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 or 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

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

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

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

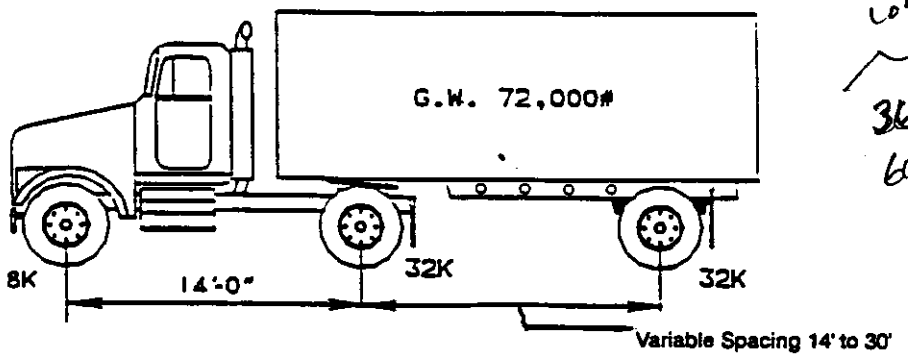
M_{cap} = Ultimate Moment Capacity
M_{dl} = Actual Dead Load Moment
A_1 = Load factor to be applied to live load plus impact
2.17 Inventory Rating
1.3 Operating Rating

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
36 T INVENTORY
60 T OPERATING



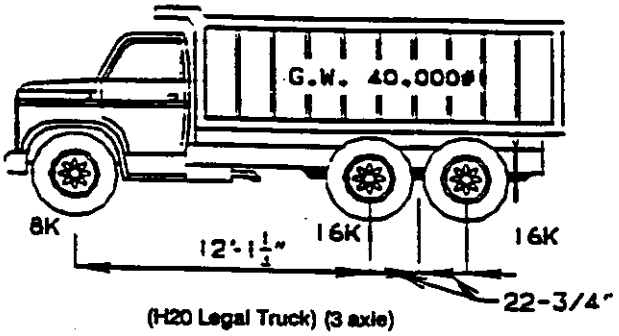
(HS20 Truck)

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

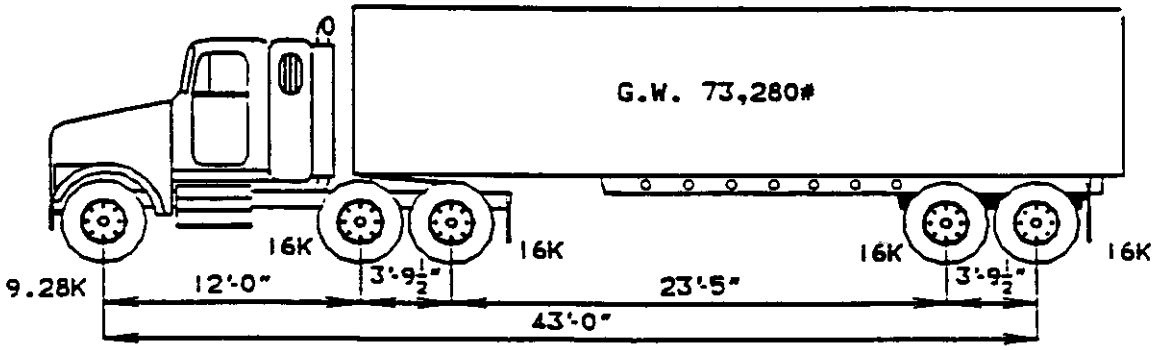
POSTING VEHICLES

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.



