vary by bridge type and include strength and serviceability limit states as specified in the *MBE*. Load rating for the fatigue limit state is not required on steel bridges as part of a normal load rating analysis.

For NBI purposes and for load posting considerations, a standard set of vehicles is required for the rating analysis on all structures. The standard trucks that shall be included in all load rating submittals are provided in Table 753.15.14.

When doing load ratings with the load and resistance factor method, submittal of values for the HL93 design vehicle is also required in addition to the trucks listed in Table 753.15.14. For analysis purposes, the CZSU and CZRT shall be categorized as legal loads when determining appropriate live load factors to use for a load and resistance factor analysis. The MO5 and 4S3P rating vehicles shall be considered as special permit vehicles when determining appropriate live load factors. Live load factors for the EV2 an EV3 emergency vehicles shall be in accordance with the *MBE*.

When a load rating review identifies the need for a load posting on a bridge, the load posting should be done in accordance with the criteria provided in EPG 753.15. The submitted load rating information shall include the recommended load posting to implement and identify whether the values are for a single unit vehicle or combination configuration. The submitted information shall also identify if the load posting recommendation is based on normal legal loads, commercial zone legal loads, or emergency vehicle loads.

Load rating calculations and summary sheets that are being submitted to MoDOT, should be submitted electronically to the email address BRINV@MoDOT.MO.GOV. The email that is submitted should indicate that they are load rating calculations and identify the bridge number and the county/city that the bridge is located in.

MoDOT has created standard spreadsheets for the reporting of load rating results for load factor ratings and for load and resistance factor ratings. Within the spreadsheets, separate tabs are provided for Design Load, Legal Load, Commercial Zone, and Other Vehicle load rating summaries. When these standard spreadsheets are used for summarizing a load rating analysis, the spreadsheet file shall be submitted to MoDOT as part of the reporting of load rating results. The standard spreadsheets titles and links are LFD Load Rating Summary Sheet and LRFR Load Rating Summary Sheet. These standard spreadsheets are also available upon request by contacting the Bridge Management Engineer, Bridge Rating and Inventory Engineer, or through the BRINV email address provided above.

The following screen shots demonstrate what is required to be reported in load rating summary tables for the Load Factor Method and the Load and Resistance Factor Method.

Design Load Tab

Load Factor Rating Summary Sheet

District:		**County:**	
Route:		**Bridge Number:**	

			Interior	**Exterior**
Project Number:				
Local Agency:		**Girder:**		
Consultant Firm:		**Other Member:**		
Rating Engineer:		**W.S. Thickness:**		
Rating Date:		**Rating Program Used:**		

Design Load Vehicle Ratings

Vehicle	Level	Impact Factor (0.xx)	Loading Mode (M, V, S, C or T)	DF Type	DF (x.xxx)	Controlling Location (1.0, 1.5, etc.)	Rating Factor (x.xx)	Tonnage Value (xxx.x)
HS20	Inventory			Single Lane				
HS20	Inventory			Multi Lane				
HS20	Operating			Single Lane				
HS20	Operating			Multi Lane				

Legal Load Tab

Legal Load Vehicle Ratings

Vehicle	Level	Impact Factor (0.xx)	Loading Mode (M, V, S, C or T)	DF Type	DF (x.xxx)	Controlling Location (1.0, 1.5, etc.)	Rating Factor (x.xx)	Tonnage Value (xxx.x)
H20L	Inventory			Single Lane				
H20L	Inventory			Multi Lane				
H20L	Posting			Single Lane				
H20L	Posting			Multi Lane				
H20L	Operating			Single Lane				
H20L	Operating			Multi Lane				
MO3S2	Inventory			Single Lane				
MO3S2	Inventory			Multi Lane				
MO3S2	Posting			Single Lane				
MO3S2	Posting			Multi Lane				
MO3S2	Operating			Single Lane				
MO3S2	Operating			Multi Lane				
SU5	Inventory			Single Lane				
SU5	Inventory			Multi Lane				
SU5	Posting			Single Lane				
SU5	Posting			Multi Lane				
SU5	Operating			Single Lane				
SU5	Operating			Multi Lane				

Commercial Zone Tab

Commercial Zone Vehicle Ratings

Vehicle	Level	Impact Factor (0.xx)	Loading Mode (M, V, S, C or T)	DF Type	DF (x.xxx)	Controlling Location (1.0, 1.5, etc.)	Rating Factor (x.xx)	Tonnage Value (xxx.x)
CZSU	Inventory			Single Lane				
CZSU	Inventory			Multi Lane				
CZSU	Posting			Single Lane				
CZSU	Posting			Multi Lane				
CZSU	Operating			Single Lane				
CZSU	Operating			Multi Lane				
CZRT	Inventory			Single Lane				
CZRT	Inventory			Multi Lane				
CZRT	Posting			Single Lane				
CZRT	Posting			Multi Lane				
CZRT	Operating			Single Lane				
CZRT	Operating			Multi Lane				

Other Vehicles Tab

Other Vehicle Ratings

Vehicle	Level	Impact Factor (0.xx)	Loading Mode (M, V, S, C or T)	DF Type	DF (x.xxx)	Controlling Location (1.0, 1.5, etc.)	Rating Factor (x.xx)	Tonnage Value (xxx.x)
MO5	Operating			Single Lane				
MO5	Operating			Multi Lane				
4S3P	Operating			Single Lane				
4S3P	Operating			Multi Lane				
EV2	Operating			Single Lane				
EV3	Operating			Single Lane				

The following screen shots demonstrate what is required to be reported in load rating summary tables for the Load and Resistance Factor Method.

