SECTION 3

Bridge Decks

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3-1 Introduction to Rating Bridge Decks

This section covers the rating of bridge decks.

Reinforced concrete decks supported by longitudinal girders, with main reinforcement placed perpendicular to traffic, and asphalt filled metal plank decks placed perpendicular to traffic will be rated with the CDOT computer programs discussed in subsections 3-2 and 3-3.

When design plans are available, use the applicable concrete strength and steel yield stress or use the values shown in table 100-1 (Year of Construction - Allowable Bending Stress Table) for the appropriate year of construction. See Subsection 100-4.

When plans are not available for a concrete deck, and the deck shows no signs of failure, then the assignment of rating values will not be required. However, if the condition of the deck indicates probable failure, then rating values shall be assigned as stipulated in subsection 600-5. The rater shall indicate on the rating summary sheet that plans are not available for the deck.

Transverse nail laminated and transverse plank timber decks are to be rated using the guidelines in Section 300, Timber Bridges.

All other types of bridge decks will be rated in compliance with the applicable guidelines within this manual and the AASHTO code. Hand computations will be acceptable.

For reinforced concrete slabs with main reinforcement parallel to traffic, see Section 600 - Concrete Bridges, for rating directions.

3-2 Concrete Slab Rating

Reinforced concrete deck slabs meeting the following conditions shall be rated with the SLAB computer program by the load factor method using current AASHTO Specifications:

A. The slab must be supported by longitudinal girders or stringers with the main slab reinforcement placed perpendicular to the girders or for skews less than or equal to 20º.

   Skew is defined as the deviation in degrees of the reinforcement from perpendicular to the girders. The reinforcement may have a different skew than the structure.

B. The slab must be continuous over three or more supports. See the current Staff Bridge Design Memo 601 for descriptions of effective span and general deck slab design information.

A load factor rating example is shown in this subsection.

Description of **Input** for Concrete Slab Rating Program

Column	Description	Units	Data Type
1	Load Type		One Numeric Character

1 = Colorado Trucks (use for bridges carrying Colorado Highways, i.e. SH287)
2 = Interstate Trucks (use for bridges carrying Interstate Highways, i.e. I70 or I25)

2 - 8	Structure Number		Seven Alpha or Numeric Characters

Use the Colorado structure number or other designation for the structure such as county or city structure number.

9 - 11	Rater		Three Alpha or Numeric Characters

Used to designate who the rater is. Typically the initials are used.

12 - 14	Highway Number		Three Alpha or Numeric Characters

Used to designate the Highway Number (i.e. I70 = 70 or SH287 = 287).

15 - 20	Batch ID		Six Alpha or Numeric Characters

The Batch ID is assigned by the Staff Bridge BRIAR Unit and uniquely identifies the structure.

21 - 41	Comments		21 Alpha or Numeric Characters

Any additional information needed to define the slab (i.e. 70 Degree Skew).