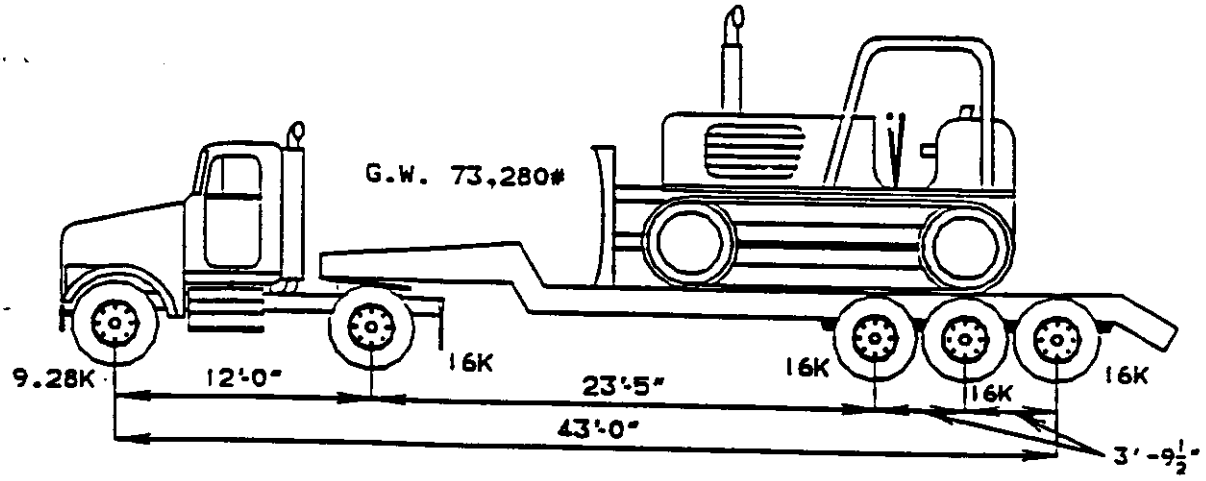
(H20 Legal Truck) (3 axle)

Single Unit Vehicle (Legal Limit = 23 Tons)



(3S2 Truck)

All Other Vehicles (Legal Limit = 40 Tons)



(MO5 Truck)

Commercial Zone Vehicle (Limit = 70 Tons)

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 = $\sqrt{\frac{n \cdot \sum x^2 - (\sum x)^2}{n(n-1)}}$