Design Load Tab

Load and Resistance Factor Rating Summary Sheet

District:		**County:**	
Route:		**Bridge Number:**	

			Interior	**Exterior**
Project Number:				
Local Agency:		**Girder:**		
Consultant Firm:		**Other Member:**		
Rating Engineer:		**W.S. Thickness:**		
Rating Date:		**Rating Program Used:**		

Design Load Vehicle Ratings

Vehicle	Limit State	Impact Factor (0.xx)	Loading Mode (M, V, S, C, or T)	DF Type	DF (x.xxx)	Controlling Location (1.0, 1.5, etc.)	Rating Factor (x.xx)	Tonnage Value (xxx.x)	Level
HL93				Single Lane				----	Inventory
HL93				Multi Lane				----	Inventory
HL93				Single Lane				----	Operating
HL93				Multi Lane				----	Operating
HS20				Single Lane					Inventory
HS20				Multi Lane					Inventory
HS20				Single Lane					Operating
HS20				Multi Lane					Operating

Legal Load Tab

Legal Load Vehicle Ratings

Vehicle	Limit State	Impact Factor (0.xx)	Loading Mode (M, V, S, C, or T)	DF Type	DF (x.xxx)	Controlling Location (1.0, 1.5, etc.)	Rating Factor (x.xx)	Tonnage Value (xxx.x)
H20L				Single Lane				
H20L				Multi Lane				
H20L				Single Lane				
H20L				Multi Lane				
H20L				Single Lane				
H20L				Multi Lane				
MO3S2				Single Lane				
MO3S2				Multi Lane				
MO3S2				Single Lane				
MO3S2				Multi Lane				
MO3S2				Single Lane				
MO3S2				Multi Lane				
SU5				Single Lane				
SU5				Multi Lane				
SU5				Single Lane				
SU5				Multi Lane				
SU5				Single Lane				
SU5				Multi Lane				

Commercial Zone Tab

Commercial Zone Vehicle Ratings

Vehicle	Limit State	Impact Factor (0.xx)	Loading Mode (M, V, S, C, or T)	DF Type	DF (x.xxx)	Controlling Location (1.0, 1.5, etc.)	Rating Factor (x.xx)	Tonnage Value (xxx.x)
CZSU				Single Lane				
CZSU				Multi Lane				
CZSU				Single Lane				
CZSU				Multi Lane				
CZSU				Single Lane				
CZSU				Multi Lane				
CZRT				Single Lane				
CZRT				Multi Lane				
CZRT				Single Lane				
CZRT				Multi Lane				
CZRT				Single Lane				
CZRT				Multi Lane				

Other Vehicles Tab

Other Vehicle Ratings

Vehicle	Limit State	Impact Factor (0.xx)	Loading Mode (M, V, S, C, or T)	DF Type	DF (x.xxx)	Controlling Location (1.0, 1.5, etc.)	Rating Factor (x.xx)	Tonnage Value (xxx.x)
MO5				Single Lane				
MO5				Multi Lane				
4S3P				Single Lane				
4S3P				Multi Lane				
EV2				Single Lane				
EV3				Single Lane				

753.15.22 Coding of Posting and NBI Load Rating Items in TMS

The following guidance is provided to assist in data entry of load rating and posting information for structures.

753.15.22.1 Coding of Load Postings

Load postings are coded as two items within the TMS data system. The load posting that is determined by Bridge Division and provided to District Offices is the Approved Posting. The load posting that is at the bridge site is called the Field Posting, which is verified by inspectors during inspection cycles. Adding and updating of Approved Postings is restricted to Bridge Division personnel. Adding and updating of Field Postings is allowed for anyone with update privileges for bridge inspection data entry.

TMS Coding New Posting Categories			
Category	**Single Unit**	**Combination**	**Other**
SW-1	----	----	----
SW-2	----	----	Ton1
SW-3	Ton1	----	----
SW-4	Ton1	----	----
SW-5	Ton1	Ton2	----
LR-1	----	----	----
LR-2	----	----	Ton1
LR-3	Ton1	----	----
LR-4	Ton1	----	----
LR-5	Ton1	Ton2	----
CZ-1	----	----	----
CZ-2	----	----	Ton1
CZ-3	Ton1	----	----
CZ-4	Ton1	----	----
CZ-5	Ton1	Ton2	----
FT-1	Ton1	----	----
K-CD	----	----	----
K-CIF	----	----	----
OT-1	Code Ton1, Ton2, Ton3 in the order on the posting sign.		