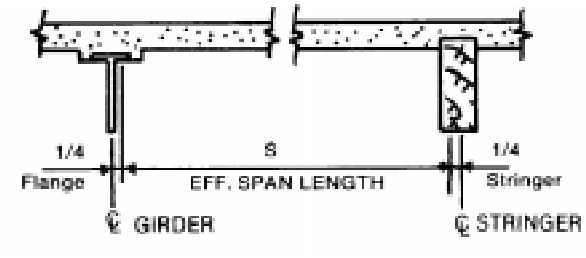
3-2 Concrete Slab Rating

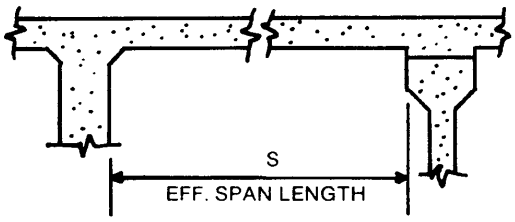
Column	Description	Units	Data Type

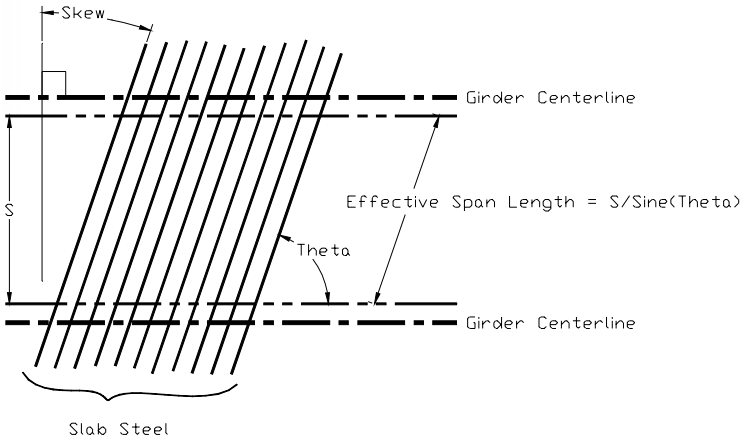
42 - 46 Effective Span Length (feet) Five Numeric Characters

The effective span length input as an integer to three decimal places, see the drawings below. The rater shall exercise care in determining the effective span length for slabs having main reinforcement placed at angles other than 90 degrees measured from the centerline of girder. For these cases, the effective span shall be the distance calculated parallel to the main reinforcing steel.

Use all decimal places even if they are zeros because the program does not recognize blank input as a zero..







47 - 51 Actual Slab Thickness (inch) Five Numeric Characters

The actual slab thickness input as an integer to three decimal places, see the drawing on the following page.

52 - 56 Distance to Top Reinforcing Steel (inch) Five Numeric Characters

The distance from the from the bottom of the slab to the center line of the top reinforcing steel as an integer to three decimal places, see the drawing on the following page.

57 - 59 Top Reinforcing Steel Area (sq.in.) Three Numeric Characters

The area of the top reinforcing steel over the girders as an integer to two decimal places, see the drawing on the following page.

3-2 Concrete Slab Rating

Column	Description	Units	Data Type

60 - 63 Bituminous Overlay (inch) Four Numeric Characters

The average asphalt thickness as an integer to two decimal places, see the drawing below.

64 - 67 f'_c for Concrete (psi) Four Numeric Characters

The value of concrete strength is from the plans or table 1-1 (Year of Construction - Allowable Bending Stress Table) for the appropriate year of construction.

68 - 72 F_y for Reinforcing Steel (psi) Five Numeric Characters

The value of steel yield stress is from the plans or table 1-1 (Year of Construction - Allowable Bending Stress Table) for the appropriate year of construction.

73 - 74 Leave Blank for Load Factor

For a load factor analysis, the rater shall leave "N" blank for program input.

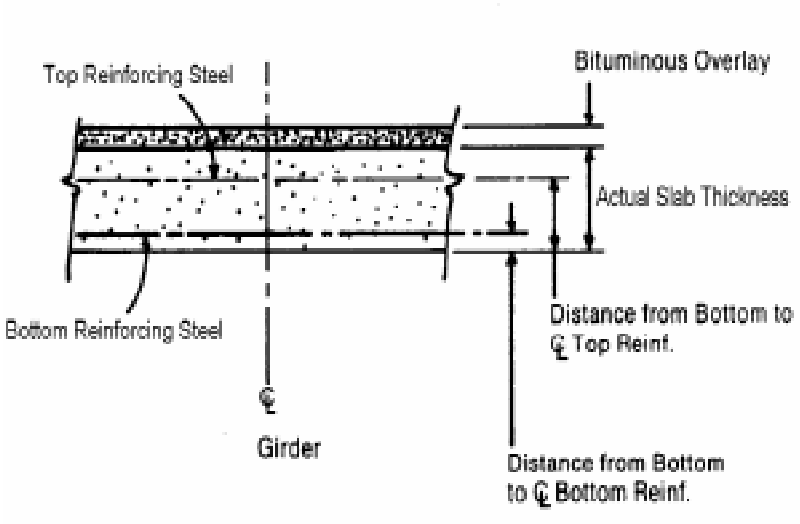
75 - 77 Distance to Bottom Steel (inch) Three Numeric Characters

The distance from the bottom of the slab to the center line to the bottom reinforcing steel, taken at a point midpoint between the girders shown as an integer to two decimal places. see the drawing below.