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

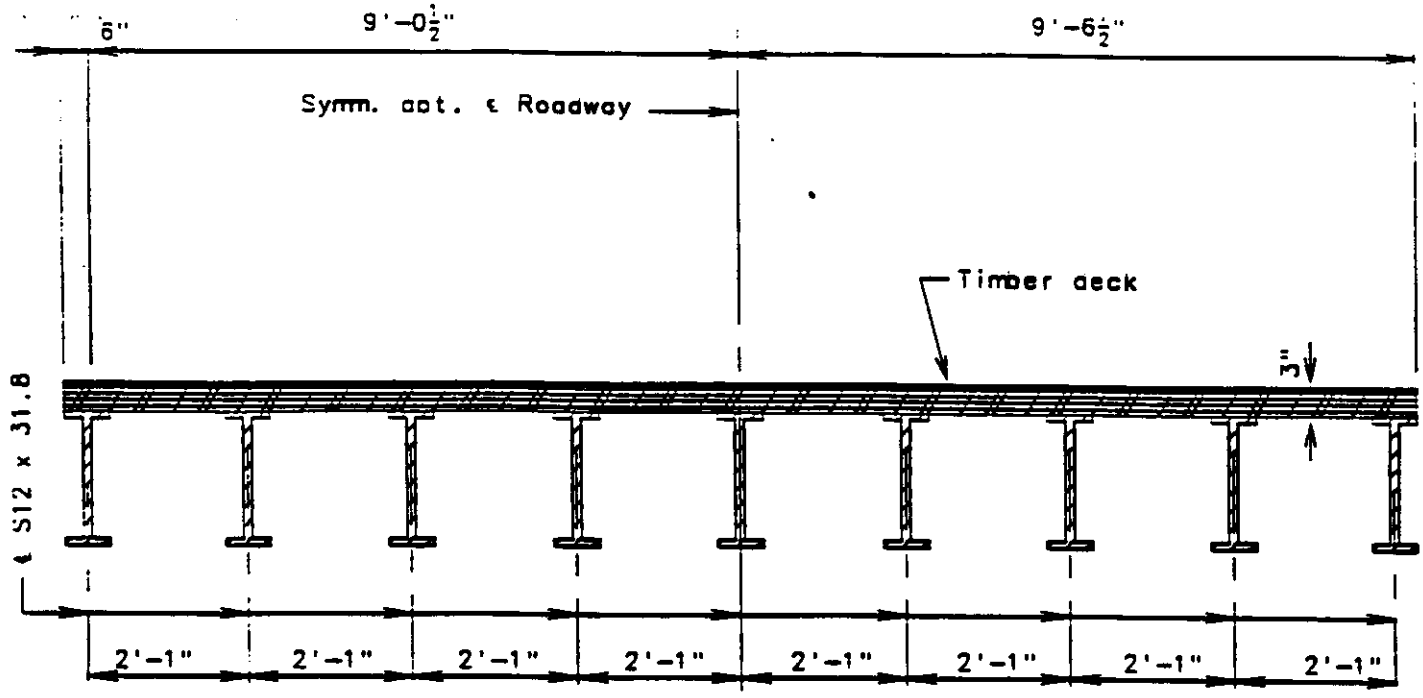
LIVE LOAD MOMENTS FOR SIMPLY SUPPORTED SPANS

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

Span Length (ft.)	HS20	H20 (Legal)	3S2	MO5
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:

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

(DO NOT IDENTIFY BY AREA AND SECTION MODULUS)

23.0
SPAN LENGTH(FT)

18.08
ROADWAY WIDTH(FT)

Timber
DECK MATERIAL

2.0833
STRINGER SPACING(FT.)

3
DECK THICKNESS(IN)

12.0
STRINGER DEPTH(IN)

--
WEB DEPTH (IN)

.35
WEB THICKNESS (IN)

5.0
FLANGE WIDTH(IN)

AVERAGE FLANGE THICKNESS(IN)

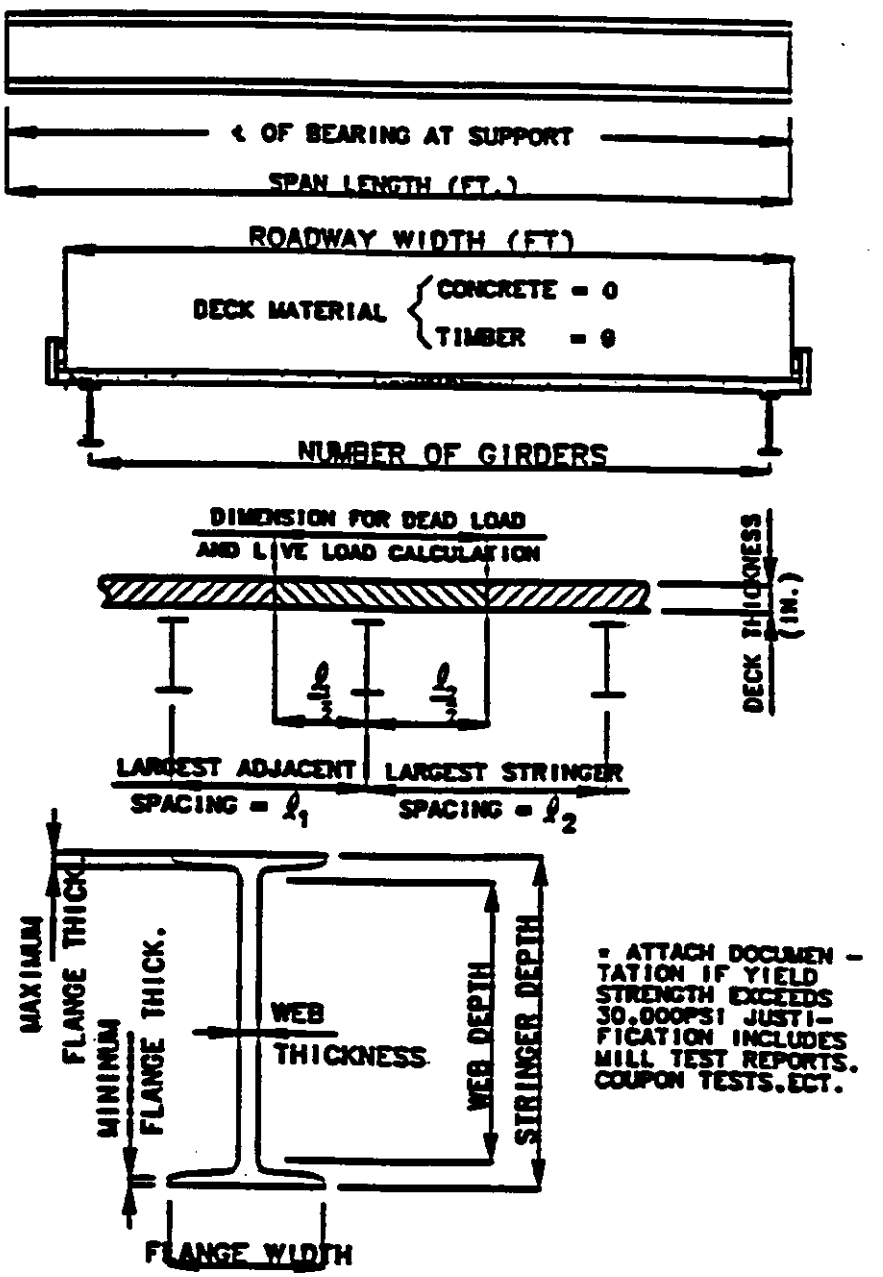
.74
MAXIMUM FLANGE THICKNESS(IN)