In general, the Approved Posting and the Field Posting should match in order to be considered compliant on a load posting. Situations are encountered whenever there are differences in these load posting values. If the Field Posting is more restrictive than the Approved Posting, then it is considered to still be a compliant load posting. If the Field Posting is less restrictive than the Approved Posting, then it is considered a non-compliant load posting and the Structure Status (Item 41) should be updated to a coding of “B”, to indicate non-compliance.

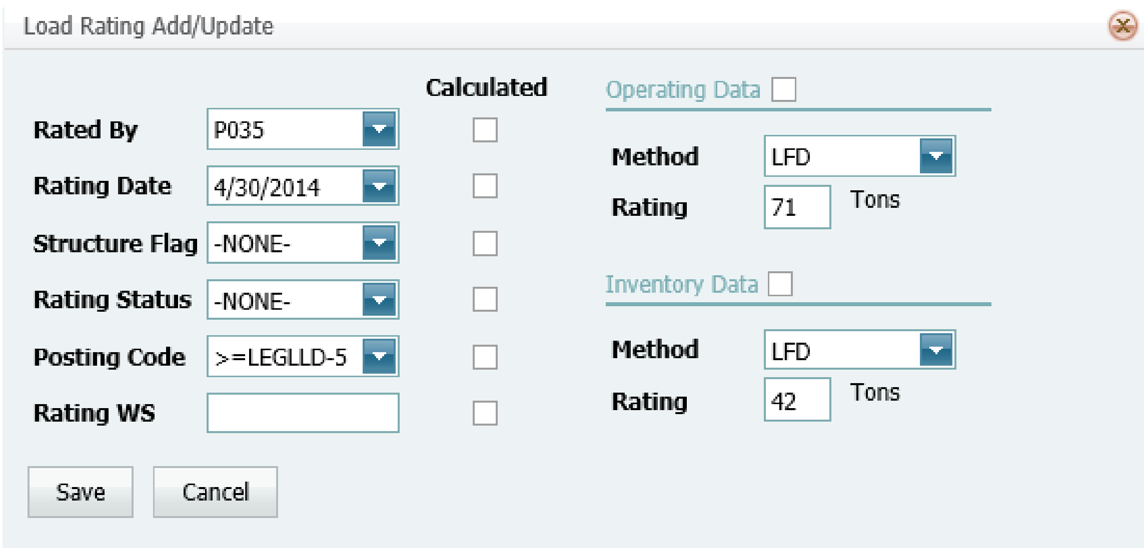
TMS Coding Legacy Posting Categories			
Category	**Ton1**	**Ton2**	**Ton3**
S-CD	----	----	----
S-CD-CIF	----	----	----
S-1	----	----	----
S-3	X	----	----
S-C3	X	----	----
S-4	X	----	----
S-5	X	----	----
S-6	X	----	----
S-7	X	----	----
S-8	X	X	----
S-9	X	----	----
S-10	X	----	----
S-11	X	X	----
S-12	X	X	----
S-13	X	----	----
S-14	X	X	----
S-15	X	X	----
S-16	X	X	X
S-17	X	X	X
S-18	X	X	----
S-19	X	----	----
S-20	X	----	----
S-21	X	----	----
S-22	----	----	----

When entering load postings into TMS, the user enters a posting category and tonnage values ranging from Ton1 to Ton3. Tonnage values are entered sequentially as they are encountered in the verbiage for the posting category. The tables shown above provide guidance on which tonnage values are entered for the different posting categories.

753.15.22.2 Coding of NBI Data

The screen capture shown below is from the Load Rating window in TMS. This window contains items that are reported on the NBI as well as items that are captured for internal MoDOT use.

The NBI items are Posting Code (Item 70), Operating Method (Item 63), Operating Rating (Item 64), Inventory Method (Item 65), and Inventory Rating (Item 66). These items are provided in the load posting letter provided by the load rating engineer. They will also be automatically determined on structures whenever detailed load rating information is loaded into the TMS system for a bridge and the Calculated checkbox is selected on an item. Typically, more detailed load rating information is loaded for MoDOT structures and not on locally owned structures.



The internal MoDOT items are Rated By, Rating Date, Structure Flag, Rating Status, and Rating WS. Rated By is used to code the entity that performed the load rating calculations, with codes used for various consultant engineers. Rating date is the date of the most recent load rating results loaded into TMS. Structure Flag is used to identify structures with condition issues or permitting issues that need to be considered when reviewing load rating results on a bridge. Rating Status defines the current status of the load rating results on a structure (i.e. Completed, etc.). Rating WS is the wearing surface thickness used in the most recent load rating analysis.