78 - 80 Bottom Reinforcing Steel Area (sq.in.) Three Numeric Characters

The area of the bottom reinforcing steel midpoint between the girders shown as an integer to two decimal places. see the drawing below.

Typically the bottom and top steel areas are the same.



3-2 Concrete Slab Rating

Description of **Output** for Concrete Slab Rating Program

I. Input Data

The input data coded by the rater is printed. The reported value of N is the calculated value for load factor analysis.

II. Output Results

A. Total dead load moment for the portion being analyzed.

B. Live load plus impact moment due to HS 20 loading.

C. Gross vehicle weight of HS 20 truck.

D. Calculated concrete and reinforcing steel stresses based on a HS20 vehicle.

E. Total member capacity at inventory and operating level.

F. Member capacity for live load plus impact at inventory and operating level.

G. Ratings in tons at inventory and operating level.

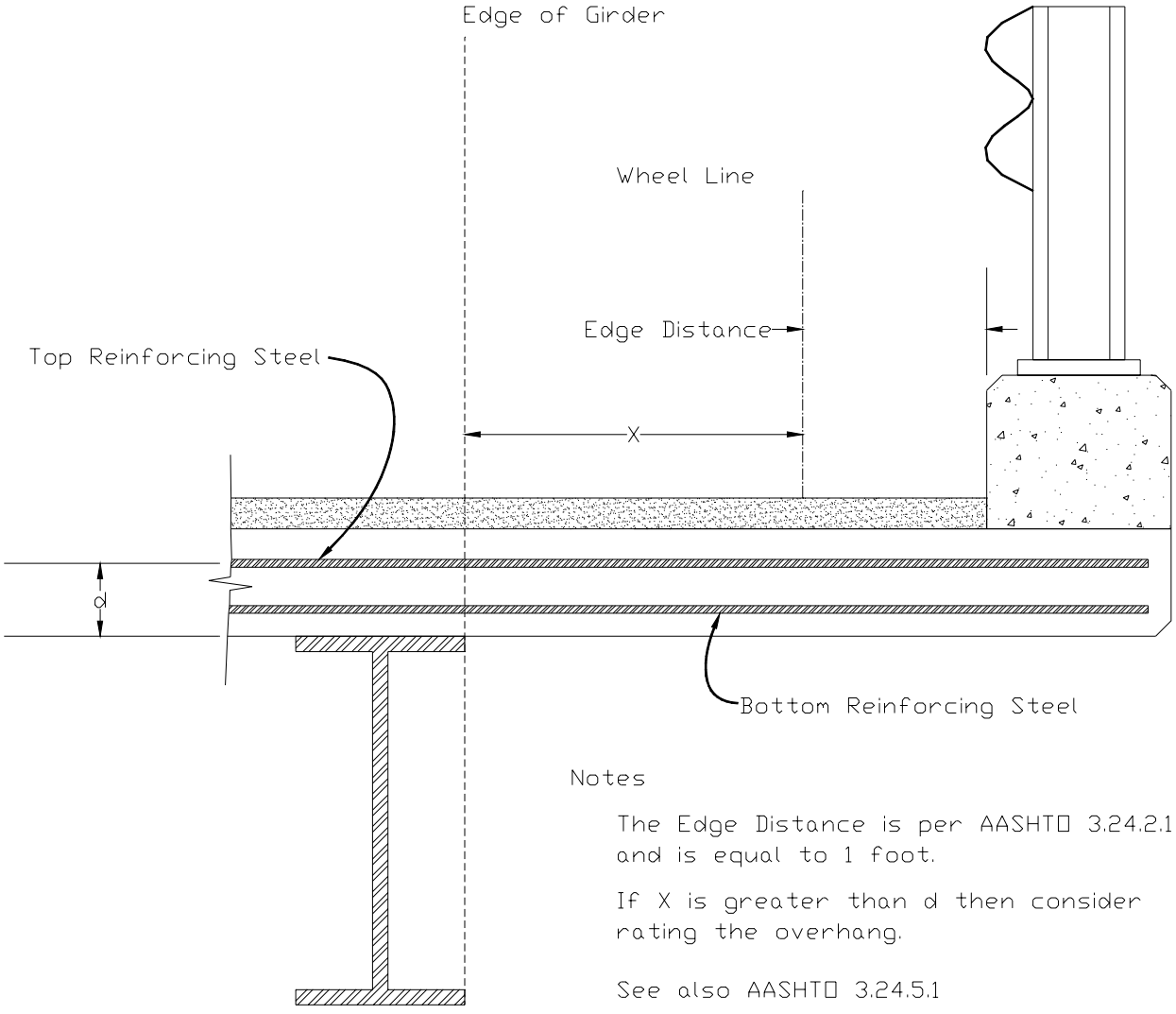
H. Ratings for posting vehicles when operating rating is less than 36.0 tons. The program analyzes either the Colorado Legal Loads or the Interstate Legal Loads depending on user input. Ratings for posting vehicles are determined from the operating capacity.