.35
MINIMUM FLANGE THICKNESS(IN)

30,000 psi
YIELD STRENGTH *

OVERLAY WEIGHT (PSF)

3.0'
MAXIMUM LATERAL SUPPORT DIMENSION (TIMBER DECK)



* 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

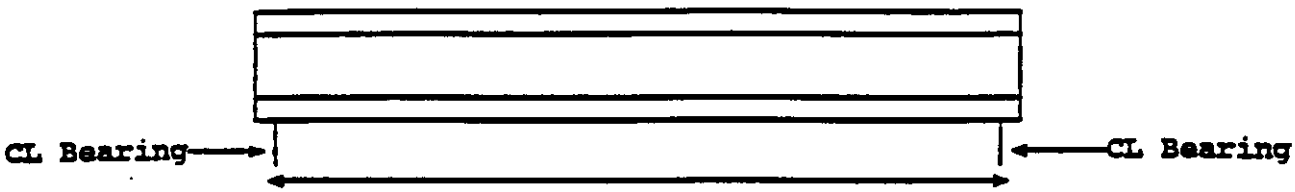
Bridge No. 9990001

OVERALL SECTION LOSS: 5 Percent

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

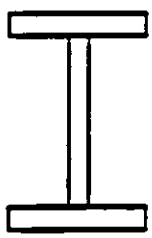
GENERAL ELEVATION:

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.

SEPT. 1993

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% = ($36.0\ in^3$)(.95)[includes 5% deterioration](1/12)(20.4ksi) = 58.1K'