3-2 Concrete Slab Rating

Guideline for Rating Cantilever Portions of Concrete Bridge Decks

Usually, deck overhangs at the exterior girder do not control the slab rating. However, the rater should use judgment in determining if the overhang should be rated. A criteria that may be used is:

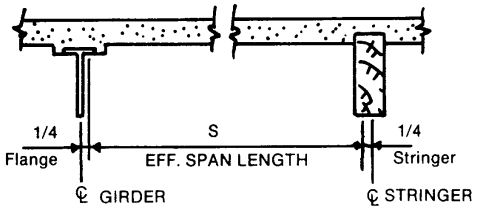
> Rate the cantilever portion of the concrete bridge deck if the wheel load can be applied outside the exterior girder by a distance equal to or greater than the distance from the bottom of the slab to the centerline of the top reinforcement, see the following drawing.

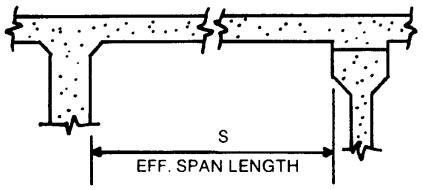


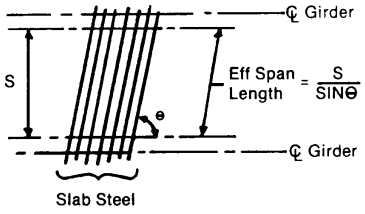
CDOT Staff Bridge Rating Manual Example

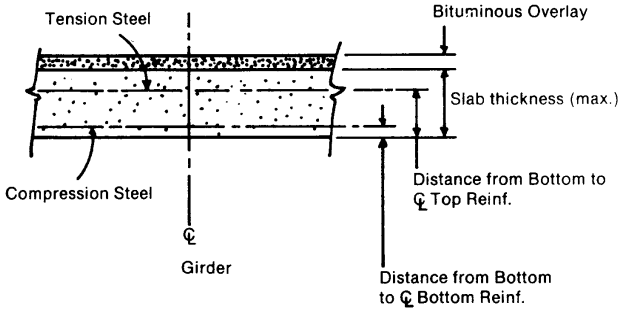
CONCRETE SLAB RATING

DESCRIPTION	INPUT	UNITS	CARD IMAGE COLS.
LOAD TYPE: 1 = Colo. Trucks 2 = Interstate	2		1
STRUCTURE NUMBER:	E-17-HY		2 - 8
RATER:	MAN		9 - 11
HIGHWAY NUMBER:	70		12 - 14
BATCH I.D.:	H73002		15 - 20
COMMENTS:	MEDIAN CLOSURE		21 - 41
EFFECTIVE SPAN LENGTH:	96.67	FEET	42 - 46
ACTUAL SLAB THICKNESS:	8.000	INCHES	47 - 51
Distance to Top Reinforcing Steel	6.188	INCHES	52 - 56
Top Reinforcing Steel Area:	0.61	In2/Ft	57 - 59
ASPHALT OVERLAY:	4.00	INCHES	60 - 63
Concrete Strength (f'c):	4500.	P.S.I.	64 - 67
Steel Yield Strength (Fy):	60000.	P.S.I.	68 - 72
Leave Blank for Load Factor:		Es/Ec	73 - 74
Distance to Bottom Reinforcing Steel:	1.81	INCHES	75 - 77
Bottom Reinforcing Steel Area:	0.61	In2/Ft	78 - 80