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

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

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

Rating Summary

Posting: Category S-3: 19 Tons

or

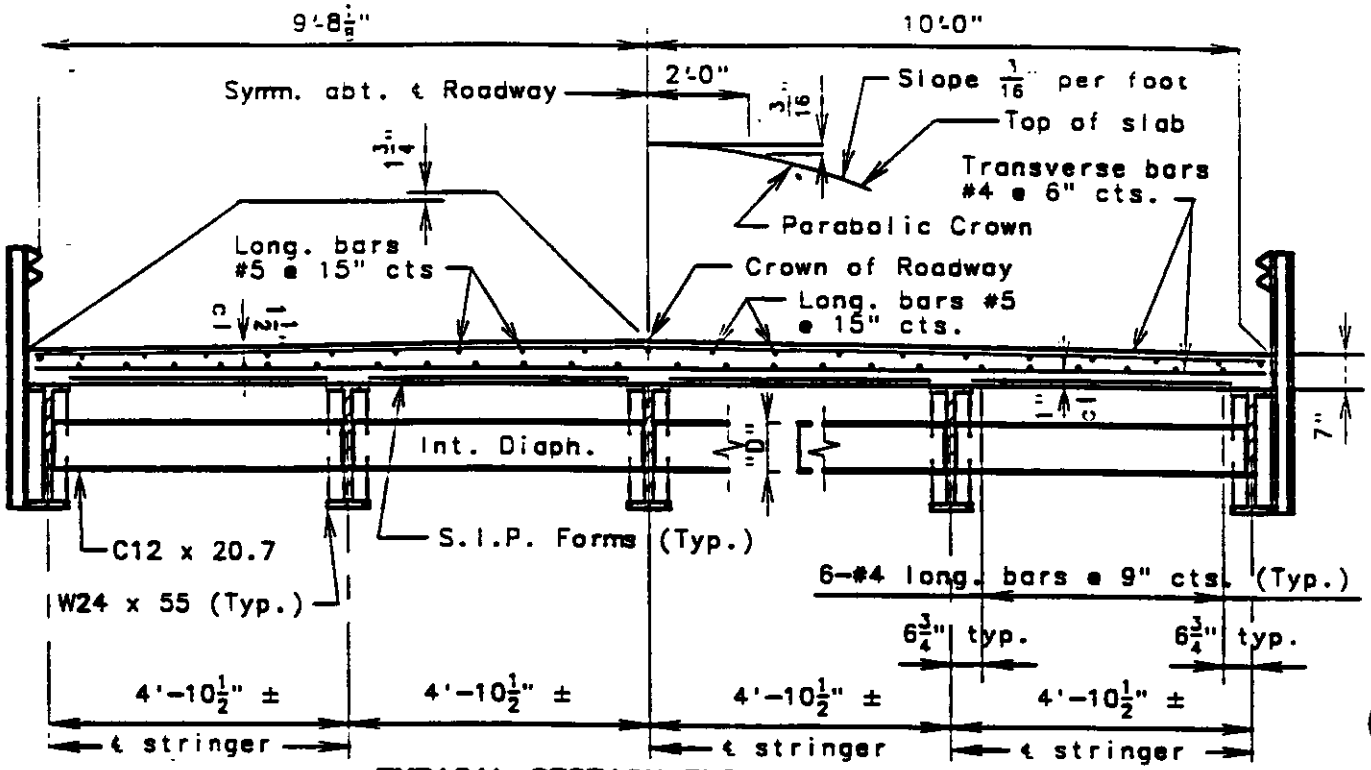
Category S-15: Single Unit 21 Tons
Others 38 Tons

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

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

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)