3-2 Concrete Slab Load Factor Rating Example

Computer Program Output

```
                          SLAB RATING Version 1.0
                               DATE: 95/03/21

     STRUCTURE NO. E-17-HY     RATER: MAN     STATE HWY NO. = 70
     BATCH ID= H73002  DESCRIPTION:  MEDIAN CLOSURE
 LOAD FACTOR RATING-COMP STEEL NOT USED---LOAD FACTOR RATING

                    INPUT DATA
                    ----- ----
     EFF. SPAN(FT)=  9.667               EFF. DEPTH(INS)=     6.188
     REINF.(SQ.IN)=   .61
     SLAB TK(IN)=    8.000               WEARING SURFACE(IN)= 4.00
     CONC. STRENGTH(PSI)  INV= 4500.  OPER= 4500.
     STEEL  YIELD  (PSI)  INV=60000.  OPER=60000.
     N=  8.
     D1= 1.81              AS1=  .61

DEAD LOAD MOMENT        1.38 K-FT
LL+I MOMENT             6.07 K-FT
GROSS WEIGHT           36.0  TONS

                                        INVENTORY     OPERATING
ACTUAL CONCRETE STRESS     (PSI)     1500.48       2325.40
ACTUAL REINF. STEEL STRESS (PSI)    27987.38      43374.04
ACTUAL COMP. STEEL STRESS  (PSI)      612.67        949.50
MEMBER CAPACITY           (K-FT)       15.89         15.89
MEMBER CAPACITY (LL+I)    (K-FT)       14.09         14.09
     RATING               (TONS)       38.60         64.33
```

Manual calculations to convert from U.S. Tons to Metric Tons

Inventory = 38.60 * 2000 / 2204.6 = 35.0 metric tons

Operating = 64.33 * 2000 / 2204.6 = 58.4 metric tons

1300-2 Concrete Slab Load Factor Rating Example

Given Information:

Structure Number: E-17-HY
Rater: MAN
Higway Number: 70
Batch I.D.: H73002
Comments: Median Closure

LOAD TYPE: $L_t := 2$
1 = Colorado Trucks
2 = Interstate Trucks
Effective Span Length (feet) = $L := 9.667$
Actual Slab Thickness (inches) = $T := 8.000$

Asphalt Thickness (inches) = $HMA := 4$

Reinforcing Steel:

	Area (in^2/ft)		Location from the bottom of the slab (inches)	
Top Mat Over the Supports=	$A_t := 0.61$	Top Mat Location =	$D_t := 6.188$
Bottom mat between the supports =	$A_b := 0.61$	Bottom Mat Location =	$D_b := 1.81$

Reinforcing Steel Yield Strength (psi) = $f_y := 60000$
Concrete Compressive Strength (psi) = $f_c := 4500$

Calculations:

Deadload:

Distributed Deadload:

Concrete: $W_c := \frac{T}{12} \cdot 150$ $W_c = 100$

Asphalt: $W_a := \frac{HMA}{12} \cdot 144$ $W_a = 48$

Total (lbs/foot) = $W := W_c + W_a$ $W = 148$

Deadload Moment (ft-k): $M_{dl} := \frac{W \cdot L^2}{8} \cdot 0.8 \cdot \frac{1}{1000}$ $M_{dl} = 1.383$

Note: 0.8 is the Continuity Factor

Live Load Moment: $M_{ll} := 16 \cdot \frac{L + 2}{32} \cdot 0.8 \cdot 1.3$ $M_{ll} = 6.067$

Note: 1.3 is the impact factor
The live load formula is from AASHTO 3.24.3.1

1300-2 Concrete Slab Load Factor Rating Example (Continued)

Resisting Moment over the Support (ft-kips):

Steel Tension (pounds) = $T_t := A_t \cdot f_y$ $T_t = 3.66 \cdot 10^4$

Concrete Compression Block (inches) = $a_t := \frac{T_t}{\left(0.85 \cdot f_c \cdot 12\right)}$ $a_t = 0.797$