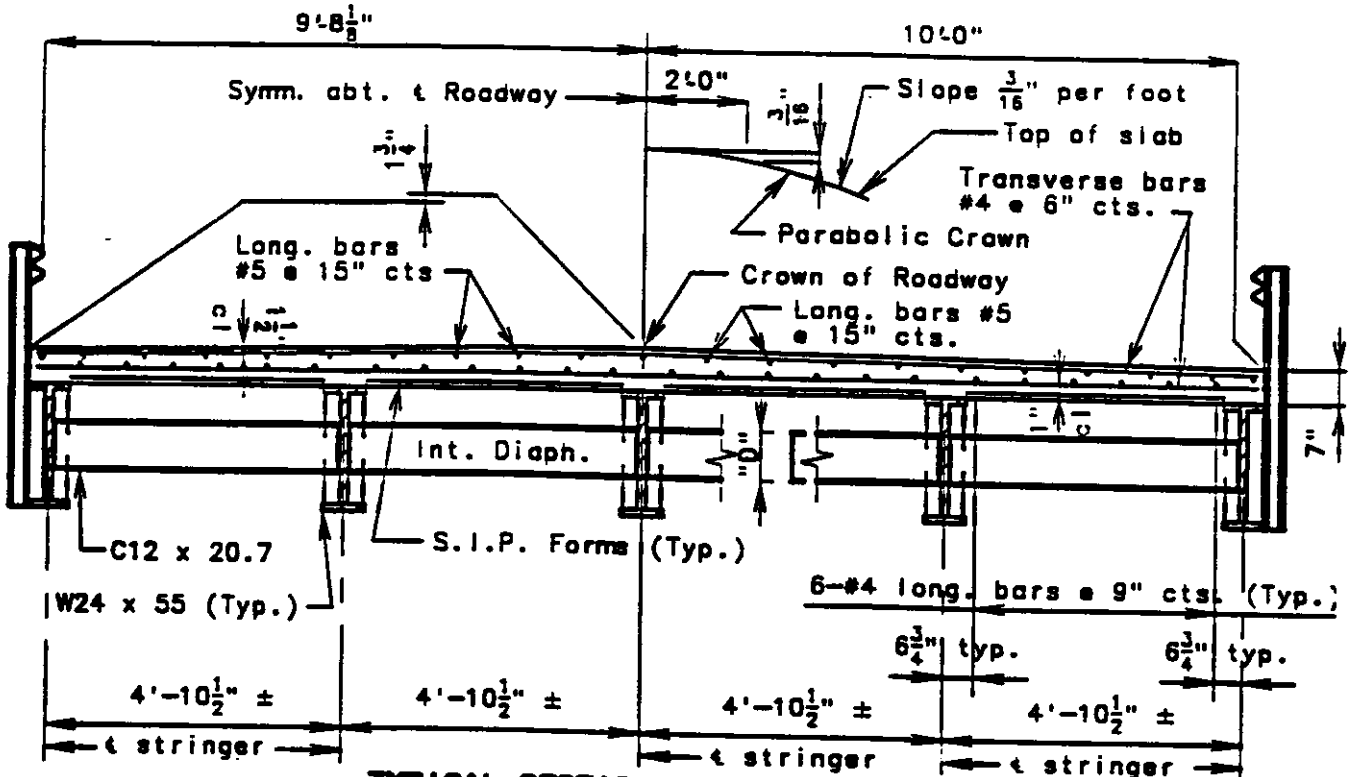
Posting (H20 Legal) = $\frac{232.6\text{k}' - 107.6\text{k}'}{145.3\text{k}'}$ (20 Tons)
= 17.2 Tons

(3S2) = $\frac{232.6\text{k}' - 107.6\text{k}'}{147.3\text{k}'}$ (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 Yield Strength	86% of Operating Rating 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 $= \frac{wl^2}{8} = (.538 \text{ k/ft.})(40)^2(1/8)$
$= 107.6\text{k}'$

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 Dc/tw = $\frac{11.28"}{.395}$ = 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

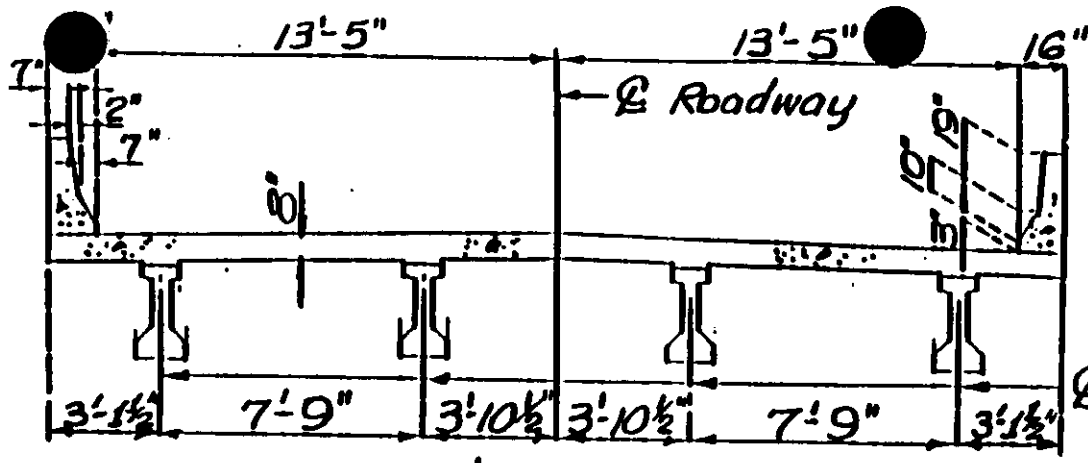
For 3S2 Vehicle = $\dfrac{342 - 1.3(107.6k')}{(147.3k')(1.3)}$ $(36.64\ Tons)(.86) = 33.3$ Tons