Strength Reduction Factor: $\phi := 0.9$

$$M_u := \phi \cdot \frac{T_t \cdot \left(D_t - \frac{a_t}{2}\right) \cdot \frac{1}{12}}{1000} \qquad M_u = 15.892$$

Final Rating:

Inventory Rating (metric tons) = $\frac{M_u - 1.3 \cdot M_{dl}}{2.17 \cdot M_{ll}} \cdot 36 \cdot \frac{2000}{2204.6} = 34.963$ ←

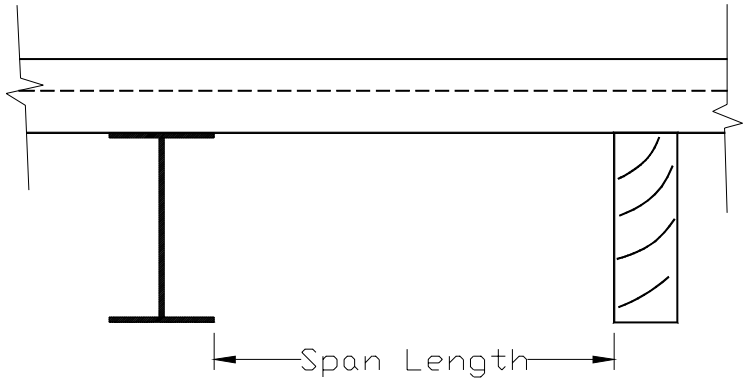
Operating Rating (metric tons) = $\frac{M_u - 1.3 \cdot M_{dl}}{1.3 \cdot M_{ll}} \cdot 36 \cdot \frac{2000}{2204.6} = 58.361$ ←

3-3 Corrugated Steel Plank Rating

The Plank Rating Program investigates corrugated metal flooring based on a one-inch strip transverse to traffic. Currently, the Plank Rating Program will only produce a working stress rating which satisfies the AASHTO specifications, except the program assumes a 20-inch by 20-inch tire contact area. However, the program can be used to generate the Deadload and Liveload Moments. The values produced by the program can then be used to generate a Load Factor Rating using the appropriate factors and formulas. The hand calculation rating analysis in this subsection illustrates the methods used by the program except for the final step which produces a Load Factor Rating.

Description of **Input** for the Plank Rating Program

Column	Description	Units	Data Type
1 - 7	Structure Number		7 Alpha or Numeric Characters
	Use the Colorado structure number or other designation for the structure such as the county or city structure number.		
8 - 10	Rater		3 Alpha or Numeric Characters
	Used to designate who the rater is. Typically the rater's initials are used.		
11 - 13	State Highway Number		3 Alpha or Numeric Characters
	Used to designate the highway number (i.e. I70 = 70, SH287 = 287, CR113 = 113).		
14 - 19	Batch I.D.		6 Alpha or Numeric Characters
	The Batch I.D. is a 6 digit Alphanumeric code assigned by the Staff Bridge BRIAR unit which uniquely identifies the structure.		
20 - 40	Comments		21 Alpha or Numeric Characters
	Any additional comments needed to define the plank or the structure.		
41 - 44	Span Length	(inch)	4 Numeric Characters
	Input the span length as an integer to 2 decimal places, see the drawing below.		



Use all decimal places even if they are zeros because the program does not recognize blank input as zeros..

3-3 Corrugated Steel Plank Rating

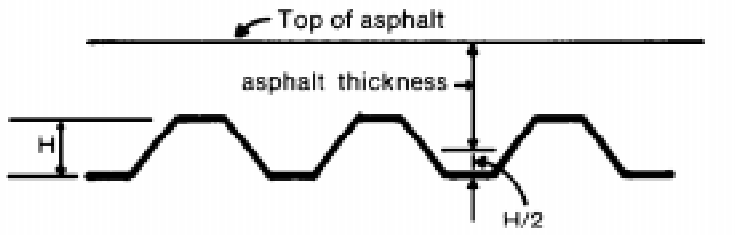
45 - 48 Section Modulus (in^3/in) 4 Numeric Characters
Input the section modulus as an integer to 3 decimal places.

49 - 51 Weight of Plank (lb/ft^2) 4 Numeric Characters
Input the weight of the plank as an integer to 1 decimal place.

51 - 54 Leave Blank 4 Numeric Characters
This field is normally used for the inventory stress of a Working Stress Rating. However for a Load Factor Rating, leave this field blank.

55 - 57 Steel Yield Strength (ksi) 4 Numeric Characters
This field is normally used for the operating stress of a Working Stress Rating. However for a Load Factor Rating, input the steel yield strength as an integer to 1 decimal place.

58 - 61 Asphalt Thickness (inch) 4 Numeric Characters
Input the asphalt thickness as an integer to 2 decimal places, see the drawing below.



Description of **Output** for the Plank Rating Program

I. INPUT DATA
The input data coded by the rater is printed.

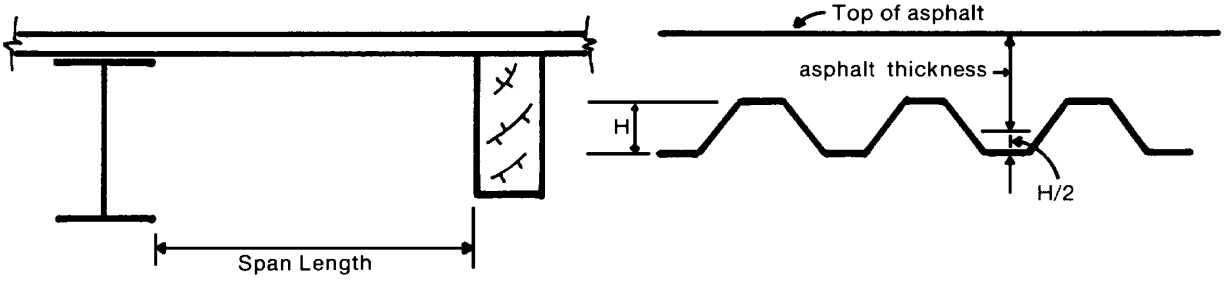
II. OUTPUT RESULTS
A. Live load plus impact moment due to HS 20 loading.
B. Dead load moment for the strip being analyzed.
C. Capacity for live load plus impact at inventory level.
D. Capacity for live load plus impact at operating level.
E. Inventory rating in tons.
F. operating rating in tons.
G. Posting ratings based on the Colorado legal loads when operating rating is less than 36.0 tons.

The Plank Rating Program will be updated to produce a Load Factor Rating directly at a future date. When the update is accomplished, this section of the rating manual will be reissued.

CDOT Staff Bridge Rating Manual Example

CORRUGATED STEEL PLANK RATING

DESCRIPTION	INPUT	UNITS	CARD IMAGE COLS.
STRUCTURE NUMBER	F-111-Q		1 - 7
RATER	MAN		8 - 10
STATE HIGHWAY NUMBER	70		11 - 13
BATCH I. D.	FIIQ		14 - 19
COMMENTS	FRONTAGE RO AD		20 - 40
SPAN LENGTH	43.55	IN	41 - 44
SECTION MODULUS	0.335	IN3/IN	45 - 48
WEIGHT OF PLANK	10.5	PSF	49 - 51
INVENTORY STRESS		KSI	52 - 54
OPERATING STRESS (F_y)	45.0	KSI	55 - 57
ASPHALT THICKNESS	5.00	IN	58 - 61



1300-3 Corrugated Steel Plank Rating Example

Computer Program Output

```
                          STEEL BRIDGE PLANK RATING
                               DATE: 3/21/95

     STRUCTURE NO: F-ll-Q
     RATER: MAN
     BATCH ID: FllQ
     STATE HWY NO: 70
     COMMENT: FRONTAGE ROAD

     NET SPAN LENGTH (IN) =    43.55
     SECTION MODULUS (IN3/IN) =  .335
     PLANK WEIGHT (PSF) =      10.5
     INVENTORY STRESS (KSI)      .0
     OPERATING STRESS (KSI)    45.0
     ASPHALT THICKNESS (IN)     5.00

     LL-1 MOMENT (IN-K) = 6.978
     (LL MOMENT BASED ON A WHEELPRINT 20IN X 201N)
     DL MOMENT (IN-K) =    .093
     INVENTORY LL-1 MOMENT CAPACITY (IN-K) =  -.093
     OPERATING LL-1 MOMENT CAPACITY (IN-K) = 14.982

     INVENTORY RATING (TONS) -.48

     OPERATING RATING (TONS)77.29
```

Note: The computer program is **only** being used to generate the Live Load and Dead Load Moments. The moment rating can then be determined from the computer values by using the appropriate Load Factor formulas and factors.