Rating Summary

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

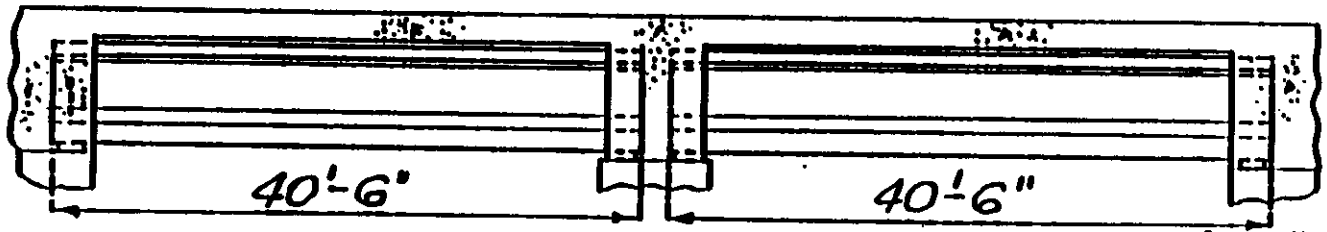
Posting Category:
S-3: 18 Tons
or
S-15: 18 Tons Single Unit
33 Tons Others
or
S-7: Trucks over 18 Tons 15 MPH on Bridge

...GIRDER EXAMPLE - LOAD FACTOR METHOD

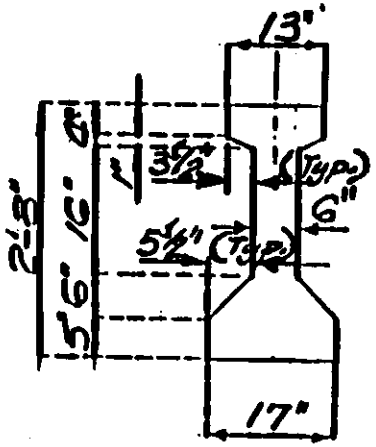


Section Thru Slab

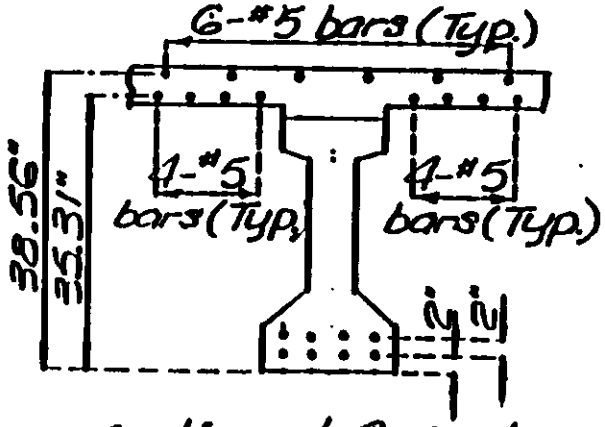
Note: 12#/sq. ft. future wearing surface is considered.