Manual calculations to produce a Load Factor rating in Metric Tons

Resisting Moment Capacity = Fy*S = 0.335 * 45 = 15.075 in-kips/in

$$\text{Inventory} = \frac{15.075 - 1.3 * 0.093}{2.17 * 6.978} * 36 * \frac{2000}{2204.6} = 32.3 \text{ metric tons}$$

$$\text{Operating} = \frac{15.075 - 1.3 * 0.093}{1.3 * 6.978} * 36 * \frac{2000}{2204.6} = 53.8 \text{ metric tons}$$

Plank Rating

Structure F-11-Q

Information from the field:

Plank:

Thickness is 5/32 of an inch

Distance between corrugations is 12"

Height of corrugations is 4"

Girder:

Spacing (feet): $S_p := 4.5$

Type: W30x99

Average Asphalt Thickness (inches): $T := 7.0$

Information derived from field information:

From AISC 8th Edition: Girder Flange Width (inches): $b_f := 10.45$

From AISI 4th Edition: Type A - 4¼x12x9ga. Plank

Steel Yield Stress (ksi): $F_y := 45$ Moment of Inertia (in^4/ft) $I := 8.83$

Weight of Plank (lbs/ft^2): $W_p := 10.5$ Section Modulus (in^3/ft) $S := 4.02$

Calculations:

Effective Span (inches): $L := S_p \cdot 12 - b_f$ $L = 43.55$

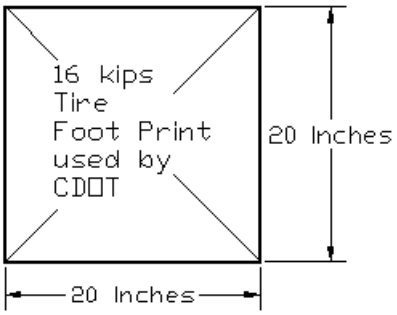
Distributed Deadload (lbs/in/in): $W := \left(\frac{T}{12} \cdot 144 + W_p\right) \cdot \frac{1}{144}$ $W = 0.656$

Continuity Factor (AASHTO 3.24.3.1) = $C_f := 0.8$

Deadload Moment (in-kips/in): $M_{dl} := \frac{W \cdot L^2}{8 \cdot 1000} \cdot C_f$ $M_{dl} = 0.124$

Distributed Live Load (kips/in/in):

$W_{ll} := \frac{16}{20 \cdot 20}$ $W_{ll} = 0.04$



Live Load Reaction (kips/in):

$R := W_{ll} \cdot \frac{20}{2}$ $R = 0.4$

Live Load Moment (in-kips/in):

$M_{max} := R \cdot \frac{L - 20}{2} + \frac{R}{2} \cdot 10$ $M_{max} = 6.71$

Impact Factor = $I_f := 1.3$

$M_{llI} := C_f \cdot I_f \cdot M_{max}$ $M_{llI} = 6.978$

3 - 3 Plank Rating Example (continued)

Calculations (continued):

Member Capacity (in-kips/inch):

$$M_{cap} := F_y \cdot \frac{S}{12} \qquad M_{cap} = 15.075$$

CDOT *Assumes the plank to be braced Noncompact which eliminates the need to do a Servicablity Rating because plastic properties are not used.*

Moment Rating (metric tons):

Inventory

$$Inv_{mom} := \frac{M_{cap} - 1.3 \cdot M_{dl}}{2.17 \cdot M_{llI}} \cdot 36 \cdot \frac{2000}{2204.6} \qquad Inv_{mom} = 32.163$$

Operating

$$Opr_{mom} := \frac{M_{cap} - 1.3 \cdot M_{dl}}{1.3 \cdot M_{llI}} \cdot 36 \cdot \frac{2000}{2204.6} \qquad Opr_{mom} = 53.688$$