Part-Section Near Girders

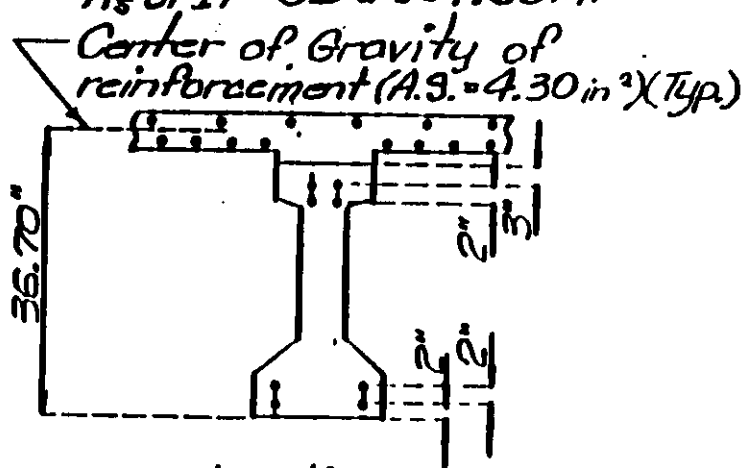


Typical Section Thru Girder



Section at ℄ Girder

A_s of 14-#5 Bars = 4.30 in.²



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 in²
AG = 317.6 in² (Includes consideration of 8 strands (.153 in²)
Es = 28,000,000 psi
Ec = 57,000 √fc
P/S steel transformed using (n-1)

Ig = 34,815.4 in⁴ Bottom of Girder to Neutral Axis = 13.84"
Sb = 2515.7 in³ Top of Girder to Neutral Axis = 18.16"
St = 1917.0 in³

Section Properties for Girder and Slab

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

$A_c = 912.8$ in.^{2}	Bottom of Girder to Neutral Axis	= 29.19"
$I_c = 152{,}760.9$ in.^{3}	Top of Girder to Neutral Axis	= 2.81"
$S_{bc} = 5{,}233.5$ in.^{3}	Top of Slab to Neutral Axis	= 12.19"

$S_{tc} = 54{,}344.0$ 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}		
$S_b = 2421.4$ in.^{3}	Top of Girder to Neutral Axis	= 17.92"
$S_t = 1902.6$ in.^{3}		

Section Properties for Girder and Slab

$A_c = 912.8$ in.^{2}	Bottom of Girder to Neutral Axis	= 29.27"
$I_c = 149{,}700.9$ in.^{3}		
$S_{bc} = 5114.0$ in.^{3}	Top of Girder to Neutral Axis	= 2.73"
$S_{tc} = 54{,}895.8$ 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 in^2
fsu^* = Average stress in prestressing steel at ultimate load AASHTO 9.17.4

$$P^* = As^*/bd = \frac{(8)(.153\text{ in.}^2)}{(93)(38.38)} = .000343$$

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"

$$fsu^* = fs'\,[1 - (y^*/B1)(p^* fs/f'c)]$$
$$= (270\text{ Ksi})\left[1 - (.40/.80)\frac{(.000343)(270\text{ Ksi})}{(4.0\text{ Ksi})}\right]$$
$$= 266.9\text{ Ksi}$$

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

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

Top of Girder (Compression) (Elastic Analysis)

$$MLL+I\ (Available) = [.4\,f'c - FF/AG + \frac{FFec}{St} - \frac{Md}{St} - \frac{MSD}{Stc}]Stc$$

$$= [(.4)(5Ksi) - \frac{183.4K}{311.5in^2} + \frac{183.4K(10.84")}{1917.1\ in^3} - \frac{257.1K'(12)}{1917.1}$$

$$- \frac{26.1K'(12)]\ (54{,}340.3)}{54{,}340.3\ in^3\ \ 12} = 3772.9K'$$

Bottom of Girder (Tension) (Elastic Analysis)

$$MLL+I\ (Available) = [6\sqrt{f'c} + \frac{F_F}{A_{concrete}} + \frac{FFec}{Sb} - \frac{Md}{Sb} - \frac{Msd}{Sbc}]\ Sbc$$

$$= [\frac{6\sqrt{5000}}{1000\frac{Lbs.}{K}} + \frac{183.4K}{311.5in.^2} + \frac{(183.4K)(10.84")}{2515.7\ in.^3} - \frac{257.1K'(12)}{2515.7\ in.^3}$$

$$- \frac{26.1K'(12)]5233.5}{5233.5\ in.^3\ \ 12} = 225.5K' \text{ Controls}$$

Ultimate Strength

Mu = 1031.1K'

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

$$= 306K'$$

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 = $\frac{526.7K'(20^T)(.86)}{129.9K'}$ = 69.7 Tons > 23 Tons O.K.

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